

PALAEOENVIRONMENTS OF THE PERMIAN-CRETACEOUS SEDIMENTS OF THE BINTUNI BAY, PAPUA

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ABSTRACT

This paper presents a part of the result of Lemigas in-house research entitled Paleogeography and Hydrocarbon Potentiality of the pre-Tertiary Sediment of the Bintuni Basin, Papua, which is financially supported by the Government through a project so called DIPA 2009. In addition, this paper specifically discusses a palaeoenvironment of the Late Permian-Cretaceous sediment of the Bintuni Bay based on biostratigraphy. Data used in this paper is mostly secondary data obtained from National Data Center and an oil company which is therefore, classified as a confidential information.

Paleoenvironment appeared in a non-marine setting during Permian-Triassic to form Ainim Formation in which, shale of this formation acts as a primary sourcerock for the studied area. Early Jurassic is characterised by a non-deposition, whilst Middle Jurassic is indicated by the occurrence of non-marine environment to deposit fluvial sandstone of the Lower Kembelangan Formation which is considered to be a main reservoir. Subsequently, environment shifted to the marine setting where deep marine shale occurred to form caprock. Mean while, the Early Cretaceous sediment disappears from the studied area suggesting massive erosion. Finally, depositional environment took place in the marine setting during the Late Cretaceous resulting in the formation of deep marine shale of Jass Formation which may contribute as a caprock in the element of petroleum system.

Key words: Palaeoenvironments, Permian-Cretaceous, Bintuni Bay.

I. INTRODUCTION

This study is a part of the investigation on pre-Tertiary sediment of the Bintuni Basin conducted by LEMIGAS Stratigraphy Group. This study is funded by the Government through a research projects called DIPA which was conducted in 2009. This in-house research entitles Paleogeography and Hydrocarbon Potential of the pre-Tertiary Sediment of the Bintuni Basin, Papua. The area of study is situated in the southern part of the Bintuni Basin covering on-shore and off-shore area. Data used in this study is mostly secondary data which was provided by some service companies. It consists of biostratigraphic data including foraminiferal, nannoplankton and palynological reports of several well sections.

Paleogeography/ paleoenvironment and hydrocarbon potentiality of the pre-Tertiary sediment of the Bird's head of Papua are poorly understood due to lack of investigation. The knowledge of paleogeography is useful for guiding geologists to define prospect area of the future exploration because it represents lateral succession of homo-chronological fenced space which shows lateral facies changes.

Stratigraphy means vertical succession of heterochronological events. In this case, events can be defined as biotic and non biotic events. The Biotic events may include base of datum, top of datum, peak abundance and discontinuity of abundance. Meanwhile, non biotic events may consist of seismic reflection events, well-log events, base and top of lithological

events, anoxic events, tectonic events, transgressive surface, flooding surface, maximum flooding surface, marker beds, thin marine deposit, siderites bearing deposits, coal seam and climatic events (Soeka, 2007).

Unlike stratigraphy, paleoenvironment basically represents lateral succession of homo-chronological fenced space. This means that in the same time, paleoenvironment may change laterally which results in the occurrence of lateral facies change (Soeka, 2007). In fact, this change will associate with horizontal lithological distribution which contributes to the appearance of the petroleum system elements. It is well known that the coarse clastics of the deltaic sediment and shallow marine deposit are favourable for hydrocarbon accumulation. On the other hand, fine clastics of the deltaic succession and distal marine deposit yielding rich organic material may act as sourcerock if this is combined with sufficient gradient geothermal.

The paleoenvironment reconstruction covers the area of Bintuni Bay in the bird's head of Papua (Figure 1). This paper is aimed to figure out the paleoenvironments which occurred during Perm to Cretaceous.

II. DATA AVAILABILITY

Data obtained from the area of study was generated from subsurface (well) samples which were provided by oil companies. Therefore, this data is then considered to be confidential.

It must be noted that this study only refers to the existing biostratigraphic data produced by the service companies. This study does not involve re-analysing new samples from the studied areas.

LEMIGAS has been mostly concentrating on Tertiary research. Only limited research was conducted on pre Tertiary successions. This results in inadequate experience of analyzing pre-Ter-

tiary biostratigraphy. Having these situations, this work relies on secondary biostratigraphic data provided by service companies. For the purpose of confidentiality, this paper hardly reveals detail information of the data such as well name, well location, operator, etc.

III. METHOD

In this study, the paleoenvironmental interpretation is based on the following aspects:

- For marine environment refers to the composition of the benthonic foraminiferal assemblages which is supported by the occurrence of planktonic foraminifera, calcareous nannoplankton and other fossils such as coral and gastropod.
- For non-marine and transitional environments refer to palynological assemblages. It is supported by:
- Lithological data and the occurrence of selected minerals such as coal, siderite, pyrite, glauconitic, calcite and gypsum.
- The wireline log pattern and seismic facies.

Marine paleoenvironmental classification refers to the combined classification of Tipsword et al (1966) and Ingle (1980) as shown in Figure 2.



Figure 1
Location map of the studied area

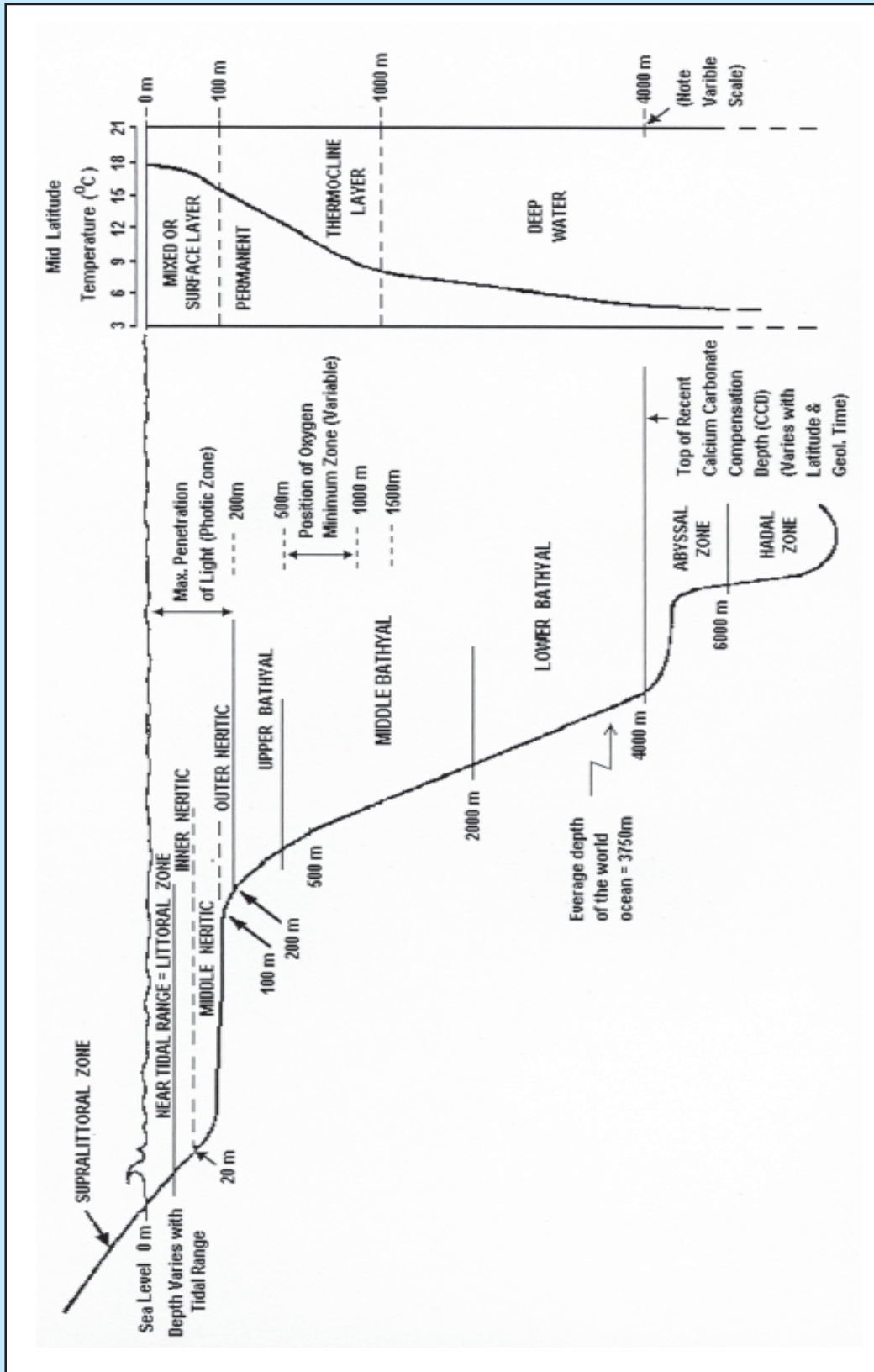


Figure 2
 Classification of Benthonic Marine Environment based on the compilation of that by Tipsword
 et. al. (1966) and Ingle (1980)

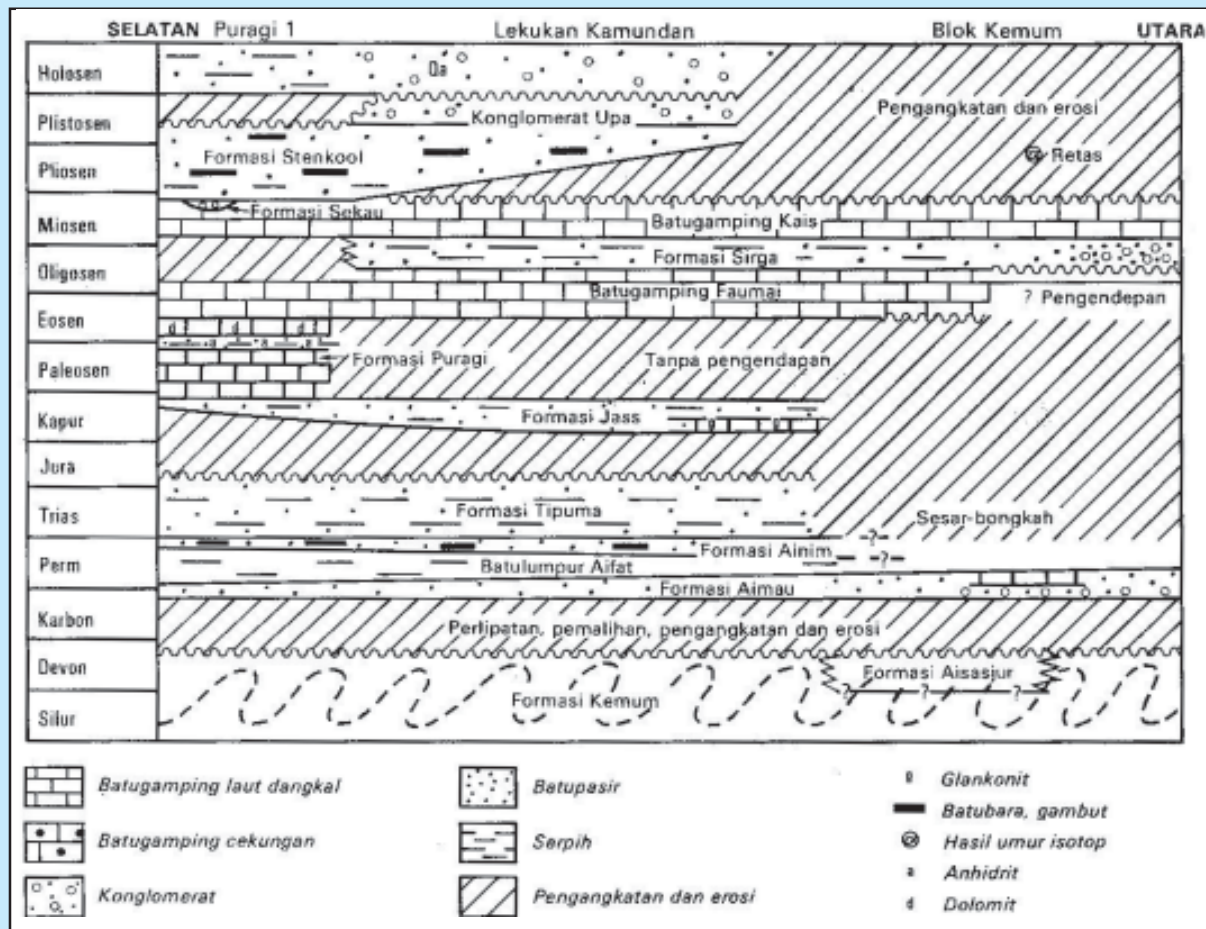


Figure 3
Stratigraphic coloumn of the area of study (Poetro et al., 1990)

This study defines biostratigraphy of the pre-Tertiary sediments occurring in the provided wells. This will be the basic of the biostratigraphic correlation which connects the sediments with the same age across the studied wells. Once the biostratigraphic correlation is constructed, the paleoenvironment appearing in each age can be defined throughout the Bintuni Bay. Detail biostratigraphy of the studied wells is presented on the project report (Lelono et al., 2009).

IV. STRATIGRAPHY OF THE STUDIED AREA

According to Center of Geological Survey (Pusat Survey Geologi/ PSG), the pre-Tertiary successions occurring in the area of study consist of (from older to younger) Kemum Formation, Aisasjur Formation,

Aimau Formation, Aifat Formation, Ainim Formation, Tipuma Formation and Jass Formation as seen in Figure 3 (Poetro et al., 1990).

The Kemum Formation is the oldest pre-Tertiary sediment in the area of study consisting of dark slate, phyllite, metamorphic greywacke, semi-metamorphic sandstone, quartzite and conglomerate with various metamorphic grains. It is interpreted that this formation was formed during Silurian-Devonian in the marine environment with turbiditic current. The Kemum Formation is inter-fingering with the Aisasjur Formation, in which both formations are overlain by the Late Carbonaceous-Early Permian Aimau Formation.

The Aisasjur Formation is composed of feldspathic-micaceous greywacke, micaceous sandstone, siltstone, black shale and slate. This formation dif-

fers from the Kemum Formation due to the occurrence of coarse and rich feldspar and muscovite. The Aisasjur Formation hardly contains micro-fossil. However, based on its inter-fingering relation with the upper Kemum Formation, it is assumed that the age of the Aisasjur Formation is Devon. This formation is predicted to represent proximal turbidite which was deposited in marine environment shallower than that of the Kemum Formation.

The Aimau Formation was unconformably deposited over the Kemum and Aisasjur Formations. It consists of red oligomictic basal conglomerate, white sandstone, black sandy shale, light green micaceous sandstone, greywacke and the intercalation of greyish limestone and argillite. The Aimau Formation is predicted to have thickness of 1200 m. It is well known to yield abundant fossils including corals, pelecypods, fusulinids and conodonts, This formation might have been deposited in the shallow marine environment (closed to shoreline) during Late Carboniferous to Early Permian.

The Aimau Formation is conformably overlain by the Aifat Formation which consists of black mudstone with calcareous lithology and fine lamination, thin laminating marl, sandy limestone and rare quartz sandstone with thin lamination (2-3 cm). The Aifat Formation yields abundant crinoids, bryozoa, coral, fusulinid, pelecypod, brachiopod and cephalopod, indicating shallow marine environment. The maximum thickness of the Aifat Formation is about 700 m. It is interpreted that the age of this formation is Early-Late Permian. The Aifat Formation is conformably overlain by the Ainim Formation.

The Ainim Formation is composed of carbonaceous silty shale, quartz greywacke sandstone, siltstone and thin coal seams (about 1 m). This formation achieves more or less 750 m thick. The Ainim Formation is defined to be formed during Late Permian which is conformably overlain by the Tipuma Formation.

The Tipuma Formation is assumed to be deposited during Triassic-Early Jurassic age. This formation consists of silty claystone to claystone with green to red colour and thick layers, quartz greywacke and unconsolidated sandstone. Due to the absence of fossil, the age of this formation is based on its stratigraphic position which is situated above the Ainim Formation. The thickness of the Tipuma Formation is

approximately 300 m. This formation is unconformably overlain by the Jass Formation.

The Jass Formation is the youngest pre-Tertiary succession in the area of study which was formed during Middle-Late Cretaceous. This formation is composed of black-brown calcareous mudstone with thin-thick lamination, greenish grey-brown sandstone, marl with high content of glauconite and sandy limestone with 2-5 m thick. It contains belemnite and ammonite which are abundant in the lower formation. Planktonic foraminifera of *Globotruncana* spp. is also found within this formation. It is interpreted that the Jass Formation was deposited in the shallow water environment. The Tipuma Formation possibly exceeds 400 m thick.

V. PALEOENVIRONMENTAL INTERPRETATION

Based on biostratigraphic analysis and paleoenvironmental interpretation, the stratigraphic correlation of the studied wells can be constructed as shown in Figure 4. The paleoenvironment of the area of study is separated into five age units including Permian-Triassic, Middle Jura, Late Jura, Early Cretaceous and Late Cretaceous.

A. Permian-Triassic paleoenvironment

The Permian-Triassic sediment is absent in O-1 well which may be caused by the erosion. This data may also indicate the occurrence of non-marine environment. Meanwhile, the Permian-Triassic sediments appear in the W-4 and A-2 wells which were formed in supra-littoral environment. The depositional environment is getting deeper toward western side of the study area as shown by the occurrence of littoral environment in R-1, W-1 and S-1 wells. The paleoenvironment continues to shift into deeper marine setting in neritic as proved in Vorwata-1 well (western side)

Overall, it can be concluded that the Permian-Triassic environment varies from non-marine (supra-littoral) to neritic environment. The supra-littoral environment is situated in the southern part of the study area spanning to western part (Figure 5). The environment gradually changes into deeper setting in littoral toward East. Finally, the paleoenvironment shifts into deeper marine in neritic environment in the eastern part of the study area. In fact, geochemical study on non-marine shale of Ainim Formation indicates

Figure 4
 Biostratigraphic and paleoenvironmental correlation of the studied wells.

rich in organic content. The basin modeling of the studied area shows the occurrence of sufficient thermal maturity throughout this formation. Therefore, it is inferred that the non-marine shale lithology is considered to be the primary sourcerock for this area.

B. Middle Jurassic paleoenvironment

Early Jurassic age is characterised by the absence of sedimentary succession which may indicate erosion throughout the study area. This may be caused by the up-lifting activity which emerges the Early Jurassic deposit above the sea.

In fact, most wells in the northern part of the study area hardly recover Middle Jurassic sediment as proved by the W-1, S-1, A-2 and M-1. The sediment may be removed by the erosion process. Meanwhile, it is possible that the disappearance of the Middle Jurassic deposit may be related to the occurrence of high area due to up-lifting as supported by the appearance of shallow marine environment within other wells such as the O-1, W-4, R-1 and V-1 wells (Figure 6). Paleoenvironment of the O-1 and W-4 wells is littoral which then changes into deeper setting in inner neritic toward the East (the R-1 well). The environment is getting deeper into shallow middle neritic (bathymetry of 20m-50m) toward Northeast (the V-1 well).

Overall, it can be concluded that the Middle Jurassic paleoenvironment shows some changes from non-marine environment in the Northwest into shallow marine environment (littoral, inner neritic and shallow middle neritic) in the Southeast. The occurrence of fluvial sandstone of the Tipuma/ Lower Kembelangan Formation acts as a main reservoir within the studied area (Hadipandoyo et. al., 2005).

C. Late Jurassic paleoenvironment

Interestingly, Late Jurassic paleoenvironment shows different pattern than the previous paleoenvironment. The deeper marine environments are situated in the North (on-shore) and in the South (off-shore). The deeper environments are separated by the shallower marine environment lying in the middle of these environments. It seems that the marine environment opens to the North and the South (Figure 7).

The environment of the W-1 well indicates littoral which is the shallowest environment along the

study area. The environment gets deeper toward Southeast as proved by the occurrence of outer neritic environment in the O-1 well. In addition, the littoral environment of the W-1 well changes into deeper marine setting Northeast ward as shown by the appearance of inner neritic in the R-1 and V-1 wells. The paleoenvironment keeps moving into deeper marine environment into outer neritic toward North as found in the S-1 well.

Having the above discussion, it can be summarised that the paleoenvironmental trend of Late Jura changes compared to that of Middle Jura. During Middle Jura, the depositional environment was getting deeper toward the Southeast which means that the basin was opened toward the Southeast. The basin orientation changed during Late Jura in which it was opened toward the North and the South (Figure 7).

D. Early Cretaceous paleoenvironment

Most Early Cretaceous successions disappear from the studied wells. These successions are only found in the A-2 and S-1 wells. This situation might be caused by extensive erosion which occurred during Early Cretaceous.

Based on foraminiferal analysis, the Early Cretaceous sediment was deposited in deep middle neritic (bathymetry of 50m-100m) to outer neritic (bathymetry of 100m-200m).

Due to limited occurrence of Early Cretaceous sediment, the paleoenvironment is only interpreted based on A-2 and S-1 wells which indicates deep middle neritic to outer neritic (Figure 8).

E. Late Cretaceous paleoenvironment

The Late Cretaceous age is dominated by marine sediment which was deposited in the various bathymetries. The shallow marine environment in the North changes into deep marine toward the South which then returns to shallower environment toward the South. It is shown that the depositional environment is getting shallower toward the North and the South (Figure 9).

The Late Cretaceous sediment of S. Ainim section indicates inner neritic to shallow middle neritic. This environment also occurs in A-2 and M-1 wells suggesting that inner neritic to shallow middle neritic is spread out across the Northern part of the studied area. The paleoenvironment gradually changes into

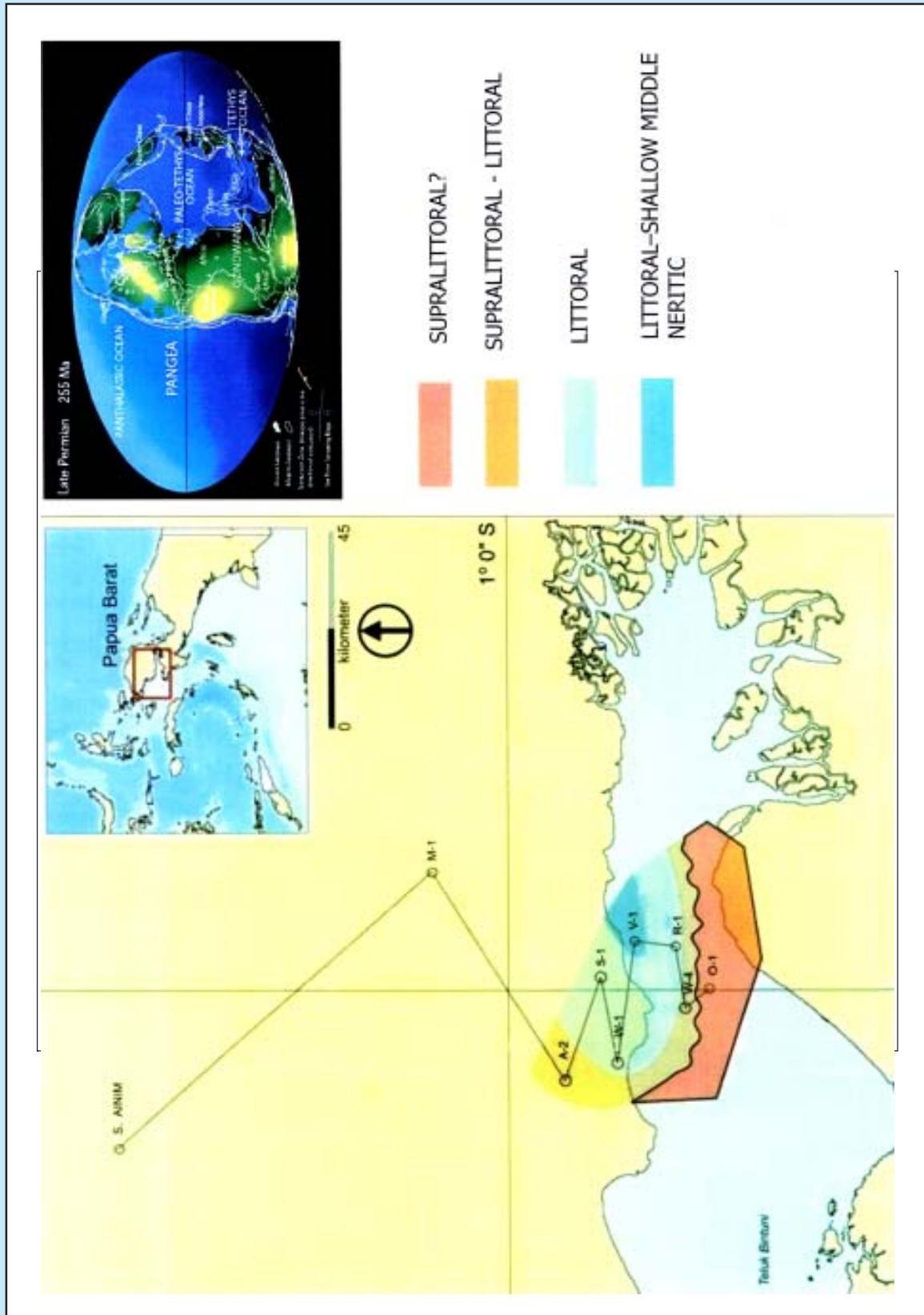


Figure 5
 Paleoenvironmental map of the Permian-Triassic age (255 Ma)

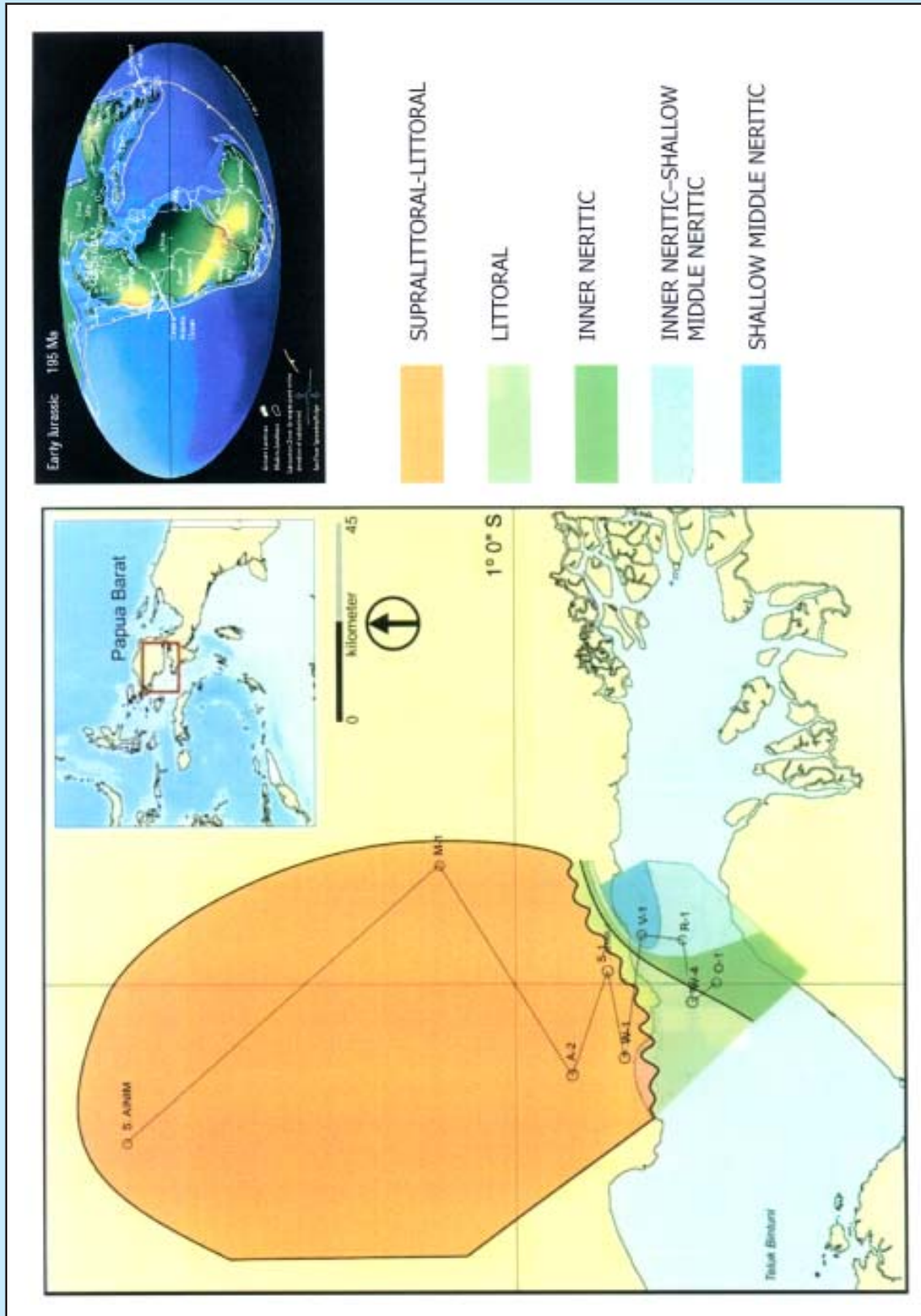


Figure 6
 Paleoenvironmental map of the Middle Jurassic age (161 Ma)

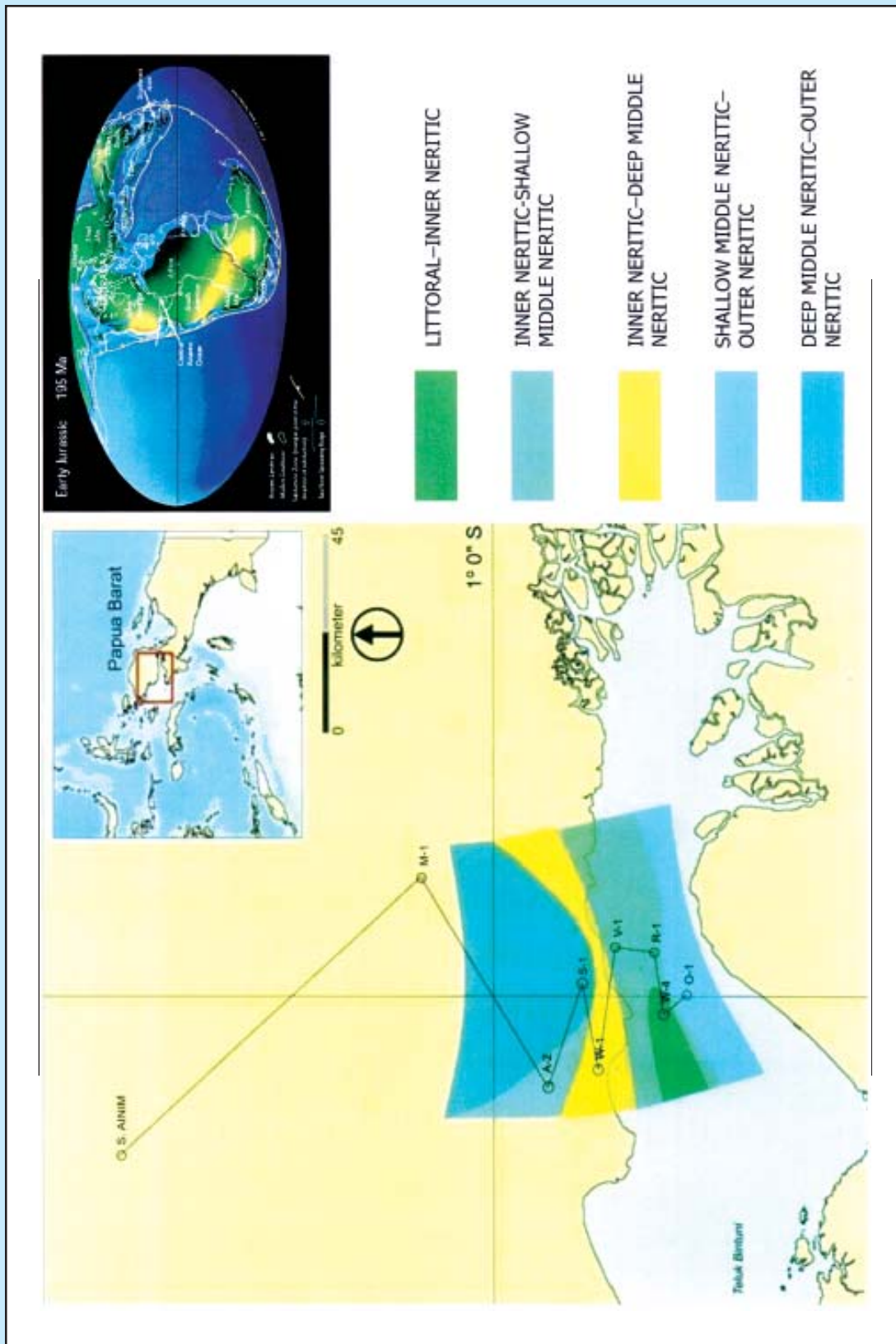


Figure 7
 Paleoenvironmental map of the Late Jurassic age (145.5 Ma)

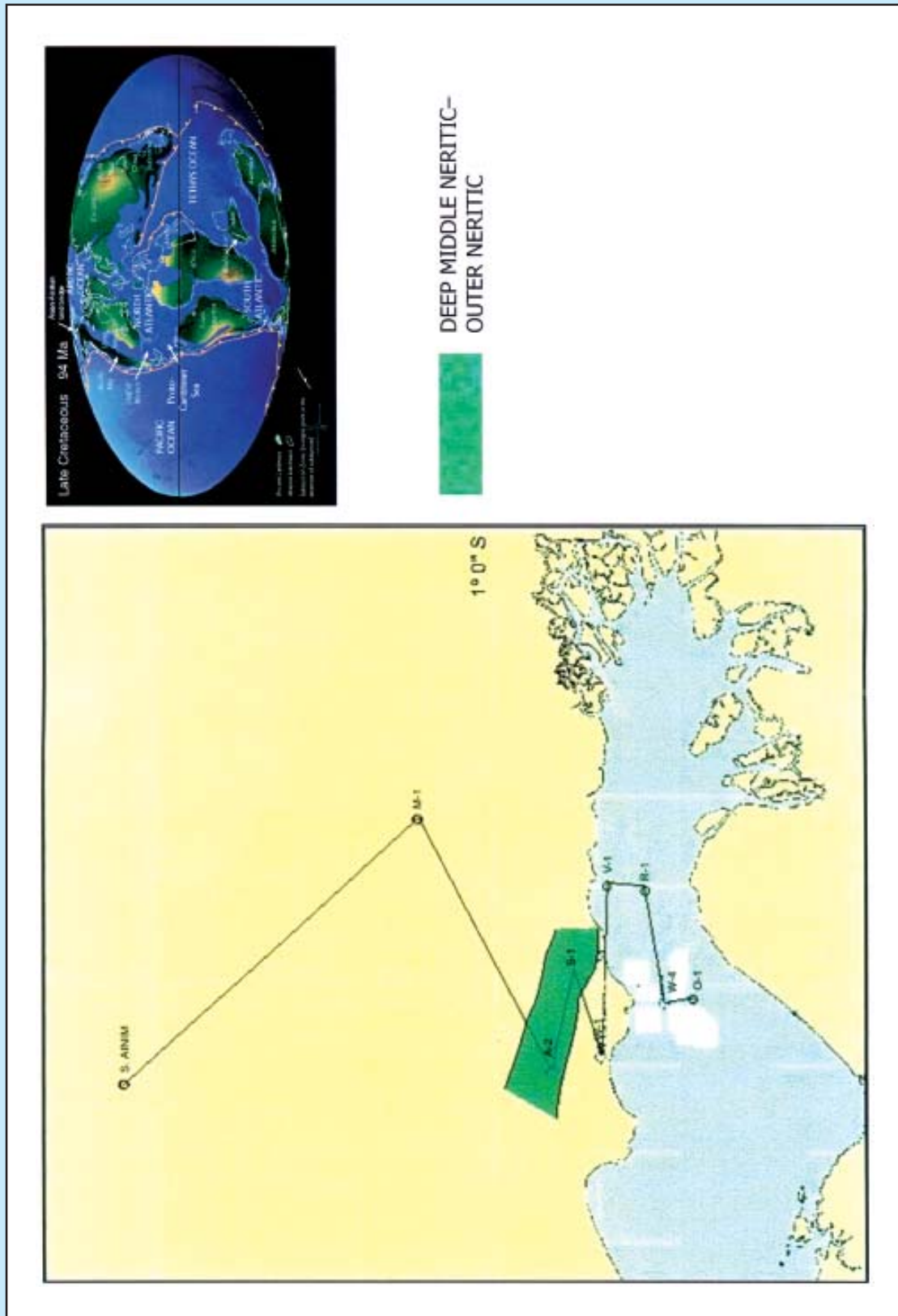


Figure 8
Paleoenvironmental map of the Early Cretaceous age (99.6 Ma)

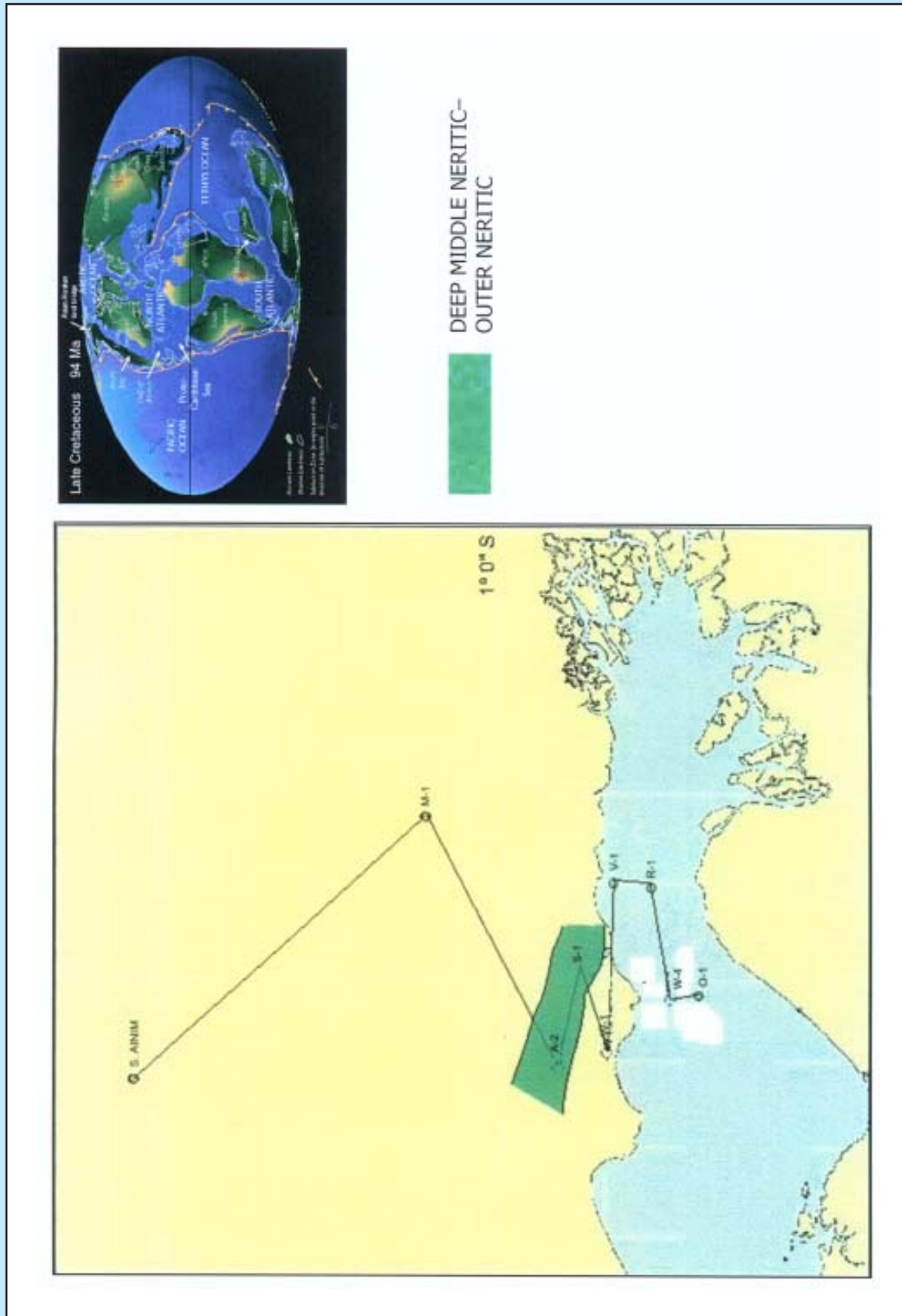


Figure 9
Paleoenvironmental map of the Late Cretaceous age (66 Ma)

deeper setting toward Southeast as suggested by the occurrence of outer neritic to upper bathyal environment in the S-1 and W-1 wells. Subsequently, the depositional environment keeps moving into deeper marine setting toward the Southeast as shown by the appearance of lower bathyal environment in the V-1 and W-4 wells. On the other hand, the depositional environment returns into shallower marine environment in outer neritic to upper bathyal toward Southeast as found in the O-1 and R-1 wells.

Referring to the above discussion, it can be inferred that the Late Cretaceous paleoenvironment varies from inner neritic to lower bathyal. The inner neritic to shallow middle neritic situated in the North (S. Ainim section, A-2 and M-1 wells) changes into deeper marine environment in outer neritic to upper bathyal toward southeast. In addition, the depositional environment gets deeper into upper to lower bathyal toward Southeast. From this situation, the depositional environment returns to the shallower environment in outer neritic to upper bathyal toward Southeast. The occurrence of deep marine environment is important because it facilitates the deposition of shale Jass Formation which contributes as caprock.

VI. SUMMARY

The Permian to Cretaceous depositional environment of the Bintuni Bay is interpreted based on the biostratigraphic analyses performed on the pre-Tertiary sediment which was collected from the selected well samples.

The depositional environment initially occurred in a non-marine environment during Permian-Triassic to form Ainim Formation, where shale of this formation is considered to be a primary sourcerock for the studied area. The absence of Early Jurassic sequence might have been caused by a non-deposition event. Meanwhile, the appearance of the Middle Jurassic fluvial sandstone of the Tipuma/ Lower Kembelangan Formation indicates the occurrence of non-marine environment. In fact, this fluvial deposit is considered to be the main reservoir. Subsequently, in the Late Jurassic, the depositional environment moved to the marine setting resulting in the occurrence of deep marine shale to form caprock.

The Early Cretaceous age is characterised by the disappearance of the sedimentary succession across the area of study indicating massive erosion. Finally, the Late Cretaceous environment took place in the marine setting to form deep marine shale of the Jass Formation which may contribute as a caprock in the element of petroleum system.

VII. ACKNOWLEDGMENT

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