THE RE-ANALYSIS OF THE MATURE WESTERN AREA OF INDONESIA BASINS FOR FINDING ADDITIONAL OIL AND GAS RESOURCES

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First Registered on 19 May 2009; Received after Corection on 26 June 2009
Published Approval on : 30 June 2009

ABSTRACT

The oil and gas exploration activities in the last two decades in the mature sedimentary basins in the western area of Indonesia can be said has been in the stagnation phase. The activities are still limited in the effort of discovering shallow structures as the exploration targets which are of Miocene age and not older than Early Miocene. On the other hand, the oil and gas exploration on hydrocarbon plays, as well as new Paleogene sediments or others, has not been done intensively. Some problems which cause difficulty in finding new resources are such as lack of innovation in the exploration activities, and this is because the exploration operators are reluctant to bear the failure risk in the development of exploration activities that they do; which leads the exploration program carried out mainly focused only on the target or objective reservoir that is known.

The effort of finding oil and gas resources in the future on the mature basins can be done by reanalyzing and revisit the evaluation on how the historical development of a sedimentary basin, that includes the development process and the tectonic sedimentation during the Tertiary era in relation to the formation of hydrocarbons. The reanalysis should be supported with the latest subsurface data, up-to-date geosciences concepts and sophisticated software and hardware which are able to perform the analysis of petroleum system in order to find new hydrocarbon-play as a new exploration target in the future.

Various proposed activities in the re-evaluation of the Tertiary sedimentary basins in Indonesia are the analysis of the Paleogene graben system of the back-arc basins of Sumatra and Java, the analysis of Miocene-Pliocene lowstand sediment, and the analysis of Miocene carbonate sediments, which have not been evaluated intensely so far.

Keywords: reanalysis, mature sedimentary basins, new oil and gas resource

I. INTRODUCTION

The oil and gas industry is a strategic source of energy. It is a source of revenues (about 35%), a direct source of foreign exchange, and as a raw material for petrochemical industry. So it is expected that the oil and gas production rate can be maintained and even increased in accordance with the increasing demands. The characteristics of the oil and gas industry are strategic, compact of capital and technology, high-risk, and found in the areas that are difficult and not renewable. These need to be aware because the oil and gas so far, even for-the future, still holds an important role for the smoothness of the national development and the prosperity of the nation.

On the other side, the size of the oil and gas reserves is around 9,480 billion barrels oil with an average production of 478.2 million barrels per year, it means only enough for about 20 years, relying on the current knowledge and technological capabilities. To maintain or increase the production rate, new resources have to be found, or increasing the revenue from the existing reserves by implementing the results of research and development of oil and gas tech-

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nology in the future. One of the strategies proposed for finding oil and gas resources in the future is the re-analysis of tertiary sedimentary basins, i.e. the re-evaluation of tertiary sedimentary basin using the up-to-date geological concept and the exploration technology, that will be a new insight about the hydrocarbon potentials to be developed in the future.

II. OIL AND GAS EXPLORATION ACTIVITIES

Geologically, the Indonesian archipelago consists of approximately 60 sedimentary basins, of which 20 new sedimentary basins have been intensely explored and produced (Figure 1). The exploration of oil and gas activities is only limited in the tertiary sediments in the western Indonesia areas. This can be explained further that the hydrocarbons exploration target in the basins is mainly focused on the main oldest structure of the traps in the sediments of the Early Miocene age, ca ± 20 million years (Figure 2), while the exploration for older sediments has not been intensely done yet.

The oil and gas exploration activities are very important activities in the oil and gas industry and these activities includes all activities in discovering hydrocarbon within the basin. In general it can be said that the oil and gas exploration activities can be grouped into activities that require solid support of technologies that involves the natural phenomena. The activities mainly involve a lot of various disciplines in geosciences such as geology, geophysics, geochemistry and biostratigraphy, of which they are all related each other for the optimal results.

Another problem is the decreasing of the oil or gas production in some basins which will affect the

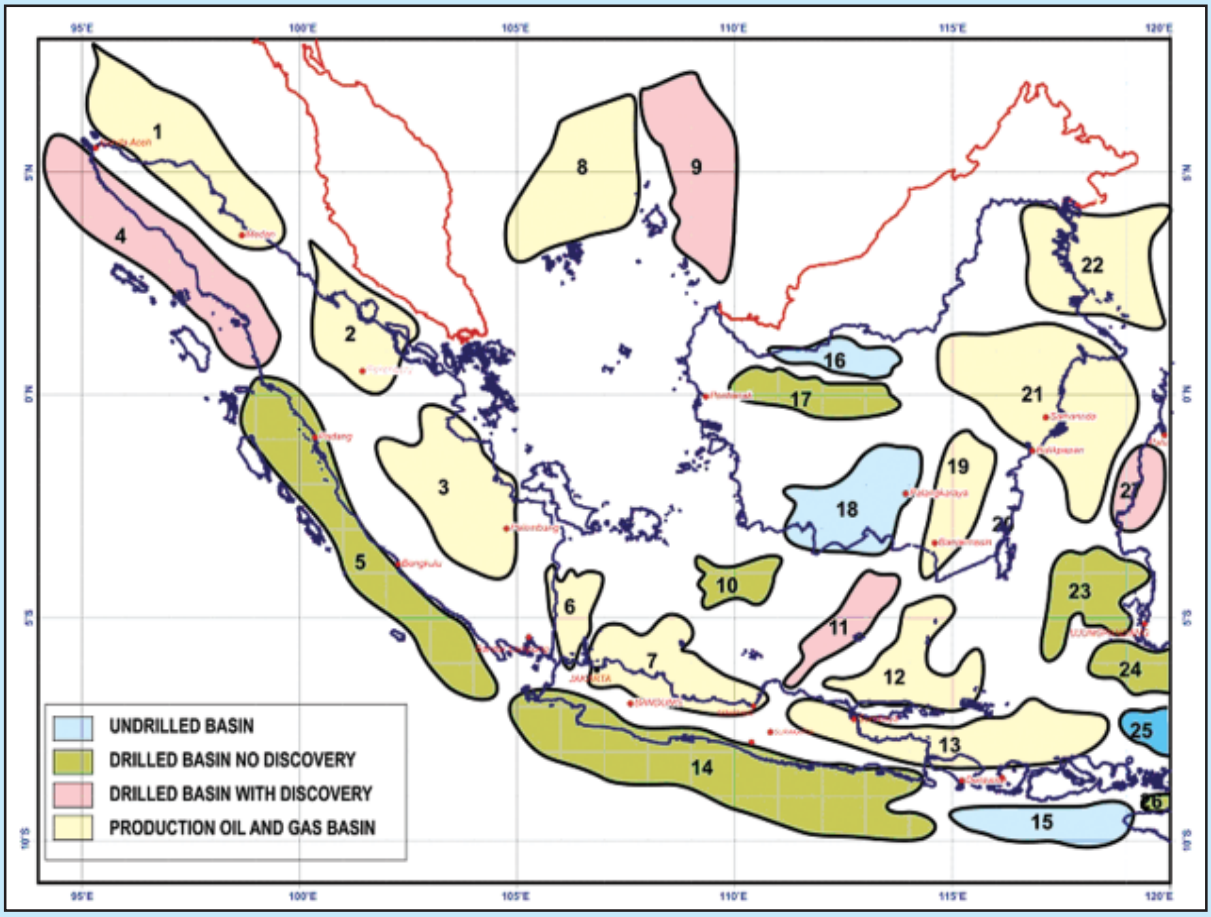

Figure 1
Sedimentary basin map of the western Indonesian region (Lemigas,2004)

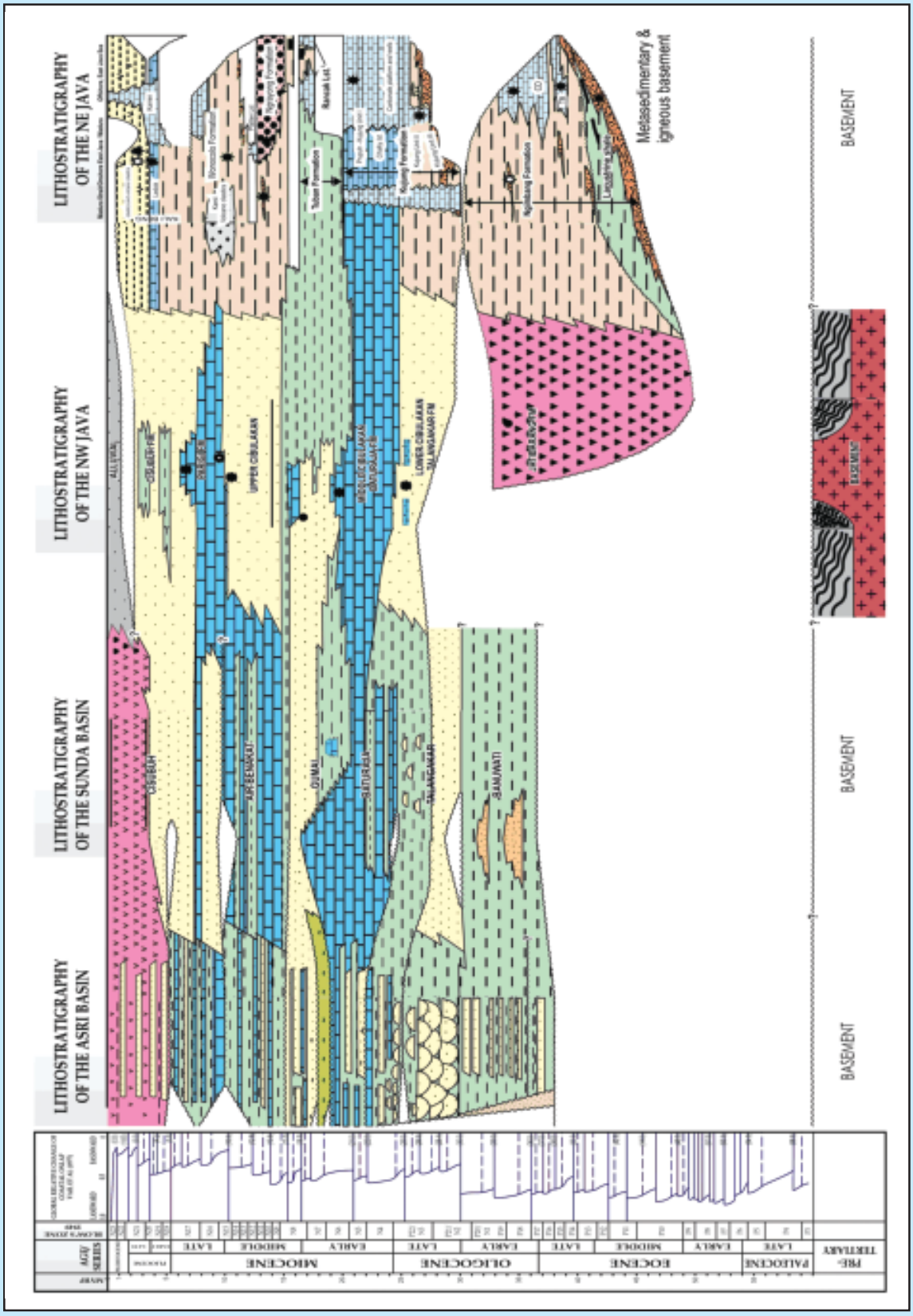

Figure 2.
Chronostratigraphy scheme of the western part of Back-arc Java basin (Lemigas,2004)

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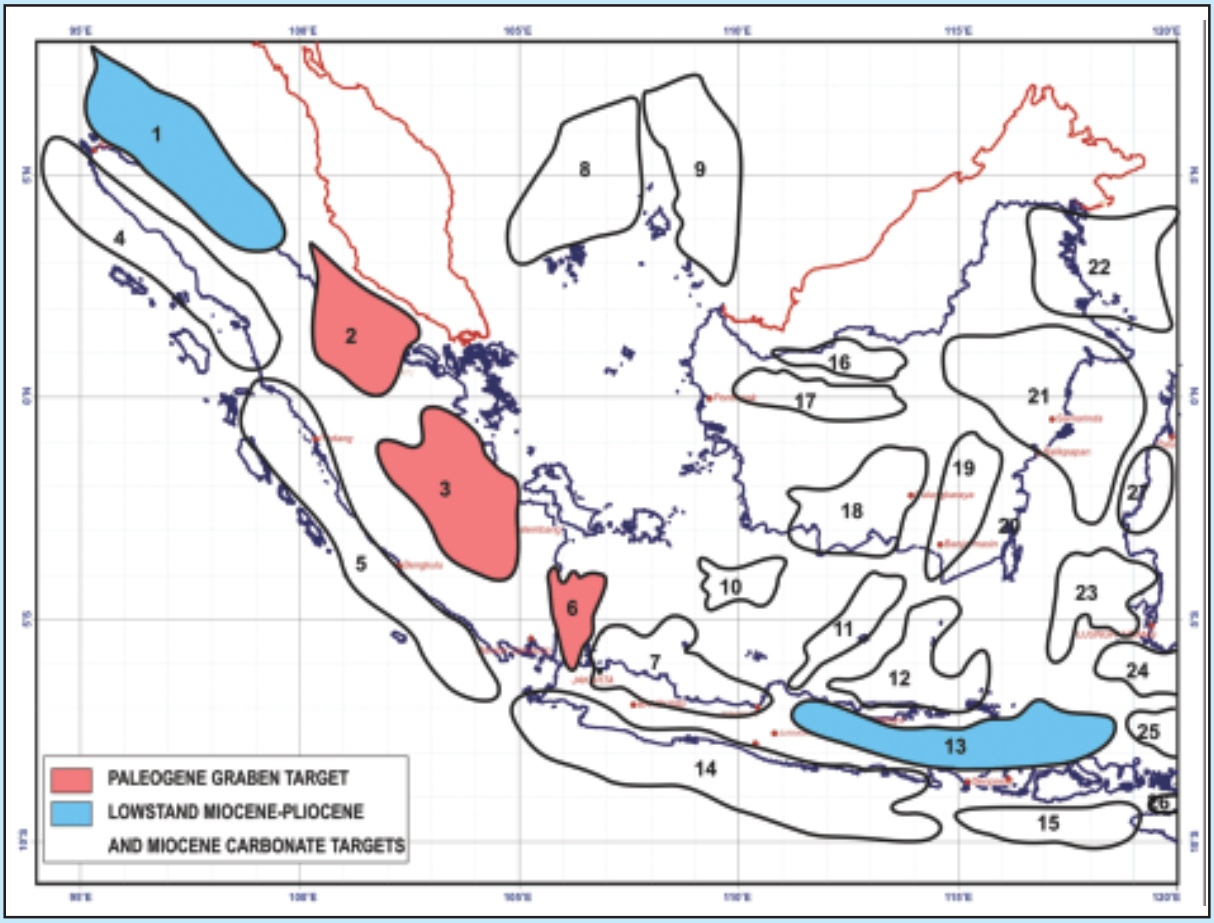

Figure 3
Re-analysis targets for finding additional oil and gas resources

country main incomes. Meanwhile, the effort in finding new oil and gas resources over two decades is relatively more difficult. Hence a dilemma happens, on one hand the oil production tends to decrease, on the other hand the addition of oil and gas reserves by discovering new resources is getting more difficult.

Some problems which may cause the difficulty in finding new oil and gas resources, among others, because of:

- The lack of innovation in the exploration activity in the mature sedimentary basins, of which the exploration is only focused on the target or objective of the reservoir that is known, and generally not older than Early Miocene.
- The implementation of the new exploration concepts that is used is relatively far behind to be compared with that used in other areas in the world.

III. RE-ANALYSIS OF THE MATURE SEDIMENTARY BASIN OF THE WEST ERN INDONESIA AREA FOR FINDING NEW RESOURCES IN THE FUTURE

The problems faced in the oil and gas industry is the increasing difficulty to find new oil and gas resources in Indonesia. Statistically, discoveries of approximately 90% of new resources in the period between 1990-1998 are gas, while hitting oil is relatively small. The situation is slightly improved with the discovery of new oil resources in the three locations, namely in the Makassar Strait by Unocal, in Cepu by EMOI, and in Natuna by Conoco. Those findings which are expected to increase the Indonesian oil production around 300,000 barrels per day are discoveries of the new hydrocarbon plays in the area.

Some obstacles encountered by the oil and gas

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industry at this time that are difficult in discovering hydrocarbon resources in the sedimentary basin in Indonesia. Thus means that the overall challenges faced by oil and gas industry are to intensify the exploration activities in the tertiary sedimentary basins to find oil resources. To anticipate the effort in discovering new resources in the future, it is proposed to re-visit the mature tertiary sedimentary basins in the basin which have been proved to contain hydrocarbons. The purpose and intention of re-analyzing are to better understand the evolution and the development of the basins related to the petroleum system. By understanding the system, it is expected that there will be opportunities to find new hydrocarbon resources within the play in the basin. Some of the activities proposed in the re-analysis are (Figure 3):

1. To evaluate the Paleogene graben system
2. To analyze the Lowstand Miocene-Pliocene sedimentation.
3. To evaluate the tertiary carbonate rocks.

A. *Evaluation of the Paleogene graben system*

Although the history of oil and gas exploration activities in Indonesia has already been more than 100 years, the geological knowledge about the Paleogene graben system whose geological age older than 25 million years old is very limited. The exploration target in the Paleogene graben is relative deeper to be compared with the previous target and too risky to be done. The lack of not geologically understand about the system completely is the main reason of all of the limitations. The problems encountered in conducting such study is about the time and mechanism of the development of the system; whether it was formed in the Eocene or Late Oligocene; or was it happened due two pulling, i.e. first in the Eocene time and second in the Oligocene time. The difference in the pulling phase controlled the development of the system which will influence the deposition process of the sedimentation filling into the graben. Another possibility is that systems, the Eocene and the Oligocene graben systems were overlapping each other. Furthermore, another geological problem that has not been known is the possibility of the development of the graben systems of fore-arc of Sumatra and Java. It was interpreted that the system is located in the same tectonic setting with that found in the back-arc area which may increase the level of trust in the availability of a hydrocarbon kitchen which can ensure the investor's interest in the oil and gas to operate in this area.

Some considerations in proposing to do a deep geological study of the Paleogene graben system are:

1. The availability of the hydrocarbon source rocks

The source rock potential of the Paleogene graben system is already proven in some sedimentary basins in the western area of Indonesia, for example in the Central Sumatra basin, and in the Arjuna Subbasin in the offshore area of West Java. The development of the knowledge of the Paleogene source rock in the basin will be a help in solving the mystery of the hydrocarbon forming kitchen in some other tertiary basins in Indonesia. In addition it will also help in reconstructing or revising the petroleum system in the basins.

From the results of the evaluation conducted in several sedimentary basins in Sumatra showed that the hydrocarbons source rocks is derived from the lacustrine sedimentation; as an example that the brown shale of the Pematang Formation found in the Central Sumatra basin was formed in the Eocene graben system (Figure 4). Two types of organic facies of Pematang brown shale can be identified, namely the *algal-amorphous* facies and the carbonaceous facies (BPPKA Pertamina, 1996). The algal amorphous facies is interpreted as the oil producing source rock, while the carbonaceous facies is likely to produce gas and condensate.

Unlike the Eocene lacustrine sediments, the potential of the source rock that might be formed on the Oligo-Miocene graben system; as well as in the South Sumatra basin, is interpreted derived from the sea transition sediment which is equivalent with the Talangakar Formation (Lemigas, 2001).

2. The reservoir rock

The paleo-geographical reconstruction of the Paleogene graben system shows that the sedimentation process during Eocene, which is especially dominated by the continent deposit, in the form of fluvial and alluvial fan deposits. These deposits can be potentially act as reservoir rocks that can be used as one of the hydrocarbons exploration target activity in the future (Yulihanto, 1992) . Two (2) models of the reservoir rock that can be developed in the Eocene graben system, such as:

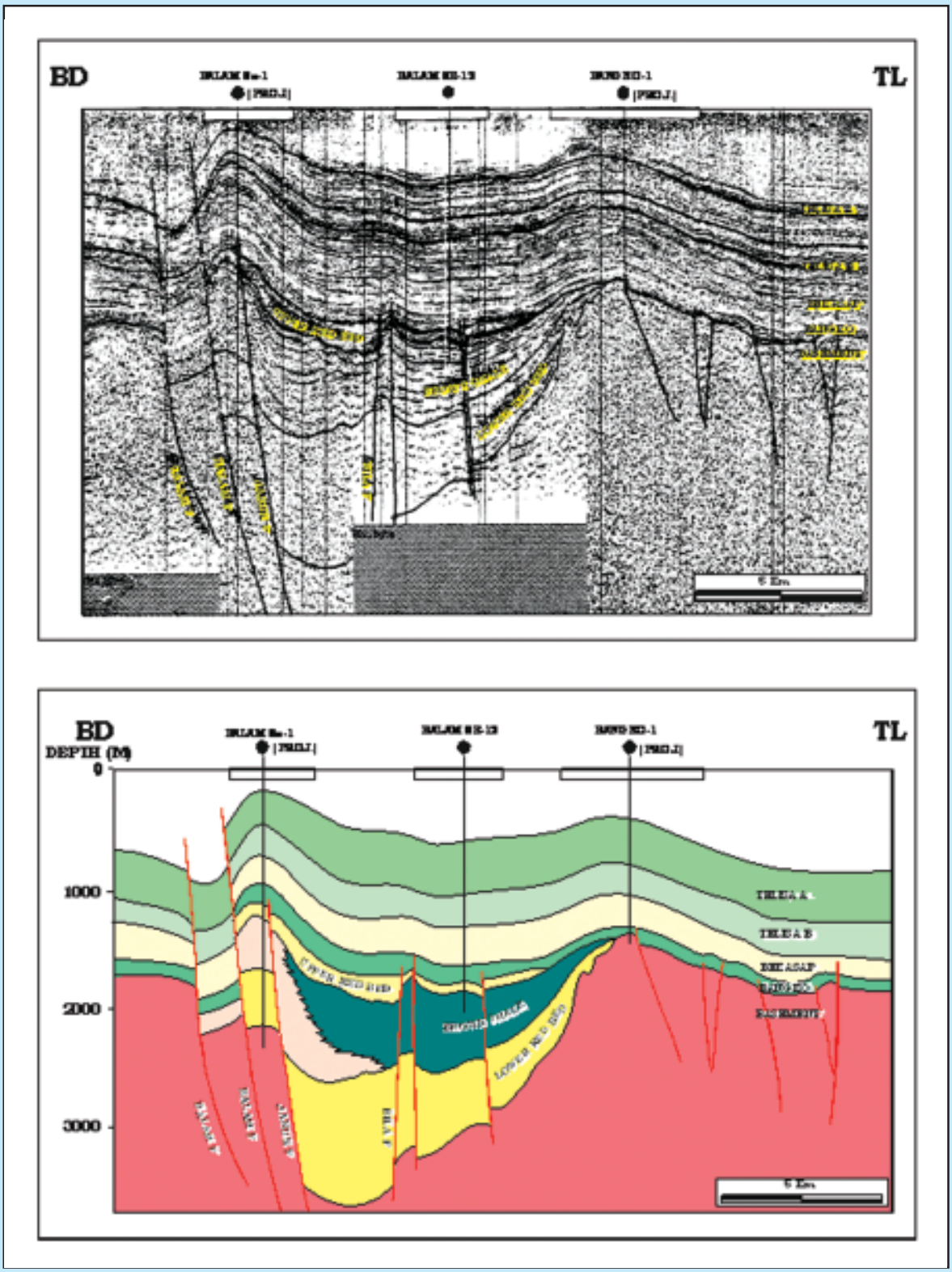

Figure 4
Geological profile of the Paleogene graben system in the Central Sumatra (IPA, 1994)

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- Type A: half graben with the continental interior drainage, of which the side of the hanging wall is generally dominated by coarse clastic of deltaic fan sediment, and toward the center of the deposition of the system the facies change into fine clastic lacustrine sediment. On the foot-wall side, it is dominated by fan alluvial sediment (Leeder & Gawthorpe, 1987).
- Type B: continental half-graben with axial drainage trough, of which the side of the hanging wall is mainly dominated by the fluvial deposit which was flowing and deposited in the direction of the direction of the Paleogene main fault system. Similar to the Type-A, on the foot-wall side is also dominated by the alluvial fan deposit.

In the Oligo-Miocene graben system, it is interpreted that the transition deltaic deposit will be more developed, and the deposition was ended by a carbonate layer. The deposition model of carbonate rocks in Paleogene graben system is the *half-graben carbonate shelf*. In this model it can be seen that the limestone which is one of the potential reservoir rock will be developed on both fault sides.

Thus it can be concluded that the hydrocarbon explorations in the future should be primarily directed to find reservoir rocks of fluvial deposit type which was formed during the early phase of the development of the Eocene graben system, and the carbonate deposition of the limestone which was formed on the Oligo-Miocene graben.

3. The availability of seal rocks and the hydrocarbon traps

Another factor in the hydrocarbons exploration activities which is attractive in the Paleogene graben system is the availability of the seal-rocks, which seals the hydrocarbons in the reservoirs not to migrate to the surface. The main available seal in the Eocene graben system is the fine sediment of the lacustrine deposition. It's also found the existence of a shale deposition of Early Miocene which can act as a regional seal rock of the reservoir in the Paleogene graben system.

B. The evaluation of lowstand Miocene-Pliocene sediment

The development of the concept of sequence stratigraphy in the analysis of a sedimentary basin can be mainly directed to the evaluation of the possibility of the lowstand deposits of the Miocene-Pliocene sediments in Indonesia. The analysis is proposed to be considered as one of the activities of the hydrocarbons exploration target in the effort of finding new oil and gas resources in the future, by means of finding new hydrocarbon plays in the sedimentary basins.

The forming of lowstands deposits are generally close by related to the fast regression period of the sea level in a sedimentary basin. In the western area of Indonesia the occurrence of the sea level lowstand was closely related to the tectonic inversions of the basin which are varied from one basin to another. The inversion was started at the end of Lower Miocene (Yulihanto, 1989 & 1991), ca 20 million years, until Plio-Pleistocene. The sea level regression caused the erosion outcropped in some areas in the basin, and further of the coarse clastic sediment will be deposited back to the basin as lowstand sediment deposit. In the evaluation of hydrocarbon potential in a basin, the lowstand sediment may act as a quite good reservoir rock.

The result of a detailed study of sequence stratigraphy that was done in the North Sumatra basin (Yulihanto, 1991), and the North East Java basin (Yulihanto, 1993) show that there are at least three periods of times which might developed the lowstand sediment during Upper Tertiary, ie. in the Middle Miocene, in the Upper Miocene and in the Pliocene, which were related to the big sea level tide during that time.

The forming of the lowstand deposits of Middle Miocene were interpreted to be close by related to the sea level regression during that period. An example of this lowstand Middle Miocene is the Middle Baong Sands deposit which is found in the North Sumatra basin (Yulihanto 1989).

Lowstand deposits of Late Miocene are also observed in the North East Java basin, of which the deposition was close by related to the sea level regression during Late Miocene about 5 MY ago. The deposits are equivalent to the carbonaceous sands of the Ledok Formation (Figure 5), whereas the lowstand deposits of Pliocene is equivalent to globigerina sands (Figure 6).

The important thing which is related to the lowstand deposition is the forming of the incised val-

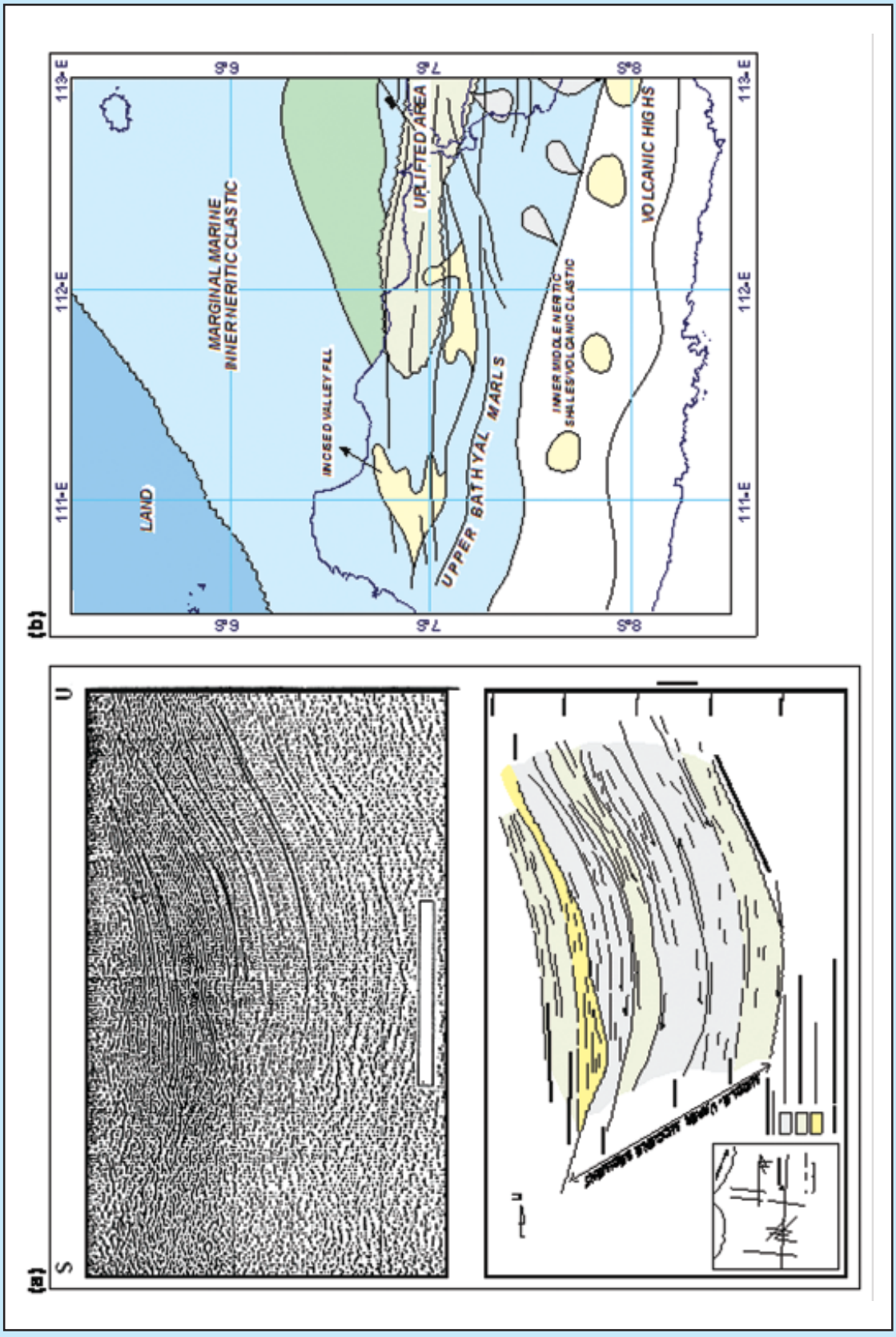

Figure 5
N-S trending seismic section showing the incised valley
(a) Paleogeographic map of the Late Miocene in the East Java (b) (Yulihanto, B, 1993)

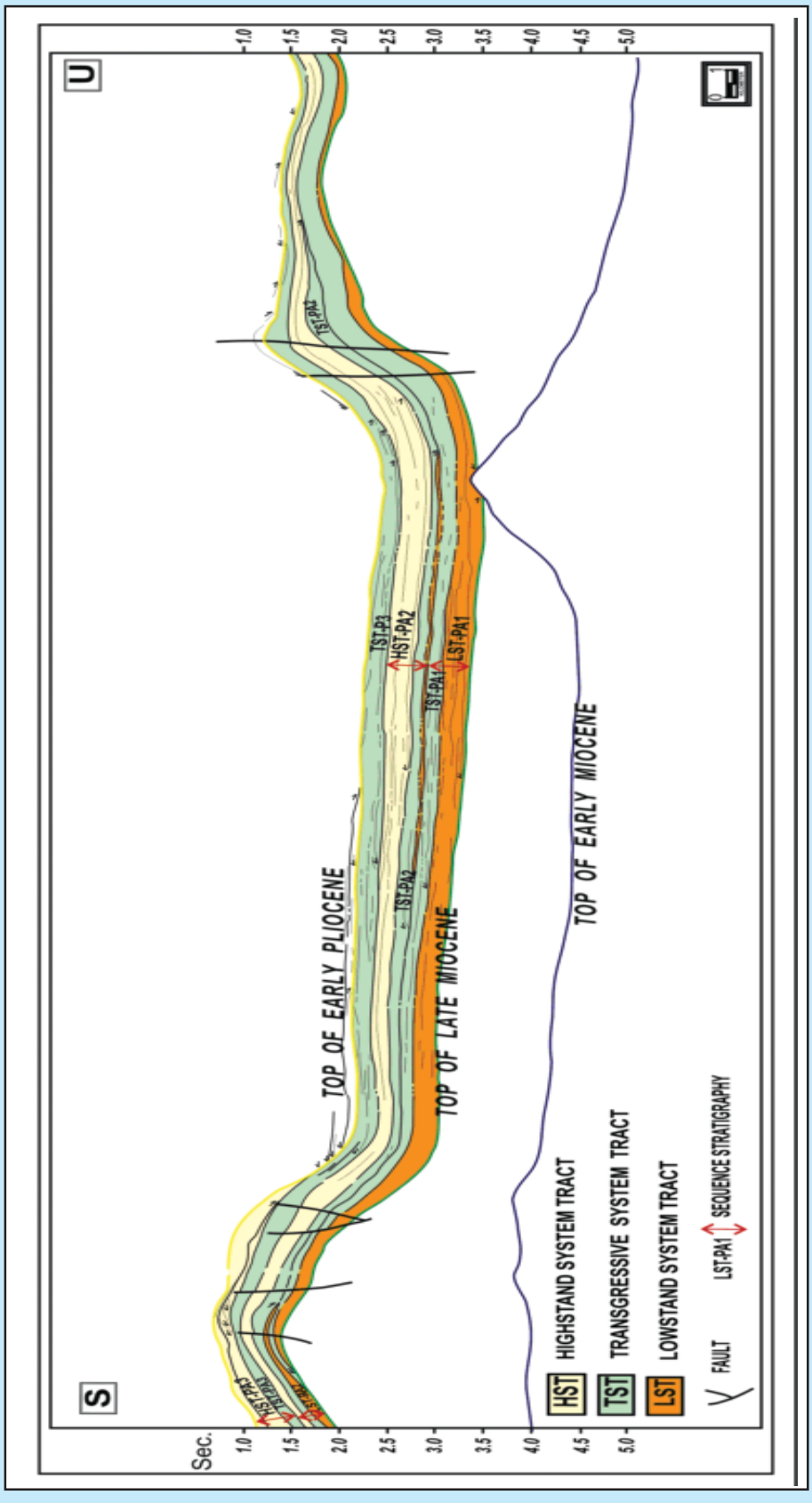

Figure 6
A N-S seismic section showing the Early Pliocene lowstand deposits.(Lemigas, 2004)

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ley which was filled with clastic coarse sediments, as can be observed in the North East Java basin (Yulihanto, 1993) (Figure 5), and in the North Sumatra basin (Yulihanto, 1989). The existence of the valley incision, as a result of the process of erosion is also an exploration target in the future. This is because the incised valley which is filled by the coarse clastic sediments is interpreted as a place for the hydrocarbon accumulation.

The tectonic inversion was occurred in the western region of Indonesia during Late Miocene to Pliocene, about 5-10 MY ago, as well as a control of the maturation process of hydrocarbons in the basins, Thus, in the oil and gas exploration activities in the future required a thorough analysis on the relationship among the tectonic inversion, the process development of the lowstand deposits, the forming and the trapping of hydrocarbons. Another factor that should be considered in the analysis is that the occurrence of the tectonic inversion in some basins occured several times, which results the hydrocarbon migration from a structure to another due to the re-structuring of the tectonic. Hydrocarbons could also migrate to the surface through fractures which cannot be trapped.

C. *Evaluation of the Miocene carbonate*

The information about the characteristics of Miocene carbonate rocks in Indonesia is very limited, although in some basins the carbonate reservoir has been proved as one of quite large hydrocarbon producers in Indonesia, for example: the Arun Gas Field in the North Sumatra basin, and in the Banyuurip Field in the North East Java basin.

Detailed analysis of carbonate rocks may help in understanding the development of carbonate rocks in the Tertiary sedimentary basin in Indonesia. The results of the analysis on the carbonate rock in the basin include the characteristic of the sedimentation model, the facies distribution which would help in the effort of finding other reservoir carbonate rocks in Indonesia.

Some targets of the carbonate rock study in Indonesia are the deposition of the Oligocene-Lower Miocene limestone. This sediment is spread out in almost all sedimentary basins in the western regions of Indonesia, such as the Peutu Formation in the North Sumatra basin, the Baturaja Formation in the South Sumatra basin, the Berai Formation in the Barito basin of Kalimantan, and the Kujung Unit-1 Formation in the North East Java basin which is equivalent to that found in the Banyuurip-1 and Mudi-1 wells. In addition, this analysis also focused on the carbonate deposition of Upper Middle Miocene age, as well as the Parigi Formation which is widespread in the South Sumatra basin and North West Java basin.

IV. STRATEGY OF THE OIL AND GAS EXPLORATION IN THE FUTURE

In the effort of finding new hydrocarbons resources in the future, a reanalysis of mature Tertiary sedimentary basins in the western region of Indonesia is a very essential to be done in the near future. A consideration that can be used as a notice in implementing the analysis is to perform an integrated reanalysis in order to achieve the optimum results. The study can be done together between the oil companies (PSC/Pertamina), who operates in the basin, coordinated by a national R&D institution of oil and gas.

The beneficial of these joint activities are:

- The geological problems that faced by each operating oil company in this area can be solved together by using an accepted geosciences concept that has been agreed to be used
- The geological problems can be solved by a sophisticated technology which is applied together in the sedimentary basins.
- The geological understanding of the basin will be regionally better rather than a small-scale of each operating area of the PSCs.
- The financial problems in conducting such study can be funded together.

In addition to achieve the maximum results an agreement on the use of the data used in this study is required. The use of data for the study will be very helpful in solving geological problems; however, the confidentiality of data must be kept fixed in the sense that the data is only used during the study.

V. CONCLUSION

1. The new oil and gas discoveries (especially oil) in the last two decades are more difficult.
2. An intensive exploration activity is one of the efforts to maintain the oil production rate in the future, by means of an integrated reanalysis of the

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Tertiary mature sedimentary basins in the western area of Indonesia.

3. The recommended reanalysis activities is as follows:

- The evaluation of the Paleogene graben system
- The analysis of the Miocene-Pliocene lowstand deposition
- The evaluation of Tertiary carbonate rocks

4. To achieve the maximum results of the reanalysis this should be done in an integrated way, using good data and the sophisticated technology. It is also recommended to involve the national R&D of oil and gas institutions.

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