GEOLOGY OF SPERMONDE PLATFORM

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ABSTRACT: The spermonde islands are a reef complex trending north – south in the western coastline of South Sulawesi. The development of the reef is controlled by geological processes forming Makassar Strait. The strait arises since rifting between Kalimantan and Sulawesi in Paleocene Era and followed by spreading to form Makassar Strait. The geological process allows the reef complex developed along the Spermonde platform in the west coast of South Sulawesi. Beside the geological factor (such as sea floor morphology), global sea level fluctuation in the Quaternary Time also controlles the development of the reef complex. Klerk (1982) has studied the reef development with reference of P. Langkai, P. Kapoposan and P. Samalona. He found (based on C-14 dating) that there was an sea level fall during the period of 7000 year to 1000 year. Morphology of the islands within reef complex of Spermonde changes at any time following the seasonal changes. This change is controlled by sea currents and waves. Taking the example of Kodingarengkeke Island which was measured its shoreline during October 1979 - November 1980 and 2008 showed that the island has changed its morphology and shoreline, particularly in northern part. In the dry season (April to August) the northern coast tends to prolong east - west, but in the rainy season the coast extends north - south.

Keyword: Spermonde, reef complex, morphology, Makassar Strait.

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INTRODUCTION

Spermonde (Sangkarang) Islands is one of coral reef complex in the Makassar Strait trending north-south direction following the shoreline of South Sulawesi. The reef complex develops from Takalar Regency in the south through to Pangkep Regency in the north which has an area around 40 – 50 km^2 (Figure 1). Initial development of the reef is influenced by tectonic of the Makassar Strait. The strait developed due to the separation between Kalimantan and Sulawesi during Eocene (Hall at all. 2009). Based on grafity study, the rifting occurs asymetrically and forms different bathymetry between deep ocean of western part (Kalimantan side) and shallower one of eastern part (Sulawesi side) of the Makassar Strait.

The Spermonde Archipelago existes in the eastern part (closed to South Sulawesi shoreline) in which it develops since 20.000 year BP corresponding to the opening of Makassar Strait (De Neve, 1982). Some outhers define that reef is characterized by wave-resistance, rigid framework of organic skeletons, has relief above the surrounding sea floor - from 1 to 10s of meters, wave resistant (affecting surrounding environment – causes zonation of depth and water energy: fore reef/back reef lagoon).

The spermonde reef complex is interesting to study not only the unique geological process but also morphology of the islands, the oceanography condition and many others. Therefore, in recent years this reef complex takes a serious concern for geologist, oceanographers and environmental activists. The existence of coral reefs is regarded as a barometer of environmental change in the ocean.

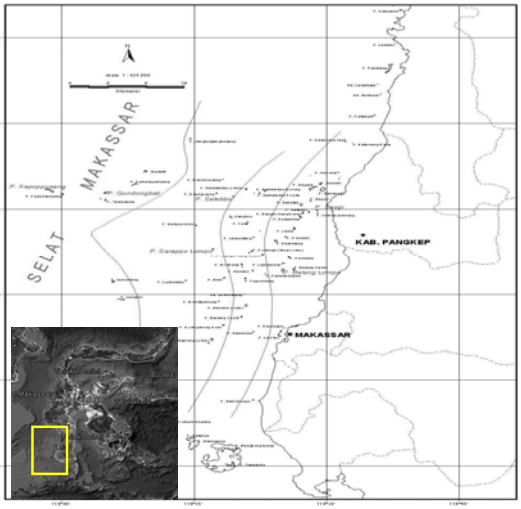

Fig. 1 Location of Spermonde Islands along the west coast of South Sulawesi, Indonesia.

Wood (1999) found that the distribution of modern reefs in the world is only 0.2% of the ocean area. They are limitedly spread out to the tropical regions in the shallow marine environment. Condition of reef within the Spermonde Islands has been studied in many researchers. The results study by De Klerk (1982) suggest that the number of species of coral built up the islands and submerged reefs scattered on the Spermonde continental shelf.

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Based on geography, geomorphology and distance to the shore, van Vuuren, 1920 in Pusat Studi Terumbu Karang Universitas Hasanuddin (2002), has divided the Spermonde Archipelago into four groups which is trending north – south parallel to the west coast of South Sulawesi (Fig. l). Another research has shown that this group has a different composistion in biotic and abiotic parameters (de Klerk, 1982 and Moll, 1983).

The effect of environmental change both as a global factors such as climate and local factors such as pollution and sea current influences most modern tropical marine ecosystems. These disturbances changed the biological community towards a different equilibrium or decreasing diversity and area of reef colony. The study of Jompa over 12 years (1983-1996) shows a decreasing of coral reef both diversity and cover as much as 20%. This study highlights the development of the cluster of coral islands Spermonde in geology point of view with reference in the district of Makassar (Pusat Studi Terumbu Karang Universitas Hasanuddin, 2002).

Formation of coral reef islands is related to the geological condition. One of geological controls that play an important role in the development of the island is tectonics. Tectonics can change sea floor by uplifting or drowning as well as change the sea level. In case of Makassar straight sea level change is due o the tectonic activities resulting spreading which allows reefs develops.

Physiography of Makassar Strait is characterized by deep sea in the middle part, with a depth of approximately 1500 - 2500 meters, and it becomes shallower toward the edges (eastern coast of Kalimantan and western coast of Sulawesi). This topographic appearance looks like terraces. This condition is affected by the trust fault trending north-south and is truncated by sliding fault of paternoster trending northwest-southeast.

The Development of the Makassar Strait

Makassar Strait is located along the east "Sunda Land" or between Kalimantan and Sulawesi. The stait is the interaction between continental plates (Asian Craton) and the Pacific oceanic plate. Makassar Strait formed since Early Miocene time initiated by rifting where South Sulawesi Arm moves eastward continues to spread out sea floor spreading. Based on the study of Guntoro (in Darman and Sidi, 2000) explains that the Makassar Straits consists of a) Basement rocks, b) Sandstone, c) Limestone, d) Shale and Marls, e) Volcanic rocks, and f) Clastic limestone.

Tectonic and Geological Structure

New 3D seismic data and recent exploration drilling suggest origin of Makassar Strait was resulted from a mid-Eocene (42 Ma) extension. This scenario is a typical charakteristics of Sunda Land (grabens and half-grabens in a continental or marginal marine setting) (Figure 2). In the central part of the Strait, up to four kilometers of sedimentary infill are present above the Late Eocene (~36 Ma) top syn-rift unconformity (Figure 2).

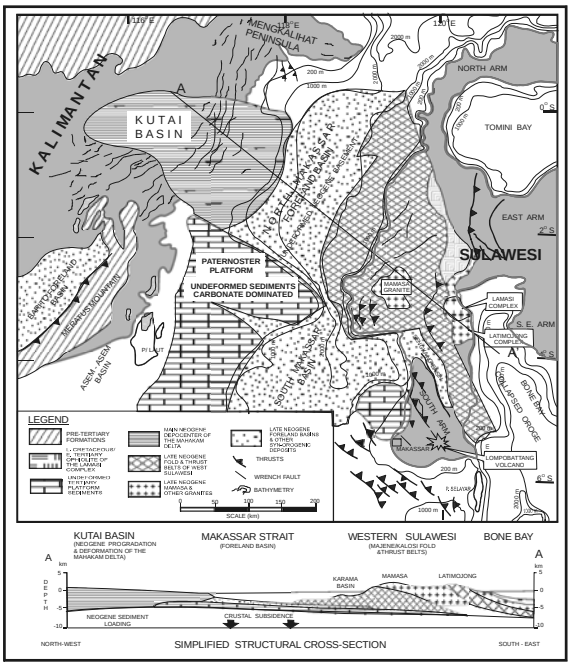

Fig. 2 Map of Geology and Geological Structure of Makassar Strait (simplified from Bergman, S.C, dkk, 1996).

Some researchers (Katili, 1980; Hamilton, 1979; Bergman, SC, et al, 1996, Darman and Sidi, 2000) explaine that Makassar Strait formed by the separation between Sulawesi and Kalimantan Islands since Miocene time or maybe older. The separation was through the process of rifting and spreading that subsequently underwent geological processes. In terms of the tectonic activities, the Makassar Strait is divided into two phases, namely: pre-spreading and post-spreading tectonics. Both of these tectonic phases produced a very different geological phenomenon as follows:

Pre-Spreading Tectonics

The pre-spreading tectonic activity took place since Lower Mesozoic era (Trias) in which Western Pacific oceanic plate subducted to East Kalimantan as an Asian Craton. The subduction created methamorphic rocks as basement of Sulawesi. This process took place until the Jura characterized by the formation of melange. Toward Cretaceous, the environmental conditions changed to marine forming flysch. The flysch was lifted and became a continent before the Tertiary. Entering Palaeogene era it became a shallow marine due to intensive tectonic activity in the eastern periphery of Borneo, followed by a subsidence and rifting as a starting point of the development of Makassar Strait.

Post-Spreading Tectonics

The development of rifting in the eastern coast of Kalimantan during Paleocene time was followed by spreading to form Makassar Strait. The process was a result of Western Pacific tectonic activity continuing untill today. In the Lower Miocene the tectonic

processes in the Makassar Strait became a more complex. The tectonics yielded volcanism and geological structures on Sulawesi and Makassar Strait. In Middle Miocene to Pliocene, subduction occured bimodally in which the Pacific Plate subducted to western direction and the Makassar Strait subducted to eastern diraction (toeard west coast of Sulawesi). The Pacific Plate subduction produced volcanic rocks of Camba and Soppeng and the other produced volcanic rocks of Pare-pare and Mamasa.

Geological Structure

Many researches (Katili, 1980; Hamilton, 1979; Bergman, SC, et al, 1996, Darman and Sidi, 2000) explained that one of the structures yielded from Pacific tectonic activity toward the Asian Craton is Walanae and Majene Faults trending north – south from Bone Bay to Makassar Strait. The faults are truncated by Paternoster Fault leaning southeast – northwest. The fault activities generate intensive seismicity (earthquake) in the Makassar Strait and surrounding areas. The most potential earthquake formed in intersection faults such as Majene- Polewali earthquakes are generated by the intersection of trust fault of Makassar Strait and West Walanae and Paternoster Faults.

Quaternary tectonic activity slowly drives Sulawesi Island to the north and to the west direction. The large influence of pressure is the Australian plate to the north direction and the Pacific plate to the west direction. Both plate movements led to the uplifting of the Makassar Straits. This uplifting was the major encouragement of the development of coral reefs in Makassar Strait known as Spermonde Islands.

The Reef Development of Spermonde Platform

As described above that the formation of the Makassar Strait is the result of spreading separating Sulawesi Island and Borneo Island. The spreading also forms Makassar Basin on Oligocene - Miocene (Katili, 1980 and Hamilton, 1979). After the tectonic activities the major control on sea level fluctuation is freezing and melting of ice on the polar during Quaternary (Damuth, 1977 in Richards, 1996). Sea level fluctuation as also influenced the development of coral reef within Makassar Strait.

Klerk (1982) have studied the origin of coral formation within Makassar Strait. Based on the dating of C-14 in samples taken at P. Langkai, P. Kapoposang, P. Samalona indicates that the coral islands developed since 7000 BP. At that time there was a rise of sea level from about 100 meters.

The results of the reconstruction of sea level fluctuations in the Makassar Strait by Klerk (1982) shows the fluctuations of sea level since 7.000 last year associated with glaciation and deglaciation. Fluctuations in sea level during the Pleistocene - Holocene has also been discussed by Guilcher (1988) with some samples of corals in the Pacific region. The sea level fluctuations affect the development of organism within the strait.

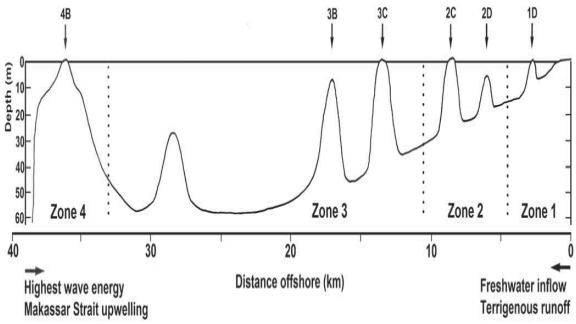

Fig. 3 Schematic cross-section of the central Spermonde Shelf (approximately W–E) from the Makassar Strait (off Langkai) to the Sulawesi mainland (Makassar). The main cross-shelf environmental gradients are indicated (arrows). (**Hoeksema, B.W., 2012).**

The development of organisms composing of coral reef within the Makassar Strait is more or less controlled by influx from main land of Sulawesi. Based on study of Mappa and Moka (1995) the dominant coral developing in this area are Pocillepora sp., Acropora, Montipora and Favia sp. Study of Coral Reef Studies Center of Hasanuddin University in 2002 shows a changing in diversity of organism. He found the development of living corals such as massive corals become dominant. The changing of organisms is controlled by changing of environment condition such as salinity, sediment suspension.

The origin of sediment flowing througt the Makassar Strait comes from terrestrial sediments driven by rivers from central and southern Sulawesi. The rivers are Mandar and Saddang rivers in the north, Pangkep, Maros, Tallo and Jeneberang rivers in the central and Takalar river in the south. Based on the current condition and rivers that flow into the Makassar Strait, it can be predicted that terrestrial sediments affect the development of coral reef in Spermonde Platform.

Another control of reef growth is ocean current by means of control on oxygen supply (Verwey in Sukarno, 1983). The study revealed that a complex reef with length of 100 m, width 10 m at a depth of 2 m, requires about 4000 liters oxygen for 12 hours. Current conditions in the Makassar Strait flows to the south yearly (Jompa, 1996) and the direction is switched to the east along the southwest coast of Sulawesi during the rainy season. In the dry season, the current flow is diverted to the west direction due to reverse current from Sundaland. At a shallow platform of the Spermonde Islands a strong current flows to the south during the rainy season and weak current to the southwest in the dry season (Moll, 1984).

Morphology of Coral Reef Island

Morphology of reef island is controlled by coral reef development. The development of coral reef itself provides evidence that the organisms can survive on seawater hydrodynamics condition. According to Wood (1999) there are three factors that control the development of reef morphology in relation to:

1. elevation of reef organisms and their durability
2. length of the growing organism
3. sedimentation rate.

In geological perspective, the morphology of modern reef can not be directly reflected the ancient reef morphology. This is because the development of coral growth is not always a single (single growth), but is a multiple phase growth and is punctuated by a hiatus. Modern reef morphology stratified by the three-dimensional shape, geographical position of the land and the dominance of its constituent organisms. Some reef morphology were identified based on the criteria mentioned above are: a) Patch reef; small, isolated, formed in low-energy region on the periphery and typically shallow marine. b) Fringing reef; linear growth in the form of parallel to the coast without significant lagoon. c) Barrier reef; equal to the fringing reef, but it has a broad and deep lagoon. d) Atoll; reef with models such as circle growth that surrounds the volcano.

Based on spread out of th reefs at the Spermonde Platform where they develop relatively parallel to the coastline, locate on the selves margin and in a relatively small form, it can be explained that the morphology of the reef is a reef margin in the form of patch reef. Individually the forms of coral reef islands within the Spermonde Platform varies, but generally shows a stretch of the north-south (Klerk, 1982). The form itself is probably afected by the current flow in the Makassar Strait. Based on the study of PSTK (2002) explains that the reef on the west and south are generally wider and larger than those in the east and north of the platform. Furthermore the growth and the reef abundance decrease toward the coastline of Sulawesi.

The development of the single reef island within the Spermonde Platform is different each other. The study of Klerk (1982) shows that Samalona Island developed well and reached sea level (at a height of 5 m from the sea floor) since 4500 years before present. However, due to regression the vertical development of the reef changed to horizontal development. The development can be traced during the second period of development that is 3000 years before present and became more wide in period of 1000 years before present (Figure 5). Similar conditions are found in the Plio-Pleistocene reefs at Bira area, Bulukumba (Imran, 2000).

In contrast to the development of the coral island of Bone Tambung, which in the same period Bone Tambung Island reached a height of ± 1 m from the sea floor. The island was growing vertically and reaches a height of 3 m at 3000 years before present eventhough at that period was an regressive condition. How ever, since 1000 years before now the island was growing laterally because it reached sea level (Figure 5).

Morphology of the islands within the Spermonde Platform changes following the season. Clerk (1982) has studied the shoreline position of Kodingarengkeke Island during October 1979 – November 1980 (Figure 6) and found change form especially in the northern part of the island. In the dry season (April to August) the northern coast extension changes to the east – west direction, however in the rainy season it changes to the north – south direction.

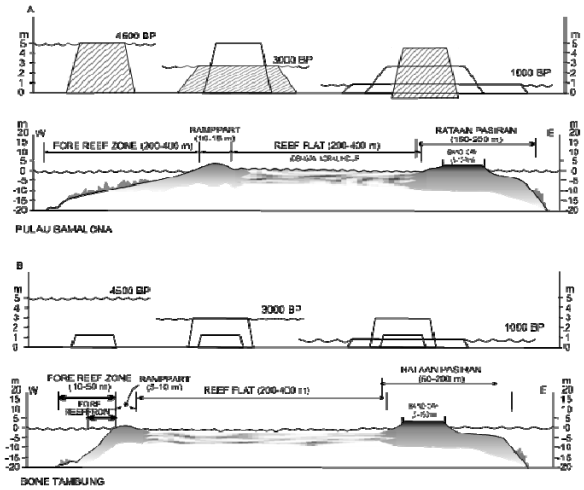

Fig. 5 The development model of the reef islands within the Spermonde Platform woth refernces Samalona Island (A) and Bone Tambung Island (B) (Klerk, 1982).

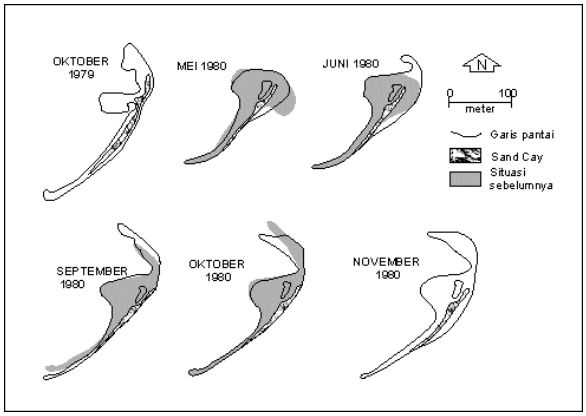

Fig. 6 Morphological change of coast line of Kodingareng Keke Island during period of October 1979 -November 1980 (simplified from Klerk, 1982).

The form of the island changes from time to time. Based on the citra image study by Haerany in 2011 found that some changes of morphology during 1998 – 2008 (Figure 7). In general the size of Kodingarengkeke island develops in correspond to its age. However, the morphology of the island changes acording to the season (Figure 7). This study found that the northernpart of the island tendd to develop east direction during April and began to change in Julai and it tends to develop west direction during November. It supports the prior study that the form of kodingarengkeke changes depending on the season.

Other study of reef isalands within Spermonde Platform explains the same tendecy. Kondongbali and Sarappo Keke Islands are experiencing a change in circumference lines of the coral reef platform as well as in coastline of islands, namely the former because of

coral mining and the later because of retrogressive process Yanuarita (2011). Other factors controlling morphodinamic of the islands in Spermonde Platform are wind and water current. Wind-generated incoming waves to the islands during west monsoon are much bigger than east monsoon. The study of water mass dynamic in the Spermonde Platform (Jalil, 2011) indicates that the surface water current occurs depending on the velocity of wind/monsoon and tide.

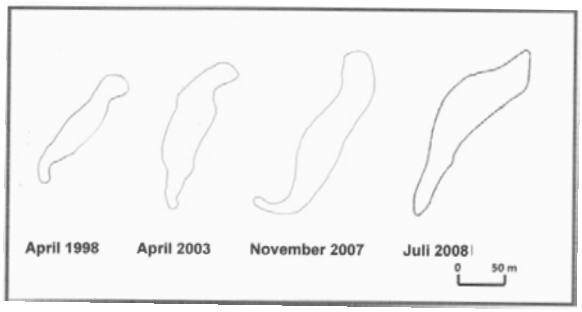

Fig. 7 Morphological change of Kodingareng Keke during 1998 – 2008 (source Haerany 2011)

Two daily current pattern occurs within Spermonde Platform, the surface current influenced by monsoon (west and east monsoon) and by tide Jalil (2011). The west mosoon initiates the surface current eastward and southeastward and east monsoon triggers the surface current westward and northward. This current more efectively control the morphodynamics of the islands. The west monsoon and the ITF from the deep sea produces eastward surface current trough the Spermonde Platform. On the otherhand, as mentioned by people in the islands of spermonde (Figure 8 and 9), the surface current direction is westward during east monsoon. This means that east monsoon plays an important role generating surface current direction westward during and ITF plays an important role during west monsoon.

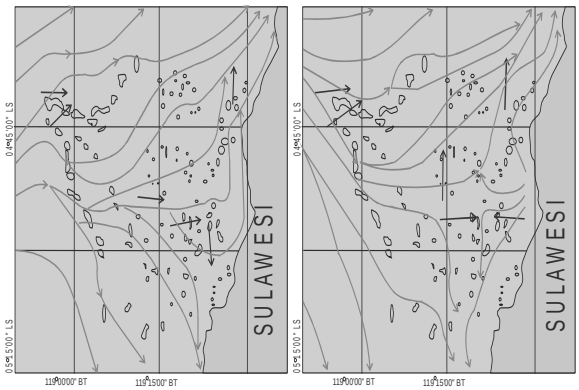

Fig. 8 Current pattern based on the interview of local residence (blue line) and simulation (brown line) in January (Jalil, 2011). (Note: Left side is high tide and right is low tide during west monsoon).

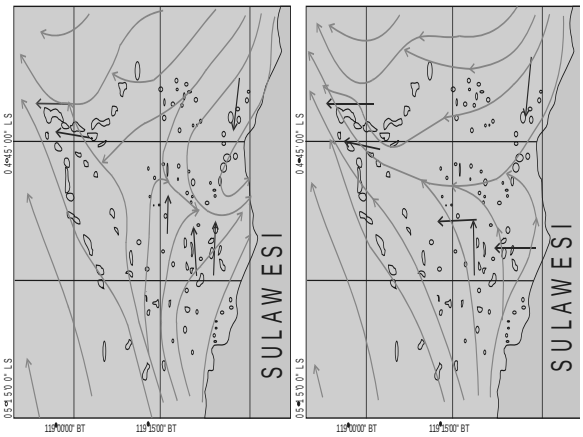

Figure 9 Current pattern based on simulation (brown line) and interview of local residence (blue line) during east monsoon (Jalil, 2011). (Note: Left side is high tide and right is low tide during east monsoon).

CONCLUSIONS

1. Makassar Strait formation started since rifting of East Kalimantan margin in the Paleocene period.
2. The eastren margin of the rifting became an area of coral reef development, especially after regional glaciation and deglasiation during Quaternary period.
3. Based on the sea level fluctuation, where about 7000 years ago there was a rise in sea level from the previous about 100 m. In that time coral reefs developed in the Makassar Strait that is now known as Spermonde Platform.
4. The C^{14} dating taken from Langkai, Kapoposang, Samalona islands show that the coral reef islands within the Spermonde developed since 7000 year ago.
5. Sea level change, currents and waves play an important role in affecting the morphology of the reef. Regression event during the development of the Spermonde Platform leds to the laterally growth of reef, and produced sediments surround the islands that always moving depending on the season.
6. The development of Spermonde Islands is controlled by the local season.

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