Variation on the coastal deposit in Nusa Tenggara Islands based on the mineralogy and petrographic analysis

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Abstract. Sand as part of sedimentary material can be consisted of single mineral fragments, rock fragments, or even biogenic materials. Nusa Tenggara is an archipelago that was formed due to the meeting of the Indian Ocean Plate and the Eurasian Plate which supported by other geological processes. The stratigraphy of these islands is dominated by carbonate rocks, volcanic rocks, coastal deposits and alluvium. Due to the variation of the rock composition, there is a large possibility that mineralogy sediment material found in the coastal area will be different from one place to other. This study aims to analyse variations on coastal deposits in a number of specific locations in the Nusa Tenggara Islands. This study was carried out by mineralogical and petrographic analysis of sand samples from six coastal areas in Nusa Tenggara Islands. The mineral composition of coastal sand was identified using hand loupe to give general understanding. After that, the petrographic analyses were implemented to give detailed mineralogical analyses of each sand. Mineralogical studies are specialized in study of the physical structure and chemical composition of each mineral, while petrographic studies can support the details of every physical information obtained through macroscopic observations. Data are retrieved by taking sand samples directly in the research field in a certain amount. This sample is separated then for macroscopic analysis while the other parts are made in a thin section. The thin section will be used for petrographic analysis under a polarization microscope. The analysis result shows that there are variations in coastal sediment components and it most likely does to different rock found around such area.

Keywords: Sand, mineralogy, petrography, Nusa Tenggara Islands

1. Introduction
Geology of coastal sand concerned with the outcrops and sediment that have been deposited along the coastal region. Nature change is a vital process that determine the characteristics of the coastal and the potential effects on some certain interests [1]. A lot of interactions along the sandy coastal make the place become a very dynamic environment. The controls actually come from physical and biological factors, such as biological communities and tidal energy. Those processes and the source material are the main component to define the composition and texture of beach sediments [2].

Nusa Tenggara is located in East Indonesia with Lombok, Sumbawa, Flores, Bali and Sumba as the main island group. Most of the islands are volcanic origin, except for Sumba Island and Timor Island [3]. According to Keep et al., these fragments of Sumba and Timor islands are part of the Eurasian plate incorporated in convergence [4].
Southeast Nusa Tenggara Islands are part of plate boundaries where convergence occurs which leads to subduction processes. This subduction process occurs between the Eurasian and Indo-Australian plates. Based on tectonic order, these islands have four structural units extending from north to south. These four units include islands and basins that fill the back-arc, inner-arc, outer-arc, and fore-arc units.

From stratigraphic view, these islands are dominated by volcano-sedimentary rocks as the effect of subduction. This subduction tends to move northward, but collides with the Australian continental plateau on the east side so that the boundary becomes unclear. As a result of this subduction transition, the volcanic islands formed are slightly deflected in the eastern part of Flores Island [5].

Figure 1 shows one of the chronostratigraphic sections of Sumbawa Island in Nusa Tenggara. From the diagram in sedimentary rocks section, we can see that volcano-sedimentary rocks have been deposited from Early Miocene to Pliocene Age [6]. This rock is a sedimentary rock whose source of material comes from volcanic rocks that were previously formed due to volcanic activity during subduction. These sedimentary rocks contain many volcanic rock fragments and the sandstone itself generally has components consisting of rock forming minerals [6].

As we see in the map of Nusa Tenggara Region (figure 2), research has been carried out in six coastal areas in the Nusa Tenggara Region, Indonesia, including the islands of Lombok, Sumbawa, Komodo and Flores. These beaches are Kenawa Beach, Mawun Beach, Lombok Beach, Gili Laba, Kelor Beach, and Pink Beach.

Kenawa Beach is located in the west side of Sumbawa Island. This island is part of a volcanic arc which was originally formed due to the subduction process of the Indo-Australian and Eurasian plates. The island is dominated by volcanic rocks such as breccia and basaltic lava aged Lower Miocene and andesitic rocks. These rocks interact with limestone layers and pyroclastic rock sequences aged Mid Miocene. Small intrusions from Upper Miocene in the form of igneous rocks such as andesite, diorite, dacite, etc. also found on this island [6].

Mawun, Gili Laba, and Lombok Beach are located in Lombok Island. Lombok Island is one part of the archipelago in southern Indonesia. The island is mostly covered by layers of young unconsolidated sediment (Tertiary to Quaternary age) on its surface.
The lithology of this island is dominated by volcanic rocks and sandstones. The eastern side is dominated by volcanic rocks, meanwhile the western side is composed of some alluvial sediments such as mud, sand, and gravels [7]. The appearances of several beach locations are showed in figure 3. Kelor Beach and Pink Beach are parts of Komodo Island and Flores Island. These islands are volcanic arcs which were formed by subduction between two plates. The subduction has caused volcanic eruptions, up-lift, and other several formations, including these volcanic islands and ocean trenches. The origin of volcanism that formed these islands are submarine volcanoes that layered by the deposit of sandstones and limestone. The next volcanic activities were dominated by volcanic breccia and other volcanic materials that intercalated with limestone aged Late Miocene to Early Pliocene [8]. By collecting a number of coastal sediment samples from these islands, this study aims to find variations in coastal sediments that are likely related to rock sources and processes that occur at the present time.

2. Methodology
We have mentioned that this research was done in six specific places in Nusa Tenggara Region, Indonesia. Those places are Mawun Beach and Lombok Beach, Kelor Beach, Pink Beach, Gili Laba, and Kenawa Beach. Most of Nusa Tenggara Islands are volcanic islands, but some of those island sides are covered by shell fragments as shown in figure 4.
Sample weighted about 600 to 700 grams was extracted directly from the beach’s sand in each location. The sampling location is about 10 meters from the shoreline so it is not much affected by sea tidal activities. Sands were washed and sorted by the size before dried in about 30 °C temperatures. This was done to obtain sand samples without fine-sized impurities such as dust and soil. Each number of samples is stored in a different bottle after that, depending on the location of extraction. Number of sand samples in the bottle weighted 500 grams from each location.

Several sediment samples from the bottle were made into thin sections sized 30 microns and analyzed petrographically under polarization microscope. This petrographic analysis is important to distinguish minerals and another composition of stones or sediments from the optical properties and other micro-sized characteristics such as microstructure. The rest of samples are observed under the geological loupe to distinguish its general physical appearance.

The result from petrographic analysis and macroscopic observation then used to see the variations in every sample of beach’s sediment in Nusa Tenggara Region. From figure 2 and figure 3, we can see that some of sands have a very different appearance even from macroscopic view, and we can analyze it more through the microscopic analysis.

3. Results and discussion

3.1. Mawun Beach
This sample has abundance shell fragments with sub-angular shape inside (table 1). Figure 5 shows that under 5 mm-sized shell fragments were found with a slight mixture of minerals such as hornblende, plagioclase and feldspar. There are some bigger shell and lithic fragments inside too. The material size tends to be fine when compared with other sample data.

3.2. Kenawa Beach
Kenawa Beach’s sample has more regular shape but still dominated by shell fragments (table 2). The shell fragment’s size is commonly larger than other samples and there is a very little mineral mixture in them other than pyroxene and quartz (figure 6).

3.3. Kelor Beach
This sample has abundance shell fragments with irregular shape inside which cover more than 60 % of overall components (table 3). The material size tends to be coarse when compared with other samples. The other materials that shown are some minerals like feldspar, pyroxene, and plagioclase, also lithic fragments (figure 7).

![Figure 4. Different physical appearance of two sand samples in microscopic view.](image)
Table 1. The composition of Mawun Beach sediment and its percentage.

| Material      | Percentage | Occurrence |
|---------------|------------|------------|
| Lithic fragments | 6 %        | Uncommon   |
| Shell fragments | 60 %       | Ubiquitous |
| Feldspar      | 7 %        | Uncommon   |
| Hornblende    | 15 %       | Common     |
| Pyroxene      | 5 %        | Uncommon   |
| Plagioclase   | 7 %        | Uncommon   |

Figure 5. Microscopic view of Mawun Beach's thin section.

Table 2. The composition of Kenawa Beach sediment and its percentage.

| Material      | Percentage | Occurrence |
|---------------|------------|------------|
| Quartz        | 10 %       | Common     |
| Shell fragments | 70 %      | Ubiquitous |
| Feldspar      | 4 %        | Uncommon   |
| Pyroxene      | 10 %       | Common     |
| Muscovite     | 3 %        | Uncommon   |
| Plagioclase   | 3 %        | Uncommon   |

Figure 6. Microscopic view of Kenawa Beach's thin section.
Table 3. The composition of Kelor Beach sediment and its percentage.

| Material        | Percentage | Occurrence |
|-----------------|------------|------------|
| Lithic Fragments| 10 %       | Common     |
| Shell fragments | 70 %       | Ubiquitous |
| Feldspar        | 12 %       | Common     |
| Pyroxene        | 3 %        | Uncommon   |
| Plagioclase     | 5 %        | Uncommon   |

Figure 7. Microscopic view of Kelor Beach's thin section.

3.4. Lombok Beach
Lombok Beach’s sand sample has different appearance compared to other samples. Figure 8 shows that this sample has abundance minerals inside, dominated by feldspar and plagioclase. Lithic fragments can be found in common, but the shell fragments are hardly found in this area. The mineral shapes are mostly sub-angular with various sizes (table 4).

3.5. Pink Beach
In Pink Beach, Komodo Island, the materials are dominated by shell fragments (figure 9). The size average of materials in this sample is around 5 mm with sub-rounded shape. Lithic fragments and feldspar are commonly found, but other minerals like hornblende, pyroxene, and plagioclase rarely found inside (table 5).

3.6. Gili Laba Beach
Gili Laba Beach’s sample has both minerals and shell fragments in similar number (figure 10). Feldspar dominated the materials beside pyroxene, shell fragments, and lithic fragments. The other mineral like pyroxene are little hard to found (table 6).

From the petrographic analysis, it can be seen that there are differences in the variation of components from beaches located on certain islands. Minerals have certain optical properties when viewed through a polarization microscope so that they can be clearly distinguished, while shell fragments do not show these characteristics.

Mawun Beach, Gili Laba Beach, and Lombok Beach originated from Lombok Island generally have mixed compositions of minerals and shell fragments. The sediment of Mawun Beach has more shell fragments than minerals, while the Lombok Beach’s sediment has more minerals than shell fragments, but the ratio differences of both components are not too wide. The Gili Laba beach sedimentary component has a mineral presentation and shell fragments that are not much different.
Kenawa Beach in Sumbawa Island has components that are highly dominated by shell fragments with very little mineral mixture. Sumbawa Island itself is a volcanic island that intercalates with limestone. Kelor Beach and Pink Beach originated from the islands of Komodo and Flores also have components which are dominated by shell fragments. These islands are also volcanic islands that are layered with limestone and sandstones.

Tidal processes and past climate changes also certainly affected the growth of coral reefs in coastal areas so that some of the shell fragments found in sand samples might not entirely sourced from coral fossils in limestone but also from dead coral in recent age. It can be seen from the physical appearance and forms of shell fragments in microscopic observation (figure 3). The recent aged shell fragments have not undergone petrification like fragments from limestone so they still have the original shell texture.

![Figure 8. Microscopic view of Lombok Beach's thin section.](image)

| Material          | Percentage | Occurrence |
|-------------------|------------|------------|
| Lithic fragments  | 12 %       | Common     |
| Shell fragments   | 8 %        | Uncommon   |
| Feldspar          | 25 %       | Common     |
| Hornblende        | 17 %       | Common     |
| Pyroxene          | 13 %       | Common     |
| Plagioclase       | 25 %       | Common     |

![Figure 9. Microscopic view of Pink Beach's thin section.](image)
Table 5. The composition of Pink Beach sediment and its percentage.

| Material    | Percentage | Occurrence |
|-------------|------------|------------|
| Lithic fragments | 10 %       | Common     |
| Shell fragments     | 65 %       | Ubiquitous |
| Feldspar      | 12 %       | Common     |
| Hornblende    | 5 %        | Uncommon   |
| Pyroxene      | 5 %        | Uncommon   |
| Plagioclase   | 3 %        | Uncommon   |

Figure 10. Microscopic view of Gili Laba Beach's thin section.

Table 6. The composition of Gili Laba Beach sediment and its percentage.

| Material    | Percentage | Occurrence |
|-------------|------------|------------|
| Lithic fragments | 15 %       | Common     |
| Shell fragments     | 25 %       | Common     |
| Feldspar      | 40 %       | Ubiquitous |
| Hornblende    | 7 %        | Uncommon   |
| Pyroxene      | 13 %       | Common     |

4. Conclusion

From this research, it can be concluded that even though the islands in Nusa Tenggara Islands mostly formed by volcanism, but we found out that several islands have covered by shell fragments from sea creatures. The result shows that most island sediments dominated by shell and lithic fragments except for East Lombok and Gili Laba which dominated by minerals. In some samples, the abundance of shell fragments reaches more than 70 % of overall components. Mawun Beach has the finest size sediment, meanwhile Kenawa Island, Kelor Beach, dan Gili Laba have the coarsest size sediment. Both Pink Beach and Lombok Beach tend to have about 5 mm sized sediments.

We can also see that getting to the east side, minerals are diminishing, replaced by shell fragments. On the east side, coarse-sized shell fragments are dominantly found and very few minerals are found, whereas on the west sides there are only few shell fragments.

This may be caused by the difference of sediment sources and main lithology of each area.

The East Lombok and Gili Laba beaches which are dominated by minerals can be interpreted to be caused by the dominant volcanic rock source in the region which has also been explained that the
island is dominated by volcanic and sandstone rocks and some other sides of the island are alluvial that initially formed from the same source of rock.

Other coastal locations which consisting mainly of shell fragments may obtain sediment sources from coral reefs in the ocean mixed with limestone lithology in the region which partly intercalated with volcanic rocks so that in some areas both volcanic material and limestone appear to be mixed like on Mawun beach.

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