Menanga Formation as volcanic submarine fan deposit of Woyla Arc in Sumatra, Indonesia

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Abstract. The Menanga Formation is part of the Woyla terrane, the last large terrane amalgamated formed island of Sumatra. Woyla terrane consist of Cretaceous arc assemblage and relatively lack of research has been done on this formation in Lampung and surrounding areas. This study aims to identify the facies of the Menanga Formation. Research was carried out by making a measured stratigraphic and dividing it into facies and facies associations. The data were taken from two places, in Gunungkasih, Tanggamus and Way Sabu, Pesawaran, Lampung. The results showed that the Menanga Formation has nine facies, there are graded bedding sandstone (F1), loadcast sandstone (F2), parallel lamination coarse sandstone (F3), parallel lamination medium sandstone (F4), parallel bedding fine sandstone (F5), ripple fine sandstone (F6), lamination red sandstone (F7), grey claystone (F8), and parallel lamination red claystone (F9). The Menanga Formation facies were grouped into three facies associations, AF1 consist of F1, F2, F3, F4, and F5 shown channel geometry, fining upward trend, and Bouma classical turbidite deposit, while AF2 consist of monotonous interbedded of F5, F6, and F7 as upper part of the turbidite sequence, while AF3 shown distal facies association (AF3) consist monotonous interbedded of F8, and F9. The stacking pattern shows fining upwards and thining upwards trend interpreted to be channel-levee deposits in the midfan lobe of the submarine fan, while the monotonous of interbedded claystone with thin layers of sandstone in upper part interpreted to be deposited in the outer fan lobe submarine fan. Menanga Formation sandstone consists of lithic graywacke whose grains are dominated by lithic minerals, small amounts of feldspar and minor quartz. The discovery of indicates the relative age this formation ranging from Jurassic to Cretaceous. The discovery of radiolaria *Pantanellium* sp. indicates the relative age this formation ranging from Jurassic to Cretaceous. The Menanga Formation interpreted to be deposited in submarine fan environment whose sediment with material originates from the Woyla volcanic arc.

1 Introduction

Mangga et al. [1] and Amin et al. [2] carried out regional geological mapping of the Lampung area and grouped Mesozoic age sedimentary rocks into the Menanga Formation. The rocks of Sumatra Island can be grouped into three groups based on the age of the rocks and the tectonic terrane formation [3]. The Tapanuli Group is Carboniferous-Permian in age, the Peusangan Group is Permian-Triassic in age, and the Woyla Group is Jurassic-Cretaceous in age. This rock group was uplifted due to the collision between the terranes that formed Sumatra Island which occurred in the Paleozoic and Mesozoic [3, 4, 5, 6, 7]. The formation of the island of Sumatra began with the closure of the Paleotethys ocean plate in the Permian age, which was marked by the collision between the Sibumasu terrane and the West Sumatra terrane, then in the Cretaceous age the Mesotethys ocean plate closed, marked by the collision between the West Sumatra terrane and the Woyla terrane, which is a volcanic arc [3, 5, 6, 7].

In Lampung presence of pre-Tertiary rocks is always associated with the base rocks of the Gunungkasih Complex [1, 2]. Research on Menanga Formation in Lampung areas is still limited, especially research on facies, facies association, depositional environment, and provenance. The purpose of this study was to reconstruct the depositional environment and paleogeography.

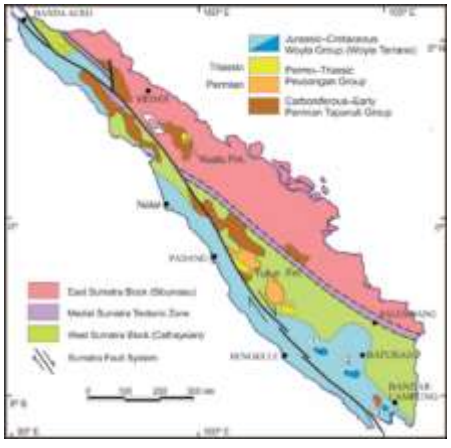

Fig. 1. Distribution of terranes in the Sumatra island [4]

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2 Literature review

The Menanga Formation has a lithology of calcareous shale, mudstone and sandstone interbedded with chert [1, 2]. The calcareous shale is dark brown to blackish gray, dense, firm and well layered with quartz veins. Sandstone has a brown – blackish to stained color, has fine-coarse grains. The mudstone is greenish gray to brown, and contains radiolaria. Chert is gray – brownish to red brown, dense and hard [2]. According to Alditian [8], the Menanga Formation around Gunungkasih has characteristics of red mudstone, layered sedimentary structures, carbonate sandstone lenses, radiolaria fossils, and manganese minerals in rock fractures. The Menanga Formation was deposited in a marine environment characterized by coral reefs, radiolaria, foraminifera contained in shale, and chert [1,2]. Based on the fossil Orbitulina sp. The Menanga Formation found is estimated to be Cretaceous age [1].

Research on the Menanga Formation is still relatively limited, several studies conducted regional research only providing a general description but not detailed [1, 2]. Research on paleomagnetism to determine the depositional position of the Menanga Formation has been carried out [19] but the description of the rocks and their depositional environment only refers to previous research without anything new.

Fig. 2. Geological map of the Lampung area [1,2]

3 Methodology

Research was carried out by making a measured stratigraphic and dividing it into facies and facies associations. The data were taken from two places, in Gunungkasih, Tanggamus and Way Sabu, Pesawaran. Provenance analysis was carried out on six thin section samples of sandstone. Analysis using a polarizing microscope with the point counting method according to the method introduced by Gazzi-Dickinson [10]. The grain size interval used in this method is between 0.0625 to 0.0625. 2 mm (fine sand to very coarse sand). The point counting sample includes 6000 points per incision. Component calculations include quartz, plagioclase, and rock fragments which will be plotted in triangle diagrams Qt-F-L and Qm-F-Lt [11] and Qt-F-L and Qm-F-Lt [11]. Radiolaria identification using Catalog of Mesozoic radiolarian genera [12].

4 Results and Discussion

4.1 Litology

The field observation showed that the Menanga Formation has nine facies (Fig 3 and Fig 4), there are graded bedding sandstone (F1), loadcast sandstone (F2), parallel lamination coarse sandstone (F3), parallel lamination medium sandstone (F4), parallel bedding fine sandstone (F5), ripple fine sandstone (F6), lamination red sandstone (F7), grey claystone (F8), and parallel lamination red claystone (F9).

The Menanga Formation facies were grouped into three facies associations, channel facies association (AF1), levee facies association (AF2), and distal facies association (AF3). AF 1 and AF2 can be observed in the Sabu River, AF1 consist of F1, F2, F3, F4, and F5 shown channel geometry, fining upward trend, and Bouma classical turbidite deposit, while AF2 consist of monotonous interbedded of F5, F6, and F7 as upper part of the turbidite sequence, while AF3 is well exposed in the Gunungkasih area shown distal facies association (AF1) consist monotonous interbedded of F8, and F7 with thin layer F7 in upper part (Fig. 4). The stacking pattern shows fining upwards and thinning upwards trend interpreted to be channel-levee deposits in the midfan lobe of the submarine fan, while the monotonous stacking pattern of interbedded claystone with thin layers of sandstone in upper part interpreted to be deposited in the outer fan lobe submarine fan environment [13].

4.2 Provenan

The compositional characteristics of a rock can be determined from the distribution of components, including minerals, rock fragments, matrix and cement, which can be observed in thin sections. Base on sand classification [14] Menanga Formation sandstone classified as lithic graywacke (Fig. 5). In Menanga Formation quartz found in small quantities (7-12%), in the form of monocrystalline quartz (Qm), generally euhedral in shape, round to medium-tapered. Feldspar found in the plagioclase feldspar type, with a composition ranging between 15-30%, generally euhedral in shape, roundness tapering to half-rounded, in an alternating condition. Rock fragments are present in the most abundant quantities (35-56%) predominantly in the form of igneous rock fragments, and matrix range from 16-24% (Table 1, Tabel 2). Based on the discriminant diagram [11], the provenance of the Menanga Formation originates from the transitional arc to undissected arc (Fig. 6). The tectonic setting of Arcs is a condition resulting from the partial meeting of two earth plates, thus creating volcanoes which are the source of sedimentary material [15]. This is in line with the characteristics of the Woyla rock group which is associated with volcanic arcs by several previous researchers [3, 9, 16, 17].

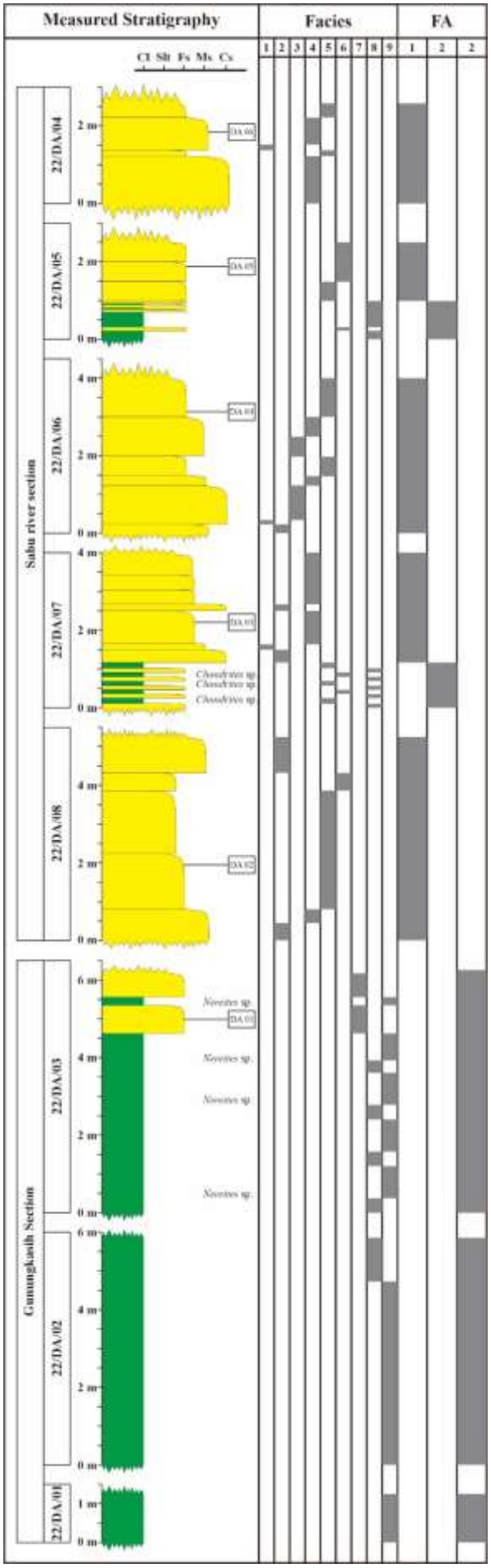

Fig. 3. Measured stratigraphic section of the Menanga Formation

Table 1. Point counting of Menanga Fm.

	22/DA/1	22/DA/2	22/DA/3	22/DA/4	22/DA/5	22/DA/6
Qm	72	54	40	46	71	45
Qp	0	0	0	0	0	0
PF	91	108	157	179	168	104
KF	0	0	0	0	0	0
Lv	336	312	270	264	210	312
Ls	0	0	0	0	0	0
Lm	0	0	0	0	0	0
Mat	96	114	126	108	144	126
Asc.	6	12	6	0	6	12

Table 2. Mineral composition of the Menanga Fm. (in %)

	22/DA/1	22/DA/2	22/DA/3	22/DA/4	22/DA/5	22/DA/6
Qm	12	9	7	8	12	8
Qp	0	0	0	0	0	0
PF	15	18	26	30	28	17
KF	0	0	0	0	0	0
Lv	56	52	45	44	35	52
Ls	0	0	0	0	0	0
Lm	0	0	0	0	0	0
Mat.	16	19	21	18	24	21
Asc.	1	2	1	0	1	2

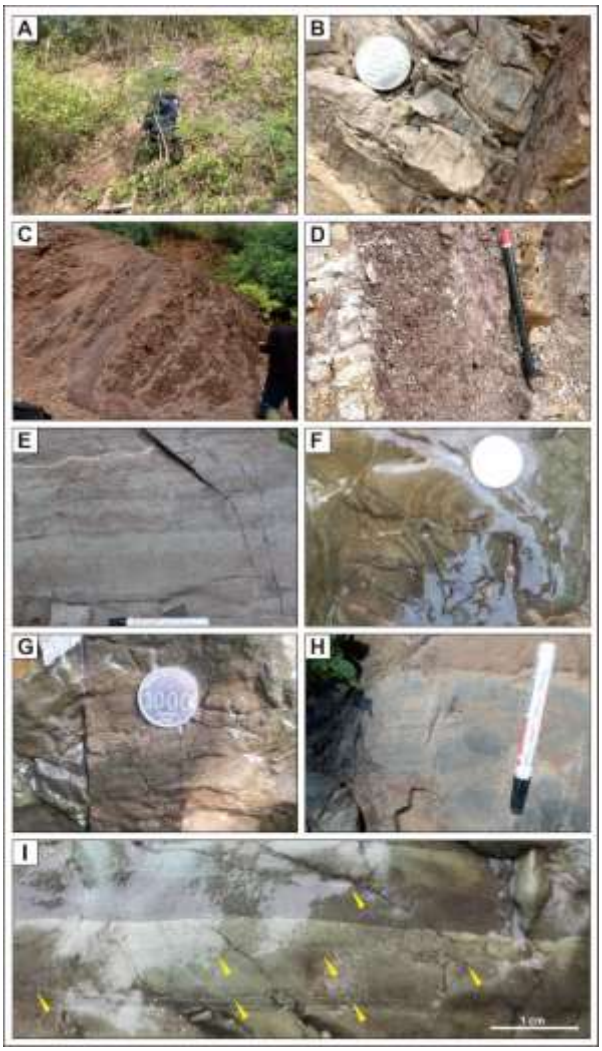

Fig. 4. Caption of the Figure 1. Below the figure. Outcrop of Menanga Formation (A) Outcrop interbedded claystone and sandstone in Gunungkasih, B) Parallel lamination claystone, (C) Outcrop of red claystone in Gunungkasih, (D) Bedded red claystone, (E) ripple and lamination sandstone, (F) Loadcast sandstone, (G H) lamination sandstone, (I) Lamination claystone with ichnofossil *Chondrites* sp.

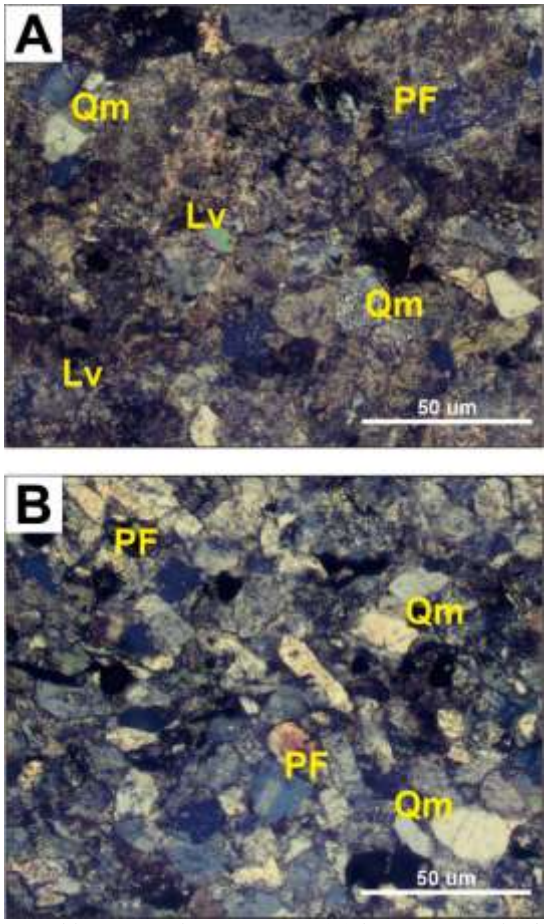

Fig. 5. Thin secton of Menanga Fm (A) lower part section/DA 2 (B) Upper part section/DA 6, shown monocrystalline quartz (Qm), lithiv vulcani (Lv), and plagioclas feldspar (PF).

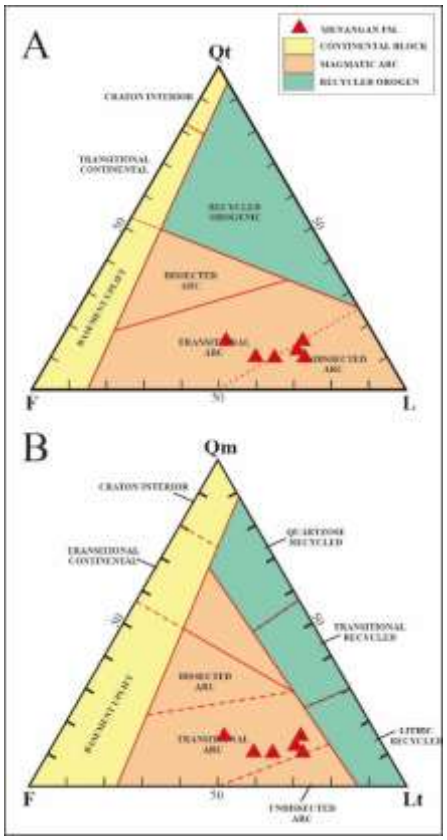

Fig. 6. Provenance analysis from six sandstone of Menanga Fm. Show transitional arc to undissected arc tectonic provenance in Provenance diagram [11]

4.3 Relative Age

In red mudstone, radiolaria extraction was carried out which showed the presence of radiolaria from the genus *Pantanellium* sp. (Fig. 7). Fossil radiolaria from the genus *Pantanellium* sp. have long range from Jurassic-Cretaceous age [12]. *Pantanellium* sp. genus was also found in radiolaria research in Indonesia such as in the Banggai-Sula Islands [18], Timor Island [19], and Sabu Island [20]. The presence of this radiolaria genus indicates a warm water environment relatively close to the equator [18] so it is interpreted that the Menanga Formation was deposited in the Mesotethys Ocean.

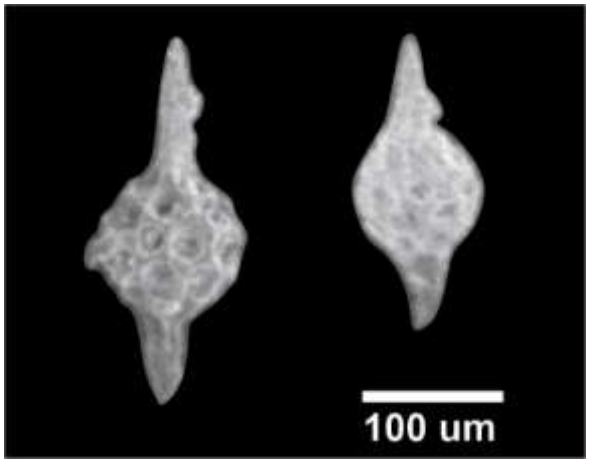

Fig. 7. Radiolaria from genus *Pantanellium* sp. in Menanga Formation

The Woyla terrane from the west moves relatively eastward due to the opening of the India-Australia oceanic plate, thus closing the Mesotethys Ocean plate [9, 17]. Subduction between the India-Australia plate under the Mesotethys Ocean plate causes an island arc type volcanic arc [17] containing material varying from lava to clastic volcanics [16]. Ongoing subduction conditions can be a source of clastic volcanic material that forms sedimentary rocks in the Menanga Formation. The sand facies interpreted to be turbidite deposits that occurred due to high sediment supply or could be the result of uplift that triggered underwater landslides, while the presence of ichnofossils *chondrites* sp. interpreted to be formed in the final phase of turbidite deposits which deposit relatively fine-grained sediment in suspension allowing trace fossils to be preserved.

5 Conclusion

The results showed that the Menanga Formation has nine facies, there are graded bedding sandstone (F1), loadcast sandstone (F2), parallel lamination coarse sandstone (F3), parallel lamination medium sandstone (F4), parallel bedding fine sandstone (F5), ripple fine sandstone (F6), lamination red sandstone (F7), grey claystone (F8), and parallel lamination red claystone (F9). The Menanga Formation facies were grouped into two facies associations, namely channel facies association (AF1) and levee facies association (AF2). AF1 consist of F1, F2, F3, F4, and F5 shown channel geometry, fining upward trend and Bouma classical

turbidite deposit. While AF2 consist of monotonous interbedded of F6, F7, F8, or F9 as upper part of the turbidite sequence. The Menanga Formation shows claystone dominance with sedimentary structure formed due to turbidit current and stacking pattern show fining upward thinning upward indicate midfan lobe environment. The Menanga Formation interpreted to be deposited in submarine fan environment with sediment material originates from the Woyla volcanic arc. Menanga Formation sandstone consists of lithic graywacke whose grains are dominated by lithic minerals, small amounts of feldspar and minor quartz. The discovery of indicates the relative age this formation ranging from Jurassic to Cretaceous.

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