STRATIGRAPHY AND TECTONIC DEVELOPMENT OF MENTAWAI ISLANDS, WEST SUMATERA, BASED ON PLATE TECTONIC THEORY

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ABSTRACT

The Mentawai Islands are situated on the Indian Ocean westwards of West Sumatera Province forming a non-volcanic island arc. Stratigraphic and tectonic development of the islands are strongly related to the subduction between the Indian Ocean and Eurasian Continental Plate. Tectonic activities have occurred since Early Tertiary - Late Pliocene. It has happened simultaneously with the Indian Ocean Plates collision moving northwards and subducted below the Sunda/Eurasian Continental Plate. The Ophiolite and Melange Complexes were exposed and overlain unconformably by the acceleration prism of sedimentary rocks (Mentawai Group) formed as a pond sedimentation deposited within a small basin situated between active thrust fault fragments.

Based on the age determination gained from paleontological analysis, tectonic configuration, basin development, and sedimentation rate, the Mentawai Islands are believed to be formed by mélange complexes comprising part of an uplifted accretionary complex of a non-volcanic island arc.

Keywords: stratigraphy, tectonic, mélange, Mentawai Islands

SARI

Kepulauan Mentawai terletak di Samudera Hindia bagian barat Propinsi Sumatera Barat dan membentuk busur kepulauan bukan gunung api. Perkembangan stratigrafi dan tektonika di kepulauan ini berhubungan erat dengan kegiatan penunjaman antara Lempeng Samudera Hindia dan Lempeng Benua Eurasia. Kegiatan tektonika telah terjadi sejak Tersier Awal-Pliosen Akhir. Kejadian ini menerus seiring dengan tubrukan Lempeng Samudera Hindia yang bergerak ke arah utara dan menunjam di bawah Lempeng Sunda/Benua Eurasia. Kompleks ofiolit dan mélange muncul dan ditindih secara tak selaras oleh pergerakan mengerucut batuan sedimen (Kelompok Mentawai) yang terbentuk sebagai endapan kolam (*pond deposit*) di dalam suatu cekungan kecil yang terletak di antara pecahan-pecahan sesar naik yang aktif .

Berdasarkan penentuan umur yang diperoleh dari analisis paleontologi, konfigurasi tektonika perkembangan cekungan, dan laju pengendapan, Pulau Mentawai diyakini terbentuk oleh kompleks bancuh yang terdiri atas pengangkatan kompleks akrasi busur kepulauan tak bergunung api.

Kata kunci: stratigrafi, tektonik, bancuh, Kepulauan Mentawai

INTRODUCTION

The Mentawai Fault is a strike-slip motion which corresponds to the fore-arc domain (Malod and Kemal, 1996), and it lies just to the east of the outer-arc ridge and is indicated to be intersected with other faults on the Mentawai Islands (Samuel *et al*., 1995). Stratigraphically, the Mentawai Islands comprise a part of an uplifted accretionary complex (Andi Mangga & Burhan, 1984). Two main stratigraphic units were defined. Firstly, the tectonite rock units, known as the ophiolite and mélange complexes which were formed prior to the Oligocene. The deep marine sediments were then unconformably deposited above it in trench slope basins. Secondly, the Miocene - Pliocene sedimentary succession which is characteristized by a shallowing-up marine sequences covered the previous deposit.

The stratigraphy and tectonic development of the Mentawai are slightly similar to the Sumatera Fore-arc (Kusnama *et al*., 1993), while the development of the arc is controlled by the plate motion of the subduction system. The Mentawai Islands lie on the boundary between the fore-arc ridge, which is believed to be part of the accretionary prism, on the other hand, the Sumatera fore-arc basin is located in a continental domain.

The detailed sedimentological and biostratigraphical studies of the sedimentary successions led to the construction of an up dated stratigraphy of Mentawai.

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The rock samples collected had been analyzed sedimentologically and it was combined with structural data over the entire islands. Therefore, the geological and tectonic evolution of the Mentawai Islands can be interpreted in a different way.

Geographically, the Mentawai Islands are located in the west of Sumatera Island extending NW-SE direction which is parallel to the Sumatera mainland which is representing the subduction zone. The islands consist of three main islands, Siberut, Sipora, and Pagai in the southernmost part. The area can be reached by a regular voyage from Padang to those three islands or by plane to small air terminals in Siberut and Sipora.

The current research is concentrated in a highly tectonized area, and the research was carried out by collecting, analyzing, and comparing rock samples from different areas.

GEOLOGICAL SETTING

Physiographically, Mentawai Islands are a non-volcanic chain included within the Outer Sunda Arc. The islands appear to be gentle hills with elevation of less than 400 m above the sea level, while the surrounding areas occupy a place of less than 50 m above the sea level.

Stratigraphy of the Research Area

The studied area consists of sedimentary rocks (clastic and carbonate rocks) and a tectonized rock unit (mélange complex). The Oceanic Crust rocks origin (ultramafic and sedimentary clastics) are tectonically mixed to each other as a result of subduction occurred in Early Tertiary. They formed a tectonized and imbricated mass. The ultramafic rock unit is the oldest rock unit and was tectonically

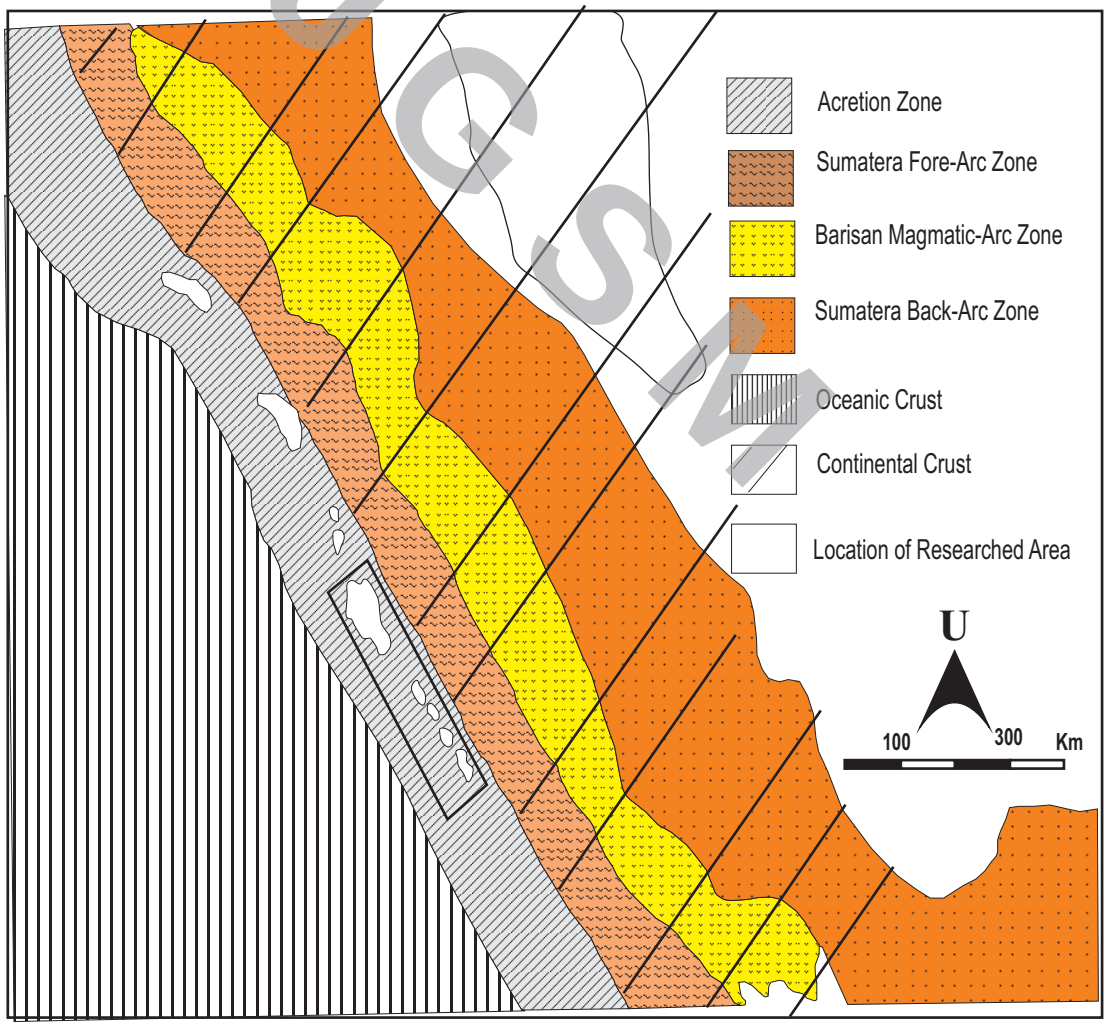

Figure 1. Location of researched area.

covered by sedimentary rock unit (Mentawai Group) interpreted as a pond deposit.

Stratigraphically, the oldest rock of the Mentawai Islands is the rock formation and hydrothermal alteration of oceanic crust and mantle derived from ultramafic (ophiolitic) basement rocks consisting of serpentinite, pyroxenite, and serpentinised dunite. The rock unit has commonly already been chloritised, sheared, jointed, and brecciated, and the ultramafic rock unit is commonly found in the north side of Sipora Island. The ultramafic rock of ophiolitic complex in the Sipora Island is believed to be part of the lower part of the Oceanic Crust (Andi Mangga & Burhan, 1984), while in the Pagai Island it is part of upper part of the Oceanic Crust. Therefore, the north/northwest of Sipora Island was uplifted higher than the southern part of Pagai Island. Evidence of radiolarian cherts within ophiolite complex indicates that the rock has an age ranging from Middle - Late Eocene.

The emplacement and uplift of the deep marine sedimentary basement rocks lying unconformably on the top of the ophiolitic basement rock are represented by the Late Eocene - Early Oligocene Tolopulai and Maonai Formations which are exposed in the Sipora and Siberut Islands.

The extension of basement and development of the basins comprise mudstone-shale, tuff, and conglomerate of the Batumonga Formation in the Pagai/ Sipora Islands, while the Saibi and Sagulubek Formations are exposed in the Siberut Island. Both were deposited unconformably above deep marine rocks. They have an age between Middle Oligocene - Middle Miocene. Kalea Formation in the Siberut Island shows an evidence of uplift that took place during Early - Middle Miocene by the appearance of conglomerate marker beds comprising a reworked ophiolitic basement and deep marine sediments.

Regional subsidence occurred in Middle - Late Miocene as indicated by shelfal to upper bathyal sedimentary rocks, small amount of diatomites, tuff, and limestone marker. During Plio - Pleistocene, a rapid uplift occurred and continued by mud volcanism represented by shallow marine siliciclastics elevated reef complexes of the Simatobat Formation.

Mentawai Mélange Complex

The mélange complex was formed by a mud diapirism consisting of rock fragments of various ages, and size of rock fragments of different orientation within matrix of mudstone completely tectonised by clay (scaly clay). The rock fragments are made up of greywacke, shale, conglomerate, quartz sandstone, arkose, serpentinite, gabbro, basaltic lava, red chert, calcilutite, meta sandstone, phyllite, micaceous schist, amphibolite, granitic gneiss, diorite, granodiorite, diabase, andesite, and numulitic limestone. Within the greywacke, a boudinage structure with N310E direction and basaltic lava are present.

The age of the mélange was determined by fossil within sheared claystone and limestone blocks. Claystone blocks contain planktonic foraminiferas such as : *Globigerina venezuelana* HEDBERG, *Globorotalia peripheroronda* BLOW and BANNER, *Globigerinoides subquadratus* BRONNIMANN, *Praeorbulina transitoria* BLOW, P*raeorbulina glomerosa* BLOW, *Globoquadrina altispira* CUSHMAN and JARVIS, *Globigerinoides trilobus* REUSS. This fossil assemblage shows the age ranging from Early-Late Miocene, zone N8, within outer sublitoral environment (Purnamaningsih Siregar and Budiman, 1982; personal communication)

The limestone blocks contain macro foraminifera fossils consisting of *Nummulites* sp., *Discocyclina* sp., *Pellatispira* sp., dan *Borelis pygmaeus* HANZAWA. They indicate Late Eocene age (Purnamaningsih Siregar and Budiman, personal communication). On the basis of the above fossil assemblages, the age of the rocks is estimated to be in the range from Oligocene - Early Miocene.

The distribution of the Mélange Complex in the Pagai and Sipora Islands is commonly found in the central part of the islands and in the surrounding small adjacent islands. The complex exposure is discontinuous and it is parallel to the island length axis (west-southeast); it formed a gentle hill morphology. The Mélange Complex was well exposed in Cekungan and Simatutu Rivers (North Pagai Island) and may be correlated with the Oyo Complex in the Nias Island (Hehanusa, 1977; cited by Sukamto & Barber, 1979).

In the Siberut Island, the tectonized rocks were grouped into Tarikan Mélange Complex. The Complex is composed of polymict rock fragments of different ages and sizes within the matrix of very fine sand and sheared clay. The fragments are clastic rocks (greywacke, conglomerate, quartz sandstone, meta sandstone); ultramafic rocks (pyroxenite, serpentinite, dunite, basalt); metamorphic rocks (slate, phyllite, micaceous schist, amphibolite, geneiss) and sedimentary & volcanic rocks (marl, shale , tuff, chert, and limestone).

The age of mélange rock was determined by fossils found in limestone, marl, and sheard tuffaceous clay. In the limestone boulders macro foraminifera fossils were found including *Lepidocyclina* sp., *Spiroclypeus* sp., and *Miogypsinoides* sp. which range in age between Late Oligocene and Early Miocene, period low Te-upper Te, and were deposited within shallow marine environment (Budiman, 1983, written communication).

In sheared tuffaceous claystone, planktonic fossils such as *Globoquadrina altispira* (Cushman & Jarvis), *Globorotalia siakensis* (Le Roy) and fossils of benthic formaninifera (*Gyroidina* sp., *Nodosaria* sp., *Eponides* sp., *Globocassidulina* sp) were found. The fossil group shows Oligocene - Middle Miocene age, probably deposited within neritic-inner sublitoral zone environment deposition (Budiman, 1983 personal communication). Based on the age determination of above age, therefore, the age of the unit is estimated to be Middle until Late Miocene.

The distribution of the unit is commonly found in the central part and some places in the southeastern part of the east coast; it is exposed separately, however, in the same direction with the long axis of the island (northwest-southeast) and formed a gentle hill. The mélange complex is well exposed in the Tarikan River on the northwest coast; and the Saibi and Mauku Rivers one of the Saibi River tributary, south of Siberut.

Based on the youngest boulders and sediments covering the Mélange Complex in the Sipora and Pagai Islands, they are interpreted as having the Early Oligocene-Early. While in the Siberut Island, the age ranges from Middle to Late Miocene. The Mélange rock complex zone shows an age younging to the western part of the Sipora Island.

Sedimentary Rocks

The sedimentary rock of the Mentawai Islands comprises clastic and carbonate rocks with lignite intercalation (Budhitrisna & Andi Mangga, 1983). In the Sipora and Pagai Islands, the sedimentary rock of the Mentawai Group was included into the Tolopulai, Maonai, and Batumonga Formations. The Early Miocene Tolopulai Formation was deposited within the shallow marine environment, probably as fore-reef, and overlain by the Maonai Formation. The later interfingers with the Batumonga Formation of Middle-Late Miocene - Pliocene age deposited within an inner littoral environment.

In the Siberut Island, the sedimentary rock of Mentawai Group includes the Saibi, Sagulubek, and Kale For-mations. These three rock units shows an interfingering relationship, however, the Saibi Formation is relatively older than the other rock formations. The age of the Saibi Formation is Late Miocene - Early Pliocene, and the depositional environment is deep marine. While, the Sagulubek Formation has an age of Late Miocene - Late Pliocene and was deposited in a deep marine environment. The Kalea Formation of Late Miocene - Pleistocene age was deposited within an open marine-outer sublittoral environment.

The Lower part of the Mentawai Group (Tolopulai, Saibi, and Sagulubek Formations) has a direct contact with the Mélange Complex, and it was strongly folded with dipping between 50 - 80 and struct to northwest-southeast direction. The unit was sheared and jointed, and deposited at a deep marine environment. Going up the younger rock unit, the Maonai, Batumonga, and Kalea Formations are weakly folded, with a gentle dipping northwest - southeast strike. The unit was also sheared and faulted, and probably deposited within inner-outer littoral, marine environment.

The Mentawai Group has a characteristic of a pond deposit and was deposited on a basin between two mélange highs. The mélange high was formed as a result of the movement of thrust faults.

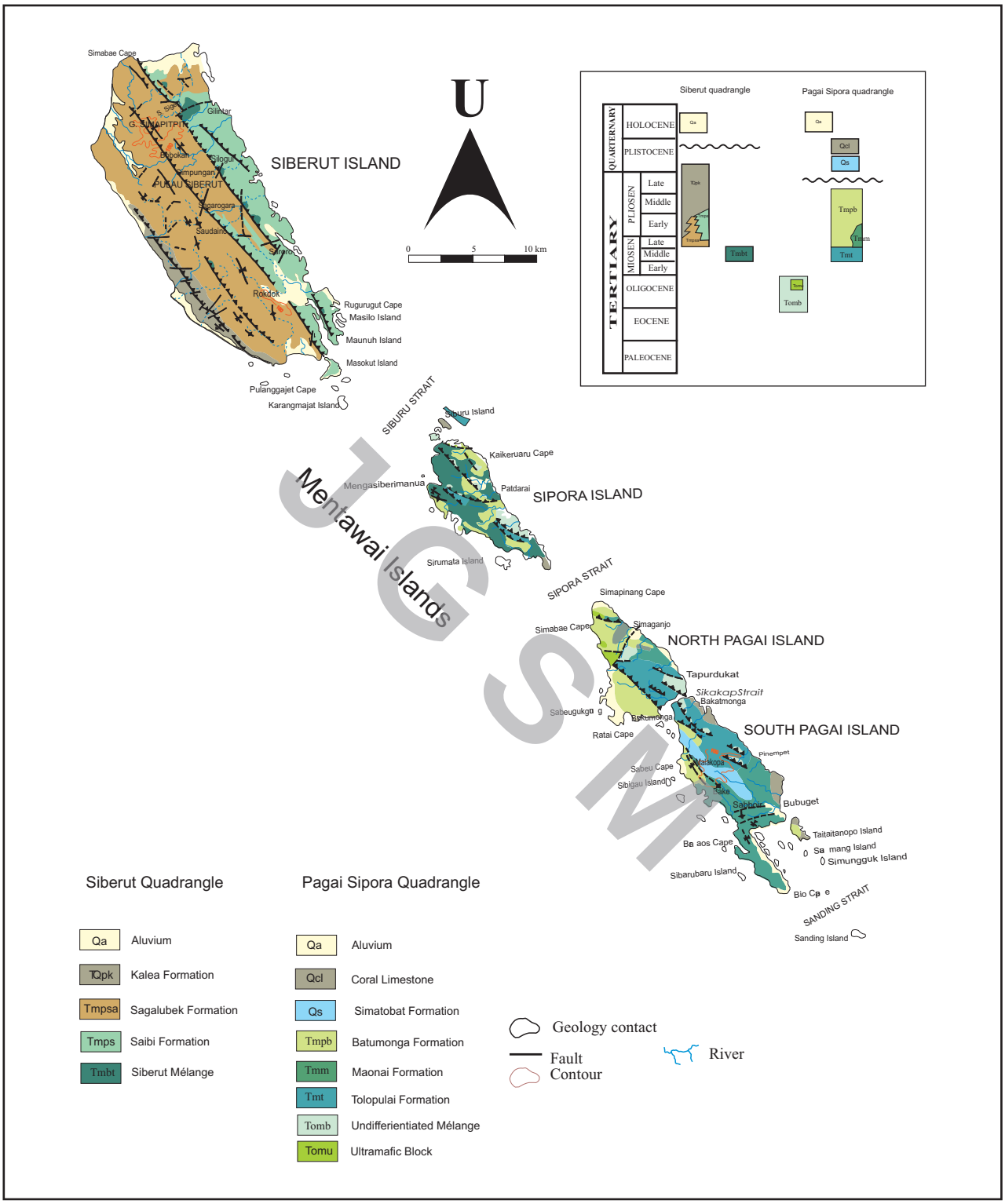

Figure 2. Geologic map of the Pagai, Sipora, and Siberut Quadrangle, Sumatera.

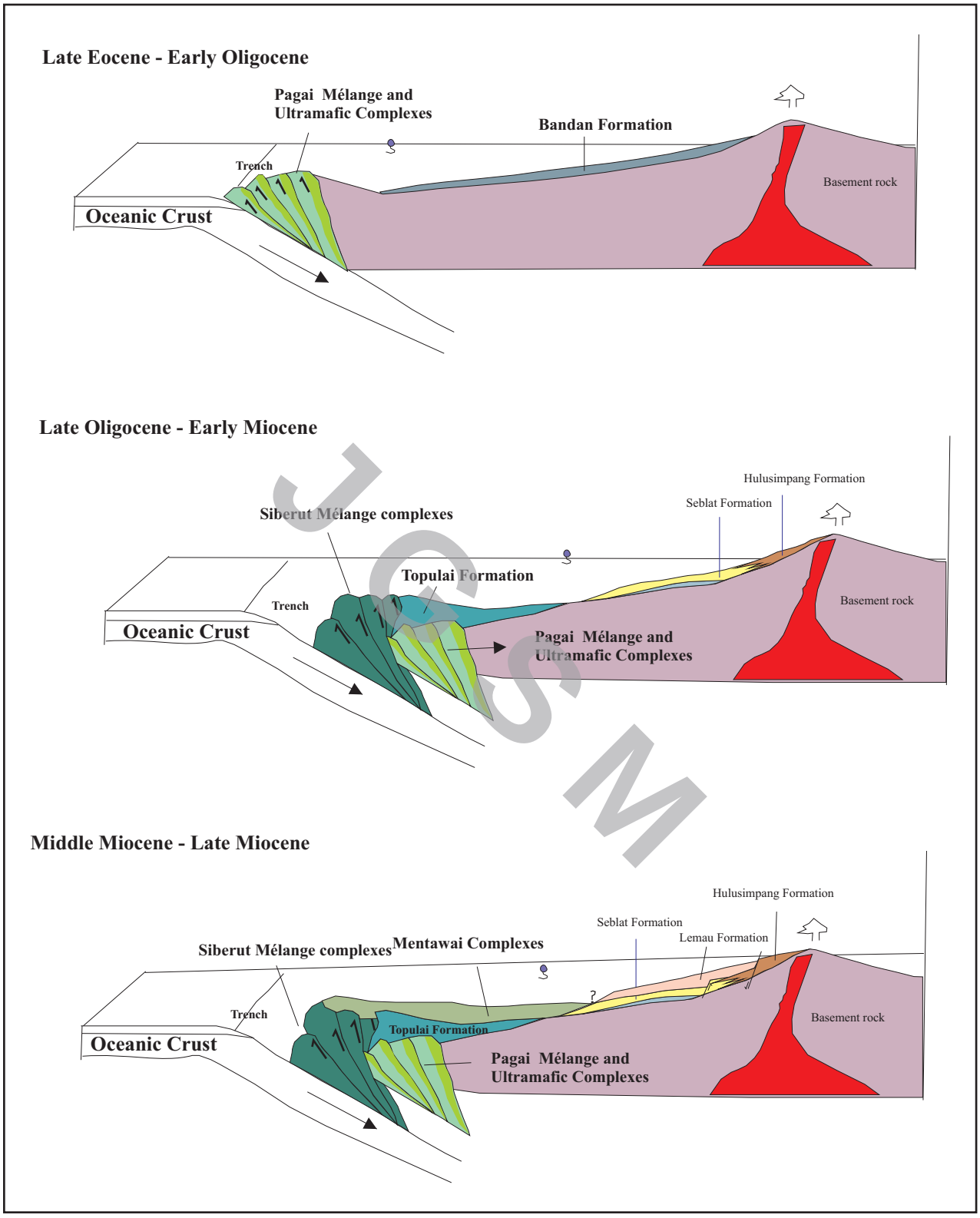

Figure 3. Schematic section showing the tectonic development of the Mentawai Islands.

Structure & Tectonics

Andi Mangga & Burhan (1984) indicated that Mentawai comprised part of an uplifted accretionary complex of a non-volcanic island arc. The Mentawai Fault extends from the south of Nias to the Pagai Island. Therefore, the fault is bounded by elongated sliver microplate which corresponds to the fore-arc domain. The tectonic pattern of this fault suggests a strike-slip motion of mud diapirism (Karig *et al*.,1978). The displacement towards the north of the Mentawai microplate as a single block is related to the extention in the Nias Island.

Fold structures formed anticline and syncline and they commonly well developed within the sedimentary rocks such as the Tolopulai, Saibi, and Sagulubek Formations.

The folds mainly developed to become thrust faults, specifically within the older sedimentary rock unit. The thrust fault commonly has a northwest-southeast direction or they are almost parallel to the long axis of the island. The dipping of fault plane is around 30-50 heading to the northeast.

Tectonic activity in the Mentawai Island occurring in Early Oligocene - Early Miocene was caused by the collision between the Indian Ocean Plate moving northward with the stable Eurasian Plate. The subduction resulted in the mixing of the oceanic rock and continental rock, origin which led to the mélange deposition.

In the Early and Middle Miocene the collision between the Indian Oceanic and Eurasian Plates have resulted in the occurrence of Mélange Complex in the Siberut Island (Tarikan Mélange Complex). In contrast, in the Sipora and Pagai Islands the Mélange Complex was overlain by sedimentary rocks of the Tolopulai Formation which was formed in the basinal area of the Mélange Intra High.

In Late Miocene - Early Pliocene clastic sedimentary and carbonate rocks (Maonai, Batumonga, Saibi, Sagulubek, and Kalea Formations) were formed in the basinal area between mélange high as a pond deposit. In the lower part, the rock unit shows tectonically contacts with strongly folded and faulted of mélange complex, while on the upper part, it indirectly contacts with mélange complex which was weakly folded and shows shallower depositional environment.

Tectonic activity in Late Pliocene has caused the younger rock unit to fold and fault, and some formed a basinal area, where the shallow marine rock formation well developed. The tectonic activity has been going on until nowadays; the evidence was recorded by the raise of reef coral and the emerge of some islands around the western and southern side of the Pagai Island.

CONCLUSIONS

The Mentawai mélange complex has occurred since Late Eocene as recorded in macro foraminifera fossils contained in limestone blocks collected from the Pagai and Sipora Islands. It seems to be the mélanges do not form a basement to the sedimentary succession on the Mentawai Islands chain, and they tend to be distributed mostly in the south of Pagai and Sipora Islands.

There are two periods of tectonism that have occurred in the Mentawai Islands. Firstly, in the Late Oligocene - Early Miocene when the collision between the Indian Ocean Crust with the Eurasian/Sunda Continental Crust took place which formed Mélange Complex in the Sipora and Pagai Islands; secondly, the tectonic activity occurring in the Early - Middle Miocene, when both crusts subducted and moved towards the southwest (acretionary prism) which formed the Mélange Complex in the Sipora Island.

The sedimentary rocks of the Mentawai Group which were deposited in the basin of the mélange high formed a pond deposit. The lower part of the group contacts with mélange complex by a strong fold and fault, and further up the fold is getting lesser and the depositional environment is getting shallower.

The present day tectonic activity occurred simultaneously as marked by the development of raised coral which had grown around western and southern part of the Mentawai Island.

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REFERENCES

Andi Mangga, S. & Burhan, G., 1984. The stratigraphic development of Mentawai Islands and its relation to stratigraphic of Sumatera Mainland, *PIT III IAGI*, Bandung.

Budhitrisna, T. & Andi Mangga, S. 1983. Pagai and Sipora Geological Report, Sumatera in scale 1: 250.000. *Geol. Res.Dev.Centre*. Open file report.

Karig, D.E., Suparka, S, Moore, G.F. & Hehanusa P.E. 1987. Structure and Cenozoic evolution of Sunda Arc in the Central Sumatera Region, *CCOP SEATAR workshop on the Sumatera Transect Parapat, Indonesia*.

Kusnama, Andi Mangga, S & Sukarna,D. 1993. Tertiary stratigraphy and tectonic evolution of Southern Sumatera. *GSM Bulletin No.33* , p. 143-152.

Malod J.A. & Kemal B.M. 1996. The Sumatra margin: oblique subduction and lateral displacement of the accretionary prism. In : *Tectonic Evolution of Southeast Asia*. Hall, R.& Blundell, D. (eds), 1996, *Geosoc*. *Spec.Publ. No.106*, p. 19-28.

Samuel, M.A., Harbury,N.A., Jones, M.E. & Matthews,S.J. 1995. Inversion controlled uplift of an outer-arc ridge: Nias Island off shore Sumatra. *Geological Society London. Spec. Publ. 88*. 473-492.

Sukamto,Rab & Barber A.J. 1979. *Tectonic of the western Indonesia. Geol.Surv.Bull. 5*. Bandung, Indonesia.