Sedimentation mechanism and provenance of sediment deposition in Sidenreng Lake, Sidrap District, South Sulawesi Province

Risqa Permatasyara Mu’min¹, A.M. Imran², and Safruddim²
¹Bachelor Student of Geological Engineering, Faculty of Engineering, Hasanuddin University
²Lecturer of Geological Engineering, Faculty of Engineering, Hasanuddin University
Email: risqatsyr@gmail.com

Abstract. Sedimentation is the deposition of rock material that has been transported by water or wind power. One result of the accumulation of sediment in a basin is siltation, which can cause flooding as it did at Lake Sidenreng. This research located in Teteaji Village, Tellu Limpoe District, Sidenreng Rappang Regency, South Sulawesi Province. This research aims to determine the characteristics of the Sidenreng Lake Quaternary sediments, specifically in the mechanism of transportation and provenance. Determining the sediment characteristics is important as the basis of planning in overcoming various problems in the lake. The methods used in this study are granulometric analysis and petrographic analysis. The sieve analysis results that the average grain size at the study site consists of 3 (three) types of sedimentary fractions, namely medium sand, fine sand, and very fine sand. This material deposited with a bed load transport distribution system and weak depositional energy. Sand material is spreading from the southwest and is gradually smoothing to the northeast at the study site. The petrographic analysis results that the provenance of sediment deposited material in Lake Sidenreng comes from volcanic breccia rocks of the Camba Formation, lava tracts of Parepare Volcano Members, and the Sandstones of the Camba Formation and Walanae Formation.

1. Introduction
Lake Sidenreng is one of the lakes included in the Tempe Lake system where during the rainy season, the lake merges with Lake Tempe to form a large lake. Moreover, the shores of Lake Sidenreng often experience flooding during the rainy season. This condition is thought to be a result of high levels of sedimentation in the area so that Lake Sidenreng has siltation, and water quickly overflows during the rainy season [1].

Sedimentation is the deposition of rock material that has been transported by water or wind power. When erosion occurs, water carries rocks flowing into rivers, lakes, and finally reaches the sea [2]. Sedimentary material that accumulates in lake basins comes from various sources and transports by various mechanisms. One effect of the accumulation of sediment in the basin is siltation, which can cause flooding as it did at Lake Sidenreng. However, there are no studies on the characteristics of Lake Sidenreng sediments. Consequently, the authors researched the analysis of the characteristics of
Quaternary sedimentation, which includes the mechanism of sedimentation and the source of surface sediment material in Lake Sidenreng, Sidrap Regency, South Sulawesi Province. This study aims to determine the grain size zoning and sediment transport mechanism, determine the distribution of minerals in the sedimentary material, and determine the provenance of the sedimentary material that dominates the study area. Administratively, the research area is located in Teteaji Village, Tellu Limpoe District, Sidenreng Rappang Regency, South Sulawesi Province. Geographically, the study area is located at 3°59′15.12″ - 3°59′36.38″ South Latitude and 119°50′15.22″ - 119°50′42.36″ East Longitude.

The methods used in this study are granulometric analysis and petrographic analysis. Field data taken are surface sediment samples found in Lake Sidenreng totaling 8 lines, each line consists of 5 sampling points, and each is about 50 meters between points. The first point is taken at the water level at high tide, then continues towards the lake where the water level is shown in the dotted line with a water depth of approximately 50 centimeters. The sample taken is approximately 5 cm deep. The research location is located between the mouth of the Lajarakaria River and the Lari'e Ditch. The Lari'e Ditch is located in the northern part and is ± 81 meters from the study site, and the Lajarakaria River in the south is ± 55 meters from the study site.

2. Geological Outline
The regional geology of the study area is included in the Geological Map of the Majene and the Western Part of the Palopo [3]. The morphology of the Majene and surrounding sheets consisted of mountains and plain. Some of these mountains are formed by volcanic rocks with an average altitude of 1500 meters above sea level to the east of this series of mountain ranges, which are relatively narrow and lower with weak to strong undulating morphologies. The research area is included in the morphology of the plain [4]. In the Pangkajene and West Watampone areas, there are two mountain ranges that extend almost parallel to the north-northwest direction and are separated by the Walanae River valley. The western mountains occupy almost half the area, widening in the south (50 Km) and narrowing in the north (22 Km). The highest peak is 1694 m, while the average height is 1500 m. Its formation is mostly volcanic rock [3].

2.1. Stratigraphy
Stratigraphy of regional geology in the study area from oldest to youngest are Tertiary Miosen Soppeng Volcanic (Tmsv), Tertiary Miosen Camba (Tmc), Tertiary Pliocene Walanae (Tpw), Tertiary Plioen Lava (Tppl), and Quarten Alluvium (QA) [3]. *Quarter Alluvium* (QA), consisting of clay, silt, sand, and gravel. *Tertiary Pliocene Parepare Lava* (Tppl). The Lava Rock Parepare Lava Member consists of trachy lava, light gray to white, with pillars

*Tertiary Pliocene Walanae* (Tpw). The Walanae Formation consists of conglomerates, a small amount of glauconite sandstone and shale; contains cocuina, mollusks and foraminifera, which indicate the age of Pliocene, while the depositional environment is land to shallow sea. To the south, in the western Pangkajene and Watampone Sheets [3], sandstones increasingly dominate and intertwine with siltstone, tuff, marl, conglomerate, and limestone. Limestones in Tacipi are called Tacipi Members. Formation thickness of not less than 1700 m [4].

*Tertiary Miocene Camba* (Tmc). The Camba Formation consists of marine sedimentary rocks interspersed with volcanic rocks; tuff sandstone alternating with tuff, sandstone, siltstone and claystone; insertion with marl, conglomerate limestone and volcanic breccias, and locally with coal, white, brown, red, yellow, light gray to black. Generally hardened and partially less hardened, with bedding in the form of thickness between 4 cm and 100 cm. Tuff is fine-grained to lapilli; red, colored tuffs containing many biotite minerals; conglomerates and their breccias are mainly andesite and basal components with sizes between 2 cm and 40 cm; sandstone limestone and limestone sandstone containing coral and mollusk fragments; limestone mudstone and napal containing small forams and mollusks; 40 cm thick coal insert was found at S. Maros. Generally well coated, weakly folded with a slope of up to 30° [3].
Tertiary Miocene Volcanic Soppeng (Tmsv). The Soppeng Volcanic Rock consists of volcanic breccia and lava, with sand-to-lap tufa inserts, and claystone; in the north, there is more tuff and breccias, while in the south there is more lava; partly composed of pyroxene basalt and partly basal leucite, the content of leucite is increasing more towards the south: some of the lavas are cushioned and some are breccified; the components are between 5 cm - 50 cm; the color is mostly dark gray to greenish gray [3].

2.2. Tectonic
In the west, the carbonate rock was deposited very thick and broad from the Late Eocene to the Early Miocene. This symptom indicates that during that time, there was extensive exposure to shallow seas, which gradually declined along with the deposition. The tectonic process in the western part lasts until the Early Miocene, while in the eastern part, the volcanic activity has begun again during the Early Miocene, represented by the Kalamiseng and Soppeng Volcano [3].

The end of the Early Miocene volcanic activity was followed by tectonics, which led to the beginning of the Walanae depression, which later became the basin where the Walanae Formation was formed. This event most likely took place from the beginning of the Middle Miocene and declined slowly during sedimentation until the Pliocene Period. The decline of the Walanae Terbane is limited by two normal fault systems, the Walanae fault, which is entirely visible to the present in the east, and the Soppeng fault, which is only exposed uncontrollably to the [3].

During the Walanae formation, in the east volcanic activity occurred only in the south while in the west volcanic activity occurred almost evenly from south to north, taking place from the Middle Miocene to the Pliocene. The main faults from north to northwest occur from the Middle Miocene, and grow until after the Pliocene. Large direction trending almost parallel to the main fault is thought to have formed due to horizontal pressure trending approximately east to west in the time before the end of the Pliocene. This pressure also results in the presence of local hood faults that amplify the pre-Late Cretaceous rocks in the Bantimala Region, which are then depressed through tertiary rocks [3].

Relatively smaller enlargements in the east of the Walanae Sheet and in the western part of the western mountains that run northwest-southeastst and tilted, are most likely to occur by moving horizontally to the right along a large fault [3].

3. Sedimentation Mechanism and Provenance of Sediment Deposition in Sidenreng Lake

3.1. Sedimentation Mechanism
The interpretation of the sedimentation mechanism that occurs in Lake Sidenreng sediments concluded based on the results of granulometric analysis and grain morphology. Based on the results of granulometry analysis, each curve shows a bimodal curve (Figure 1), which interpreted as the influence of sediment transport velocity or current, which is relatively different. However, it generally shows the highest mode in class 3ϕ or very fine sand. The difference in mode class interpreted as a result of the influence of the season where during the rainy season, the study area experiences flooding so that the current velocity can increase. When the current speed is low, water will only carry fine particles in suspension, and some sand-sized particles will move by rolling and saltating. Whereas when the current speed is high, the particles will move tractionally and generally in this condition more dominated by coarse material [5]. Therefore, it interpreted that the Lake Sidenreng sediment material is transported or transported by the bedload transport distribution system.

Generally, currents that occur in lakes are horizontal currents that are influenced by wind and shoreline or basin. The shallower the lake, the more the wind will influence the velocity of the current. However, the influence of inlet and outlet also cannot be ignored. The average surface water motion of a lake, which has a depth of ± 5 meters, is around 13 liters/minute or $21.67 \times 10^{-4}$ cm$^3$/ s [6].
Figure 1. Chart of Grain Size Distribution of Sedimentary Material Sidenreng Lake That Generally Show a Bimodal Curve

Based on the mean grain size, the Sidenreng Lake sedimentary material consists of three zones of sediment fraction, namely a very fine sand zone (0.125 mm-0.063 mm), fine sand (0.25 mm-0.125 mm), and medium sand (0.5 mm-0.25 mm). The zoning map of grain size shown in Appendix 1. Sand material will deposit at a speed of 20-30 cm/s [5]. Hence, based on the fraction of sediment and sand sedimentation rate by Nichols (2009) in Figure 2, it can be interpreted that Sidenreng lake sediment material transported by the system of distribution of bedload transport. Although the bedload transport distribution system transports the three sediment fraction zones, the depositional velocity is different because the finer the grains will require slower speeds to deposit.

Figure 2. Distribution System of Sidenreng Lake’s Sedimentary Material Based On Mean Zonation of Grain Size and Flow Velocity by Nichols (2009) Refers to Press & Siever Classification 1986 (in Nichols 2009)

Sand is spreading from the southwest and getting smoother towards the northeast which does not align the theory when viewed from a distance with the inlet. However, when viewed from the factors that influence differences in grain size, it can be interpreted that the material carried by the Lari Trench is very far from the source of the rock compared to the material carried by the Lajarakaria River. The second factor is the variation in the size of the original rock grains that differ from the original rocks transported by the Lajarakaria River, which in this case concerns mineral resistance or the potential for abrasion during the sediment distribution process. The third factor is the condition of the Lari e ditch water flow, where when there is a flood, material from Lake Sidenreng may enter the
trench, whereas when the flood recedes, this material is carried back into the lake. So that material is transported back and forth, allowing more significant abrasion potential, which causes the material that is close to the trench, will be finer than material that is close to the Lajarakaria River.

When viewed from sphericity, the material at the study site shows a trend toward changes that are near equant and oblate. Fine material with an equant size easily transports with a suspension distribution system. The more the shape of a material is shaped, the easier it will be to deposit. Meanwhile, when viewed from the roundness, generally, each sedimentary material shows a subangular-sub-rounded shape, which indicates that the material has transported quite far. However, in this case, the particle resistance factor is also very influential so that particles with high resistance will tend to maintain their original shape even though they have experienced distant transportation [7].

Based on the results of granulometric analysis and morphology of these grains, bedload transport with low current velocity or weak transport energy dominates the sedimentation mechanism of Sidenreng Lake surface sediment material and has been transported quite far from the original rock.

3.2. Provenance

The interpretation of provenance is based on the results of petrographic analysis and the physical characteristics of rocks found in the regional geology of the study area. Based on petrographic observations, both grain morphological observations and thin section observations found five types of material that dominated the study area. The type of material found is quartz mineral, feldspar mineral consisting of plagioclase and orthoclase minerals, pyroxene, and lithic (rock fragments).

Quartz found in relatively clear colors with a degree of transparent clarity. Moreover, reddish clear quartz minerals also found which indicate that the quartz originated from rocks that have undergone oxidation or come from sedimentary rocks. Based on this and the similarity with the mineral content of the Walanae Formation sandstone, the quartz in Lake Sidenreng sediment material originates from the sandstone of this formation.

The presence of unstable minerals, such as pyroxene at a considerable distance from the source, indicates that the original particle relief area is a high-relief area. The presence of quartz minerals and feldspar, which is quite high, indicates that this material comes from plutonic rocks. While the quartz mineral found in reddish color indicates that this material comes from rocks that have undergone oxidation or come from sedimentary rocks, therefore, it can be interpreted that this material originates from the erosion of sedimentary rocks which may originate from the sandstones of the Camba Formation and Walanae Formation in the southwest of the study site and transport by the Lajarakaria River water flow.

![Figure 3. Petrographic of Very Fine Sand Zone (Mesh 0.5 mm and 1 mm) (a) Grain Morphological Observation; (b) Thin Section in X Nikol; (c) Thin Section in // Nikol. (Qtz=Quartz; Pl=Pagioclase; Px=Pyroxene; Lt=Lithic)](image-url)
The presence of unstable minerals, such as pyroxene at a considerable distance from the source, indicates that the original particle relief area is a high-relief area. The presence of quartz minerals and feldspar, which is quite high, indicates that this material comes from plutonic rocks. While the quartz mineral found in reddish color indicates that this material comes from rocks that have undergone oxidation or come from sedimentary rocks, therefore, it can be interpreted that this material originates from the erosion of sedimentary rocks which may originate from the sandstones of the Camba Formation and Walanae Formation in the southwest of the study site and transport by the Lajarakaria River water flow.

When viewed from lithic, the presence of volcanic rock fragments indicates that the sediment deposition material of the study site came from volcanic rocks. Aphanitic rock fragments that are reddish-brown, probably originating from the volcanic breccia of the Camba Formation, while the light gray colored fragments may originate from lava tracts in the Parepare Volcano Members to the west of the study site and may be transported by the Amparita and Lajarakaria rivers.
4. Conclusion
The conclusions from the research on Sedimentation Mechanism and Provenance of Sediment Deposition in Sidenreng Lake are as follows:

- Lake Sidenreng’s sedimentary material consists of three zones of sedimentary fraction, namely medium sand, fine sand, and very fine sand. The sand material is spreading from the southwest, then gradually smooths to the northeast at the study site, and the bedload transport distribution system dominates the sediment material due to low current velocity and weak transport energy.

- The constituent mineral of Lake Sidenreng sediment consists of quartz, plagioclase, orthoclase, pyroxene, and lithic with relatively equal percentage mineral distribution at each station. Grain morphology generally indicates roundness subangular-sub-rounded with sphericity elongate equant to equant indicates that this material has undergone quite a distance transportation of rock origin.

- Sedimentary material on Lake Sidenreng comes from volcanic rocks of the Camba Formation, lava tracts from Parepare Volcano Members, as well as sandstones from the Walanae Formation and the Camba Formation. The Camba Formation and the Walanae Formation are southwest of Lake Sidenreng and are interpreted that the Lajarakaria River water flow transports the material from this formation. The Pare-pare Volcano Members are located west of Lake Sidenreng and are interpreted that the Amparita River and Lajarakaria River waterways transport the material from these member rocks.

References
[1] Whitten T, Henderson G and Mustafa M 2002 The Ecology Of Indonesia Series Volume IV (Singapore)
[2] Selley R C 2000 Applied sedimentology (Elsevier)
[3] Sukamto R 1982 Geologi Lembar Pangkajene dan Watampone Bagian Barat (Bandung: Pusat Penelitian dan Pengembangan Geologi, Direktorat Geologi dan Sumberdaya Mineral)
[4] Djuri, Sukido, Sudjatmiko and Bachri S 1998 Geologi Regional Lembar Majene dan Bagian Barat Palopo edisi II (Puslitbang Geologi)
[5] Nichols G 2009 Sedimentology and stratigraphy (New Jersey: John Wiley & Sons)
[6] Ravera O 1979 Biological Effects of Ionizing Radiations in Aquatic Environment Biological Aspects of Freshwater Pollution (Elsevier) pp 179–97
[7] Pettijohn 1975 Sedimentary Rock 3rd edition (New York: Harper and Row Publisher)