AUSTRALIAN PALINOMORPHS FROM THE BUYA FORMATION OF THE SULA ISLAND

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ABSTRAK

Penelitian ini berhasil membuktikan kehadiran kumpulan palinomorf umur pra-Tersier pada Formasi Buya di Kepulauan Sula. Palinomorf-palinomorf ini memiliki kekerabatan dengan palinomorf Australia yang umum dijumpai di cekungan-cekungan berumur Mesozoikum di Australia dan Papua New Guinea. Kumpulan palinomorf ini didominasi oleh spora dan dinoflagelata. Berdasarkan kehadiran spora indeks dapat disusun tiga zona mikro-flora, yaitu (dari tua ke muda): zona *Contignisporites cooksoniae,* zona *Murospora florida* dan zona *Retitriletes watheroensis.* Sebaliknya berdasarkan kemunculan dinoflagelata indeks dapat dibuat empat zona dinoflagelata, yaitu (dari tua ke muda): zona *Caddasphaera halosa,* zona *Wanaea clathrata-Wanaea indotata*, zona *Dingodinium swanense* dan zona *Criboperidinium perforans*-zona lebih muda. Baik zona mikro-flora dan zona dinoflagelata menunjukan bahwa umur Formasi Buya adalah Jura Tengah-Akhir atau setara dengan Bathonian-Tithonian. Secara paleogeografis, kesamaan antara palinomorf yang ditemukan di Formasi Buya dan palinomorf yang ada di sedimen umur Mesozoic di Australia menunjukan bahwa Kepulauan Sula dan Australia adalah satu daratan pada umur Jura Tengah-Akhir. Ini berarti bahwa pada umur Jura Tengah-Akhir, Kepulauan Sula merupakan bagian dari Kontinen Australia dan terletak jauh di selatan dari garis Katulistiwa. Kepulauan Sula baru berada di posisinya sekarang pada umur Neogen.

Kata kunci: *Palinomorf Australia, Formasi Buya, Kepulauan Sula*

ABSTRACT

This research has proved the occurrence of pre-Tertiary palynomorphs within the Buya Formation of the Sula Island. Most palynomorphs have Australian affinity and appear in most Mesozoic basins in Australia and in Papuan Basin of Papua New Guinea. The palynomorph assemblage mostly consists of spores as well as dinoflagellates. Three micro-flora zones can be defined referring to the existing index spores, including (from older to younger zone) Contignisporites cooksoniae zone, Murospora florida zone and Retitriletes watheroensis zone. Meanwhile, four dinoflagellate zones enable to be constructed such as (from older to younger zone) Caddasphaera halosa zone, Wanaea clathrata-Wanaea indotata zone, Dingodinium swanense zone and Criboperidinium perforans zone-younger zone. Both zonations suggest that the age of the Buya Formation is Middle to Late Jurrasic or Bathonian to Tithonian. From the palaeobiogeographic point of view, the similarity between palynomorphs from the Buya Formation of the Sula Island and those from the Mesozoic sediment of Australia suggests land connection between both areas during Middle to Late Jurassic. It suggests that, during this age, the study area attached the Australian Continent which was situated far South from the equatorial. The study area appears in its recent position during Neogene.

Keywords: *Australian Palynomorphs, Buya Formation, Sula Island*

I. INTRODUCTION

This paper presents the result of the palynological study on the pre-Tertiary sediment appearing in the Sula Island. This study is actually a part of geological investigation in the Sula Island in order to evaluate hydrocarbon potential within this area which was performed by the LEMIGAS Exploration Division in 2010. This study is funded by the government through a research project so called DIPA. It is well known that the hydrocarbon bearing formations in the eastern Indonesia are found in the pre-Tertiary successions. One important aspect to evaluate their potentiality is to understand the stratigraphy of pre-Tertiary sediments. This understanding can be approached by employing biostratigraphic tools to investigate the biological contents including micro-flora and fauna. In this study, it is applied palynology to study micro-flora (palynomorph) deriving from ancient vegetations. Unfortunately, the information concerning pre-Tertiary palynomorph in eastern Indonesia is rarely published. This fact prevents biostratigrapher to comprehend the pre-Tertiary stratigraphy of the potential sequences. This situation is partly caused by the reality that most pre-Tertiary samples collected during drilling campaigne were sent aboard for analysis. The result of this analysis is kept by the companies for their own purpose and hardly shared for public. Therefore, for this particular reason the Sula project was proposed.

The palynological study on the Buya Formation is intended to record all pre-Tertiary palynomorphs occurring within this formation. It is believed that these palynomorphs have Australian affinity as the Sula Island orinally came from Australian Continent. The study area is tectonically active due to interaction of three major plates including Asian, Australian and Pacific Plates (Figure 1). The Banggai-Sula Plate is interpreted as a micro-continent deriving from Northwest Australia which was formed during Paleozoic and drifted to the West into its current position, so called Allochthonous Paleozoic Microcontinent (Kemp *et al*., 1992). Its movement was controlled by sinistral strike-slip fault which is known as Sorong fault system. The Banggai-Sula micro-continent, also recognised as the Banggai-Sula platform is defined as a rock complex consisting of Carbonaceous metamorphic rocks, Permo-Triassic plutonic and volcanic rocks which are unconformably overlain by a series of Jurassic passive margin sediment, Cretaceous calcilutite sediment and Tertiary carbonate platform.

Paleogeographically, the area of study was situated far south from the equatorial, attaching the Australian Continent during pre-Tertiary age.

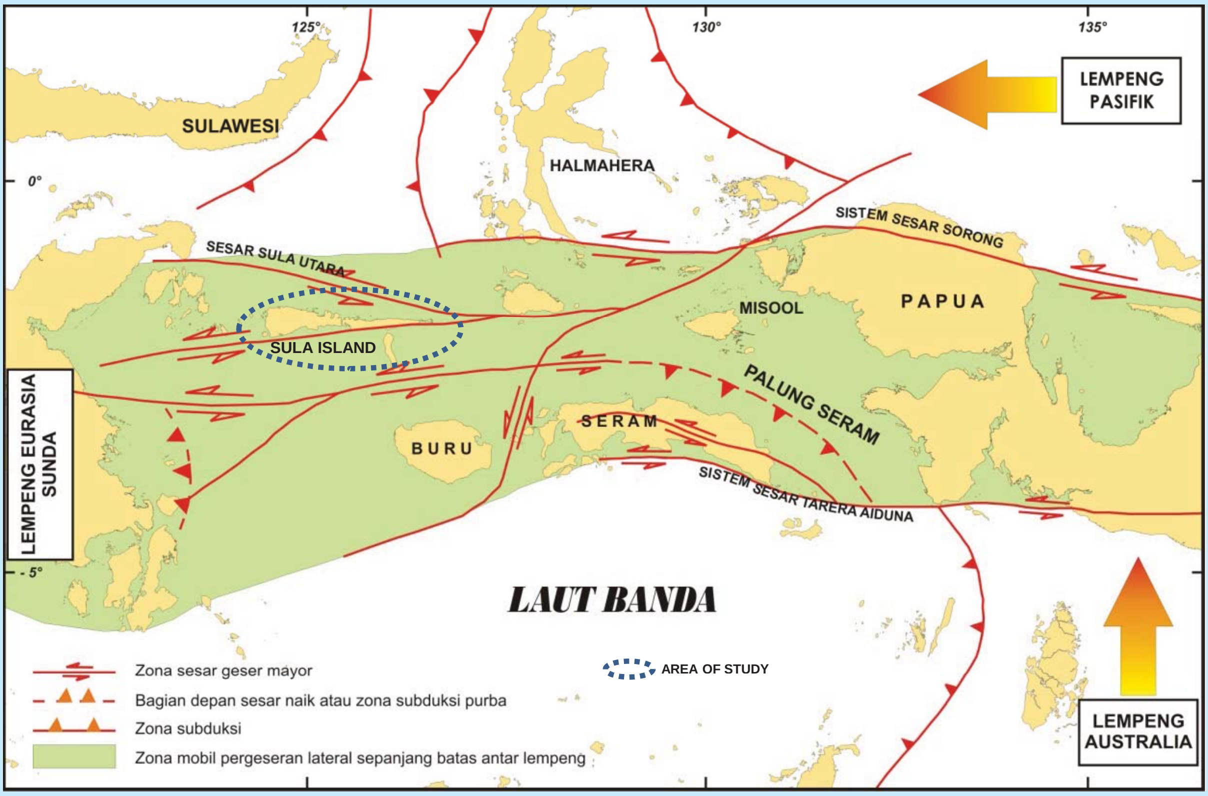


Figure 1
Tectonic element of the Banda arc and its surrounding
(Kemp and Mogg, 1992 with small modification)

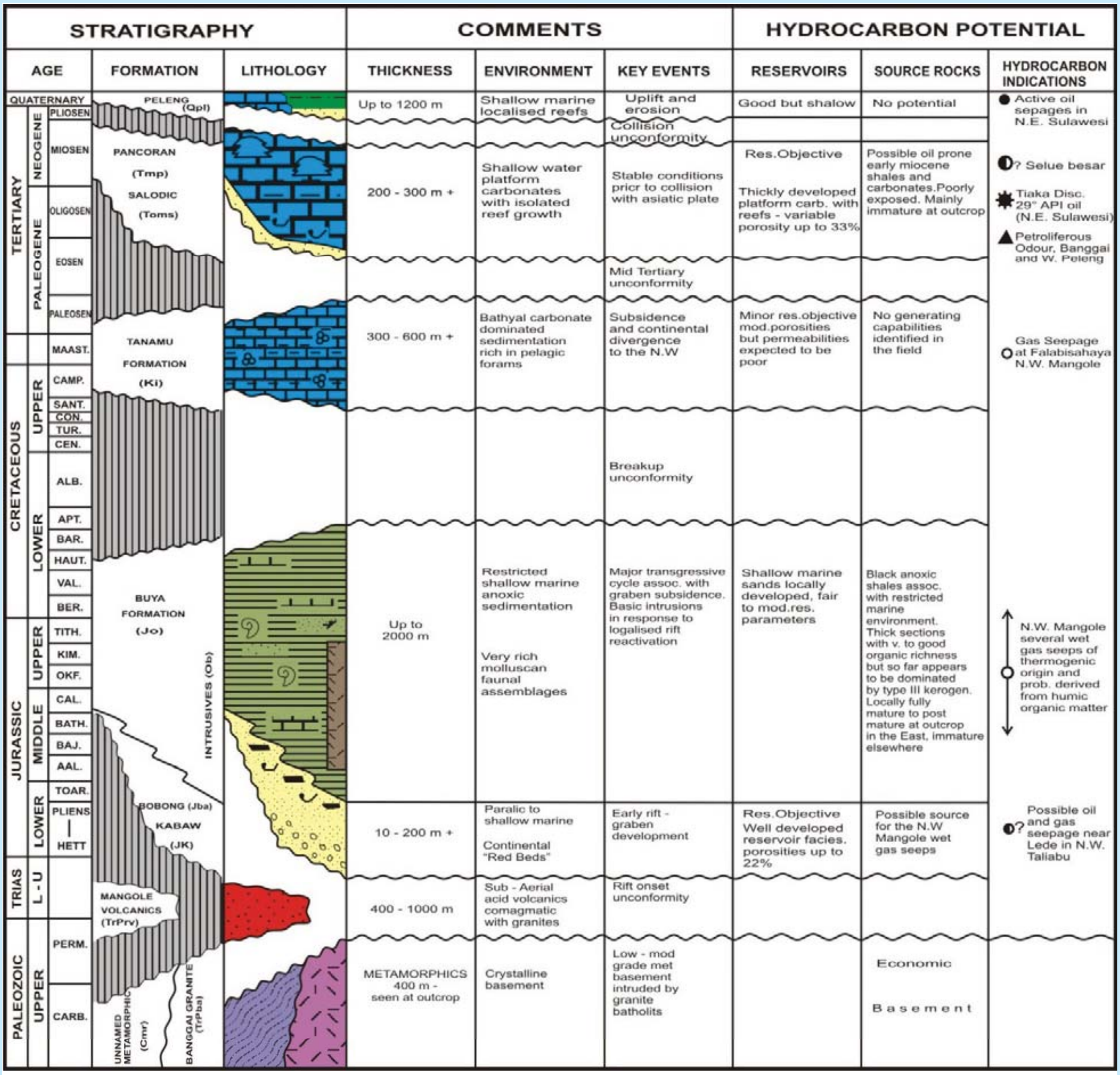


Figure 2
Regional stratigraphy of the Banggai-Sula (Garrard *et al*., 1988)

The study area appears in its recent position during Neogene (Garrard *et al*., 1988). This study provides the evidence of high abundance and diversity of micro-fauna and flora within pre-Tertiary deposits which allows interpretation of age and paleoenvironment. This is for the first time to access fossil content of Jura-Cretaceous sediments. Most studied samples were deposited in the shallow marine environment. This situation allows biostratigrapher cross checking the result of palynological analysis with other micropaleontological desciplines such as foraminifer and nannoplankton to gain accurate interpretation.

III. GENERAL STRATIGRAPHY

The stratigraphy of the studied area refers to that introduced by Garrad *et al*. (1988) as seen in Figure 2. Based on lithological association, fossil content and age, the stratigraphy of the Baggai-Sula platform is separated into four main units including Pre-Jurassic

Basement Unit, Mesozoic Sedimentary Unit, Miocene Limestone Platform and Quarternary Unit (Surono and Sukarna, 1985). The pre-Jurassic Basement Unit consists of volcanic and meta-sedimentary rocks with local intrusion of granite and pegmatite (Sukamto, 1975). The volcanic rock includes rhiolite, dacite, lithic tuff and volcanic breccia. On the other hand, meta-sediment rock is represented by schiss, gneiss, argillite, marble, amphibolite and quartzite. This basement unit was presumably formed during Permian to Triassic (Pilgram *et al.*, 1984).

The basement unit is then unconformably overlain by the Mesozoic Sediment consisting of Menanga, Bobong, Buya and Tanamu Formations. These Mesozoic formations represent transgrssive phase at the period of tectonic extention. The Menanga Formation is composed of crystallised limestone, schiss and phillite with quartzite intercalation. This formation is unconformably overlain by the Bobong Formation which is characterised by quartz sandstone, claystone and conglomerate with coal intercalation. This formation was deposited in shallow marine environment (neritic). The Buya Formation consits of siltstone, shale and the intercalation of thin limestone. This formation is also indicated by the occurrence of fragmens of carbon debris and glauconite which suggests shallow marine environment (50m-100m) with reduction condition. The youngest Mesozoic sediment is the Tanamu Formation which conformably overlies the Buya Formation. It is characterised by calcilutite and yellowish grey marl. The occurrence of Cretaceous planktonic forminifera of *Globotruncana* sp. indicates that the Tanamu Formation was deposited in deep marine environment (more than 200m) during Cretaceous.

Subsequently, it is unconformably formed the Miocene limestone platform over the Mesozoic Sedimentary Unit composing of Salodik and Pancoran Formations. The Salodik Formation consists of reef limestone and coral reef with the intercalation of sandy limestone, marl and conglomeratic basal in the lower formation. This formation is interpreted to be deposited in shallow marine environment (littoral) during Eocene – Middle Miocene (Supanjono *et al.*, 1993). On the other hand, the Pancoran Formation is identfied by reef limestone with less occurrence of claystone and sandstone. It is presumably formed in the Middle Miocene.

Finally, the Miocene Carbonate Platform is unconformably overlain by the youngest succession of Quarternary Unit which is well known as Peleng Formation. It is composed of terrace deposits of shallow marine limestone with the intercalation of thin shale and claystone containing mollusc, algae and forminifer. The Peleng Formation is assumed to have an age of Middle Miocene.

III. METHOD

The area of study is located in the small town named Modafumi and its surrounding area. This location is selected due to the existence of the pre-Tertiary Buya Formation which is exposed along the Mahigo River (Figure 3). Some samples were collected from this exposure for micropaleontological study including forminiferal, calcareous nannoplankton and palynological analyses.

Two major works were conducted within this study. The first was fieldwork for collecting surface samples and the second was laboratory work to separate palynomorphs from the rock. Fieldwork was divided into two methods which include logging the lithology and collecting the samples. Logging was aimed to record the lithological variation and to estimate the lithological thickness. Therefore, it allows statigraphers to reconstruct the lithological column of the studied area which is dominated by non-calcareous claystone with siltstone intercalation (lower section) and with limestone and sandstone intercalations (upper section) as shown in Figure 4. The result of logging was used to determine interval for sample collection. Here, sampling interval very much depended on lithological variation and lithological thickness. For palynological analysis, sampling was focused on the sediment with fine grain lithology. Ideally, every distinct lithology should be sampled. However, limestone and other coarse grain lithologies such as breccia, conglomerate and coarse sandstone were avoided as these sediments certainly provide poor recovery (Cross, 1962). In addition, samples with high organic contents as indicated by dark colour were preferable including brown or black shale, lignite and coal. It can be emphasised that sampling was done to the sediments consisting of fine grain lithology and yielding high organic content. A set of seven samples situated in the lower section was selected for palynological analysis including MGH-1, MHG-2, MHG-4, MHG-6, MHG-9, MHG-11 and MHG-12.

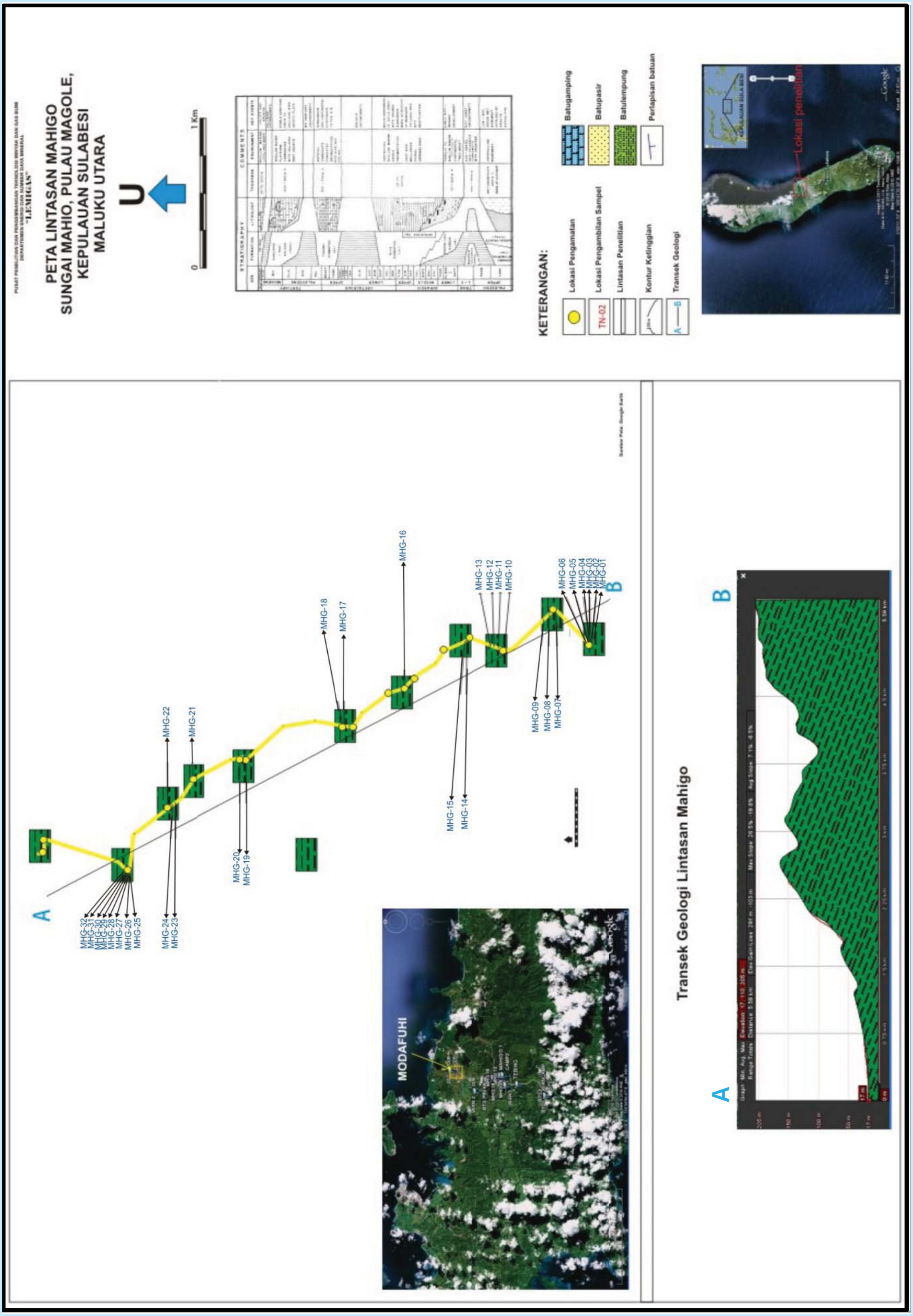


Figure 3
Location of surface sampling along the Mahigo river

The aim of laboratory work (here is sample preparation) is to release any palynomorphs from minerals or sediments which enclose them or obscure them in order to make them clearly visible and concentrated enough for microscope study and photography. Basically, the sample preparation adopted the modified technique which was proposed for Paleogene sediments by Lelono (2001). Approximately 5 g of sample was cleaned up to avoid surface contamination. It was then crushed to reduce the surface sample and hence, speed up the sample maceration using HCl, HF and HNO_3. The important key within the maceration was heating the sample while reacting with nitric acid (HNO_3). The suitable heating resulted in the maximum recovery of plant microfossils. Following this maceration, sample was treated in alkali solution using 10% KOH in order to clear up the residue. The proper duration time of alkali treatment determined the number of palynomorphs turning up in the residue. It was necessary to sieve residue using 5 microns sieve to collect more palynomorphs by separating them from debris materials. Finally, residue was mounted on the slides using polyvinyl alcohol (p. v. a) and canada balsam.

Palynomorph examination was taken under the transmitted light microscope with an oil immersion objective and X 12. 5 eye piece. The result of examination is recorded in the determination sheets and used for the analyses. In addition, every palynomorph appearing within the studied samples was photographed to complete the existing pre-Tertiary collection which was obtained from other pre-Tertiary localities.

IV. AGE INTERPRETATION

This study applied other biostratigraphic disciplines to gain a reliable age of the sediments occurring within the Buya Formation including foraminifer and calcareous nannoplankton. The ideal section for this study was found along the Mahigo River. Approximately 31 samples were collected from these sections. However, only four samples situated on the upper section are available for marine microfossil examination as these are the only samples with calcareous content. These samples are labeled MHG-28, MHG-29, MHG-30 and MHG-31 which are situated in the upper section (Figure 4). Lithologically, they consist of limestone and calcareous claystone.

Foraminiferal analysis showed the domination of benthic forams such as *Astacollusdictodes*, *Bulimina ovata*, *Bulimina pupoides*, *Nodosaria* spp. and *Haplophragmoides* sp. suggesting deep middle neritic environment (50m-100m). Unfortunately, planktonic foraminifer is only represented by single occurrence of *Dicarinella algeriana* in sample MHG-28 (bottom) indicating Late Jurassic/ Turonian Stage (Lelono *et al*., 2010). In addition, nannoplankton investigation on the same samples as those for foraminiferal analysis proved the appearance of some index taxa including *Stephanolithion bigotti* and *Zeugrhabdotus embergeri*. These taxa indicate the nanno zone of NJ-17 along sample MHG-28 to sample MHG-31 which equals to Late Jurassic/ Turonian Stage (Lelono *et al*., 2010). After all, it is concluded that sediments occurring in the upper section (MHG-28 to MHG-31) may have been formed during the Late Jurassic age (Turonian Stage). Having the above data, it is assumed that samples below MHG-28 (including palynological samples) can be assigned to Late Jurassic or older.

V. POLLEN ZONATION

Common palynomorph assemblage occurs within the studied samples which is dominated by the Australian affinity (Figure 5). It mostly consists of spores as well as dinoflagellates. Unfortunately, many of them remain unnamed due to the limitation of pre-Tertiary references. This is actualy the challenge for Indonesian palynologists to develop pre-Tertiary palynology especially for eastern Indonesia. The identification of existing palynomorph refers to those occurred in the Australian Mesozoic successions. These were published by the Association of Australasian Palaeontologists in 1987.

The palynomorph assemblage is dominated by spores which can be used to construct micro-flora zonation. These spores are represented by *Polycingulatisporites crenulatus*, *Callialasporites turbatus*, *Callialasporites dampieri*, *Dictyotosporites complex*, *Contignisporites cooksoniae*, *Murospora florida*, *Retitriletes watheroensis* and *Clavatipollenites hughesii*. Based on the occurrence of these index spores, three micro-flora zones can be defined including (from older to younger zone)

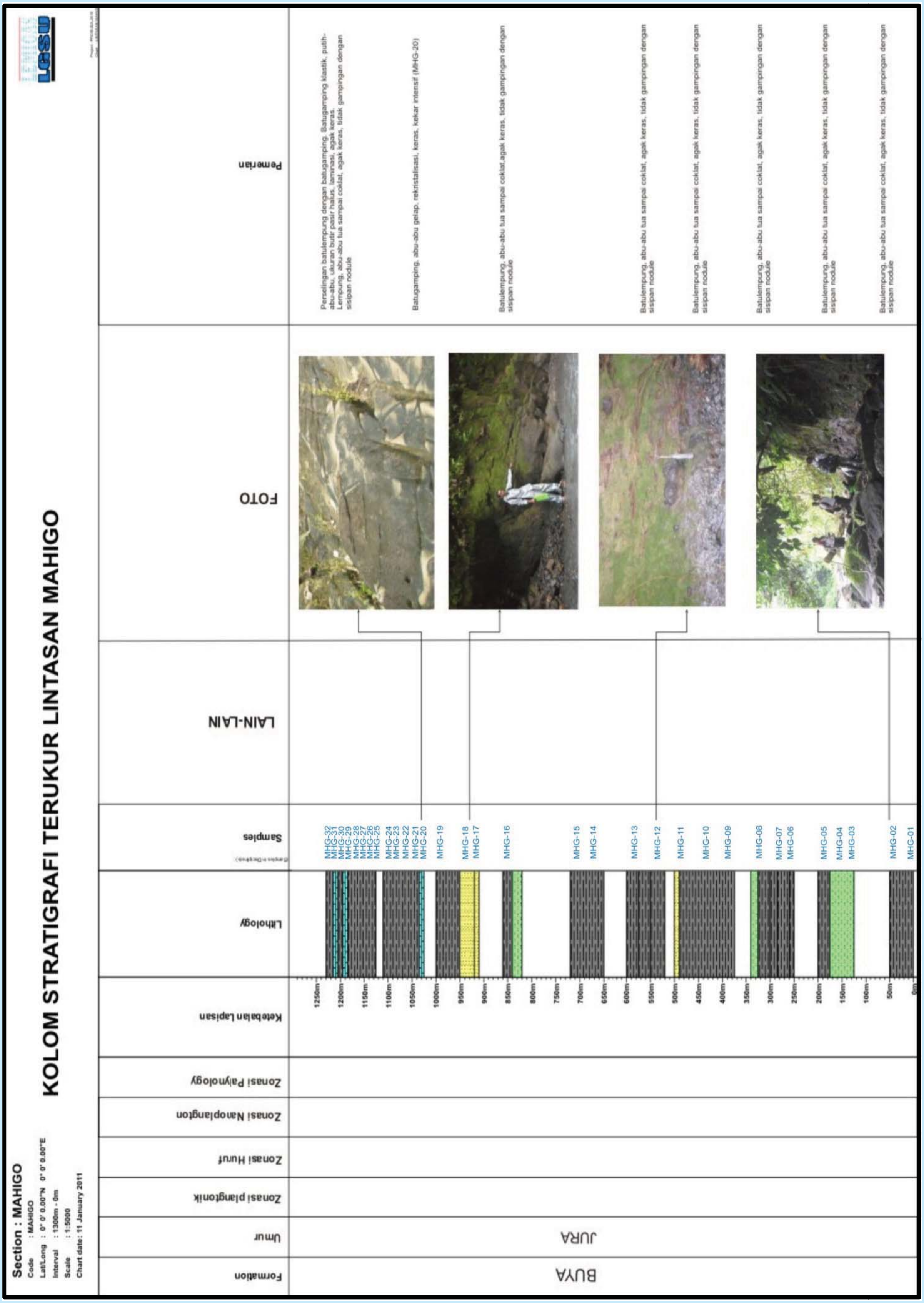


Figure 4
Lithological succession of the studied formation

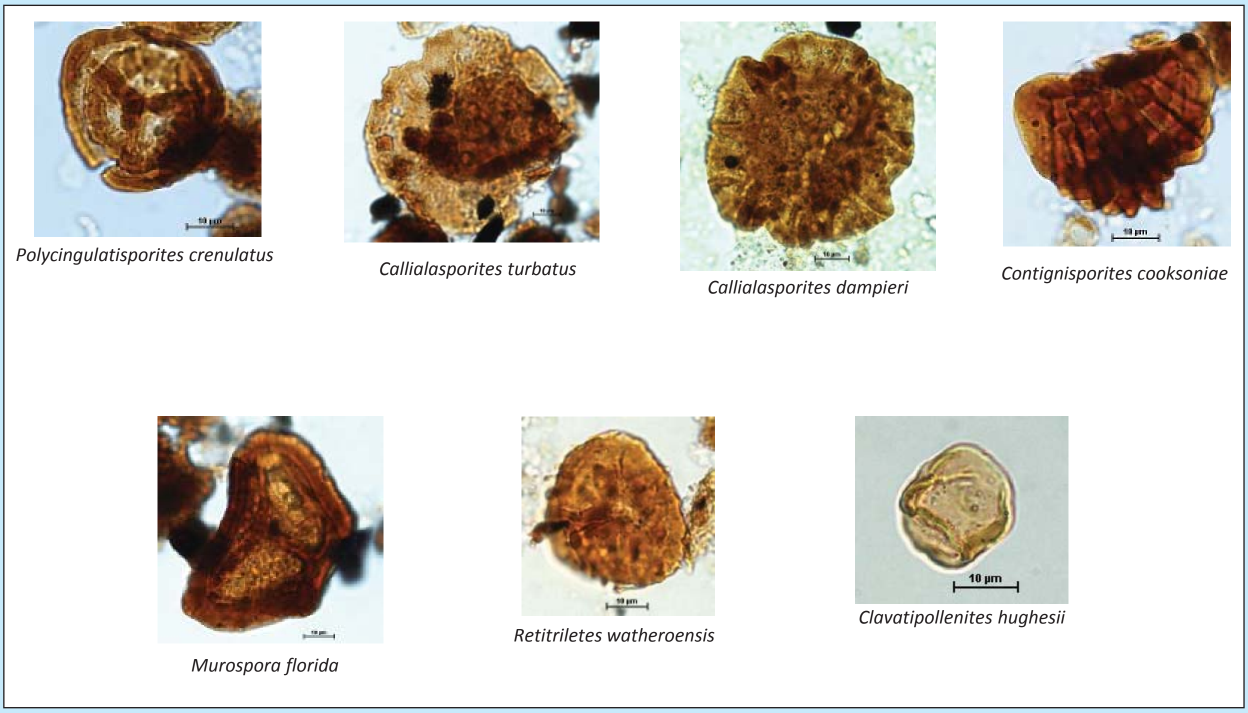


Figure 5
Some index spores which define micro-floral zones occurring within the studied section

Contignisporites cooksoniae zone, Murospora florida zone and Retitriletes watheroensis zone (Figure 6). These three zones can be grouped into two super-zones i. e. Callialasporites dampieri superzone and Microcachryidites superzone which equal to Middle to Late Jurassic (Helby *et al.*, 1987).

On the other hand, dinoflagellates are represented by the appearance of *Rhaetogonyaulax rhaetica*, *Dapcodinium priscum*, *Dapsilidinium langii*, *Caddasphaera halosa*, *Pareodinia ceratophora*, *Wanaea indotata*, *Wanaea clathrata*, *Dingodinium swanense*, *Dingodinium jurassicum*, *Criboperidinium perforans*, *Omatia montgomeryi* and *Egmontodinium torynum* (Figure 7). Referring to the occurrence of these taxa, it can be constructed four dinoflagellate zones such as (from older to younger zone) Caddasphaera halosa zone, Wanaea clathrata-Wanaea indotata zone, Dingodinium swanense zone and Criboperidinium perforans zone-younger zone which cover three superzones including Pareodinia ceratophora superzone, Pyxidiella superzone and Fromea cylindrical superzone (Helby *et al.*, 1987). These dinoflagellate zones is equivalent to Middle to Late Jurassic (Figure 8). After all, it can be inferred that the age of the Buya Formation is Middle to Late Jurrasic or Bathonian to Tithonian.

VI. PALAEOBIOGEOGRAPHY

Palynological study on the Buya Formation cropping out in the Sula Island shows significant occurrence of palynomorphs which mainly derive from Australian continent. Most of them are key palynomorphs including *Polycingulatisporites crenulatus*, *Callialasporites turbatus*, *Callialasporites dampieri*, *Dictyotosporites complex*, *Contignisporites cooksoniae*, *Murospora florida*, *Retitriletes watheroensis* and *Clavatipollenites hughesii*. In addition, other palynomorphs also appear to confirm Australian elements such as *Corolina* sp., *Araucariates* sp., *Gleicheniidites* spp., *Matonisporites* sp A, *Excecipollenites tumulus*, *Ceratosporites equalis*, *Klukisporites variegatus*, *Classopollis martinottii* and *Retitriletes austroclavatidites* (Figure 9). In fact, these taxa are also found in most Mesozoic basins in Australia and in Papuan Basin of Papua New Guinea (Helby *et al.*, 1987). The similarity between palynomorphs from the Buya Formation and those from Australian formations is an evidence of land connection between Sula Island and Australia during Middle to Late Jurassic. These data suggest that, during Middle to Late Jurassic, the study area attached the Australian Continent situating far south from the equatorial. According to Kemp *et al*. (1992), the area of study (the Banggai-Sula Plate) is interpreted as a micro-continent deriving from Northwest Australia which was formed during Paleozoic (Kemp *et al*., 1992). It appears in its recent position during Neogene (Garrard *et al*., 1988). Therefore, this study confirms the origin of Sula Island from the Australian Continent.

Moreover, this study shows the appearance of some index dinoflagellates with Australian affinity including *Rhaetogonyaulax rhaetica*, *Dapcodinium priscum*, *Dapsilidinium langii*, *Caddasphaera halosa*, *Pareodinia ceratophora*, *Wanaea indotata*, *Wanaea clathrata*, *Dingodinium swanense*, *Dingodinium jurassicum*, *Criboperidinium perforans*, *Omatia montgomeryi* and *Egmontodinium torynum*. Other dinoflagellates occurring in the studied samples are *Wuroia capnosa*, *Scriniodinium kemplae*,

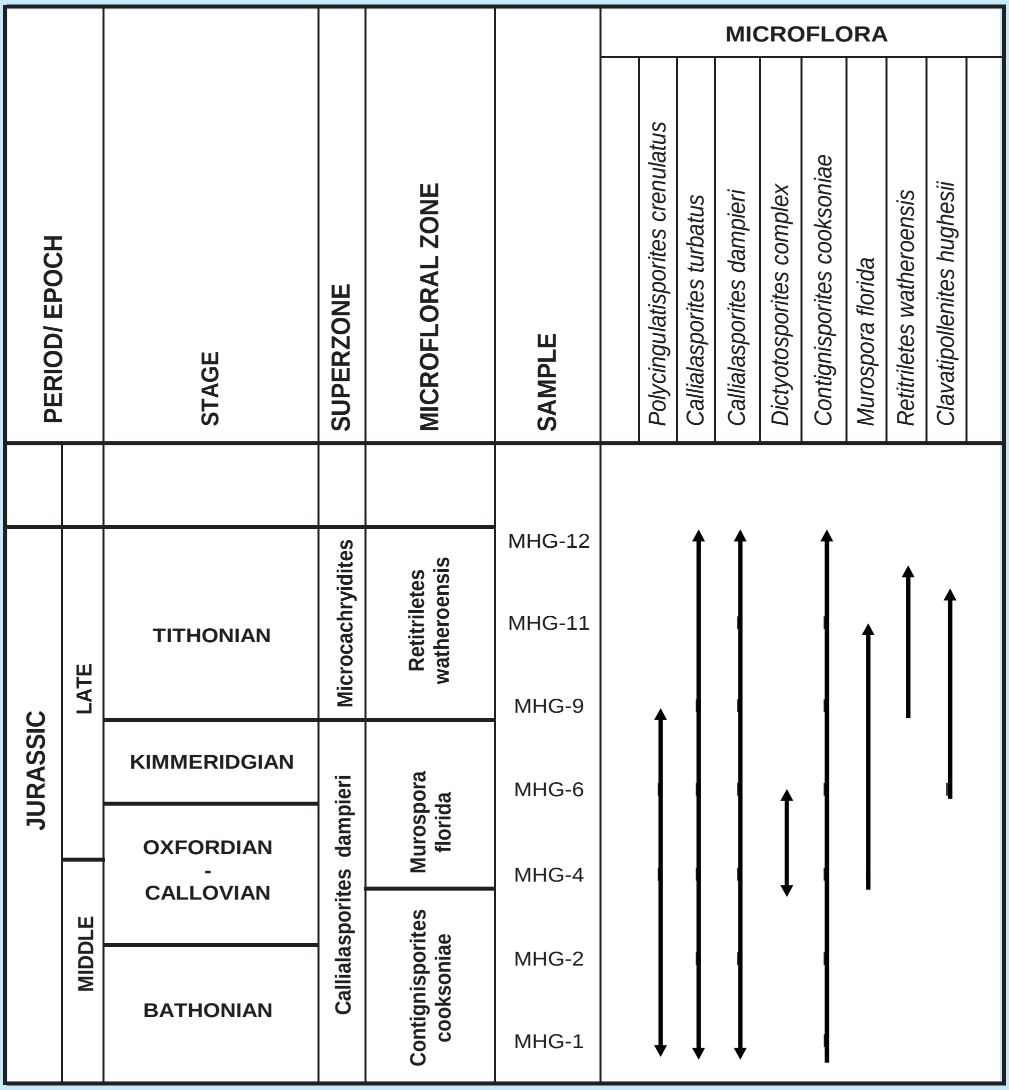
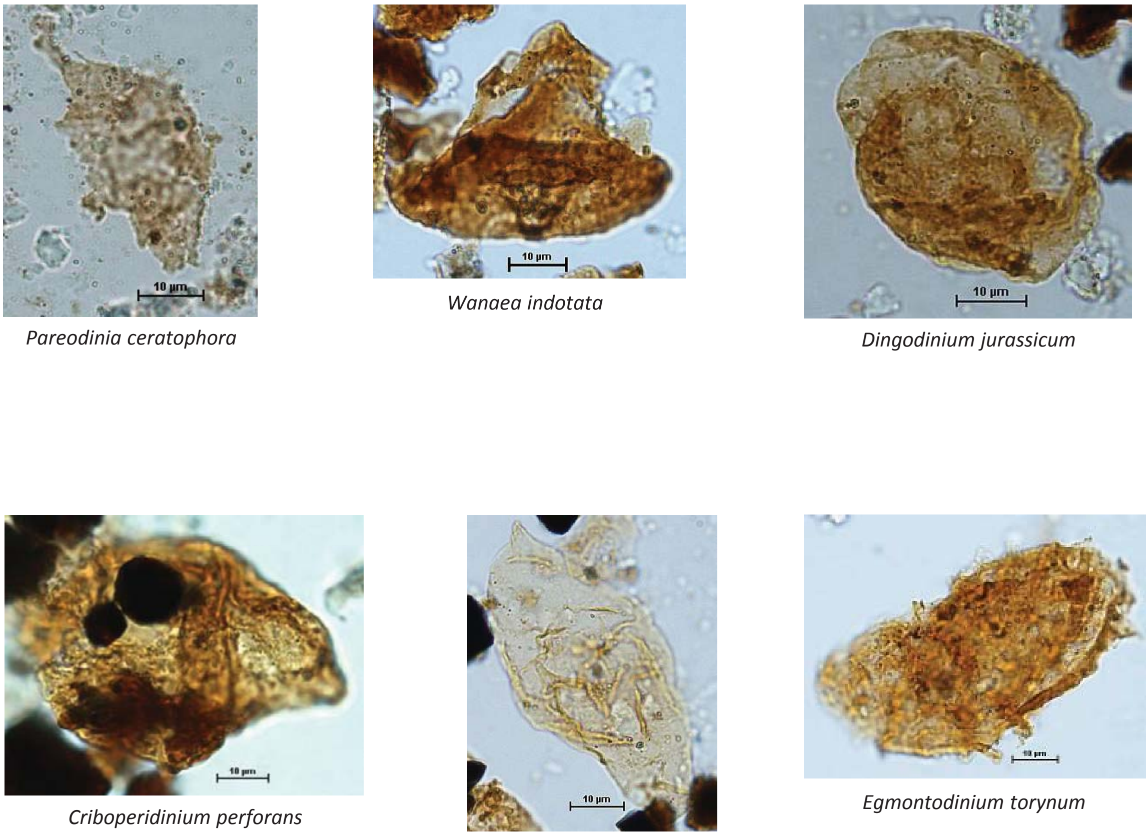


Figure6
Palynological zonation of the studied section based on the occurrence of the index spores



Pareodinia ceratophora — *Wanaea indotata* — *Dingodinium jurassicum*

Criboperidinium perforans — *Omatia montgomeryi* — *Egmontodinium torynum*

Figure 7
Some index dinoflagellates which determine dinoflagellate zones occurring within the studied section

Scriniodinium crystallinum, *Leptodinium eumorphum*, *Apteodinium granulatum* and *Cassiculosphaeridia magna* (Figure 10). Similar to spores mentioned above, dinoflagellates found in the study area posses Australian affinity. These spores were recorded from the Jurassic sediments of the Australian Basins (Helby *et al*., 1987). This fact agrees with the data provided by spore analysis as stated in the above paragraph. Having the above discussion, it is inferred that the area of study was a part of Australian Continent which was paleogeographically situated far south from its recent position during Middle to Late Jurassic.

VII. CONCLUSION

This study has proved the significant occurrence of pre-Tertiary palynomorphs throughout the Buya Formation. This is for the first time to access fossil content of the pre-Tertiary sediments. This study has also revealed the fact that most palynomorphs originally derive from Australian Continent. Palynomorph assemblage appearing in the Buya Formation mainly consits of spores and dinoflagellates. This research has been successfuly identifying biostratigraphic markers of spores and dinoflagellates which allows biostratigrapher to construct biostratigraphic zonation and to define the age of the studied section.

Based on the occurrence of index spores of *Polycingulatisporites crenulatus*, *Callialasporites turbatus*, *Callialasporites dampieri*, *Dictyotosporites complex*, *Contignisporites cooksoniae*, *Murospora florida*, *Retitriletes watheroensis* and *Clavatipollenites*

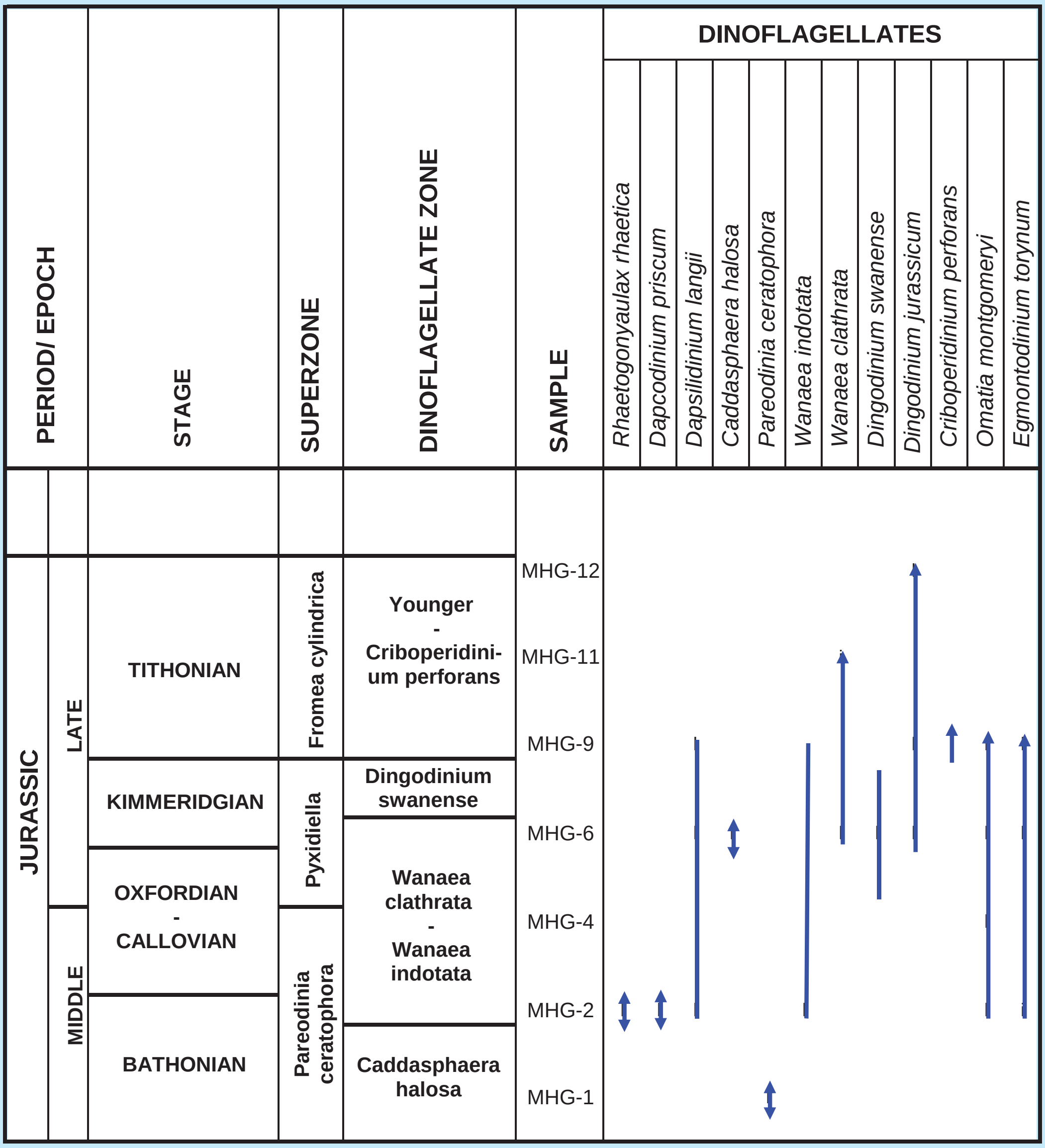


Figure 8
Dinoflagellate zones appearing in the studied section constructed based on the occurrence of some markers

hughesii combined with the appearance of index dinoflagellates of *Rhaetogonyaulax rhaetica*, *Dapcodinium priscum*, *Dapsilidinium langii*, *Caddasphaera halosa*, *Pareodinia ceratophora*, *Wanaea indotata*, *Wanaea clathrata*, *Dingodinium swanense*, *Dingodinium jurassicum*, *Criboperidinium perforans*, *Omatia montgomeryi* and *Egmontodinium torynum*, it can be interpreted that the age of the Buya Formation appearing on the study area is Middle to Late Jurassic.

Meanwhile, the above taxa are also found in most Mesozoic basins in Australia and in Papuan Basin of Papua New Guinea. The similarity between palynomorphs from the Buya Formation and those from Australian formations suggests land connection between Sula Island and Australia during Middle to Late Jurassic. It suggest that, during Middle to Late Jurassic, the study area attached the Australian Continent which was located far south from the equatorial.

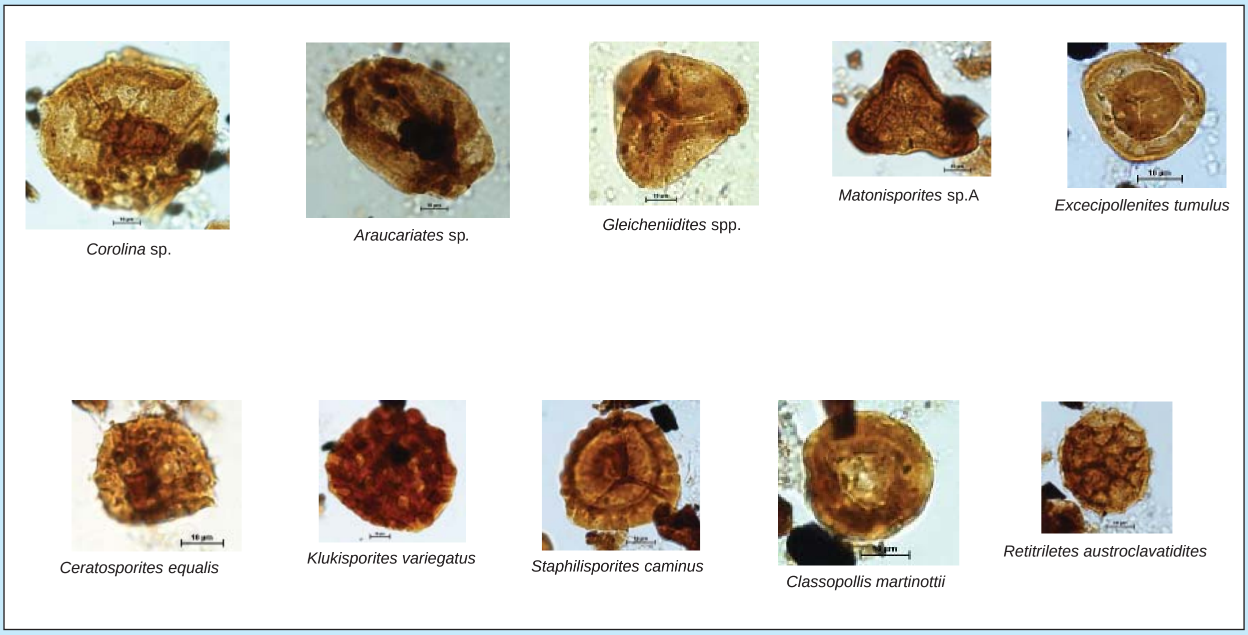


Figure 9
Some spores occurring in the studied samples which have Australian affinity

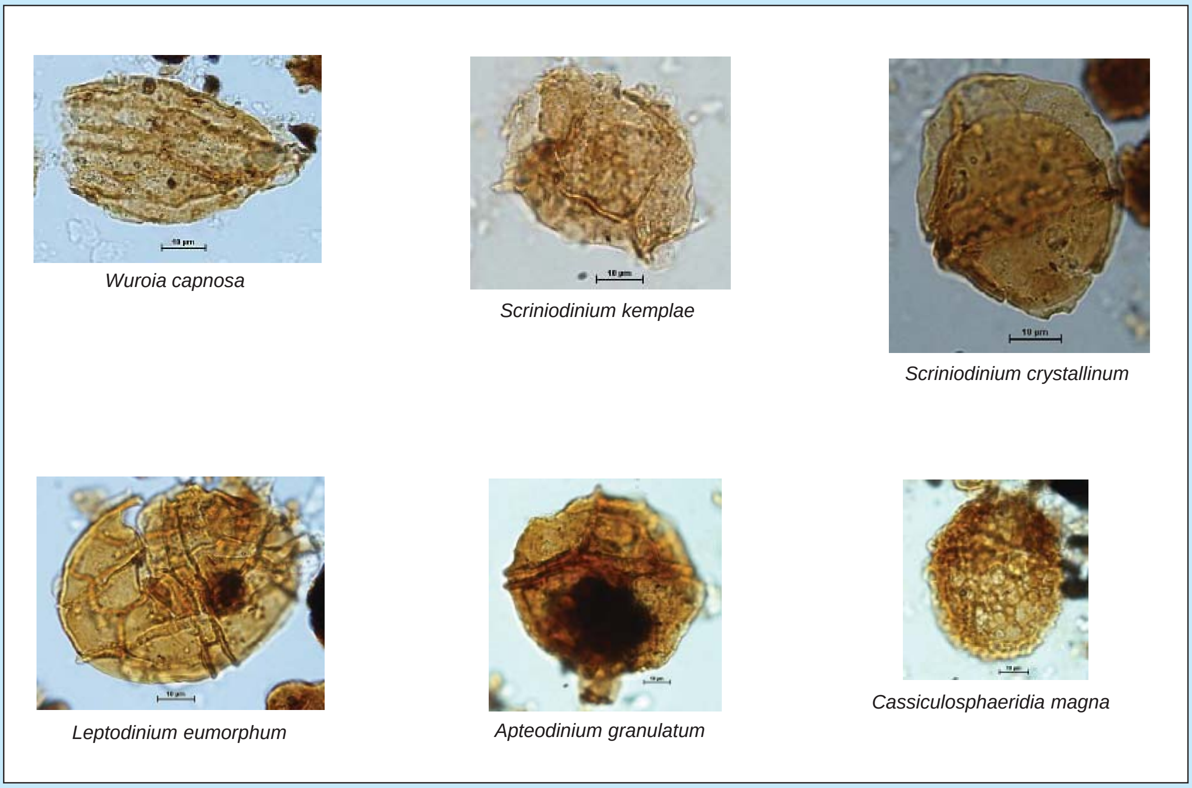


Figure 10
Some dinoflagellates occurring in the studied samples which have Australian affinity

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