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GEOMORPHOLOGICAL DEVELOPMENT OF THE MURIA PALAEO-STRAIT IN RELATION TO THE MORPHODYNAMICS OF THE WULAN DELTA, CENTRAL JAVA

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ABSTRACT

The research area is situated in the Demak, Jepara, Pati and Kudus regencies of the Central Java Province. The objectives of the research are: (1) the investigation of the geomorphologic development of the Muria Palaeo-Strait in Central Java and (2) the analysis of the morphodynamics of the Wulan Delta. A morphographic – morphogenetic approach was used to interpret the genesis and subsequent evolution of the coastal lowlands in the surroundings of the Muria Volcano. The data analysis techniques, based on cause-effect assessment and analogy, were implemented in four steps, such as: (a) descriptive, (b) comparative, (c) associative and (d) causative stages. The results of the research can be summarized as follows: The coastal plain situated to the south of the Muria Volcano was originally a shallow strait and subsequently became a mangrove-covered tidal flat with many creeks. Ultimately this tidal flat evolved into an alluvial/coastal plain with natural levees and back swamps. The coastal area in the west was still inundated by the sea around 6,000 yrs BP. This is evidenced by the 14C-dating 6,530 ± 120 yrs BP of a coral reef situated at 25 cms a.s.l. The present beach ridge has an age 4,600 ± 100 yrs BP and originated as a barrier bar. The coastal area in the east is characterized by the occurrence of four sequential beach ridge complexes at elevations of 580, 520, 220 and 125 cms respectively. They have been 14C-dated 5,860 ± 110 yrs BP, 5.090 ± 100 yrs BP, 3,530 ± 100 yrs BP and 1.760 ± 120 yrs BP. Since 1,760 yrs BP no further beach ridges were formed, a tidal flat developed instead. The shape of the Wulan Delta changed from actuate to digit ate in the period of 1925 - 1995, mainly due to human interference with the river for purposes of irrigation. The growth of the Wulan Delta affected the hydro dynamical situation offshore of Jepara. These hydrodynamic changes resulted in marine erosion in the rural areas in the Jepara Regency and chewier formation in the rural areas of the Demak Regency.

Key words: palaeo-geomorphology, delta geomorphology, coastal dynamics

INTRODUCTION

The alluvial plain situated to the south of the Muria Volcano and the adjacent coastal zones are of special geomorphic interest because initially the area was a shallow strait [*Bemmelen,* 1970; *Graaf* and *Pigeaud* ,1989; *Lombard,* 2000; *Eko,* 2002]. The rapid growth of the anthropogenic Wulan Delta in the mouth of the Serang Delta and the related changes of the adjacent parts of the west coast since the introduction of technical irrigation [*Verstappen,* 1986], also invite to further geomorphologic research. The Wulan Delta was cuspate in 1911 but developed into an elongated delta around 1944 [*Bird* and *Ongkosongo,* 1980]. The objectives of the research carried out by the author [*Sunarto.* 2004] thus comprise of: (1) an analysis of the geomorphologic development of the Muria Palaeo-Strait and (2) the study of the morphodynamics of the Wulan Delta based on data available for the period of 1925-1995.

THE METHODS

The lowlands of the survey area were initially a shallow palaeo-strait separating the Muria Volcano from Java. The strait had a protected position and thus was characterized by a low-energy environment, where wave action was minor and sea currents slow. As a consequence the Muria Palaeo-Strait silted up with fine-grained materials and mudflats and salt mashes thus were formed where creeks and mangrove swamps gradually developed. This environment ultimately evolved into the present coastal alluvial plain with levees and back swamps.

When these plains, in the course of the centuries, became increasingly used for (irrigated) agriculture, the cultivated fields were frequently affected by inundation; especially those situated in back swamp areas. To control flooding in the cultivated lands, dikes were constructed at both sides of the Serang River, the main drainage line of the area. As a consequence of these dikes, the Serang River thereafter deposited much of its sediment load at the outfall and a delta thus was formed. At the same time the level of its bed increased. The delta has grown ever since and its geomorphology changed continuously. The morphodynamics of the Wulan Delta caused changes in the alongshore drifting that resulted in abrasion of the updraft-affected shoreline in the Jepara Regency and deposition and Chenier formation in the downdraft-affected shoreline in the Demak Regency. The theoretical framework of the geomorphologic development of the Muria Palaeo-Strait and its influences and of the Wulan Delta is shown in the conceptual model of Figure 1.

The research methods were selected on the basis of the variety of the occurring coastal landforms and related factors of geological structure, topography, geomorphologic processes, and chronology and sediment types. Geomorphologic processes, shoreline dynamics and beach ridge formation were items of special interest for sampling. The field data collection comprised of: (1) topographic profiles of coastal areas, (2) analysis of sedimentary material: types, grain size, stratigraphic characteristics, (3) oceanographic data: waves and currents, (4) geomorphic phenomena of coastal abrasion and marine deposition, (5) sampling of sedimentary material for laboratories analysis: grain size, molluc shells and radiocarbon dating. The secondary data collecting comprised (a) climatic data from Indonesian Meteorological, Climatological and Geophysical Agency (BMKG), (2) data of wind velocity, wind direction, current velocity, current direction, wave height, wave periods from The Agency For the Assessment and Application Technology (BPPT), (3) literature study; (4) maps: topographic, geological, The Indonesian Institute of Sciences for Oceanography Study (LON-LIPI), and hydro-geological. A morphographic – morphogenetic approach was used to evaluate the genesis and the further evolution of the coastal area in the surroundings of the Muria Volcano. Data analysis techniques based on cause-effect assessment and analogy was implemented in four steps: the (a) descriptive, (b) comparative, (c) associative and (d) causative stages.

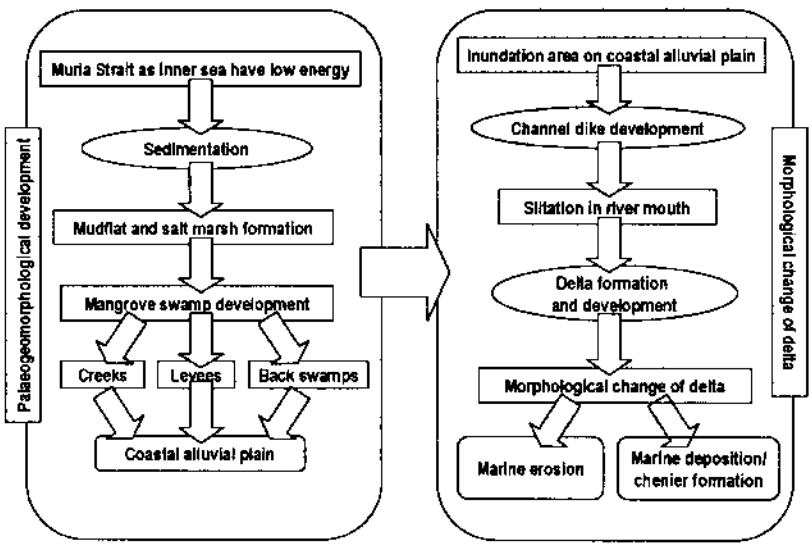

Figure 1. Theoretical Framework of the Geomorphologic Development and Its Influences

RESULT AND DISCUSSIONS

Geomorphologic Evolution of the Research Area

The Java Sea is the northern limit of the research area at both sides of the extinct Plio-Pleistocene Muria volcanic complex. To the South the research area is bound by the fold-ridges of the Rembang and Kending Hills that date back to the Middle Pleistocene. The research concerns in particular the coastal and alluvial plains that were formed between the Muria Volcano and the unmentioned fold-ridges. The Muria volcanic complex is the oldest part of the research area. The Patiayam Volcano, the relics of which occur in the SSE-Muria foot slopes, dates back to the Pliocene (1,600,000 yrs BP) according to *Zaim* [1990]. The sea level then was 25 - 50 m higher than at present [*Tjia,* 1970]. In the Lower Pleistocene (700,000 – 1,600,000 yrs BP) several eruptions of the Muria Volcano and of the Genuk Volcano (that rises from the northern Muria slopes) occurred [*Sartono et al.,* 1978; *Suwarti* and *Wikarno,* 1992]. The eruption activities of the Patiayam and Muria volcanoes continued during Middle Pleistocene (125,000 – 700,000 yrs BP) and clay sedimentation in the Muria Palaeo-Strait resulted in the formation of a lagoon [*Zaim,* 1990]. In the Upper Pleistocene air temperatures fluctuated between 18,000 and 40,000 yrs BP [*Bellwood,* 2000] and sea level changes from -40 m to +60 m are on record from the period 15,000 – 18,000 yrs BP [*Dunn* and *Dunn,* 1977]. The same authors found an abrasion notch indicating that the sea level was 10 - 15 m above the present level around 9,000 yrs BP. The eruptions of the Muria Volcano came to an end [*Sartono et al.,* 1978]. Between 3,000 and 6,000 yrs BP the sea level fluctuated and reached a level of +5 until +6 m a.s.l. [*Bellwood,* 2000; *Whitten,* 1999; *Tjia,* 1970]. *Huffma* [1998] mapped the palaeoecological conditions of Central Java in the Plio-Pleistocene using a palaeophysiographic model. According to this model, the surroundings of the Muria Volcano still formed part of the marine environment.

The lowlands of the research area have been the scene of many geomorphic changes in the Quaternary that were brought about by climatic fluctuations, sea level changes and coastal dynamics. They include the development of plains in the Muria Palaeo-Strait, the growth of the Wulan Delta, coastal abrasion, the formation of Cheniers and beach ridges and the formation of marine notches on the slopes of the volcanic hills.

The coastal and alluvial plain situated to te south of the Muria Volcano was originally a shallow strait and subsequently became a mangrove-covered tidal flat with many creeks. Ultimately this tidal flat evolved into an alluvial/coastal plain with natural levees and back swamps. The coastal area in the west was still inundated by the sea around 6,000 yrs BP. This is evidenced by the 14C-dating

6,530 ± 120 yrs BP of a coral reef situated at 25 cms a.s.l. The present beach ridge has an age of 4,600 yrs ± 100 yrs BP and originated as a barrier bar. The coastal area in the east is characterized by the occurrence of four sequential beach ridge complexes at elevations of 580, 520, 220 and 125 cms respectively. They have been 14C-dated 5,860 ± 110 yrs BP; 5,090 ± 100 yrs BP; 3,530 ± 100 yrs BP and 1,760 ± 120 yrs BP. Since 1,760 yrs BP no further beach ridges were formed; a tidal flat developed instead.

The Growth of The Wulan Delta

The shape of the Wulan Delta changed from actuate to digit ate in the period 1925 – 1995 (see Fig. 2). This was mainly caused by human interference with the river for purposes of irrigation. The morph metrical development of the delta is shown in Table 1. It follows from this table that the delta increased in size 0.393 km^2/yr, that the length of the deltaic shoreline increased yearly 0.34 km and that the length of main channel increased 0.073 km/year.

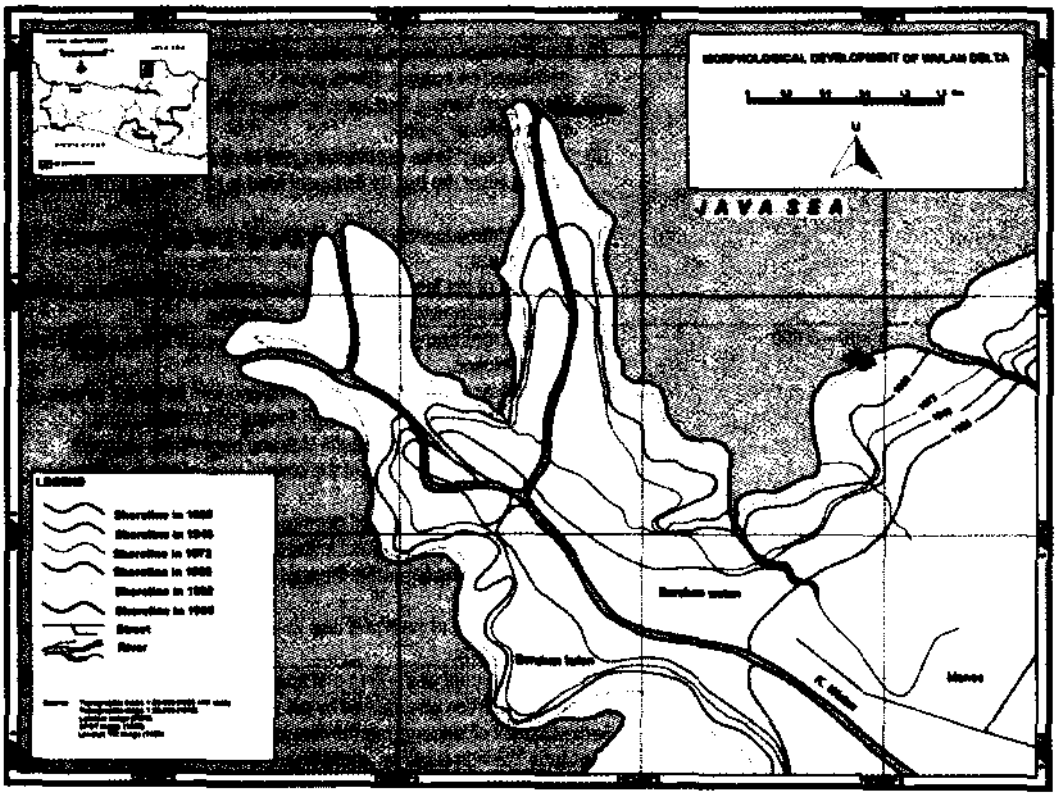

Figure 2. Morphological Development of the Wulan Delta in the period 1925 - 1995

Table 1 Morphometrical Development of Wulan Delta in the period 1925 – 1995

Year	Range (years)	Length of shoreline delta (km)	Length of main stream (km)	Form of delta	Trend of development delta (°NE)	Width of delta (km^2)	Development mean of delta width (km^2/year)
1925-1946	21	7.2	5	Actuate	302°WNW	1.9	0.09
1946-1972	26	10.8	3.6	cuspate	331°NNW	4.25	0.16
1972-1988	16	13.2	4.2	Digit ate	335°NNW	5.26	0.33
1988-1992	4	16.8	5.1	Digit ate	337°NNW	6.95	1.74
1992-1995	3	23.7	5.1	Digit ate	337°NNW	9.15	3.05
Total	70						
Mean		0.34 km/year	0.073 km/year			0.393 km^2/year	

Table 2 Palaeogeomorphological Developments of the Coastal Areas around the Muria Volcano a Synthesis

Epoch	Period (years BP)	Palaeogeomorphological Development
Holocene	Present – 1,760	(1) Mangrove swamps on the south coastal area of Muria Volcano developed be coastal alluvial plain. (2) Flood from Serang and Juwana Rivers have frequently run down the coastal alluvial plain. (3) In 1892 begin to be developed a pair of dike to flood control from Serang River, so that its sediment load to be brought until Serang River Mouth. (4) For the consequence, Wulan Delta is formed and developed in Serang River Mouth. (5) Because of the formation and development of Wulan Delta, marine erosion is happened along Jepara shoreline
	1,760 – 6,000	(1) Beach ridges and swales complex were formed in the coastal area of Muria Volcano. (2) In the east coastal area of Muria Volcano was formed 4 stripes of beach ridges. Mean rate of beach ridge formation is 1,055 years. (3) Eruption activities of the Muria Volcano begin to be stopped. (4) Formation of beach ridge in the coastal area of Muria Volcano begins to be stopped also. (5) Tidal flat in the Muria Strait developed be mangrove swamps.
	6,000 – 9,000	(1) Tidal flat begin to be formed in the Muria Strait. (2) Barrier bars was formed in the east and west coastal area of Muria Volcano. (3) Marine terrace of coral reef was formed in the west coastal area of Muria Volcano.
	9,000 – 10,000	Sea level in the past was +15 m msl now that is indicated by the Tritip Notch.
Pleistocene	Upper 10,000 – 125,000 Middle 125,000 – 700,000 Lower 700,000 – 5,000,000	Sea level fluctuation was caused by palaeoclimatic changes Sedimentation of lagoonal marine clay in the Muria Strait. The Muria Volcano is still an island where is separated from Java Island by the Muria Strait.

The growth of the Wulan Delta affects the hydro dynamical situation offshore of Jepara. The changes of these marine processes in turn affect the coastal

morph dynamics in the Jepara Regency. When, during the West monsoon, the northward alongshore current passes the Wulan Delta, a clock-wise rotating eddy is formed to the north of its outfall. This generates a southward updraft countercurrent that causes abrasion in the rural areas along the Jepara shoreline. The recession of this coast is demonstrated by the occurrence of a characteristic minor scarp along the beach. The Demak shoreline, situated to the south of the outfall, to the contrary is developing under the influence of the northward alongshore current and the related downdraft beach processes. As a result deposition of lipoclastic sandy material and chewier formation characterize the rural areas in the coastal zone of Demak.

CONCLUSIONS

1) Three phases of the Holocene development of the Muria Strait can be distinguished:
   a. 0 – 2,500 yrs BP the youngest beach ridge in the east was formed.
   b. 2,500 – 5,000 yrs BP the mature beach ridges in the east and one beach ridge in the west were formed.
   c. 5,000 – 7,500 yrs BP the oldest beach ridge in the east, a marine terrace in the west and the alluvial plain in the former Muria Strait were formed.
2) The shape of the Wulan Delta changed from actuate to digit ate during the 70 years of observation (1925-1995). The delta width increased 0.393 km^2/yr; the length of the delta shoreline increased 0.34 km/yr and the length of the main channel increased 0.073 km/yr.
3) Marine erosion by updrift current during the west monsoon. The growth of the Wulan Delta caused a change in alongshore current direction north of the Wulan outfall. This caused marine erosion of the Jepara coastline.
4) Deposition of lipoclastic sandy material and chewier formation to the south of the outfall of the Wulan River during the west monsoon.

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