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Olistostrome and its implications to geological disaster on coastal area with special reference to the Bantimala tectonic complex, Pangkep Regency South Sulawesi Province

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Abstract. Olistostrome is clastic sedimentary rock, its formation related to tectonic activity along the plate subduction edge on the front region of the accretion prism. Its formation is a submarine landslide with a mudflow sediment mass. The material components can be mixed from various continental and oceanic sources. As in the complex area of Bantimala tectonics, olistostrome shows typical properties of ugly sorting, floating rock blocks in the sandy matrix, tectonite textures, and constituent rocks generally in the form of metamorphic rocks of subduction and plate collision. The criterion shows the submarine sludge deposits formed in the subduction tectonic area of the marine trough environment where there is an increase in slope due to subduction accretion. This study aims to examine the characteristics of olistostrome as a landslide deposit in the subduction zone about the correlation of disaster in convergent tectonic areas in the present. In the area of Bantimala, the exposure of olistostrome rock is large enough with large dimensions with a mega-landslide. This can happen by earthquakes or critical slope in the past. This phenomenon can be a reference to disaster present-day in subduction areas, as in the island arc of Indonesia, which is a collision area of three plates very vulnerable to this disaster. A submarine landslide can cause disaster to infrastructure, telecommunication cable, gas hydrate dissolution, tsunami disaster and environmental destruction of marine benthos.

1. Introduction

The coastal area is the zone of interaction between the oceans and the land, from the geological aspect is usually a meeting zone of oceanic plates with a continental plate that can form deep ocean trenches with steep slopes [1]. Indonesia including this category other than earthquake-prone, volcano, the tsunami also avalanches under the sea that can cause a catastrophe or huge losses.

Olistostrome is widespread in Bantimala tectonic complex area Pangkep including submarine landslide sediment with the characteristics that have a very poorly sorted, tectonite texture and deposited in the deep sea [2, 3, 4]. Its formation is related to the tectonic subduction in trench areas on the active continental margin with the gravity flow sedimentation system and turbidity currents.

The metamorphic components contained olistostrome in the Bantimala tectonic complex, showing their formation in the subduction zone region, then the influence of pressure caused by the interaction



of the two plates causes the deformation and destruction of the rock layer as a material prone to landslides [5, 6, 7, 8].

The presence of olistostrome in the Bantimala Tectonic Complex area is evidence that there has been a massive avalanche in the past (Mesozoikum) which can be the actual reference for the continental margin areas where there is active subduction today.

This research is focused on the correlation of olistostrome as ancient landslide sediment with a present submarine landslide which the aim to understand the similarity of physical characteristics it possesses so that anticipation and mitigation of disaster can be done earlier in the coastal area.

2. Research Method

This data collection was conducted through:

1. Literature review

Collect preliminary data relating to or support research, in the form of regional geological data including stratigraphy, tectonics and structure, submarine landslide too and its impact assessment.

2. Field research

Includes observation and sampling of rocks, measurement of structural and stratigraphic aspects as well as photo taking and outcrop sketches.

3. Laboratory Analysis

The petrographic analysis which aims to determine the type and texture of the other constituent minerals on the thin section that is then identified then calculate the percentage of each type of mineral. This analysis was conducted in the petrography laboratory of Geology Department of Hasanuddin University.

3. Results and discussion

3.1. Regional Geological and Tectonic Framework.

The Bantimala tectonic complex is composed of metamorphic rocks such as glaucophane schist, hornblende-mica schist, eclogite, granulite, phyllite, and quartzite in the Triassic period[9], mélangé with components of schist, quartzite, metachert, metabasalt Jurassic- Cretaceous age and sedimentary rocks including shale, sandstone, claystone and radiolarian chert. The ophiolite blocks consist of harzburgite and serpentinite, formed of obducting on the Tertiary rocks in this area, while the sedimentary type of continental margin as Balangbaru-Paremba flysch in Cretaceous age, unconformably overlain by the Mallawa sandstone and Langi tuff in Paleocene-Eocene time[10,3,8,11].

The Cretaceous tectonic on Bantimala Tectonic Complex according to Iskandar Zulkarnaen[11] and Maulana, et al. [12], that the formation of high-pressure metamorphic rocks associated with low-grade rocks, mélangé, and ultrabasic in the Bantimala Complex region is the result of the subduction of oceanic crust into the continental margin plate of the Jurassic to the Early Cretaceous age, about 114 to 132 million years. Based on the calculation of pressure-temperature of garnet rocks - glaucophane shows temperatures around 580 - 640°C and 18 - 24 bar pressure. This condition occurs at depths of about 65 - 85 km at various levels and pressures. According to them, radiolarian chert at Bantimala Complex is unconformable with the schist breccia contained beneath which Albian - Cenomanian age about 100 million years [3].

3.2. The Occurrences and Physical Characteristic of Olistostrome.

The process of subduction of the Pacific plate against the Kalimantan continent in the Jura period begins the process of forming the Bantimala olistostrome [6, 7, 13, 14]. At that time, tectonic deformation, brecciation, and metamorphism occur on both colliding and rubbing plates, accompanied by the formation of a trench as a settling environment. The continental and oceanic plate that has undergone low-grade metamorphism is brecciated to form blocks of rock that display texture of tectonite.

On critical slope conditions based on Yamada *et al.* experiment [4] and Festa [15, 16, 6] submarine avalanches occur in trench areas, ripen material falling in the form of streams or slumping and

widespread into the deep sea environment in the form of chaotic materials sourced from continental and oceanic components.

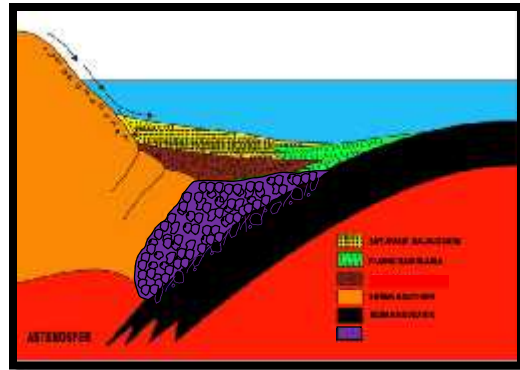


Figure 1. Tectonic section of the formation the olistostromes and melange.

Figure 1 shows the formation of the olistostromes and melange of Bantimala region, subduction of Pacific oceanic plates to the Asian continental plate, Lower Cretaceous. Characteristics of the olistostrome component in the Bantimala tectonic complex show various rock types that are polyolithic consisting of material from rock rework of tectonic deformation from schist, serpentinite, metachert, quartzite and gneiss [17, 18, 19].



Figure 2. Tectonic texture of olistostrome.

Figure 2 explains of olistostrome component size varies from 1 - 150 cm with very poorly sorting, floating block components on the matrix masses, subangular-very angular component forms. The matrix and cement appear reddish indicating the cement of the chert as deep sediment (trench) or as a transported sediment material. The component material exhibits a tectonic impression (tectonic texture) in the form of lenses, cracks, pseudoexfoliation or slurry texture in chaotic sediments.

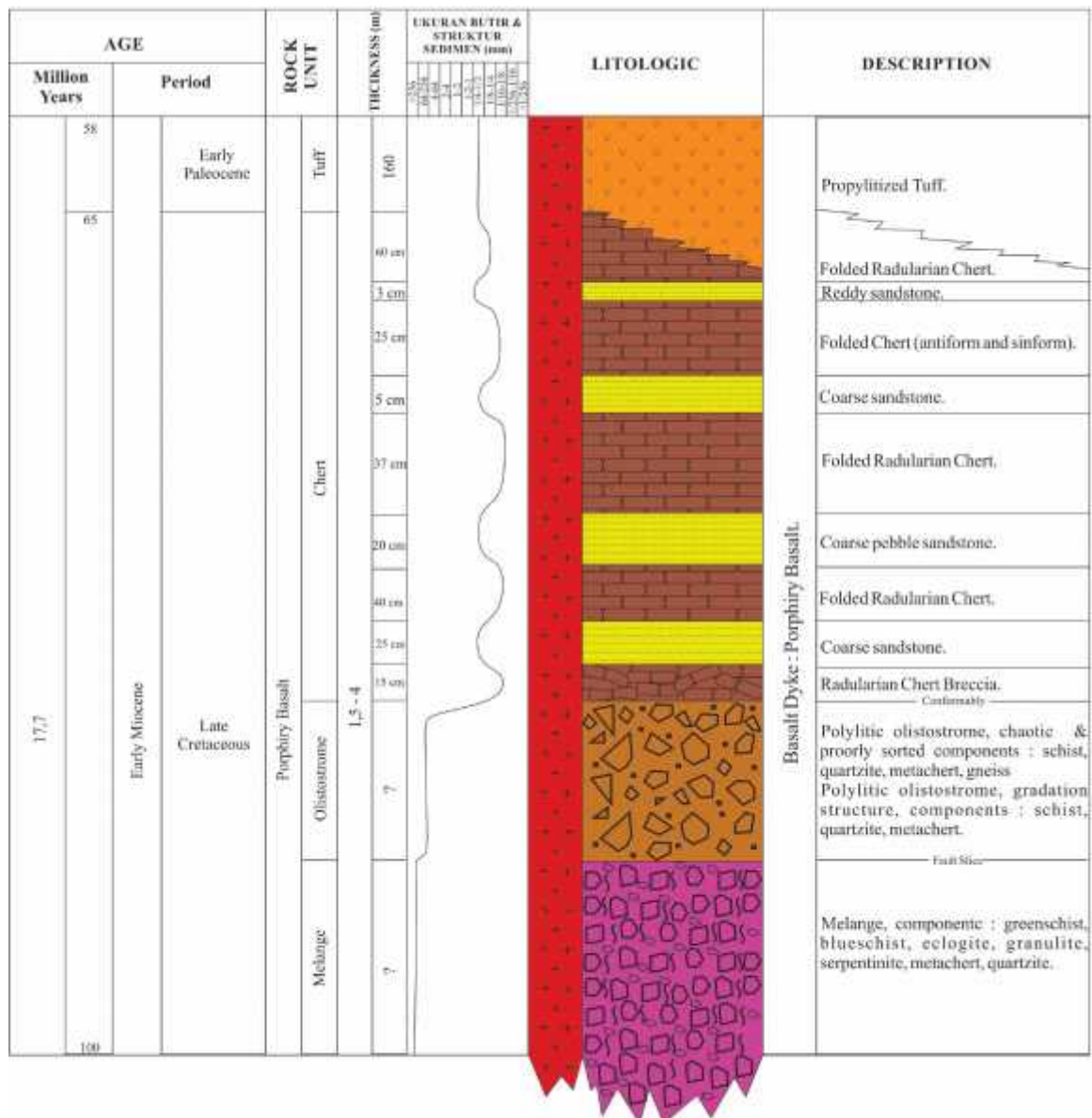
Based on the appearance of the field, olistostromes layer at the bottom of Pateteyang River Bantimurung, there are at least four times avalanche/sedimentation of rework material that alternating with chert, that is:

- First sedimentation in the form of avalanches and slumping, of course, materials in the form of blocks/blocks of rocks with a thickness of at least 340 m. The size of fragments between 1 - 150 cm, angular and boudin. Components consist of chlorite schist, mica schist, amphibole schist, gneiss, and quartzite.
- The second sedimentation, before this second sedimentation, is preceded by the deposition of a thin layer of granulated film of gravel and 20 cm thick schist sand. Then there was an avalanche of

pebble –sand material (2 - 40 cm), relatively fine more than the first avalanche, about 150 cm in thickness.

- The third sedimentation, also mediated by a layer of chert with a thickness of about 60 cm. This third layer is composed of coarse schistic sand with a thickness of 25 cm.
- The fourth sedimentation over the layer of chert (120 cm thick), a thin layer of sand schist with a thickness of about 20 cm.

Table 1. Lithologic column of olistostromes and melange of Bantimala area



Petrographic observations on the components consisting of schist, chert, and sandstone showed the following results:

1. Components of fragments of schist and quartzite.

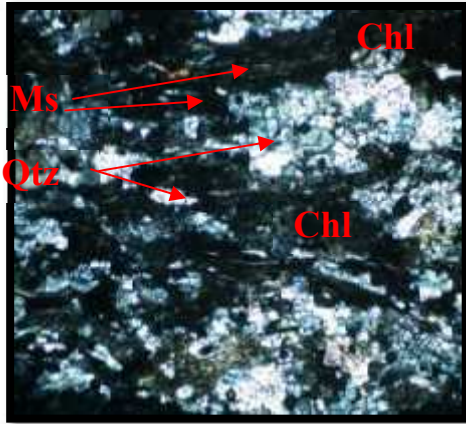


Figure 3. Photomicrograph of muscovite schist (Qtz = Quartz; Chl = Chlorite; Ms = Muscovite)



Figure 4. Photomicrograph of quartzite (Qtz = Quartz; Bt = Biotite Ms = Muscovite)

Figure 3 and 4 shows a photomicrograph of fragments components of schist and quartzite.

- Fragment schist (OL, 5C), composed of 40% muscovite minerals, 30% quartz, 20% chlorite, 5% actinolite, 5% opaque mineral, lepidoblastic texture, name of rock is quartz-muscovite schist
- Quartzite fragments (OL, 5D), composed of 75% quartz mineral, 12% muscovite, and biotite 10%, opaque mineral 3%, granoblastic texture, name of rock is quartzite.

2. Schist and greenschist

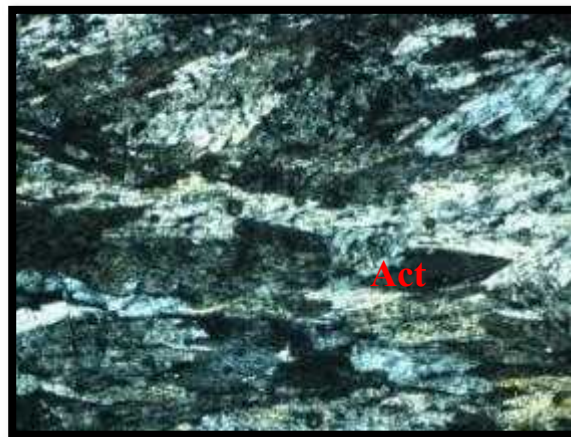


Figure 5. Photomicrograph of actinolite schist (Act = Actinolite)

Figure 5 shows a photomicrograph of fragments components of greenschist :

- Schist olistolith sekis (OL, 2B), lepidoblastic texture composed of muscovite minerals 65%, 20% quartz, 5% chlorite, 6% albite, and 4% mineral, the name of rock is schist muscovite
- Greenschist (ML, 3B), lepidoblastic texture composed of mineral actinolite 90%, 5% quartz, 3% chlorite, 2% opaque mineral, the name of rock is actinolite schist.

3.3. Correlation and Implications to Geological Disasters on The Coastal Area In Recent Time.

Submarine landslides according to Vanneste *et al.* [2, 20] can be through three phases: 1. The pre-conditioning phase is the change in the slope value from stable to instability by the accumulation of sediment. 2. The actual triggering of the movement that triggers the occurrence of avalanches such as the earthquake and 3. Finally, the landslide progress or run-out is the overflow or drainage of materials in the form of debris flow and turbidite. This condition can occur in the continental margin area which has a trench that extends parallel to the shoreline.

In the Bantimala tectonic complex area, there are indications of continental margin fossils that have undergone subduction tectonic processes shown by high and low-grade metamorphic rock groups, mélangé accumulation complexes, olistostrome, sandstones, flysch, and chert.

In the Cretaceous, the pre-conditioning phase of subduction of oceanic plates dipped under the continental margin with metamorphisms, deformation, and destruction of rock layers by tectonic activity. Material crushed rocks in the form of mud mixed blocks accumulate as rework sediment.

The accumulation of sediment along the shear zone, the formation of the accretion prism and deepening of the trough on the offshore, leads to a critical slope. By an earthquake trigger of the collision and plate moving, sliding into the deep ocean (trench) forms an olistostrome deposit in gravity flow and turbidity sedimentation system as semi-fluid sediment, widespread along trench as a run-out phase. Poorly sorting with large blocks of rock components up to tens of meters in diameter indicates deposition of the run-out type as flow regime [2, 20].

According to Vanneste *et al.*, [2] the consequences of the submarine landslide by a debris flow or turbidite currents, can pose great disaster to oil and gas pipe, installations of telecommunication and electric and generate tsunamis.

- Damage to infrastructure, roads, ports and other buildings in coastal areas can be damaged if located in landslide zones, especially in buildings that are not strong or in a fault zone and shear areas
- Damage to the installation of communications cables and underwater power lines due to ground shifts and turbidity currents, as happened in Pingtung, Taiwan in 2006 [21]
- Tsunami generator, rapid mass flow movement with turbulent character suddenly causing disturbed water mass balance can generate large waves, extending in all directions to form tsunami as happened in offshore of Sumbaya and Java coast, where the earthquake occurred in 1977 [20]

In addition to the above, submarine landslides can also lead to the dissolution of hydrates gas and environmental damage to biota, especially coral reefs as happened in Aceh earthquake in 2004 ago, where an earthquake destroyed the coral reefs, tsunami and submarine landslides.

4. Conclusion

1. Characteristic of olistostromes in the Bantimala complex showing by heterogeneous components with polymictic breccias consisting of schist, gneiss, quartzite and metachert component, very poorly sorted, typically gravity flow and turbidite deposits.
2. Olistostromes in the Bantimala tectonic complexes whose submarine landslide formation with its characteristics can indicate that the area was once an active continental margin with all its phenomena in the Mesozoic era (Cretaceous)
3. Based on the characteristics possessed and from the aspect of its formation, olistostrome can be correlated and used as a reference for the continental margin area that is active in handling disaster
4. A submarine landslide in which olistostrome is formed has been shown to damage infrastructure, telecommunication cables in Pingtung, Taiwan in 2006 [21] and caused a tsunami in the earthquake of 1977 [20], and also coral reef biota damage on earthquake and tsunami of Aceh in 2004

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