COASTAL CHARACTERISTICS OF IRON SAND DEPOSITS IN INDONESIA

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ABSTRACT

Coastal features of Indonesia are controlled by the geology and geomorphology of the hinterland and the bordering adjacent marine environments. Tectonic instability manifested as frequent earthquakes combined with volcanic eruptions and sea level changes also affect Indonesian coastline. Unstable air and heavy rainfall zone known as intertropical convergence zone (ITC) which migrates to the north and south of the equator together with orographic factor of mountain ranges in Sumatra, Java and Nusatenggara are also controlling coastal landforms. Large sediment quantities resulted from a combination of deeply weathered rock in steep elevated hinterlands and frequent heavy rainfall are transported to the coast and built extensive deltas and broad coastal plains. Iron sands in Sumatra, Java, Bali and Nusatenggara Islands are largely derived from denudation of andesite and old andesite formation enriched in magnetite and ilmenite minerals. In certain cases periodic eruptions of active volcanoes supply fluvial sand to maintain the prograding shoreline. Wave regime in Indonesian coastal waters resulted from strong swells of Indian Ocean in the south and Pacific Ocean in the northeast has much influence various coastal features. Coastal zones especially the southern parts of the Neogene Sunda Banda magmatic arc are the area of potential and producing iron sand deposits which extend from northern Sumatra to eastern Indonesia. Beach sediments enriched in magnetic minerals of such coastal zones are typically black or grey. The iron sand deposits have been mined either by state company or by local people. Small scale mining helps to improve the economy of the community. Application of regulations and good guidances of these artisanal minings will not destructive to the natural environments.

Keywords : Coast, characteristic, iron sand, marine environment

1. INTRODUCTION

The islands of Indonesia show considerable diversity of coastal features, related partly to contrasts in the geology and geomorphology of the hinterland and the bordering sea floors, and partly to variations in adjacent marine environments. Due to its occupation in global tectonics between the Indo-Australian, Pacific, and Eurasian plates; the region experiences continuing instability, marked by frequent earthquakes and volcanic eruptions. Its bordering seas are underlain by unstable shelf areas, especially towards the Java Trench - the subduction zone that lies to the south of the Indonesian island-arc.

The past and present tectonic instability, volcanic eruptions, and changes of sea level affect Indonesian coastlines. Outburst of volcanic lava and ash have influenced coastal features both directly and indirectly; and vertical movements of sea level have resulted in complicated sequences of emergence and submergence of island coastlines (www.unu.edu).

Many characteristics of Indonesian coastal landforms are related to their development under tropical -especially humid tropical-conditions. The position of the intertropical convergence zone (ITC) influence climatic characteristics of this region. ITC are determined largely by a zone of unstable

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air and heavy rainfall which migrates north and south over Indonesia that crosses the equator in May and November each year and reaches latitudes of about 15 south in January (www.unu.edu). Indonesian climatic stations generally show a more pronounced wet season when the ITC is to the south, when westerly winds prevail; the dry season occurring after it migrates away to the north, and winds move around to the south-east. The pattern of rainfall is influenced by the orographic factor, notably where moist air is forced upwards as it moves eastwards across mountain ranges, particularly in Sumatra, Java, and Irian Jaya or Western Papua (www.unu.edu).

In Java, Sumatra, Kalimantan, and Irian Jaya, the combination of steep elevated hinterlands of deeply weathered rock, recurrently active volcanoes, and frequent heavy rainfall produces large river systems that carry substantial quantities of sediment down to the coast. Deposition of this material has built extensive deltas and broad coastal plains. The lithology of outcrops within each catchment area of the mentioned islands determines the nature of the weathered mantles and strongly influences the composition of sediment loads carried downstream by the rivers (www.unu.edu). Where sandy material is carried down to the coast it is reworked by waves and deposited as beach formations along shorelines adjacent to river mouths.

Beaches of sand and gravel are extensive around the coasts of Indonesia, especially near the mouths of rivers delivering this kind of material, adjacent to cliffs of sandstone or conglomerate, and along shorelines. Beach sediments of volcanic origin are typically black or grey. Quartzose sands are of very localized occurrence in relation to quartz-arenite outcrops along the coast and within hinterland river catchments (www.unu.edu). Volcanic activity has served to maintain the fluvial sand critical to maintaining a prograding shoreline; such as occurred on the central south coast plain of Java that would probably be subject to shore erosion were it not for the maintenance of its beach fringe by fluvial sand supplies regenerated by periodic eruptions of the Merapi; volcano north of Yogyakarta.

Where high country extends to the coast it terminates in steep coastal slopes. The slope base has often been undercut by wave action, which has removed weathered material to expose rocky outcrops or boulder accumulations on the shore. Because of this basal undercutting, landslides occur frequently on steep coastal slopes. Steep coasts of this kind are extensive in Indonesia. Cliffs have developed along sectors of the southern coasts of Sumatra, Java, and the islands east to Sumba, which are exposed to the relatively strong wave action generated across the Indian Ocean. They are best developed on sandstones, limestones, and outcrops of volcanic rock.

Rocky shore outcrops are subject to intense physical, chemical, and biological weathering. Such disintegration can be seen on sandstones and volcanic rocks exposed to the action of surf and spray, salt corrosion, solution by rain water and percolating ground water, and the effects of wind scour. Such features are well known on humid tropical coasts, especially in Indonesia.

The shaping of these various coastal features has been much influenced by the wave regime in Indonesian coastal waters. A strong swell transmitted from the Southern Ocean moves in from the southwest to the south coasts of Sumatra and Java. A Pacific swell moves southwards through the Philippine Sea to reach the north coast of Irian Jaya, weakening as it diffuses through the Moluccas. Between April and November south-easterly winds are dominant over sea areas south of Indonesia and waves from this direction are important along the south-facing coasts of Java, Bali, Lombok, and Sumbawa. At this season, winds over the Java Sea are easterly to northeasterly. In the wet season the winds over Indonesian waters are gentler and more variable but typically westerly (www.unu.edu).

High demands of iron sand nowadays especially from China to fulfill its steel industries needs has made this mineral being explored to accomplish these high demands. Demands are also come from national cement industries. Indonesia iron sand mostly is spread at coastal zone, thus study on coastal characteristic of the deposit will give better understanding about its accumulation process. The iron sand deposits are formed by particles of magnetite, hematite and ilmenite with associated elements of S, P, Mg, Zn and Al_2O_3.

In Indonesian Archipelago, iron sand mostly is distributed in the west coast of Sumatra and south coast of Java (Figure 1). These two coastal zones are dominated by wave action from the Indian Ocean, and receives a relatively gentle southwest-

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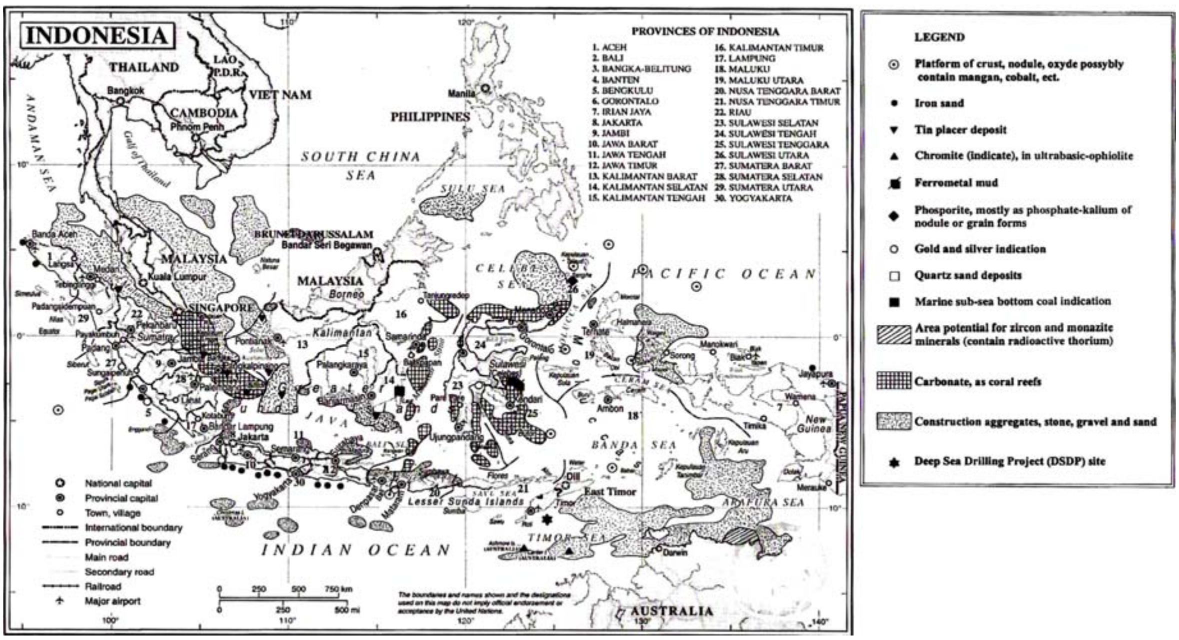

Figure 1. Coastal and offshore Indonesian minerals map shows iron sand distribution in southern coastal zones of Sumatra and Java

erly swell of distant origin and stronger locally generated south-easterly waves that move shore sediments and deflect river outlets westwards, especially in the dry season (www.unu.edu). It is dominated by steep and cliffed sectors and long, sandy beaches. On these two island coasts, the extent of shoreline changes in historical times on this rocky and sandy coast have been relatively slow eventhough powerful wave action from the Indian Ocean strikes the coast.

2. GEOLOGY OF IRON SAND DEPOSITS IN INDONESIA

Physiographically, coastal area of potential and producing iron sand deposits are located in the Neogene Sunda Banda magmatic arc which extends for 3700 km from northern Sumatra through Java to eastern Indonesia (Carlile & Mitchell, 1994 in Kurnio et al, 2005 in press). Lower Tertiary to Recent subduction of the Indo-Australian plate under Sumatra, Java and eastern Indonesia has given rise to the extensive magmatic arc. Magmatic rocks in the arc are predominantly eruptive andesites which include 12 and 13 million years (Ma) granite, granodiorite and diorite intrusions. The developed geological structures of folds and faults are the main control of mineralization. Basement rocks of the magmatic arc are belong to metamorphic rocks of Cretaceous age.

The Neogene arc magmatism is related to oblique and low angle subduction in the present Java trench with collision rates of 7 cm/year, while the magmatism is essentially andesitic and mainly calc-alkaline in composition.

The areas mentioned above are known as the place for distribution of metallic minerals in the old volcanics and granitic rocks (Widodo, 2003). Iron sands resulted from denudation of the magmatic arc are spread on the coastal zones at the western and southern of the islands downstream of the volcanics and granitic hinterlands.

3. COASTAL MORPHOLOGY OF IRON SAND DEPOSITS

Coastal lowlands contain a variety of landforms which are geologically young due to the rapid postglacial sea-level rise stabilized some 6000 years ago (www.fao.org and www.unu.edu). The formation and properties of today's coastal landforms depend on fluvial processes interact with marine processes. Three factors are important for coastal landform formations (apart from global sea level fluctuations): (1) the input of fluvial water and sediment in relation to marine redistribution, (2) the energy of waves and currents, and (3) the amplitude of the tides ('tidal range'). The combined actions of fluvial and marine processes determine whether or not a depositional body can form at the mouth of a river and what kind of body will form. If the rate of fluvial input of sediment exceeds marine sediment redistribution, the depositional sequence will 'prograde' seawards to form a 'delta'. If marine redistribution can handle the input of fluvial sediments, a depositional body may develop that is not prograding, but only aggrading: an 'estuary'.

Dunes are of limited extent and present locally around Indonesia. They spread chiefly behind the beaches of sand of volcanic origin which is exposed to strong waves and relatively strong wind action such as occurred on the south coast of Java and the south-west coast of Sumatra. Such geomorphological feature is a potential form for the accumulation of iron sand deposits. The coast sands are also rich in heavy minerals, notably titaniferous magnetite that produce rutile and ilmenite.

Java

Java is an island about 1,000 kilometres long and up to 250 kilometres wide which is passed through by a mountain range which includes several active volcanoes. To the north are broad deltaic plains on the shores of the Java Sea; to the south steeper coasts, interrupted by sectors of depositional lowland, face ocean waters (www.unu.edu).

The geomorphology of south Java coast shows the smooth outlines of depositional sectors. These are largely due to wave-energy regimes and seafloor topography. The sediment loads of rivers flowing southwards from the mountainous watershed are dispersed by high-wave energy on the south coast. The coarser sand fraction is concentrated in substantial beach and dune formations on the south coast. The steeply shelving sea floor off the south coast allows larger waves to move into the shoreline. Nevertheless, silt and clay carried in floodwaters settles in the small valleys between successively built beach-ridge systems along the southern coast (www.unu.edu) or moving further offshore which deposited in seafloor through suspension system below wave agitation zone.

Topographically the area of the iron sands deposits is generally flat and composed of dunes of sand, which are elongated parallel, to the shore line, in Cilacap; the elevation varies from 0 to 15 m above sea level.

Sandy beaches are typically backed by swash ridges, and multiple beach ridges occur on sectors that have intermittently prograded. Coastal dunes are developed in southern Java, where the fluvially nourished beaches take place. Many beaches show evidence of a continuing supply of sandy, or gravelly, sediment to maintain or prograde the shoreline.

The South coasts of Java are micro-tidal coastal regions (tidal range less than 2 m) which have a steep gradient shelf. Due to these conditions, the south coast deltas are classified as wave-dominated river deltas. In this way, waves attain the energy needed to attack and dissipate freshly deposited fluvial sediments. If the main direction of the wind is perpendicular to the main delta axis, fluvial sediments will be redistributed laterally, in sandy beach ridges parallel to the coast. As a consequence, 'wave-influenced delta plains' have commonly straight outlines.

Depositional or constructional coastlines, with adequate sediment supply are prograding coastlines where accumulation of clastic sediments outweighs erosion by the sea. The clastic material deposited on the coast may be provided by nearby rivers and transported by along-shore currents.

The coastline of Jepara – northern coastal zone of Central Java is almost straight at the fringe of a broad depositional plain. According to Niermeyer (1913: quoted by Van Bemmelen 1949 in www.unu.edu) the Muria volcano where Jepara is located in its western flank was still an island in the eighteenth century, when seagoing vessels sailed through the strait that separated it from the Rembang Hills, a strait now occupied by marshy alluvium.

Beyond Jepara the coast steepens on the flanks of Muria, but the shores are beach-fringed rather than cliffed. To the east Tuban has beaches and low dunes of quartzose sand, supplied by rivers draining sandstones in the hinterland, but otherwise the beaches on northern Java are mainly of sediments derived from volcanic or marine sources. Hilly country continues eastwards until the protrusion of the Solo River delta.

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The southern shores of Madura Strait are beach-fringed, the hinterland rising steeply to the volcanoes of Bromo and Argapura. Beach sediments are grey near the mouth of rivers draining the volcanic hinterland.

The east coast of Java is steep, with streams radiating from the Ijen volcano, but to the south a coastal plain develops and broadens. This consists of low beach ridges built mainly of volcanic materials derived from the Ringgit upland.

The Bay of Grajagan south of Banyuwangi is backed by a sandy barrier enclosing a river-fed estuarine lagoon system with an outlet to the sea at the western end, alongside the old volcanic promontory of Capil. Farther west the coast becomes indented, with cliffed headlands of Miocene sedimentary rock and irregular embayments, some with beaches and beach ridges around river mouths. Nusa barung - a large island of Miocene limestone modifies oceanic wave patterns on the sandy shores of the broad embayment in such a way as to generate longshore drifting from west to east so leading to a cuspate foreland with multiple beach ridge.

The coastal plain then narrows westwards and gives place to a steep indented coast on Miocene sedimentary formations with bolder promontories of andesite near Tasikmadu. At Puger and Meleman there are beach-ridge systems surmounted by dunes up to 15 metres high, with a thick vegetation cover, in sequence parallel to the shoreline.

At Baron a river issues from the base of a cliff and meanders across a beach of black sand that has evidently been washed into the valley-mouth inlet by ocean waves, the sand having come from seafloor deposits supplied by other rivers draining the volcanic hinterland.

At Parangtritis the cliffs end, and the broad depositional plain of central south Java begins. The Opak and Progo rivers, draining the southern slopes of the Merapi volcano, are heavily laden with grey sands and gravel derived from pyroclastic materials. During floods these are carried into the sea to be reworked by wave action and built into beaches with a westward drift. The coastal plain has prograded, with the formation of several beach ridges separated by swampy swales. It appears that the alignment of the shore is being maintained, or even advanced seawards, as the result of successive increments of fluvial sand supply. Finer sediment, silt and clay, is deposited in bordering marshes and swales, or carried into the sea and dispersed by strong wave action.

On some sectors, especially near Parangtritis, the beach is backed by dune topography, typically in the form of ridges parallel to the shoreline and bearing a sparse scrub cover. At Parangtritis there are mobile dunes up to 30 metres high, driven inland by the south-easterly winds. The presence of mobile dunes, unusual in this humid tropical environment, may be due to a reduction of their former vegetation cover by sheep and goat grazing, and by the harvesting of firewood (Verstappen 1957 in www.unu.edu). Whereas the present beach and dune systems consist of incoherent grey sand, readily mobilized by wind action in unvegetated areas, the older beach-ridge systems farther inland are of more coherent silty sand which can be used for dry-land cultivation. The silt fraction may be derived from airborne (e.g. volcanic dust) or flood-borne accessions of fine sediment, or it may be the outcome of in situ weathering of some of the minerals in the originally incoherent sand deposits.

To the west of the southern coast of Java the depositional lowland is interrupted by a high rocky promontory of andesite and limestone, the Karangboto Peninsula. There are extensive sand shoals off the estuary, which washes the margins of the rocky upland, and there appears to have been rapid progradation of the beach to the east-and also in the bay to the west-where sand has built up in front of a former sea cave which used to be accessible only by means of ropes and ladders when men descended the cliff to collect birds' nests. Rapid accretion may have been stimulated here by the catastrophic discharge of water and sediment that followed the collapse of the Sempor Dam in the hinterland in 1966.

The sandy and swampy coastal plain resumes to the west of the Karangboto Peninsula, and extends past the mouth of the Serayu River. In this sector it has been disturbed by the extraction of magnetite and titanium oxide sands (Kurnio, 2006).

West of Segara Anakan the beach ridge plain curves out to the tombolo of Pangandaran, where deposition has tied an island of Miocene limestone (Panenjoan) to the Java mainland, and continues on to Cijulang, where the hinterland again becomes hilly. Beaches line the shore, and many of the rivers have deflected and sand-barred mouths.

At Genteng, southern coast of Sukabumi West Java, a beach-ridge plain develops, curving out to a tombolo that attaches a former coralline island, and beach ridges also thread the depositional lowlands around the mouths of the Ciletuh and Cimandiri rivers flowing into Pelabuhanratu Bay. The beach ridges indicate past progradation, but no information is available on historical trends of shoreline change in this region. West of Pelabuhanratu the coast steepens, but is still fringed by surf beaches, some sectors widening into depositional coastal plains with beach and dune ridges and swampy swales, including the isthmus which ties Ujong Kulon as a peninsula culminating in Java Head.

Sumatra

Sumatra is 1,650 kilometres long and up to 350 kilometres wide, with an anticlinal mountain chain and associated volcanoes. The south-west coast of mainland Sumatra is partly steep along the fringes of mountainous spurs, and partly low-lying, consisting of depositional coastal plains. Swell from the Indonesian Ocean is interrupted by the Mentawai Islands and arrives on the mainland coast in attenuated form. The large sediment yield from rivers draining the high hinterland is causing coral reefs are rare along the central part of the south-west coast of Sumatra. Pleistocene and Holocene raised beaches are extensive. Farther south the coast shows the effects of vulcanicity. Some parts of western Sumatran coastal zone are controlled by geological structures. Near Cape Cina the steep coasts of Semangka Bay and Tabuan Island are related to en echelon fault scarps that run north-west to south-east, and the termination of the coastal plain near Bengkulu result from tectonic displacement transverse to this coastline.

Padang is built on beach ridges at the southern end of a coastal plain that stretches to beyond Pariaman. The extensive shoreline progradation that occurred here in the past has evidently come to an end, for there are sectors of rapid shoreline erosion in Padang Bay, where groynes and sea walls have been built in an attempt to conserve the diminishing beach. North of Pariaman the cliffed coast intersects the tuffs deposited from the Manindjau volcano, and farther north there is beach ridges in broad swampy coastal plain built by wave action reworking fluvially supplied sediment derived from the andesite cones in the hinterland. This plain is interrupted by reef-fringed headlands of andesite on the margins of a dissected Pleistocene volcano. Beach erosion has become prevalent in the intervening embayments, the swampy nature of the coastal plain here due to subsidence, which might also explain the recession of the coast. Broader beach ridge plains occur farther north which runs back to the steep hinterland at Sibolga. Next comes the broad lowland on either side of the swampy delta of the Simpan Kanang, in the lee of Banyak Island, and beyond this the coast is dominated by sandy surf beaches, backed in some sectors by dune topography, especially in the long, low sector that extends past Meulaboh – Aceh Province.

At the northern end of Sumatra the mountain ranges break up into steep islands with narrow straits scoured by strong tidal currents. Weh Island is of old volcanic rocks, terraced and tilted, up to 100 metres above sea level. At Kutaraja the deltaic shoreline of Aceh River has been smoothed by waves from the north-west, so that the mouths of distributary channels have been deflected behind sand spits and small barrier islands. Beach ridges built of fluvially supplied sediment form intersecting sequences where successive depositional plains have been built and then truncated, and there is an eastward drift of beach material towards Lhokseumawe along the northeastern coast of Aceh.

Kalimantan

The western and southern coasts of Kalimantan are extensively swampy, with mangroves along the fringes of estuaries, inlets and sheltered embayments (www.unu.edu). The hilly hinterland approaches the west coast north of Pontianak, and to the south depositional progradation has attached a number of former volcanic islands as headlands. The Pawan and the Kapuas rivers have both brought down sufficient sediment to build deltas but in general the shoreline consists of narrow intermittent sandy beaches backed by swamps. Further south a ridge of Triassic rocks runs out to form steep-sided cape and the hills on the islands. The south coast of Kalimantan is mostly swampy extensions rather than deltas. Sand of fluvial origin has drifted along the shoreline to form the straight spit to the east, partly enclosing mangrove-fringed Sampit Bay, and the recurved spit of Tanjung Puting to the west. Near Banjarmarsin, ridges of Cretaceous and Mio-Pliocene rock run through to form the headland where the swampy shores change to the more hilly coastal country of eastern Kalimantan.

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The east coast of Kalimantan has many inlets and swamp-fringed embayments. Coarse sandy sediment derived mainly from ridges and valleys in the Samarinda area is prominent in Mahakam delta downstream from the city. The delta has numerous distributaries branching among the swampy islands (Magnier et al. 1975, Allen et al. 1976 in www.unu.edu).

Sulawesi

The coasts of Sulawesi is known as tectonically active. There are long sectors of steep coast with terraced features indicating tectonic uplift or tilting. Coral reefs have been raised to various levels up to 600 metres above present sea level which some of them transversely distorted and faulted. Rivers are short and steep, with many waterfalls and incised canyons, and there are minor depositional plains around the river mouths. Volcanic activity has modified coastal features locally, for example on Menado-tua -the active volcano off Menado in the far north of the island. South and south-east of Sulawesi there are many uplifted reef patches and atolls, the highest 200 metres above sea level (Kuenen 1933 in www.unu.edu), and Muna is a westward-tilted island with reef terraces up to 445 metres above sea level (Verstappen 1960 in www.unu.edu).

Bali and Nusatenggara

At northwestern coast of Bali, a lowland behind Gilimanuk is a narrow coastal plain along the northern shore, giving place to a steeper coast on volcanic rocks near Singaraja. In the eastern part of Bali the coast is influenced by the active volcanoes, specially Agung, which generate lava and ash deposits that move downslope and provide a source of sediment that is washed into the sea by rivers, particularly during the wet season (December to April). These sediments are then distributed by wave action to be incorporated in grey beaches. Sanur beach is a mixture of fluvially supplied grey volcanic sand and coralline sand derived from the fringing reef (Tsuchiya 1975,1978 in www.unu.edu).

West of the broad sandy cape near Sanur that links mainland Bali to the Bukit Peninsula (of Miocene limestone) to the south, is developed grey sand of volcanic origin, with beaches interrupted by low rocky headlands and shore benches. Longshore drifting to the north-west is indicated by spits that deflect stream mouths in that direction, and as wave energy decreases, the beaches become narrower and gentler in transverse gradient.

Many of the features found on Bali are also found on the similar Lesser Sunda islands to the east. Cliffs of volcanic rock extend along the southern coasts of Lombok, Sumbawa, and Sumba but elsewhere the coasts are typically steep rather than cliffed. There are many volcanoes, some of them active: Inerie and Iya in southern Flores and Lewotori to the east have all erupted in recent times and deposited lava and ash on the coast, as has Gamkonora on Halmahera. Rivers have only small catchments, and depositional lowlands are confined to sheltered embayments, mainly on the northern shores. Terraces indicative of uplift and tilting are frequently encountered on these eastern islands (Davis 1928 in www.unu.edu).

Papua

Tectonic movements have influenced coastal changes in parts of Irian Jaya, mainly in the north, and in the extensive swampy lowlands to the south. On the north coast of Irian Jaya the Mamberamo has built a substantial delta, the western shores show creek enlargement and landward migration of mangroves, while the eastern flank is fringed by partly submerged beach ridges with dead trees, all indicative of subsidence (probably due to compaction) and diminished sediment yield from the river. Verstappen (1964a in www.unu.edu) related this diminished yield to an intercepting zone of tectonic subsidence that runs across the southern part of the delta, marked by a chain of lakes and swamps, including an anomalous mangrove area. The largest of the lakes, Rombabai Lake, is adjacent to the levees of the Mamberamo, and at one point the subsided levee has been breached during floods and a small marginal delta has grown out into the lake.

In September 1979 a major earthquake (force 8 on the Richter scale) disturbed the islands of Yapen and Biak, north of Irian Jaya, initiating massive landslips on steep coastal slopes, especially near Ansus on the south coast of Yapen. According to the United States Geological Survey it was the strongest earthquake in Indonesia since the August 1977 tremor on Sumbawa which had similar effects. Tsunami generated by these and other earthquakes were transmitted through eastern Indonesia.

4. IRON SAND ORIGIN

In Indonesia, the magnetite bearing iron sands are derived from chemical and physical weathering of the Old Andesite of mid-Tertiary age sub-aerial volcanics, which are composed of andesitic composition which can range from basalt to rhyolite. Rivers transported to the coast as the products of erosion, including magnetite. In the high-energy near-shore marine environment, the heavy minerals, including the magnetite, were concentrated and laid down as beach sand deposits (www.antam.com).

Rivers are the main agent in delivering sediment and its associated iron sand to the coast especially under humid tropical conditions, besides derivation from the erosion of cliffs along the shore, and from the sea floor (www.unu.edu).

5. METHOD

Methods of exploration and laboratory had been stated in previous paper (Kurnio, 2006) which adopted from Antam field and laboratory operations.

6. IRON SAND EXTRACTIONS

Iron sand extractions mostly occurred at Java Island either in the northern coastal zone or southern coastal zones. These are possibly due to easy access and good infrastructures required for the transportation of the deposits.

Antam has three iron sands mines at Lumajang, Kutorajo and Cilacap. At first, Antam normally targets about 450,000 tonnes of iron sands per year. This trend has been decreasing due to diminishing demand from local cement buyers (Proceedings of the 41st CCOP Annual Session Part I, 2004). Until 2003, Antam produces iron sands from two mining operations in Central Java, one at Cilacap and the other at Kutoarjo, both situated on the south coast of Java. Cilacap has been in production since 1971 and Kutoarjo commenced production in 1989. In 2003 the iron sands division continued to have difficulty as local cement makers continued to use copper slag as a substitute. At the end of that year, Chinese buyers looking for iron ore expressed interest in purchasing iron sands which contain about 47% iron. Antam's management hopes this will revitalize this struggling business unit.

Cilacap

Exploration activities for iron sand deposits had been done by PT Antam at southern coast of Cilacap Regency (1960 – 1972); at areas 3,090.43 hectares which include KP (Kuasa Pertambangan or concession permit) numbers Du 109, 110, 207, 208, 209 and 291 (Figure 2). The deposits are formed 500 meters width from coastline landward with thickness 3 to 4 meters generally below sandy soils. Identified iron sand deposits based on information of Indonesian Exploration and Mining (Directory 1999/2000) and Potency and Figures of Mineral Resources/Reserves of Cilacap Regency Central Java Map (2003) are consisted of indicated 724,511 tons and measured 1,930,725 tons with mean grade 51.7% Fe (Herman, 2005). Iron sand extraction was initiated at August 1970 using methods of open pit mining and back filling. In the period 1971 – 1978, the company produced iron ore concentrates for export to Japan 300,000 ton/year, with grade specification 55% Fe total, 10% TiO2, 6% Al2O3 and 10% MC (Moisture Content). Period of 1979 – 2004 PT Antam Tbk. produced iron ore concentrates to fulfill national cement industries demands, with specification 48% Fe total, 68% Fe_2O_3 and 10% MC. Due to almost exhaustion of iron sand deposits; at october 1st 2003, officially Cilacap iron sand mining was closed. The closing process was still studied by relevant government competent institution Research and Development Center for Mineral anf Coal Technology (*tek*MIRA), Research and Development Agency of Department of Energy and Mineral Resources. Field observation at May 2004 (Herman, 2005), the company continued conducting ex mining sites reclamation for reuse by local community as paddy field, plantation and reforestation.

Not all concession area could be mined. Heavily occupied by settlements of area of iron sand deposits such as occurred at most of the mining concession (KP) DU 209 which located approximately 40 kms east of Cilacap City are causing the area unavailable for mining (www.antam.com).

Kutoarjo

Iron sand mining at Kutoarjo in 2003 resulted in 3.2 billion rupiahs of revenue which much higher than Cilacap (2.5 billion) and Lumajang (1.3 billion) (www.suaramerdeka.com; Tuesday September 9th 2003). These three areas producing iron sand are only capable sold 18.32 % of its production capacity (Figure 3). Thus, the company suffer defisits

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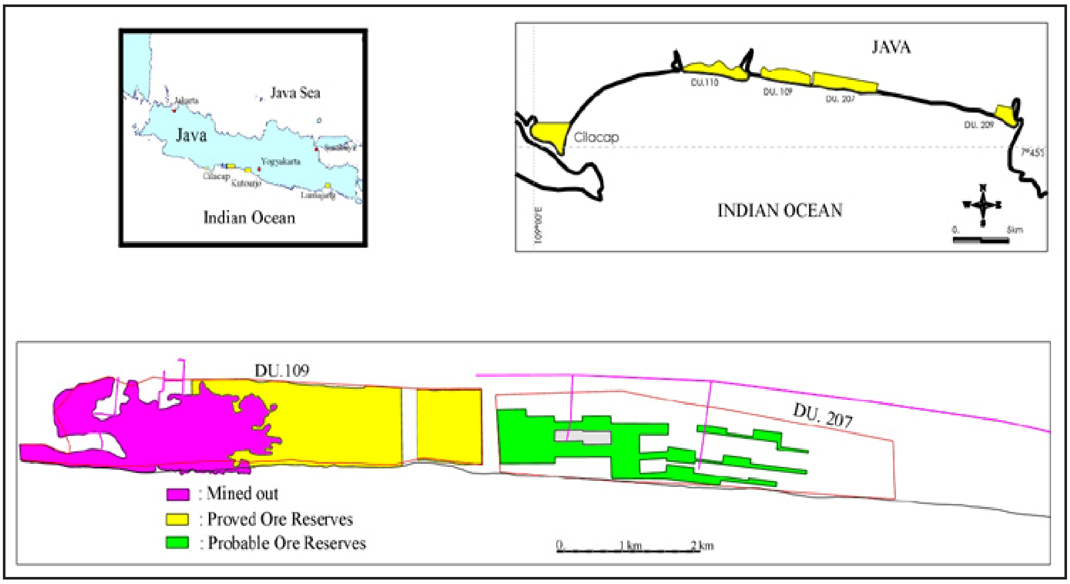

Figure 2. **Area of iron sand concession in Cilacap of PT Antam Tbk (Antam Annual Report, 2002)**

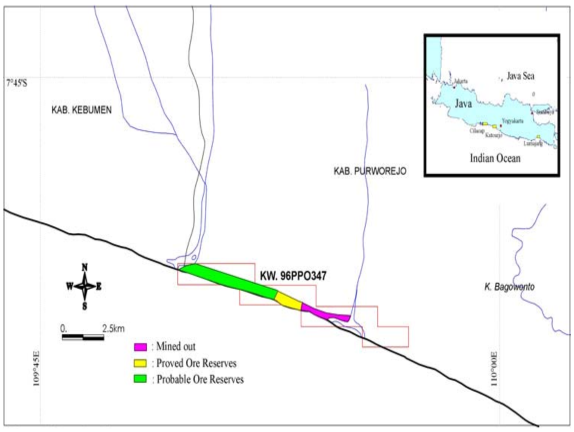

Figure 3. **Area of iron sand concession in Kutoarjo of PT Antam Tbk (Antam Annual Report, 2002)**

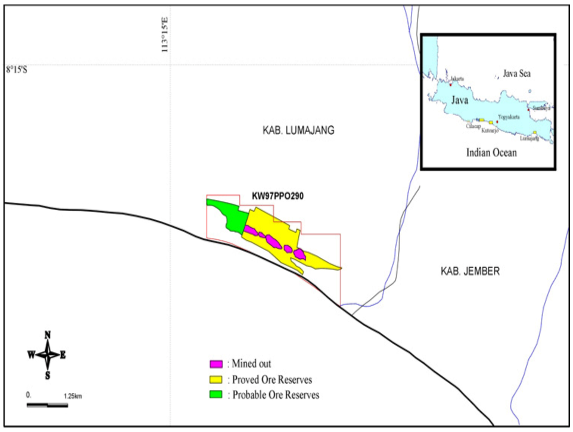

Figure 4. **Area of iron sand concession in Lumajang of PT Antam Tbk (Antam Annual Report, 2002)**

which further causing the closing of the mining areas by the management. This condition had started from 2002 deficit 1.9 billion rupiahs and in 2003 deficit 3.18 billion.

Lumajang

In Lumajang coastal zone iron-titane sand occurred along Pasirian coast (Figure 4), data of inferred resources 6,000,000 tons and measured 4,848,117 tons with contents of Fe = 59%, TiO2 = 9.629% (Widodo, 2003).

Generally iron-titan sand deposits at southern coast of East Java are utilized as raw materials for steel industries (metallurgy) and cements.

Regional geology of iron sand deposits are composed of volcanic rocks consisted of andesitic breccia, lava breccia, andesitic pyroclastics and tuffalithic rocks intruded by dioritic rocks of Oligo-Miocene age.

Geological structure of northeast-southwest and north-south faults controlled mineralization in Lumajang. Copper (Cu) mineralization indications

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are observed which revealed as oxyde copper mineral (malachite) in andesitic rocks also containing secondary magnetite. Strong argilic alteration zone with dissemination of fine pyrites and silicification zone containing stockwork of fine quartz veins are also observed in this area.

Jepara

Bijaksana et al. (2005) explored the vertical extent of iron sand deposit using ground-penetrating radar (GPR) which were successful in delineating the iron sand deposit from the bedrock. The radar method is not affected negatively by the physical properties of iron sand. The GPR survey was carried out in the coast of Bayuran in the Regency of Jepara, Central Java to map the distribution of subbottom iron sand in 2003.

On the other hand, illegal sand minings along coastline of Balong village, Kembang District, Jepara Regency by a group of miners are concerned by local people. These activities will stimulate coastal abrasion dangerous for community houses. At the beginning, the problem arises from iron sand extractions through digging out iron sand delta of dimension 400 m to 100m in front of Balong River which is now disappeared. The delta previously is acted as coastal protection for fishermen boats and houses from northern seawaves (www.suaramerdeka.com, Tuesday, September 21st 2004). The local mining agency has conducted joint research with Marine Geological Institute and LIPI Jakarta which include iron sand reserve determination of the area.

The deposits in the coastal area of Jepara, approximately tens of kilometers, are remarkable. Shoving by five fingers of hand along the mentioned coastline show how abundances the iron. The iron sands are resulted from denudation of volcanics of Muria Mountain in thousands of years which is deposited by fluvial system in coastal area of thickness tens of centimeters up to approximately more than one meter. Mining head of Jepara Regency pointed out that three big investors are permitted to mine the deposits. While the Regent (Bupati) at this time gradually stopped mining activities in all jepara coastal zone. The Bupati is still waiting mining method secure for the environment. According to local people, sand extraction is 25 to 30 trucks daily of approximately 6 cubic meters each truck (www.suaramerdeka.com, Wednesday, September 22nd 2004).

South Coast of West Java

At Tasikmalaya, iron sand deposits indicated reserves are 4.214.392,40 tons which belongs to Aneka Tambang concession areas (Source: website of Tasikmalaya Regency).

Iron sand exploitation at Cipatujah in 2004 resulted in 275,705.10 tons of sands which are delivered to national cement industries. Local mining and energy data pointed out that these deposits are extracted by seven private companies with value of 30.3 billion rupiahs. While local mining company owned by local government (PDUP Perusahaan Daerah Usaha Pertmbangan) capable to take out only 8,166.50 tons of values 898.315 millions rupiahs (www.pikiran-rakyat.com, Monday, April 25th 2005).

Local people is also extracted iron sand in Cipatujah (Figure 5). In this area the sand is found at 3 meters below surface, closed to the coastline (approximately 300 m) and sold to the local mining companies (www.pikiran-rakyat.com, Friday October 22nd 2004).

Iron sand deposits were also mined in Cianjur coast by local mining companies that nowadays are being critized by local parliament members due to its impact on the environment (www.pikiran-rakyat.com, Thursday, November 11th 2004).

A Memorandum of Understanding (MoU) has been signed by the Governments of Indonesia and China

Figure 5. Iron sand extraction in Cipatujah Tasikmalaya – south coast of West Java by local people using traditional tools

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for exploitation of titano-magnetite deposits at Ujung Genting south of Sukabumi. China invests billions of rupiahs for the exploitation.

Determination of detrital mineral and sand deposits along the coast of Pameungpeuk Garut has been done by Marine Geological Institute in 2003 (Proceedings of the 41st CCOP Annual Session Part I, 2004). Data from hand auger survey indicate that the sand beaches between the depth 65 cm until 300 cm consist of reef sand, iron sand and mixture of molucca shell and iron sand. Bedrock in the study area is andesite breccia. Mineral content of sand dunes comprises magnetite, hematite, ilmenite, epidote, rutile, hornblende, quartz, muscovite and dolomite. Georadar data indicate the backshore of sand dunes consists of coastal plains and bedrock of volcanic sediment. Sand dune profiles were measured along the Pameungpeuk coastal area and consist of sand beach with low slope (<20°), mid slope (20° - 40°) and high slope (>40°), with heights between 2 to 3 meter and sand dunes forming a zone between 40 to 60 meter from the shoreline. The zone of dunes from Sayangheulang to Cipelabuh is 3,200 km long. Sand dunes in Sayangheulang consist of three hills 16, 26 and 29 m high, with a total width of 420m and those in Darmaga consist of three hills, 14, 28 and 22 m high and 460m wide.

7. DISCUSSIONS

For the purpose of reserve determinations, map scale used for mapping of iron sand deposits should be considered. For coastal work it is necessary to include details of cliffed and steep coasts, beaches and related features. Such information should preferably be published on a much larger scale, at least 1 : 50,000 which could then be assembled in the form of an atlas. Map scales smaller than 1 :50,000 such as 1 : 100,000 and 1 : 250,000 are not suitable to map coastal features because less information presented.

Iron sand extractions certainly will cause changing of natural and community environments. It is suggested that the exploitation area is selected far away from coastal community as well as their fishing activities to prevent resistance by local community and destruction to natural environment such as occurred in Jepara.

From observation of coastal characteristics of iron sand deposits in Indonesia, it reveals that such deposits are always associated with volcanic rocks. This phenomenon could be utilized earlier for exploration of new deposits by studying the regional geology of the suspect areas.

Small scale mines by local community are active surround iron sand deposits such as occurred in Cipatujah-Tasikmalaya south coast of West Java. Such activities are beneficial for poor people in coastal of rural areas. To avoid destruction to the natural environment, regulations and guidances should be applied.

It is also strongly suggested that exploitation of iron sand apply EIA (Environmental Impact Assessment). For that purpose recognition of geological and environmental processes are important to avoid destructive exploitation to coastal and marine environments.

8. CONCLUSIONS

The geology and geomorphology of the hinterland and the bordering adjacent marine environments control the diversity of coastal features of Indonesia. Global tectonics of Indo-Australian, Pacific, and Eurasian plates are causing continuing instability of the region which manifested as frequent earthquakes and volcanic eruptions. Subduction zone lies at the south of the Indonesian island-arc create unstable shelf areas that underlying the bordering seas. Together with sea level changes, tectonic instability either in the past or present and volcanic eruptions affect Indonesian coastlines.

In Indonesia, humid tropical conditions are also controlling coastal landforms through changes of ITC (Intertropical Convergence zone) positions. This unstable air and heavy rainfall zone migrates to the north and south of the equator where at the south more pronounced wet season occur. Orographic factor of mountain ranges in Sumatra, Java and Nusatenggara also influences rainfall pattern.

Large river systems are produced by combination of deeply weathered rock in steep elevated hinterlands and frequent heavy rainfall. These river systems transport large quantities of sediment to the coast which further built extensive deltas and broad coastal plains.

Iron sands in Sumatra, Java, Bali and Nusatenggara Islands are largely derived from denudation of andesite and "Old Andesite Formation" enriched in magnetite and ilmenite minerals. The river systems carry substantial quantities of such sediment down to the coastal area. At the northern coast, such as occurred in Jepara Central Java, the iron sand is distributed closed to the pyroclastic sediments resulted from Holocene volcano activities of Muria Mountain.

Volcanic activity manifested in periodic eruptions supply fluvial sand to maintain the prograding shoreline; such as occurred on the central south coast plain of Java. The fluvial sands are derived from periodic eruptions of Mount Merapi north of Yogja City.

Wave regime in Indonesian coastal waters has much influence various coastal features. It derives from strong swells transmitted from Indian Ocean in the south and Pacific Ocean in the northeast.

Coastal zones especially the southern parts of the Neogene Sunda Banda magmatic arc are the area of potential and producing iron sand deposits extend from northern Sumatra to eastern Indonesia. Beach sediments of volcanic origin enriched in magnetic minerals are typically black or grey.

Iron sand deposits have been mined either by state company or by local people. It helps to improve the economy of small scale miners. By means of good guidances and regulations, hopefully these artisanal minings will not be destructive to the natural environments.

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