RESERVOIR POTENTIAL OF NEOGENE ROCKS IN THE BIAK ISLAND AND ITS SURROUNDING AREAS

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ABSTRACT

Biak Basin is located offshore to the immediate west and southwest of Biak Island. The basin contains up to 7,000m thick of sediments, which may be thermally mature to generate hydrocarbon if source rocks are present. The stratigraphy of the Biak Basin is generally dominated by carbonate sequences of Early to Late Neogene. The basin was drowned during the Oligocene, which could have led to source rock accumulation during this period. Then, carbonate platform facies were deposited massively above and can be of potential reservoir. The Neogene carbonates consist of two depositional sequences, namely Early Neogene sequence that contains Wainukendi, Wafordori, and Napisendi Formations; and Late Neogene sequence that contains Korem and Wardo Formations. A Late Miocene unconformity separates the two carbonate sequences.

Reservoir rock potential of the Neogene carbonates has been evaluated by using quantitative parameters. Based on the evaluation, grainstone interbedded crystal limestone from the Napisendi Fm members has porosity ranging from 8.84% – 29.5% which can be categorized as good to special. Porosity types of the rock vary from intercrystalline, intracrystalline, and fracturing to vuggy. Secondary porosity occurred due to diagenetic rocks processes such as compacting, cementing, dissolution and dolomitization.

Keywords: *Biak basin, Neogene carbonate sediments, porosity*

INTRODUCTION

The Biak Island is one of the outer islands located to the north of mainland Papua (Figure 1). This island is a high area in the northern part of Biak Basin and is dominated by massive deposition of carbonate sediments. Tectonic development of the Biak basin began in the Paleogene, as a result of a collision between northern part of the Australian Continental Plate and the Island arc (Dewey and Bird, 1970; Milsom et al., 1992; Hall, 2002; Cloos et al., 2005). The existence of three hiatus in the Biak Island is caused by changes in sea level which becomes evidences of intense sediment deposition in that area (Gold, 2014). Changes in the depositional environment have both positive and negative effects on the diagenesis processes of rock, which in turn had greatly affected the formation of rock porosity.

REGIONAL GEOLOGY

According to Hehanussa et al. (1989) and Tjiptasmara and Saefudin (2005), the morphogenesis of the Biak Island is an elevated island which is dominated by carbonate rocks. The carbonate rocks consist of porous coral limestone and limestones which cover almost the whole Island. Thus, it made the task to identify the type of rocks that lies beneath it very difficult. In addition, the presence of oceanic crusts found in East Biak has made the stratigraphic conditions in Biak Island and the surrounding areas more complex. Based on field observations, there are seven lithological units that were found in that area. The seven lithological units, from old to young order, are:

1. Metamorphic Rock Unit: This rock unit, which consists of phyllite, schist, and gneiss, is found in the southern part of Supiori Island. This unit has foliated texture with very intense joints and is filled with quartz veins (Figure 2). The quartz grains has an alignment pattern of flat minerals. Thus, it can be interpreted that the genesis of these rocks is clastic sedimentary rocks found on continental plates. Masria et al. (1981) stated that this unit is the bedrock of the Korido Formation.
2. Mafic and Ultramafic Igneous Rock Unit: This rock unit consists of peridotite, serpentinite and basalt (Figure 3). The thin section of the –

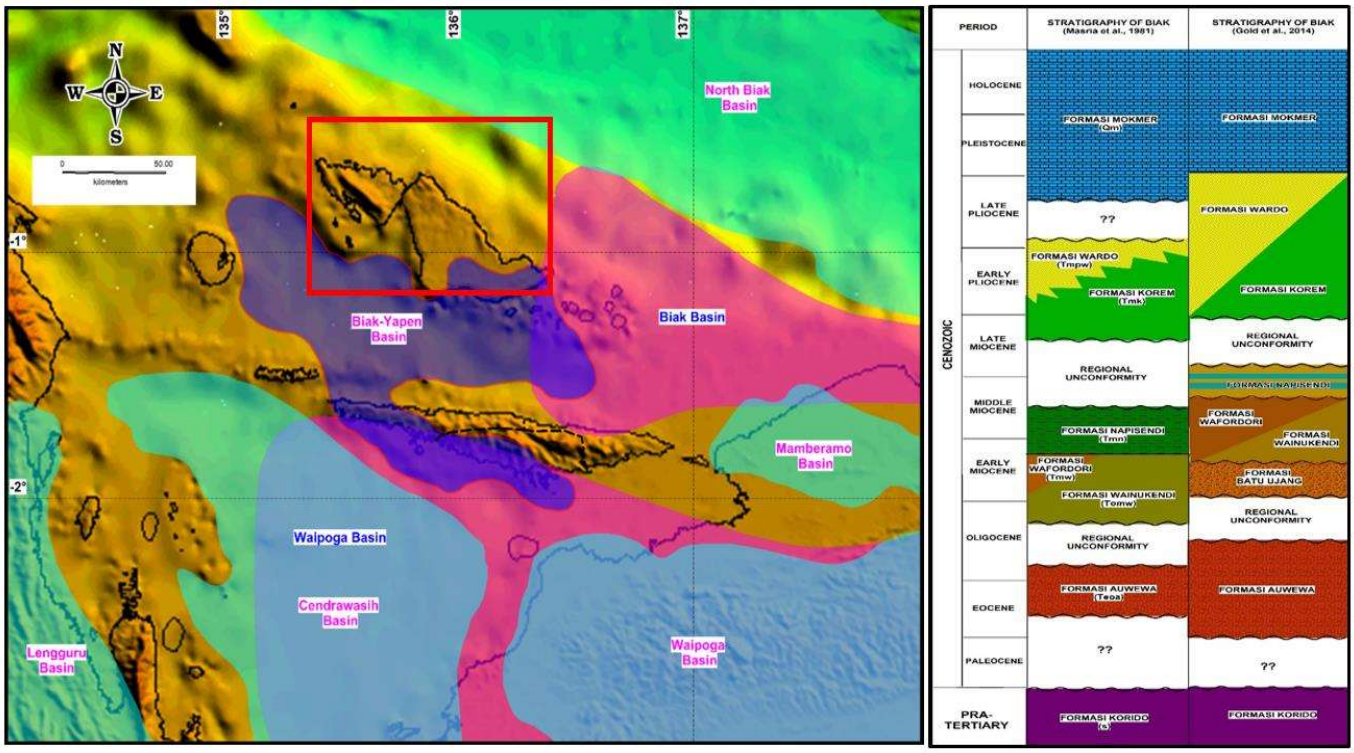


Figure 1. *Biak Basin Map and Straigraphic regional of Biak from Masria et al. (1981) and Gold (2014)*

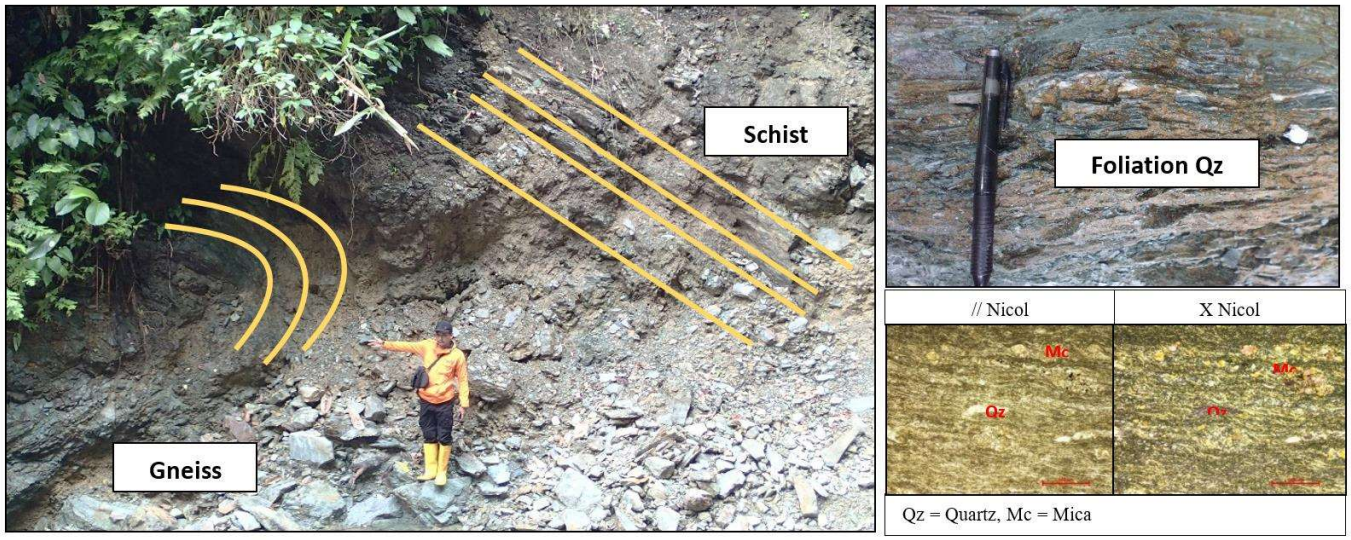


Figure 2. *Basement outcrop (Korido Fm) which shows intensive structure and foliation among granular and flat minerals. Thin section shows alignment minerals.*

serpentinite shows a typical mesh texture which is evidence of the serpentinization process. The existence of basalt was considered to be oceanic crust evidence. In the thin section of this outcrop, a diabasic texture with plagioclase that surrounded the olivine could be seen. Masria et al. (1981) stated that this unit belongs to the Auwewa Formation.

3. Volcanic Rock Unit: This rock unit is found adjacent to ultramafic and mafic igneous outcrops. This unit consists of breccia and tuff. The components of breccia are <2 mm in size with sub-angular shape and silica cement (Figure 4). The thin section of this unit shows mineral quartz as the dominant rock fragment (30%) which is then interpreted as the result of volcanic activity on the continental plate. Masria et al. (1981) stated that this unit belong to the Auwewa Formation.



Figure 3. *Basement outcrop (Auwewa Fm) which shows peridotite and intensively weathered serpentinite. Thin section show diabassic texture of basalt (A and B) and mesh texture of serpentinite (C and D).*



Figure 4. *Basement outcrop (Auwewa Fm) which shows high oxidation. Thin section shows quartz as the main rock fragment in breccia.*

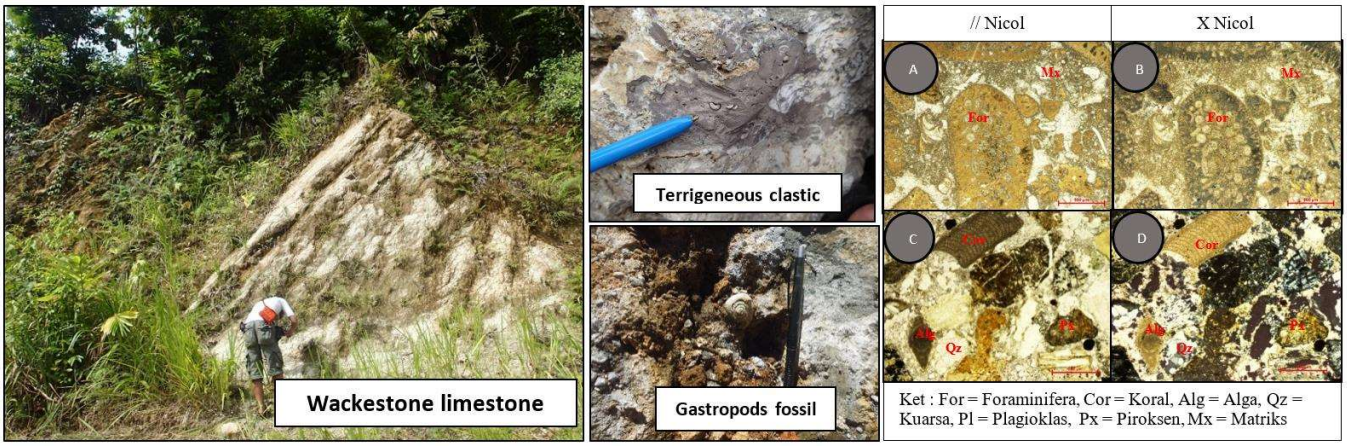


Figure 5. *Limestone with interbedded conglomerate outcrop (Wainukendi/ Wafordori Fm). Thin section shows rock fragment in conglomerate that consist of basaltic, limestone and fossil.*

4. Calcareous Sandstone Unit: This rock unit consists of calcareous sandstone, limestone, boundstone-grainstone (Dunham, 1962), with the insertion of crystal limestone. Furthermore, the interbedded layers of bioclastic-packstone and massive conglomerate could be found at the bottom. The bioclast grains in the limestone are dominated by large forams, gastropods, fragments of mollusc shell and some parts of algae and coral. Conglomerates consist of gneiss, schist, limestone, and gastropod shells, matrix of sandy limestones, and carbonate cement. The thickness of the limestone and conglomerate alternating layers was more than 80 meters. The presence of terrigenous clastic that has experienced drifted downslope, reef rudstone and bioclastic packstone (Figure 5) indicates that the deposition has happened in the facies belt - foreslope (Wilson, 1975). Micropaleontology analysis shows an Early Miocene age and was deposited in Upper – Lower Bathyal zone. Masria et al. (1981) stated that this unit belongs to the Wainukendi / Wafordori Formation.

5. Reef Limestone Unit: This unit consists of grainstone and boundstone (Dunham, 1962). The bioclasts of the limestone is dominated by both tabular and domal coral in which shelled fossils with the size of >1 cm were found (Figure 6). The thin section and SEM Imaging - of this unit showed grain-supported texture, algae bioclasts and large foraminifera that showed interparticles and moldic porosities (Figure 7). The thickness of this outcrop has reached 30 meters. The presence of head coral, coquina, and bioclastic grainstone indicates that the deposition happened in the facies belt, platform margin reef facies (Wilson, 1975). Micropaleontology analysis shows Middle Miocene age and was deposited in Outer Neritic – Lower Bathyal zone.

6. Calcareous Siltstone Unit: This unit consists of calcareous siltstone and claystone, with the insertion of chalky packstone (Dunham, 1962) and is rich in foraminifera (Figure 8). The thin section shows the dominance of small foraminifera in a grain size. The results of the quantitative micropaleontological analysis shows Late Miocene – Early Pliocene age and the depositional environment gradually moves from the Lower Bathyal – Outer Neritic zone (Table 1). Masria et al. (1981) stated that this unit belongs to the Korem/ Wardo Formation.

7. Coral Limestone Unit: This rock unit consists of coral and chalky limestones (Figure 9). The limestone has a relatively coarse texture, grain size of <1mm. It consists of coral and algae fragments and has good porosity, hardness, open fabric and intergranular porosity (Figure 10). Masria et al. (1981) stated that this unit belongs to the Mokmer Formation.

Table 1. *Microplaeontology analysis of Korem/ Wardo Formation in the North Biak*

Umur	Zonasi Planktonik (Blow, 1969, 1979)	Formasi	Satuan	Lingkungan Pengendapan: Supra-litoral	Litoral	Neritik Dalam	Neritik Tengah	Neritik Luar	Batial Atas	Batial Bawah	Komentar Biostratigrafi	No.	Sampel
Tidak lebih muda dari Pliosen Bawah	Tidak lebih muda dari N19	Korem	Batulanau Karbonatan / Napal (?)								*Globigerina venezuelana*	1	BK 20 VIII P2
Miosen Atas - Pliosen Bawah	N17-N18										*Globorotalia merotumida*	2	BK 20 VI P2
												3	BK 20 V P2
												4	BK 20 IV P2
												5	BK 20 III P2
												6	BK 20 II P2
												7	BK 20 I P2
												8	BK 20 V
											Globorotalia plesiotumida	9	BK 20 IV
Tidak lebih tua dari Miosen Atas	Tidak lebih tua dari N16											10	BK 20 III
												11	BK 20 II
											Globorotalia merotumida	12	BK 20 I

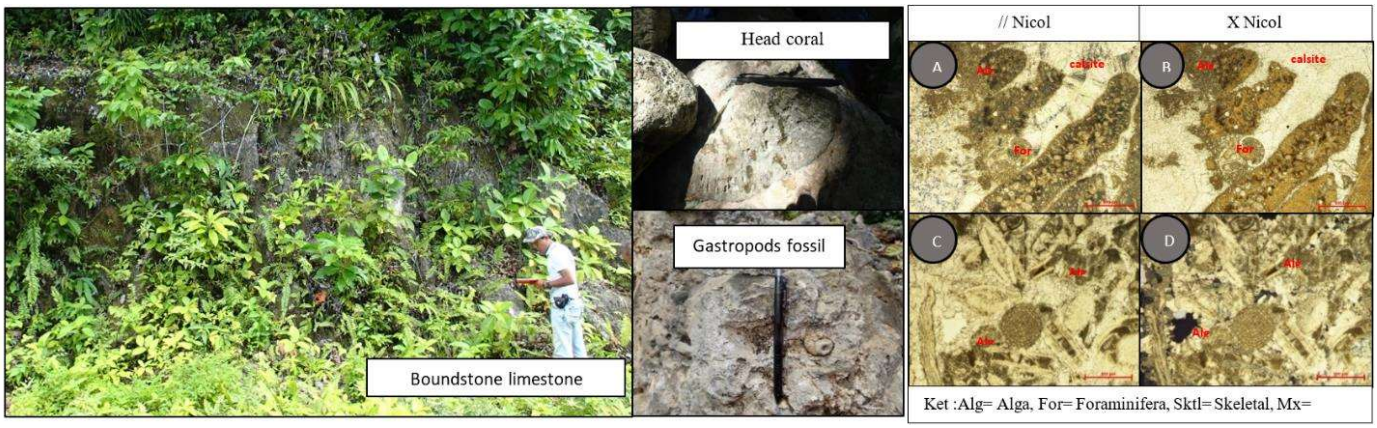


Figure 6. *Limestone with insertion of crystal limestone (Napisendi Fm) and gastropods as grain. Thin section shows bioclast such as algae and foraminifera (A and B) and coral limestone.*

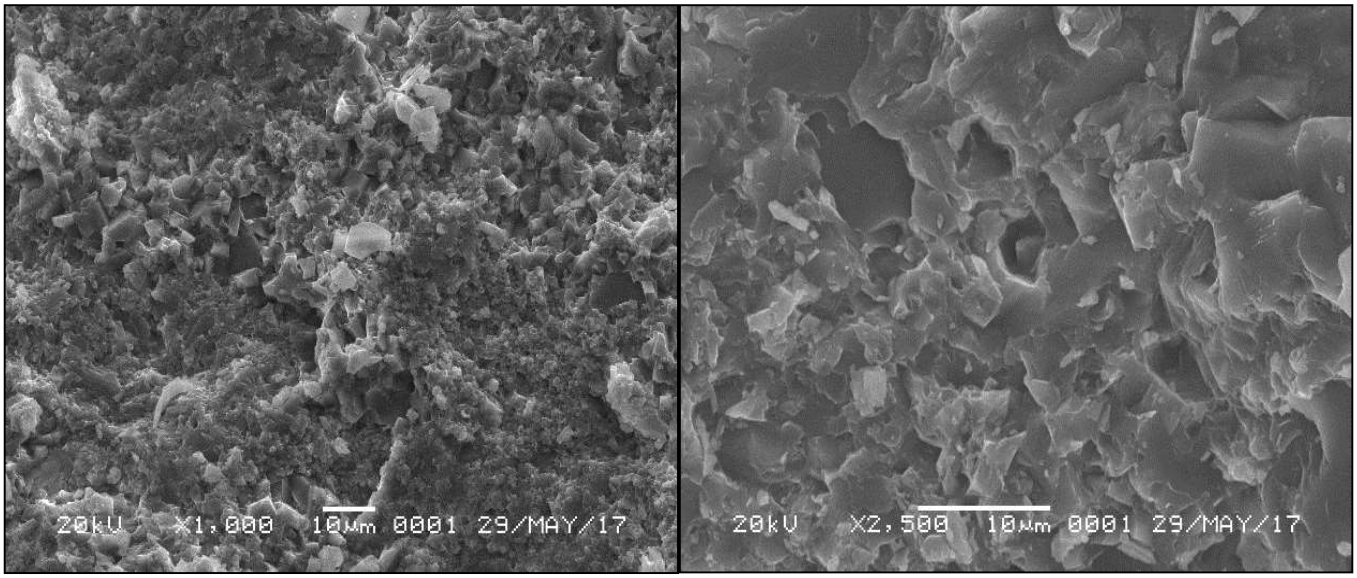


Figure 7. *SEM Imaging shows calcite as massive mineral that are rounded and anhedral. These images show intercrystalline and intracrystalline porosity.*

SEDIMENT DEPOSITION OF THE BIAK ISLAND

The stratigraphy of the Biak Island is generally dominated by massive carbonate sediment deposition. There were at least two regional events in the Neogene that affected the carbonate deposition sequence in the Biak Island (Figure 11). The first event occurred in the Early Miocene when interbedded carbonate and conglomerate were deposited at the bottom. The thickness of the conglomerate outcrops is more than 50 meters. It explains the sudden land subsidence that happened due to a significant rise in the sea level which resulted in a change of the depositional sedimentary environment to foreslope (Wilson, 1975), namely Wainukendi/Wafordori Formation. Furthermore, the depositional environment becomes shallower until it reaches the platform form was growing massively at the time (Figures 11, 1-3).

The second event was estimated to occur in the Late Miocene-Pliocene when clastic carbonate (marl) were deposited. These fine clastic carbonate are rich in foraminifera and with the insertion of packstone. Its depositional facies happened on the slope to the platform margin reef (Wilson, 1975). At this time, regional subsidence of the Biak Island is thought to happen which has changed the environment into deep water. It was evidenced by marl outcrops with the thickness of more than 50 meters that was found in the North Biak. The discovery of leaf fossils on the outcrops was considered to be the evidence of land subsidence that happened in the Middle Miocene-Late Miocene. The results of microplaeontological analysis shows shallowing depositional changes to-

younger sediments. Furthermore, the presence of massive limestone with the dominance of limestone corals was interpreted as the indication of shallowing environment. Lifting is currently thought to happen on the Biak Island (Saragih, 2018). This prediction was supported by massive carbonate terrace morphology found in the East Biak (Figure 11, 4-5).

POROSITY OF ROCKS

Porosity analysis was carried out on the rock samples in Biak Island as one step to identify the potential reservoir rocks of Biak Basin. A quantitative porosity analysis was carried out to calculate the pores in rock which was then compared to the volume of the rock. There were 14 samples of rocks that were analyzed. The samples consisted of: 5 rock samples from the Mokmer Formation, 6 rock samples from the Wardo Formation, 2 rock samples from the Napisendi Formation and 1 rock sample from the Wainukendi Formation (Table 2).

The results of porosity analysis shows two rock formations have reservoir rock potential. Grainstone with the insertion of crystal limestone which belongs to the Napisendi Formation fall into good to special category with the porosity that range from 8.84% to 29.5%. Based on microscopic observations and SEM Imaging, the porosities found in this formation were intercrystalline, intracrystalline, fracture and some parts showing vuggy (Figure 7). The secondary porosity occurred due to the diagenetic processes such as compaction, cementation, dissolution and dolomitization.

Coral limestone in the Mokmer Formation was identified as potential reservoir rocks in the Biak Basin. The results of the rock samples analysis shows the rocks porosity that range from 4.88% to 37.39%. Thus, the rocks in this formation fall into good to special porosity category. Based on the microscopic analysis and SEM Imaging, the porosities found in this formation were generally intergranular and intercrystalline porosities (Figure 10). The secondary porosity occurred due to the diagenetic processes such as compaction and cementation.

Table 2. *Quantitative measurements of porosity of rock samples from the Biak Island*

No	Rock sample	Lithology	Formation	Location	Porosity (%)	Density (gr/cm3)
1	BK15A	Limestone	Fm. Mokmer	East Biak	16.67	2.28
2	BK15B	Limestone	Fm. Mokmer	East Biak	24.10	2.07
3	BK16	Limestone	Fm. Mokmer	East Biak	8.42	2.39
4	BK25A	Limestone	Fm. Mokmer	East Biak	24.12	2.19
5	BK28	Limestone	Fm. Mokmer	East Biak	37.39	1.96
6	BK36	Limestone	Fm. Wardo	West Biak	22.87	2.06
7	BK40	Limestone	Fm. Wardo	West Biak	17.95	2.20
8	BK62	Limestone	Fm. Wainukendi	North Biak	6.20	2.33
9	BK20_P2-1	Limestone	Fm. Wardo	North Biak	29.37	2.10
10	BK20_P2-8	Limestone	Fm. Wardo	North Biak	31.85	2.02
11	BK18	Limestone	Fm. Wardo	North Biak	4.88	2.56
12	BK20	Limestone	Fm. Wardo	North Biak	8.24	2.39
13	17 BK 93 A	Limestone	Fm. Napisendi	North Supiori	29.58	-
14	17 BK 94 C	Limestone	Fm. Napisendi	North Supiori	24.49	-

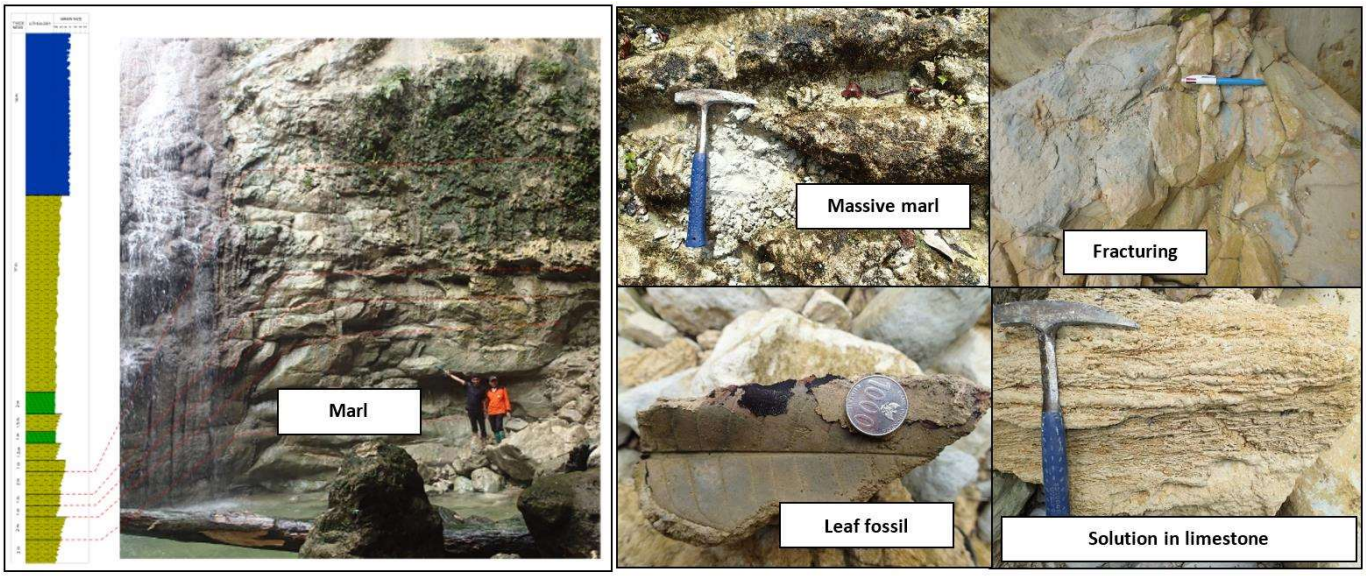


Figure 8. *Calcareous Silstone (Korem/ Wardo Formation) in waterfall located at North Biak as an indication of fault structure. Leaf fossils are indication of terrestrial material.*



Figure 9. *Coral Limestone (Mokmer Formation) with highly weathered. Some places show chalky limestone highly weathered.*

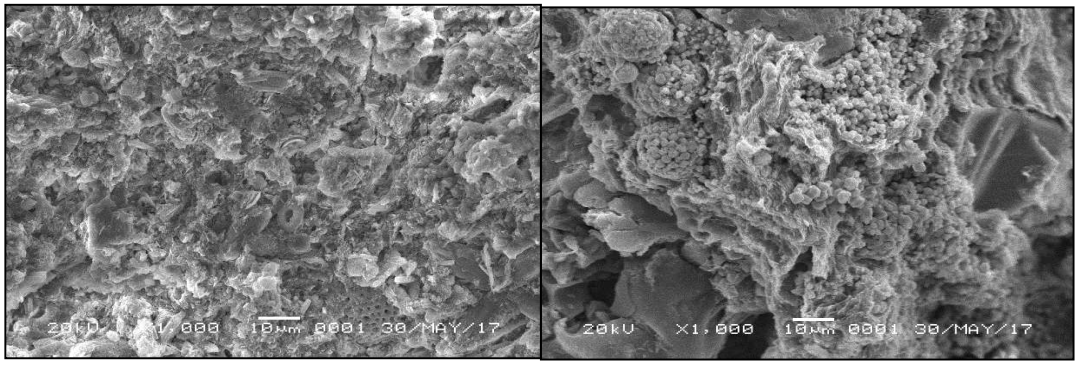


Figure 10. *SEM Imaging shows the texture of coral limestone. The images show two kinds of porosity were observed, which are intergranular and intragranular.*

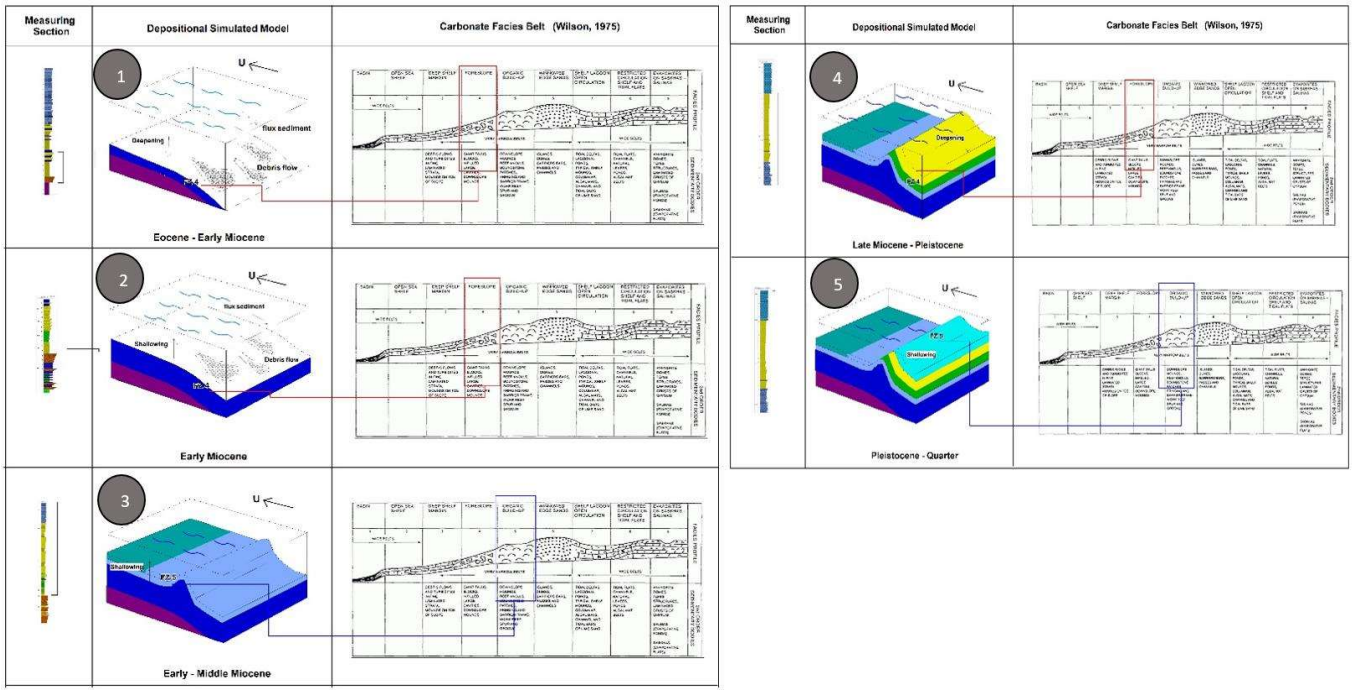


Figure 11. *Illustrated sedimentation in the Biak Island from Tertiary to Recent (modified from Wilson, 1975)*

CONCLUSION

The Biak Basin is a frontier basin located in the north of Papua with potential reservoir rock from carbonate sediments of Neogene age. Potential reservoir rocks found in the Biak Basin are within the Napisendi and Mokmer Formations. Based on the results of quantitative analysis, the porosities in those formations fall into good to special porosity category. The types of porosity found are intercrystalline, intracrystalline, fracture porosity and some parts showing vuggy porosity. The secondary porosity generally formed was caused by diagenetic process such as compaction, cementation, dissolution and dolomitization in both formations.

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