Ichnofossils study of paleocene sediment source rock cores from Bintuni basin, West Papua, Eastern Indonesia

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Abstract. Ichnofossils content of Paleocene source rock sediment were examined based on two wells cores from Bintuni Basin, West Papua, Indonesia. The cores are from Paleocene interval of Waripi - Daram Formations and known as the potential source rock sediment interval. This study aims to determine the sea level changes during the depositional of the Waripi - Daram Formations. Representative of 18 ichnogenera including: Arenicolites, Asterosoma, Chondrites, cryptic bioturbation, Glossifungites, Helminthoida, Nereites, Ophiomorpha rudis, Palaeophycus, Phycosiphon, Planolites, Rossellia, Scolicia, Skolithos, Spirophyton, Teichicnus, Thalassinoides, and Zoophycos. The sea level curve generated from both wells based on ichnofossils association, suggest that there were at least three deepening – shallowing cycles. The cycles generally begins by inner to middle neritic interval that sign by appearance of Ophiomorpha and Chondrites with few Phycosiphon, while the deeper interval of outer neritic, upper bathyal into abyssal usually indicated by Zoophycos, Helminthoida, Nereites, Spirophyton and abundant of Phycosiphon. Sea level curve reconstructions based on the depositional environment suggest that during Paleocene Well-2 was located closer to the land compared to Well-1. Rapid shift in the depositional environment could indicatem an initiation of regional uplift in the area caused by a new subduction system to the north of the Basin.

1. Introduction
This study aims to determine the sea level changes during the depositional of the Waripi and Daram Formations in the Paleocene age utilizing the trace fossils from core data from two wells. Ichnofossils studies in Indonesia have been carried out by some researcher i.e. [1,2,3,4,5]. This study presents the first ever result of the ichnofossils studies focused on the sea level changes by using core data from two wells in the hydrocarbon prolific Bintuni Basin, West Papua, Indonesia (Figure 1). The sedimentary units in this study consist of slightly calcareous grained muddy sandstone, claystone, siltstone and shale part of the Waripi – Daram Formation of Paleocene age which are considered to be the source rock for the petroleum system in the basin. Foraminifera studies have been carried out but proved to be inconclusive. Observation on the ichnofossils at a particular section from these two wells are utilised to interpret the depositional environment. Vertical succession of the depositional environment is then compiled to generate the local sea level curve during the Waripi – Daram Formation deposition period. The sea level curve can be used to support the Cenozoic tectonic evolution studies of the Bird’s Head area in Papua.
2. Geological Setting
The Bintuni Basin is located in the Bird’s Head region of Papua that was formed by compressional tectonic between the Pacific and Australian Plate since the Paleogene [6]. The well is located in the northwest shoulder of the Basin. The Paleocene interval, as a focus of this study, is part of the Waripi – Daram Formation that was deposited conformably above the Upper Kembelangan Formation. [7] interpreted this rock unit age as Paleocene due to contains no age diagnostics fossils but lies with gradational contacts between the Eocene Yawee Formation and Late Cretaceous Ekmai sandstone, but may partly be a lateral equivalent of the Ekmai sandstone. This formation consists of sandstone, claystone and shale which collectively indicate deep marine sedimentary deposit. This rock unit crops out in the western mountains of the Central Range from where it extends westwards into the southern edge of the Birds Neck [7].

3. Methods
Ichnofossils types and sedimentary structures are examined and documented during core observation. Representative core leg is shown in Figure 2. Core section from Well-1 is acquired from 8.877 ft. - 8.602 ft. deep, while from Well-2 the similar interval was acquired between 8.811 ft. - 7.590 ft. deep. However, there are some intervals missing from the core. Changes in depositional environment in the study will be based on “changes in the characteristics of ichnofossils content” or “changes of ichnofossils association”. Ichnofossils determination and depositional paleoenvironmental interpretation in general are based on [8,9], while depositional environmental zonations were based on [10]. Ichnofossils other than those contained in the literatures as mentioned above such as Phycosiphon based on [11] and Nereites were determined based on [12] while Spirophyton were based on [13]. The bathymetry of depositional environment is determined based on Bathymetric Zone classification from [14].
Figure 2. Representative core leg from well number 1 (Well-1).

Determination of ichnofossils association in each interval was carried out based on the predominant ichno taxa, the presence of ichnofossils index, or the presence of ichnofossils that appears only in specific intervals. Interpretation of depositional environments for each interval is based on the change in ichnofossils association, or their characteristics. In case of discrepancy in the depositional environment bathymetry of the studied wells, the “characteristic ichnofossils” or “characteristic ichnofossils association” from each well should be compared.

Seven depositional bathymetric zones were recognized from the ichnofossils in the section, they are: tidal, shallow neritic (inner shelf), middle neritic, outer neritic, upper bathyal, lower bathyal and abyssal. Using the available data and interpretation, vertical succession of the sea level curve during the deposition period of the Waripi – Daram Formation can be determined from the bottom to the core of each core section.

4. Results
The lithology association from the section is dominated by slightly calcareous fine-grained muddy sandstone, claystone, siltstone and brown-grey shale. Ichnofossils determination from these two wells suggest 19 ichnogenera and floral trace including: *Arenicolites*, *Asterosoma*, *Chondrites*, cryptic bioturbation, *Glossifungites*, *Helminthoida*, *Nereites*, *Ophiomorpha rudis*, *Palaeophycus*, *Phycosiphon*, *Planolites*, *Rosselia*, root structure, *Scolicia*, *Skolithos*, *Spirophyton*, *Teichicnus*, *Thalassinoides*, and *Zoophycos*. Eight ichnofossils association can be determined from each well (Table 1 and 2).

Each ichnogenera that are used as a basis for ichnofossils association are shown in Figure 3 (Well-1) and Figure 4 (Well-2). From these ichnofossils association, depositional environment for the particular section can be determined.
Figure 3. Ichnogenera found in Well-1; *Helminthoida* (3a; depth: 8.872.1 ft), *Phycosiphon* (3b; depth: 8.843 ft), *Zoophycos* (3c; Zo; depth: 8.853 ft), large *Phycosiphon* (3d; depth: 8.838 ft), *Nereites* (3e; depth: 8.837.8 ft).

Figure 4. Ichnogenera found in Well-2; *Asterosoma* (4a; depth: 8.085 ft), *Zoophycos* (Zo) (4b; depth: 8.082 ft), *Phycosiphon* (Ph) and *Zoophycos* (Zo) (4c; depth: 8.034 ft), *Arenicolites* (4d; depth: 7.872 ft), *Spirophyton* (4e; depth: 7.777.4 ft), *Ophiomorpha* (4f; depth: 7.862.5 ft), *Chondrites* (4g; depth: 7.602 ft), *Phycosiphon* (4h; depth: 7.633 ft).
### Table 1. Ichnofossils association acquired from particular depth within Well-1, Bintuni Basin.

| Ichnofossils association | Acquired depth | Depositional bathymetry |
|-------------------------|---------------|-------------------------|
| *Ophiomorpha* - *Chondrites* with few-rare of *Phycosiphon* | 8.628 – 8.602 ft. | transition zone between middle neritic and shallow neritic (inner shelf) |
| *Phycosiphon* – rare of *Ophiomorpha* and *Chondrites* disappearance *Ophiomorpha* - *Chondrites* | 8.657.17 – 8.628 ft. | middle neritic bathymetric zone |
| decreasing of *Phycosiphon* | 8.702.3 – 8.657.17 ft. | transition zone between middle neritic and shallow neritic (inner shelf) |
| Abundant of *Phycosiphon* and appearance of *Zoophycos* *Ophiomorpha* with highly decreasing of *Phycosiphon* | 8.731.4 – 8.702.3 ft. | outer neritic bathymetric zone |
| *Helminthoida* – abundant of *Phycosiphon* without *Zoophycos* | 8.842.3 – 8.770.8 ft. | bathyal bathymetric zone |
| *Helminthoida* – *Phycosiphon* with *Zoophycos* | 8.877 – 8.842.3 ft. | transition zone between upper bathyal and outer neritic |

### Table 2. Ichnofossils association acquired from particular depth within Well-2, Bintuni Basin.

| Ichnofossils association | Acquired depth | Depositional bathymetry |
|-------------------------|---------------|-------------------------|
| Few *Chondrites* – *Thalassinoides* associated with mud drapes *Ophiomorpha* - *Chondrites* | 7.601.3 – 7.590 ft. | tidal depositional area |
| abundant of *Phycosiphon* - *Zoophycos* – with some *Chondrites* and *Ophiomorpha* *Arenicolites* - *Chondrites* | 7.689 – 7.601 ft. | transition zone between middle neritic and shallow neritic (inner shelf) |
| *Phycosiphon* - *Zoophycos* | 7.869.71 – 7.689 ft. | transition zone between outer neritic and middle neritic shallow neritic bathymetric zone |
| *Rosselia* - *Skolithos* | 7.893 – 7.869.71 ft. | transition zone between middle neritic and shallow neritic (inner shelf) |
| *Zoophycos* – abundant of *Phycosiphon* | 7.975.5 – 7.893 ft. | transition zone between upper bathyal and outer neritic |
| *Scolicia* – *Zoophycos* with few *Asterosoma* | 8.002.4 – 7.975.5 ft. | transition zone between middle neritic and shallow neritic (inner shelf) |
| *Zoophycos* – abundant of *Phycosiphon* | 8.065.5 – 8.002.4 ft. | transition zone between outer bathyal and outer neritic |

5. Discussion

Regionally, Paleocene deposits represent passive continental margin sequences dominated by deep marine limestone and mudstone deposits. At the present day, Well-1 and Well-2 is located in the Bintuni Bay and at the edge of the Ayamaru Platform. However, it is evident from the ichnofossils association that contain outer neritic, upper bathyal and abyssal, sedimentary sequences in Well-1 are interpreted to
be deposited in deeper environment compared to Well-2 which contain tidal to outer neritic sequence. This suggests that land is probably emerged near the Well-2 and Well-1 is more of basinal area during the deposition of the Waripi – Daram Formation. The sea level curve generated from both wells (Figure 5 and 6), suggest that there was at least three deepening – shallowing cycles in the Bintuni Basin in the Paleocene age.

**Figure 5.** Paleocene sea level curve in the Bintuni Basin determined from the Waripi – Daram Formation in Well-1.

**Figure 6.** Paleocene sea level curve in the Bintuni Basin determined from the Waripi – Daram Formation in Well-2.
There is a notable jump in bathymetry from abyssal to middle neritic in the lower sequence of Waripi – Daram Formation in Well-1 but not so clear in Well-2. This could suggest that the start of the jump in bathymetry marks the initial regional uplift in the Bintuni Basin. Towards the top of the sequence, sedimentary units in both wells indicating shallower depositional environment. This is interpreted to be caused by a change in the geodynamic system to the north of the basin. For the last part of the Mesozoic period the Bintuni Basin was a part of Australian passive margin system. In the early Cenozoic there was a south-directed subduction system from the Pacific Plate under the Australian Plate [15]. This caused regional uplift in the overriding plate thus the rapid shallowing episodes of the basin.

The lack of limestone and the occurrence of clastics sequences within the sequence suggest that the Bintuni Basin was in a relatively close proximity to the exposed terrain as the source for its sediments in the Paleocene; they are probably sourced from the Kemum High. To the south of Well-1 is the well-known MOKA (Misool-Onin-Kumawa Anticlinorium), deeper environment of sedimentary units in Well-1 confirms that the anticlinorium was caused by a tectonic event post Paleocene.

6. Conclusion
Paleocene sea level curve has successfully been determined using ichnofossils and ichnofossils association from core data of Waripi – Daram Formation acquired from two wells in the Bintuni Basin. This research also suggests three significant sea-level fluctuations between shallow neritic, middle neritic, outer neritic, upper bathyal, lower bathyal and abyssal marine conditions in the Well-1 and between tidal, shallow neritic, middle neritic, outer neritic and upper part of upper bathyal in the Well-2. Three episodes of sea level fluctuations were recorded from the sediments; the most notable jump can be seen at the lower section of the formation. Sedimentary units in Well-1 were deposited in the deeper environment compared to those in Well-2. This suggests that land was probably emerged in the north sending sediments towards the basin in the south.

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