https://jurnal.unimed.ac.id/2012/index.php/tgeo/article/view/51546
https://doi.org/10.24114/tgeo.v13i1.51546 (Vol. 13 No. 1 – 2024)
e-ISSN: 2622-9528 p-ISSN: 2301-606X

# Identification of Marine Landforms as a Form of Coastal Area Management in Pangandaran District

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| Received: | Revision: | Accepted: |
|---|---|---|
| October 18, 2023 | January 20, 2024 | March 30, 2024 |

**Abstract**

Changes in marine landforms in coastal areas are relatively rapid and need to be analyzed to determine environmental management policies. Complex marine landforms are found in the coastal areas of Pangandaran Regency and have strong pressure to fulfill community activities, not only for local communities but also for outside communities. Basically, community activities are adapted to regional environmental conditions. The aim is to optimize the potential of natural resources and minimize environmental degradation, but this has not been fully implemented. The method used in this research is a descriptive method using a field survey approach. Marine landforms resulting from the accretion process in the Pangandaran coastal area are spit landforms, aeolian-marine sedimentation in the form of coastal dunes, fluvio-marine sedimentation in the form of estuaries and alates, organic-marine landforms and white sand beaches associated with reefs. The landforms resulting from erosion are Cliffs, notches, wave-cut platforms, stacks, and stumps. The impact of landforms resulting from sedimentation in the Pangandaran coastal area is mainly spit landforms that cover river mouths and the occurrence of flooding, puddles, and even accumulation of organic waste, landforms resulting from erosion, the impact of which is the decline of the coastline accompanied by avalanches of material towards the sea, especially on beaches that have non-resistant rocks such as sedimentary rocks and alluvial deposits. Management of the Pangandaran coastal environmental area must be carried out in an integrated manner, land buritan (hinterland), which has steep slopes and resistant rock, is designated as limited production land, and the development of the spit at the river mouth is made into a jetty, and the beach has beach cups waves with rip currents and water bathymetry. -10 meters above sea level, a wave-protecting wall must be built, and the coastal border area must be used as vegetative-based conservation land.
**Keywords:** Marine landforms, Coastal Management, Pangandaran

## INTRODUCTION

The shape of coastal areas experiences dynamic changes, and this condition is caused by many factors that have a causal relationship and influence each other. According to Sunarto et al. (2013), seven factors influence the shape of coastal areas: astrodynamics, aerodynamics, hydrodynamics, morphodynamics, geodynamics, aerodynamics, and anthropodynamics. The strength and processes of factors that occur in coastal areas can be known by observing the landscape and landforms (Davidson-Arnott, 2010; Legleiter & Marston, 2013).

The southern coastal area of West Java has a unique coastal area. Most of the coastal areas are classified as natural, namely in the Pangandaran Regency (Taofiqurohman et al., 2023). In general, the shape of the coastal area in Pangandaran Regency is a headland flanked by two bays,

namely Parigi Bay and Pangandaran, which form almost the same bay. Still, if analyzed in more depth, The landforms of each bay and headland have many variations; this cannot be separated from the strength and intensity of the factors that influence the shape of the coastal area. Since 2012, Pangandaran Regency has been a division area of Ciamis Regency and has many unique natural features as tourist attractions (Martasuganda et al., 2020). This impacts the relatively rapid development of regional infrastructure, which affects land use changes, including land changes in the region (Astuti et al., 2021). Land use in coastal areas can be maximized if managed appropriately (Kharisma et al., 2019). The scenario that can be implemented to improve the development status in the Pangandaran coastal area is progressive and optimistic (Rizal et al., 2021). Based on the research results of (Maudhi et al., 2023), the Pangandaran coastal area is dominated by vulnerable classes, generally with sandy beach geomorphology. Coasts are very vulnerable to environmental damage. Therefore, it is necessary to create a set of benchmarks for local community wisdom in carrying out coastal resource management practices that are further developed in accordance with management objectives or institutional context and social conditions of local communities as well as special policies and management of coastal areas (Rizal et al., 2022).

In line with what (Goudie, 2018) stated, the higher the population pressure in an area, the higher the changes in landforms accompanied by changes in environmental conditions. One of the sciences whose object of study is landforms on the earth's surface is geomorphology. In its development, the science of geomorphology does not only analyze landforms. Still, it is oriented towards applications such as coastal environmental management, land use, potential sources of disasters, and natural resources (Hooke, 2019). The research results of (Prayogi et al., 2021) Study of Coastal Vulnerability on Coastal Area Development Pangandaran has a multi-disaster vulnerability level, namely high waves and abrasion, earthquakes and tsunamis with the lowest vulnerability level being 50%, medium 36.97%, and high 13.01%, apart from There is also the potential for disasters in coastal areas both directly and with accompanying impacts such as liquefaction, rubbish, flooding, seawater pollution, sedimentation and inundation, and the emergence of disease vectors (Budiono & Raharjo, 2008; Keller et al., 2020; Mardiatno et al., 2020; Priadi et al., 2020). For this reason, it is important to carry out this research to analyze marine landforms and their influence on environmental conditions as reference material for integrated and sustainable environmental management of coastal areas in the Pangandaran coastal area.

## RESEARCH METHODS

The method in this research uses a descriptive method with a field survey approach and a literature study. This method aims to describe marine landforms based on the study subject of geomorphology, namely morphology, morphogenesis, morphophonology, and morpho arrangement (Zuidam, 1983). Data to describe landforms is obtained through direct measurements, although currently, landform analysis can be done through remote sensing. Field observations are done to see factual conditions (Benson, 2018). This is done to explain geomorphologies such as slope slope, slope height, and slope length and to explain the morphoarrangement. Literature studies describe morpho-chronology and morphogenesis through thematic maps such as geological, topographic, and land use maps. The classification of marine landforms used in this research is adapted from Huggett's book F (2011). Landforms can generally be classified as abrasion products and accretion/deposition results.

The coastal area used in this research is along the coast of Parigi Bay - Pangandaran Bay, which consists of the sub-districts of Cijulang, Parigi, Sidamulih, Pangandaran, Kalipucang and in these coastal areas there are tourist attractions, namely: Bojongsalwe Beach, Batu Hiu, Pangandaran, Karangnini, Lembah Putri, and Tagog. The boundaries of coastal areas use a geomorphological approach, namely based on landforms, Gunawan et al. (2005) coastal areas based on a geomorphological point of view starting from the wave breaking zone and landward to a landscape whose formation is still genetically influenced by marine activity, such as coastal alluvial plains.

## RESULTS AND DISCUSSION

### Physiography of the Coastal Area of Pangandaran Regency

The diversity of geological structures in the West Java region cannot be separated from tectonic processes, which are controlled by the collision activity of two plates, the Eurasian Plate to the north and the Indo-Australian Plate to the south. The oceanic plate is actively subducting beneath the continental plate, and this collision zone forms the morphology of an oceanic trench. Subduction zone landforms are a close combination of processes that occur at the edge of the oceanic crust and the edge of the continental crust. So many tectonic processes can occur, including strike-slip faults and normal faults. The formation of an accretionary wedge on the seabed is controlled by the tectonic activity of thrust faults, which results in an uplift process (Bird, 2008). This process includes geodynamic factors that have a geomorphodynamic relationship in the coastal areas of Pangadaran Regency.

Physiographically, according to van Bemmelen, the southern part of West Java is part of the Southern Mountain route. As a result of the subduction zone, the relief conditions of Pangandaran Regency are in the form of coastal land in the south, which gradually becomes the southern mountains. Topography starts from a height of 0 to a height of 1,000 meters above sea level. This intense uplift caused the formation of steep cliffs along the Pangandaran coast; to this day, this uplift still occurs. In several places, quite extensive coastal plains are found. In general, the morphology of the Pangandaran coastal area can be divided into three types: coastal land morphology, wavy hill morphology, and karst morphology (Sopandi et al., 2020).

Regional Map Sheet Pangandaran (Supriatna et al., 1992) shows three rock formations in the Pangandaran Coastal region, namely the Jampang Formation with volcanic breccia rocks, the Pamutuan Formation with limestone rocks, the Kalipucang Formation with reef limestone rocks, and alluvial deposits. Apart from the geological condition of coastal waters, it is also influenced by wind speed and direction. In Indonesia, the wind pattern that plays a big role is the monsoon, which is present on the southern coast of Java. Seasonal changes in wind direction and speed in the south waters of Pangandaran influence changes in the direction and speed of surface currents. West season and East season. In the western season, the dominant wind blows from the southwest to the northeast at a speed of 5.7 – 8.8 knots, causing the surface to move east at an average speed of 0.4 knots. In the east season, the wind blows from east to west at a speed of 8.8 – 11.1 knots, causing surface currents to move northwest at an average speed of 0.18 knots. Meanwhile, during the transition season, changes in wind direction and speed do not affect the direction and speed of surface currents (Fadika et al., 2014).

Changes in the wind will affect the strength and direction of the waves. On Pangandaran Beach, there are two types of waves, namely, waves generated by local winds and swell waves, which are winds that come from the Indian Ocean. The bathymetry of the Pangandaran Sea Area shows that the depth near the coast is generally shallow, and the deeper you go to

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the middle of the sea, the deeper the water becomes. Parigi Bay, to the West Coast of Pangandaran, has relatively shallow bathymetry ranging from -20 to -10 below sea level, while in Pangandaran Bay or the East Coast of Pangandaran, it is between -10 to -50 below sea level.

**Landforms Resulting From the Accretion Process**

**Estuary landform**

The Bojongsalawe estuary is located in Karangjaladri Village, Parigi District. The estuary has a river that separates several tourist attractions, namely Batu Hiu Beach and Batu Karas. Estuary formation results from energy originating from the river in the form of material transportation, which then undergoes deposition in the estuary. The rivers that flow into the Bojongsalawe Estuary include the Cikiray River, Cijulang River, and Cijalu River, plus material resulting from sea wave abrasion.

Material from the river and the results of wave abrasion are then carried by currents parallel to the coastline or longshore current, thus forming spit landforms that cover parts of the estuaries of the three rivers and form estuary landforms. Observation results show that the length of the western spit is 1.2 km, with the widest spit being 230 m wide and the narrowest being 273 m wide. The slope of the spit on the front beach is 17$^{o}$, including a rather steep slope dominated by clayey sand material. The western spit has a length of 887 m and a width of 220 m; the slope slope is 20$^{o}$.

Figure 1 Condition of Bojongsalawe Estuary Waters
(Source: Authors Documentation, 2023)

If sea waters experience the lowest tides, shallowing will occur at the bottom of the Bojongsalawe Estuary, even though a jetty has been built. This shallowing is caused by sedimentation carried by water from the three rivers. Conditions like this really impact fishermen's activities when the tides are lowest. The river conditions become shallow so that fishermen cannot go to sea and return to sea when the waves are highest.

**Coastal Sand Dunes landform**

Around Batu Hiu Beach are coastal dunes both to the west of Bojongsawale Beach and to the east of the West Coast of Pangandaran. Strong winds from sea to land will build sand mounds along the coastal area towards the coast. This mound is unstable and becomes stronger after the presence of plants as a material binder. Due to their physical conditions, plants that live in coastal areas have sandy material, which can be said to be plants that live in a dry environment (xerophytes). The sand dunes that are formed are usually bound by loop grass (Spinifex sp). Other littoral plants also creep, such as Ipomea Pescaprae.

Figure 2. Coastal Sand Dune Covered by Spinifex sp
(Source: Authors Documentation, 2023)

Coastal sand dunes in the coastal area of Pangandaran Regency are found in areas that have not yet been developed and also have the presence of beach cup waves as constructive waves. The width of the coastal dune from the coastline towards the land is 500 m, with different types of vegetation. The coastal dunes on the front coast are planted with Gelung Grass (Spinifex sp) and Pandan Luat (Pandaus Tectorius). On the back coast to the alluvial deposits in the form of coconut plantations as a form of use by the local community, a few beach pandan plants and rice fields grow, and in several places, they are used as a pond.

**Tombolo Landfrom**

Tombolo is a geomorphological unit that connects an island with a wider mainland. Tombolo formed from marine processes in the form of sediment deposition due to sea currents (Manyoe et al., 2022). Pananjung Pangandaran is an island that was originally separated from the mainland or Java Island. The island is positioned in the middle of the bay, with longshore currents carrying sedimentary material from several rivers and the results of wave erosion. Then, the material is deposited at the back of Pananjung Island. The existence of Panajung Island acts as a barrier against wave erosion at the back of Pananjung Island. So, the waves at the back of Pananjung Island are relatively not so strong, and there is more material deposition.

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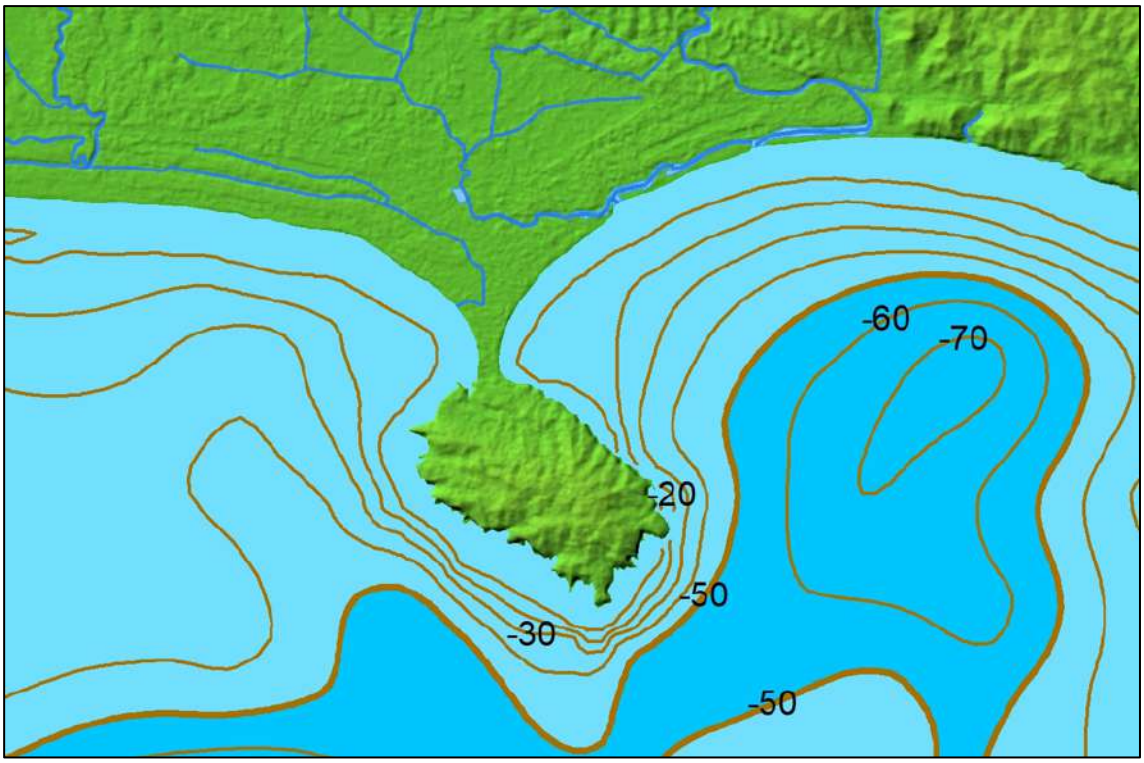


Figure 3. Tombolo landform (Source: Author's Processing Results, 2023)

Based on the Pananjung Geological Map Sheet (the Tombolo Pananjung segment area consists of 3 rock formations in the southern/front part of the Panjung it is composed of volcanic breccia (Jampang Formation) with tuff rock with lava inserts interspersed with sandstone interspersed with limestone, marl and conglomerate inserts, sandstone Diamctite gravel of Oligocene age around 34 million years - 23 million years ago.

The rear part of the Pananjung segment belongs to the Kalipucang Formation, which is composed of reef limestone with a Miocene age of around 23 yr – 5.3 yr. The sedimentary material that connects the main island, Java Island, with Pananjung I reflects the control of fluvial products, which supply sed load from the hilly areas in the northern part of the Pangandaran area. Material from the fluviatile process flows into the sea, where waves and longshore currents in mud, sand, and gravel carry it. The rivers that flow to Pangandaran Beach start from the East-West section, namely the Citanduy River, Ciputrapinggan River, Cikidang River, Cikembulan River, and Citonjong River.

**Spit Landform**

Pandaran Bay has three estuaries, from east to west, namely the Cintaduy River, Ciputrapinggan River, and Cikidang River. The three rivers that flow into Pangandaran Bay carry material in suspended and dissolved solids. As a result, the relatively large amounts of material under the river are then deposited on the coast, both on the front and back beaches. Apart from the materials carried by the Citanduy River, several rivers carry materials and empty into the Citanduy River, such as the Cibereum, Cikidang, and Cikonde Rivers. Based on data from the Citanduy River Basin Center (BBWS) 2018, the Citanduy River Estuary experienced mud shallowing of 5 million m3/year, and the deposited material was 75%.

Morphologically, because the eastern part of Pangandaran Beach forms a bay, longshore currents or currents that follow the coastline can form. These currents cause material movement initially through river water and then deposited on the foreshore through longshore drift/litoral currents (Kusmanto & Setyawan, 2013). Deposition resulting from the longshore drift process forms spit landforms, such as what happens in Pangandaran Bay; many spits cover river mouths, one of which is at Tagog Beach. The spit's formation in Pangandaran Bay cannot be separated from the material carried by the rivers that empty into Pangandaran Bay.

Even though a lot of material enters Pangandaran Bay due to the destructive beach cups, several beaches in Pangandaran Bay, such as Tagog Beach, experience a coastline retreat of around 240 m. The length of the Tagog Beach spit beach landform is 1 km with a width of 130 m, and the Ciputrapinggan River borders the rear; the slope of the spit landform is $12^0$ (sloping). The material deposited is sand as an alluvial deposit; waves and wind very easily influence this material, so it can be said that coastal changes in the spit's landform are very dynamic. These conditions also greatly influence the vegetation that can develop in the spit area. The observation results showed that there was no natural vegetation or vegetation on the spit landform. The local community planted vegetation, such as coconut trees and beach pandanus, and even then, many of them had died and were not growing.


Figure 4. Spit landform at Tagog Beach
(Source: Satellite Image Processing Results, 2023)

**The landform of White Sand Beach is Associated with Reef from**

Apart from the wave cut platform formed in the southern part of Panajung Pangandaran with a volcanic breccia rock composition, in the western part of Pananjung, there is also a waveform flatland formed by a material with a composition of white sand containing coral colonies (coral reef), which forms a reef from the landform. It has died with gravel size, as shown in the following picture.

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Figure 5. White Sand Beach Contains Grave-Sized Reef in Pananjung
(Source: Authors Documentation, 2023)

This landform can be said to be a mixed landform between organic and marine landforms. The process of forming this landform is caused by wave erosion, which erodes coral reef material; the white sand results from no material from the river mouth entering this area. This white sand is an in situ material due to wave erosion of the coral. The length of this white sand beach is 500 meters, with a coastal width of 30 m at the lowest tidal waves. This white sand area has a slope between 5 - $15^0$ or slightly sloping. The length (coral reef) is 100 m towards the breaker zone, and the depth of the coral reef is 2 meters deep.

**Landforms Resulting From The Abrasion Process**

**Wave Cut Platform landform**

Wave-cut platforms are flat parts of the sea and consist of bedrock formed by wave erosion. The process of forming a cliff due to wave erosion forms a notch, a notch, or a hanging cliff that experiences rock falls due to gravitational forces (Mulyaningsih, 2018). Wavecut platforms or flattened waveforms on Pangandaran Beach are formed in several places, especially on rocks that are relatively resistant to wave erosion and have cliffs that jut out towards the sea. The wave cut plate forms a landform on Pangandaran Beach, which is formed in the southern part of Pananjung Island.

The power of the waves becomes concentrated on the headland due to wave refraction. Refraction When waves enter shallow sea waters, they will experience refraction, which causes the direction of the waves to change according to decreasing depth. If a wave approaches a headland, the wave will experience refraction and convergence or be deflected towards the headland so that the wave energy is concentrated towards the headland.

Figure 6. Wave Cut Platform Landform in Pananjung
(Source: Authors Documentation, 2023)

The wavecut platform landform can be clearly seen when the waves are experiencing the lowest tides (low tide). This formation is in Pananjung Pangandaran when the wave conditions are experiencing the lowest tides. The length of this land is 50 meters, with a slope of 0 - 50 or flat on the wavecut platform. When the waves are highest, this land will be covered by seawater. The height of the rock cliff has a length of lk 40 m with a slope of > 90$^{o}$, including very steep slopes with volcanic breccia rock type, while the depth of the sea in front of the beach as a result of Pananjung bathymetric mapping is -10 below sea level.

**Cliff, Notch, and Stump landforms**

Batu Hiu Beach is located in the middle of Parigi Bay. In this area, there is a small hill that is composed of layered limestone, which, in geological terms, is called calcarenite. In the beginning, before the formation of the notch, it was a cliff because of strong wave erosion and basically limestone rock, which is not resistant to erosion. Hence, the rock formed a notch, and some of the notches were even found to have collapsed. As a result of this collapse, the coastline changed, namely that it retreated towards the mainland. The decline of this coastline can be proven by the existence of a stump landform, which is a rock that was originally one unit with a hill in the Batu Hiu coastal area before forming a notch landform. Due to continuous erosion, the landform formed a stack, which later became a short pillar known as a stump.

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Figure 7. Cliff and Notch landforms at Batu Hiu Beach
(Source: Authors Documentation, 2023)

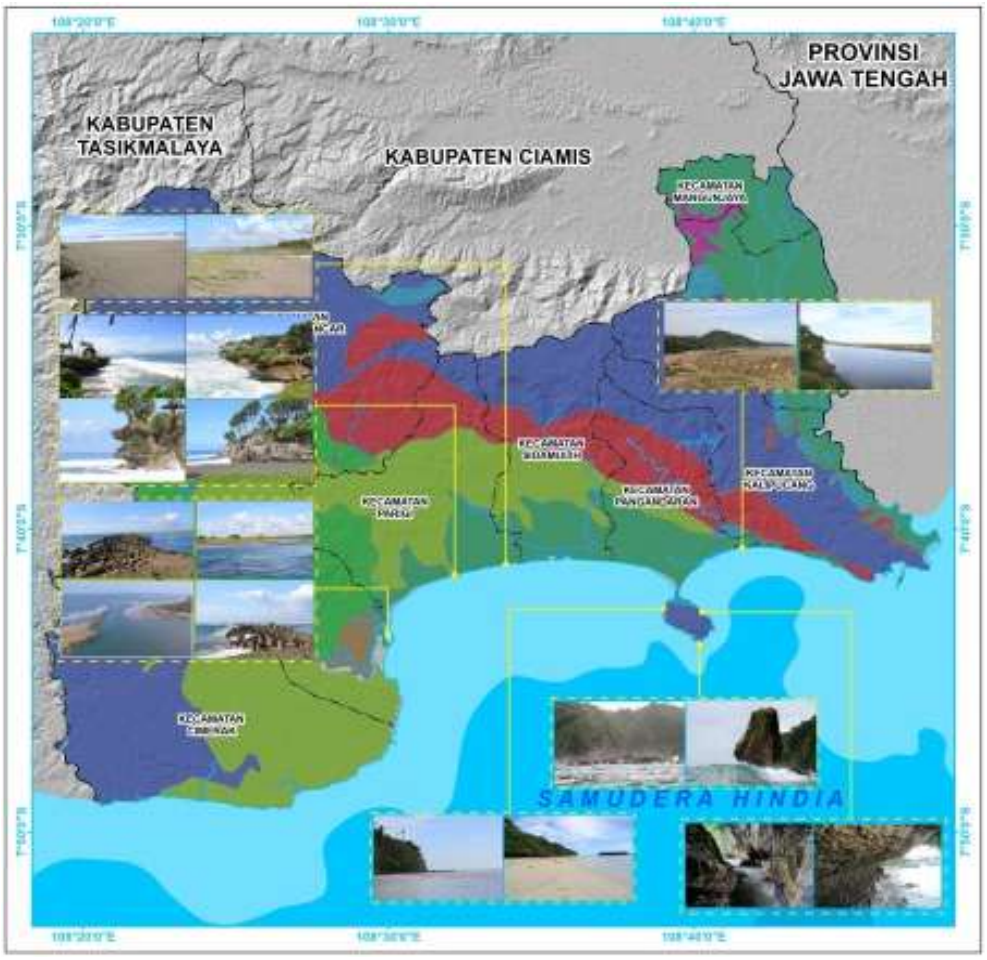


Figure 8. Distribution of Marine Landforms in Parigi Bay and Pangandaran

(Source: Author's Data Processing Results, 2023)

The terraced notch is formed at the top and at the bottom as a result of differences in wave height at the highest and lowest tides. Even though the depth of the sea in front of Batu Hiu Beach has a bathymetry of between -10 to -20 below sea level and the waves hitting the cliff are not very strong because this hill directly faces the Indian Ocean, there will be continuous erosion, and the appearance of the stump landform will also be temporary, meaning that one day due to continuous erosion the stump will be completely eroded by sea waves. The results of observations of the length of the cliff slopes at Batu Hiu Beach during the highest tidal waves at several points can reach 20 meters with an average slope of 85$^{o}$ and including very steep slopes. The following is a picture of the distribution of marine landforms in the coastal areas of Parigi Bay and Pangandaran.

The coastal area of Pangandaran Regency, physiographically, has very complex conditions that cannot be separated from the existence of subduction between the Indo-Australian and Eurasian plates. The influence of subduction between plates affects the morphological conditions and relief of coastal areas to the mainland. From its two bays, the coastal and coastal areas of Pangandaran Regency have a variety of landforms, both the result of accretion and erosion. The landforms resulting from accretion are estuaries, spits and buttonholes, coastal sand dunes, and white sand beaches associated with reefs. Landforms resulting from erosion: cliff, notch, steack, stump, wave cut platform.

The impacts of accretionary landforms in Pangandaran Regency are mainly spit landforms covering river mouths and the occurrence of flooding, puddles, and even accumulation of organic waste around the coast, erosional landforms, the impact of which is the decline of the coastline accompanied by avalanches of material towards the sea, especially on beaches that have non-resistant rocks such as sedimentary rocks. and alluvial sediment. Environmental management of the Pangandaran coastal area must be carried out in an integrated manner by structuring land use. On the mainland or buritan (hinterland) in the form of hills with resistant rock and soil conditions, it is used for limited production land, coastal areas where there are beach cup waves and rip currents with material bars of -10 m below sea level and coastal conditions in the form of Alluvial sediment material needs to be built with a wave-retaining wall to reduce erosion, a jetty will be built on the spit that covers the river mouth, and the coastal border area will be used as a vegetative-based conservative land.

areas but also requires integrated coastal area management, including river basins (DAS). Land use structuring and zoning are necessary for coastal areas, considering geological and geomorphological aspects.

## CONCLUSION

Changes and developments in marine landforms in the coastal areas of Pangandaran Regency must be identified as one of the factors controlling energy and geological processes that can influence community activities. These landform changes occur due to deposition and abrasion. Sedimentation that forms spit landforms at river mouths can impact flooding, and the decline of coastlines marked by the presence of notch, stack, and stump landforms can affect magnetics and the narrowing of coastal areas. Coastal area management not only focuses on coastal

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