A GEOMORPHOLOGICAL SURVEY MAP
OF
PADANG CITY AND SURROUNDING AREA
IN WEST SUMATRA
SHOWING
CLASSIFICATION OF FLOOD STRICKEN AREAS

1983

ISSUED BY JAPAN INTERNATIONAL COOPERATION AGENCY,
TOKYO, JAPAN

A GEOMORPHOLOGICAL SURVEY MAP OF PADANG CITY AND SURROUNDING AREA IN WEST SUMATRA SHOWING CLASSIFICATION OF FLOOD STRICKEN AREAS

1. Necessity of Geomorphologic Land Classification in Development Plan of Area

When the development plan of the area is made, the planner must know the natural environments of the area in detail. The natural environments consists of geomorphology, climate, hydrology, etc. The relationships between geomorphology, hydrology and human activities are close. For example in mountainous regions, the topography was formed by the upheaval ground movement and changed its feature by erosional action caused by torrential rainfall, etc. The change of topography results in natural disasters for the people living there. The geomorphology shows the history of the natural disasters in the area in the past. If the plan is suitable for the natural development process of the topography, natural disasters will not occur; but if the plan is not suitable, natural disasters will occur.

2. A Geomorphological Survey Map of River Basins Showing Classification of Flood Stricken Areas

After World War II Japan was facing the twin problems of food shortage and flood hazards. The staple food of the Japanese is rice, which is mainly grown in the alluvial plains devastated by frequent floods caused by typhoons. Hence, the knowledge of the topography of the alluvial plains became necessary not only to increase rice yield but to minimize flood damage. Fortunately, the Japanese geographers took great interest in the study of alluvial plains which was greatly facilitated by the availability of aerial photographs. This gave birth to the geomorphological survey maps of the river basins which were not only used for controlling floods and erecting embankments but also for proposing land use, bridge sites, etc.

A geomorphological survey map of river basins enables us not only to estimate the nature and extent of past floods but to predict their future trends as well with regard to the extent of the area submerged, the length of time in which an area would be under water, depth of the standing water, direction of flood current, changes of the river course, possibility of erosion, deposition and numerous other details. The reasons why such a survey map helps in indicating the flood types are that the relief features of a plain and its sand and gravel deposits have been formed by repeated floods. Consequently, the micro-topography of the plain and its sand and gravel accumulation well preserve traces of past floods.

Geomorphological features such as terrace, valley plain, alluvial fan, natural levee, back-swamp, delta, etc., influence the extent and nature of flooding. For example on the alluvial fan erosion and deposition of sands and gravels are common, changes of river channel are frequent, flood waters drain off quickly, on the natural levee depositions are mostly of sand, flood waters drain off well; but in a back-swamp and delta the water is generally deep and remains stationary for a long time leaving a thick mantle of silt and clay.

This clearly exhibits that by classifying the geomorphological configuration of areas which subject to frequent flooding one can define not only the types of past floods but their future trends as well.

As has been mentioned above, theoretically, we can predict the state of flooding utilizing the Geomorphological Survey Map of the River Basin Showing the Classification of Flood

Stricken Areas. But the phenomena of the natural environment are complicated.

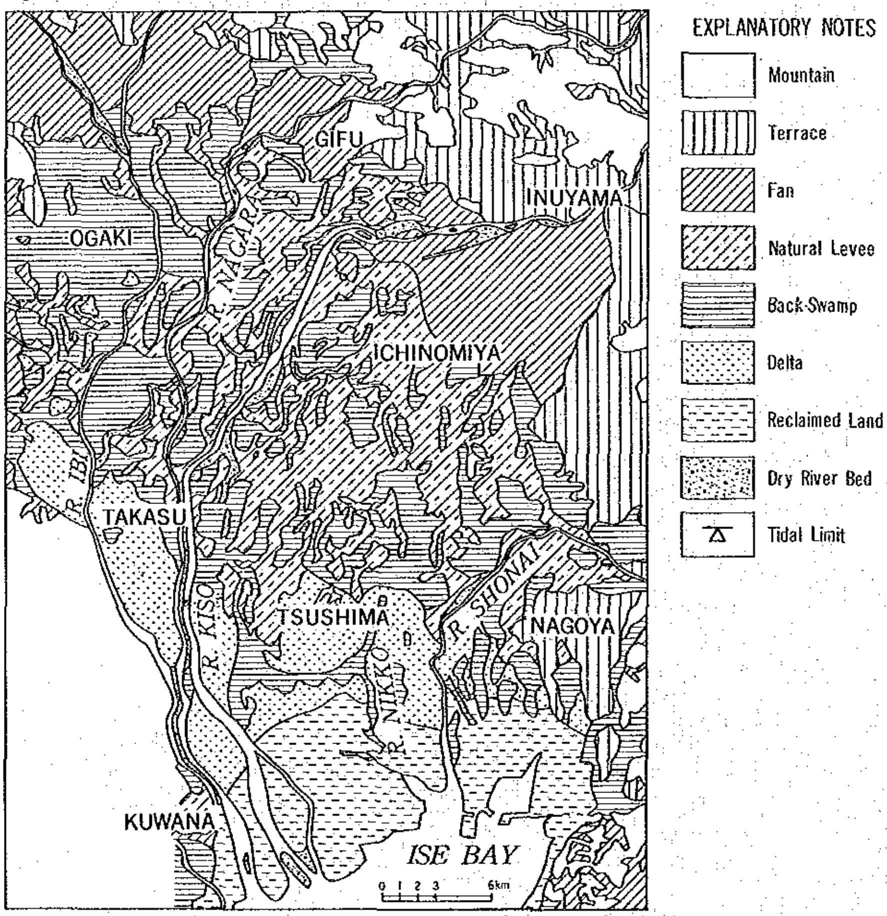
Incidentally, the Isewan Typhoon proved the accuracy of such a Geomorphological Survey Map of the River Basin Showing the Classification of Flood Stricken Areas. The southern part of the Nobi Plain (Nagoya City is located in the plain) was devastated by the high tide caused by the Isewan Typhoon, in 1959.

As a result of the disaster striking the city of Nagoya and its vicinity some 5200 persons were drowned and about 530,000 million yen (about $ 1.472.000.000) worth of property was lost.

The high tide attacked the area four years after the preparation of "A Geomorphological Survey Map". Then the high tide proved to be a test of such maps on the largest scale and of the greatest value. It was found that actual flooding was almost exactly the same as predicted in the map with respect to the area of submersion and depth and duration of inundation.

Fig. 1 shows the Geomorphological Survey Map of the Kiso River Basin (Nobi Plain). There are fans formed by the Kiso, Nagara and Ibi Rivers in the northern part of the Nobi Plain. We see three or four distinct natural levees from the fan to the city of Nagoya and Tsushima. These natural levees show the ancient main course and branch courses of the

Fig. 1 GEOMORPHOLOGICAL LAND CLASSIFICATION MAP OF THE NOBI PLAIN



by M. OYA(1957)

Kiso River before the 15th century. Back-swamps occupy the spaces between natural levees.

We see the delta from the natural levee to the south, the reclaimed land constructed since the 16th century along the coast of Ise Bay and the artificial fields filled in along the circumference of Nagoya Port. The ground level of the delta is almost in accord with sea level, and the area of ground in the Nobi Plain below sea level covered 185,4Km^2 in 1959.

We could notice the close relationship between the high tide and topography in many cases. Especially, the area of inundation was just the same as the area of the delta. The extremity of the influx was seen at the boundary of the delta, i,e, the line connecting the city of Nagoya with Tsushima.

The routes of high tide and flood-type were decided by the land-forms. The forecast of the state of flooding in the alluvial plain was possible on the basins of the relationship between the high tide caused by the Ise Bay Typhoon and land-forms in the Nobi Plain.

After preparation of the Geomorphological Survey Map of the Nobi Plain Showing the Classification of Flood Stricken Areas, not only of many important plains in Japan but also of the Vientiane Plain along the Mekong River and the Branmaputra-Jamuna, Ganges Plain in Bangladesh were also provided respectively.

3. A Geomorphological Survey Map of Padang City and the Surrounding Area in West Sumatra Showing Classification of Flood Stricken Areas

The writer (Dr. Masahiko OYA) participated in the study team on the flood control works of the Padang Area Flood Control Project organized by the Japan International Cooperation Agency. He subsequently made the geomorphological Survey Map Showing Classification of Flood Stricken Areas in the city of Padang, which is located in West Sumatra.

(Method)

Before preparing the geomorphological map, the writer made a topographic base map on a scale of 1:20,000 utilizing a map on a scale of 1:5,000.

In preparing the geomorphological map, the target area was first classified by major geomorphological elements such as steep slopes and gentle slopes on the mountains, pyroclastic flow, fan, alluvial fan, natural levee, back-swamp, sand-spits, abandoned river channels, coral reef and dry river bed utilizing aerial photographs.

It is convenient to use a photographic scale which is slightly larger than that of the projected map.

At this time the writer used photographs whose scale was 1:15,000. The initial map thus prepared was put into final form checking the results of field surveys of the area.

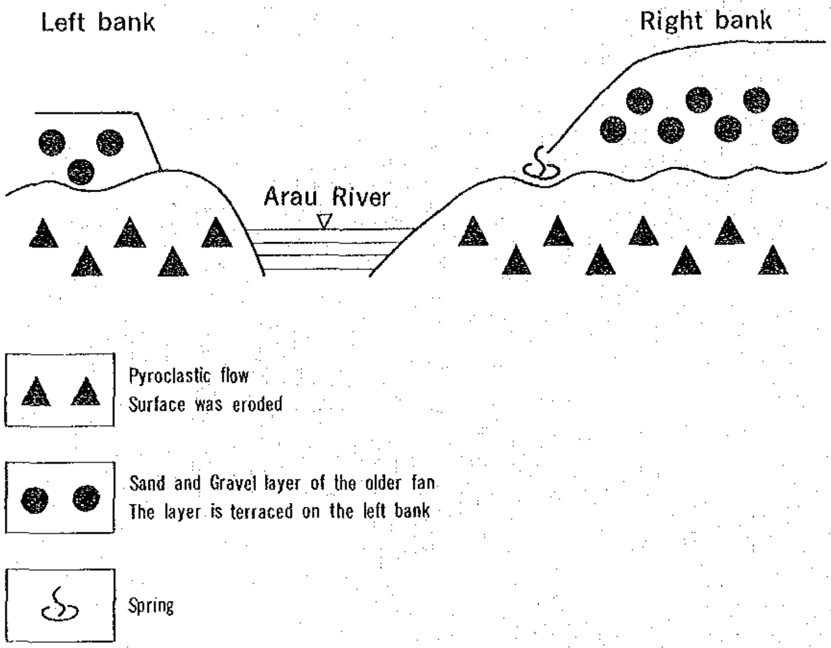
(Description of the geomorphological elements)

The area of the *mountains and hills* in the map is small. The mountains and hills consist of convex on the mountain ridge, concave slopes and gentle slopes on the mountain flanks, and steep slopes.

There are many steep slopes in the mountains along the Air Dingin River, but there are few land collapses. Almost all the mountains are covered by dense secondary forests.

The fluvial fan is remarkably well developed along the Kuranji River. Small fluvial fans are developed along the lower reaches of the Air Dingin River and middle reaches of the Arau River but none in the lower reaches.

Fig. 2 SKETCH OF THE OUTCROP NEAR KABOEN ALONG THE ARAU RIVER



The east most part of the fan of the Kuranji River is limited by the Arau River. The sketch of the outcrop (Fig. 2) shows the upper red soil layer, the brown sand and gravel layer and the reddish pyroclastic flow layer from the surface to the river bed. The Arau River and its tributary have dissected these three layers. And around the apex of the fan, ground water is located about 7 to 10m below the surface of the ground. Based on observation at the outcrop and the state of the ground water the writer estimated that the depth of the sand and gravel layer of the fan is shallow, about 5 to 10m.

The geomorphology of the fan consists of three geomorphological elements, i,e, 1) fan 2) slightly hilly area 3) alluvial fan and 4) narrow and long dissected valley.

Many slightly hilly areas are distributed radiately. And almost all villages on the fan are located in the area. The writer estimated that the slightly hilly area is natural levee on the fan or a remenant of the older fluvial fan. The area is free from flooding. The fan is dissected by the stream especially in the upper part of the fan.

The fan of the Arau River is small. The fan is developed in the upper reaches from the small canyon at Barupuiauan but none is developed in the lower reachs.

In the case of the Air Dingin River, the older fan is covered by pyroclastic flow. The alluvial fan is developed from the older fan to the coastal sand spits.

Pyroclastic Flow is well developed along the Air Dingin River especially on the right bank. The pyroclastic flow has the shape of the fan. The pyroclastic flow is dissected by long and narrow valley.

Another pyroclastic flow is seen on the river bottom and on both banks along the Air Dingin River and Arau River.

Terrace is developed along the Air Dingin River. The writer estimated that the pyroclastic flow and older fan were eroded and terraced.

Natural Levee means the slightly hilly area along the river course consisting of sand which was deposited in flood times.

There are several natural levees between the lower edges of the fluvial fans and the coastal sand spits. But these natural levees are small.

Back-swamp or delta is developed between the coastal sand spits and the lower edges of the fan. A big swampy area is located between the sand spits near the airport and the lower edge of the pyroclastic flow and the natural levee along the Laras River. The surface of the ground is covered with shrub and grass. The vegetation is universally seen in the peaty area. But the results of the boring test to a depth of about 3m, shows that almost all parts consist of soft reddish soil including the remains of vegetation and sometimes sand. (Fig. 3). The writer estimated that the vegetation disintegrated due to the high temperature and a lot of rainfall.

Back-swamps between sand spits (Interbarnal slough) are located along the coast. The drainage in the area is bad because sand-spits are developed along the sea-coast. The back-swamps located along the Baung River are the biggest. But recently the drainage has slightly improved due to river improvement.

Coral Reefs are developed at the river mouth of the Kuranji River. This is not alive but dead coral reef. Except along the sea-shore, the surface is covered by sand.

4. Geomorphological Development of the Padang Plain

Fig. 4 is a model of a geomorphological cross-section of the Padang Plain from the apex of the Kuranji River to the sea-coast.

Pyroclastic flows came down to the Padang Plain due to big volcanic eruptions, and formed the base of the fan of the Kuranji. Pyroclastic flows are seen at several places in the fan, for example, at Barupuiauan along the Arau River and or Kalawi along the Kuranji River.

Later, the pyroclastic flow was covered by sand and gravel layers about 5 to 10m thick and formed the fan. The formation age of the fan is not yet decided, but the age is estimated as the Würm Ice Age. At that time the sea water level was about 100m (about 18,000 years B.P.) lowered than that at present due to glacial eustasy.

Due to the change of climate 4000 to 6000 years B.P. the sea water level rose and reached 4 to 6m higher than that at present. The lower part of the fan was covered by marine deposits.

After that sand spits were formed. The line of sand spits increased along the sea side because of the lowering of the sea water level. Lagoons were formed at the inland side of the sand spits. During this time, coral reefs developed. At that time there was no river mouth of Kuranji at the present place.

The sand spits were cut by the Kuranji River partly because of the lowering of the sea water level and partly because of the horizontal crustal movement. The writer recognized that along the horizontal fault line near the river mouth of the Kuranji. Due to the crustal movement the Kuranji River formed the new channel at the present place and the coral reefs were killed by muddy water. The writer could see that the quality of the coral reef was changed by muddy river water.

New pyroclastic flow down along the Air Dingin River.

The fan and the pyroclastic flows have been eroded, and a new alluvial fan has been formed.

Fig. 3 GEOLOGICAL RECORD OF BORE HOLE IN THE BACK-SWAMP IS LOCATED AT THE NORTHERN PART OF AIRPORT

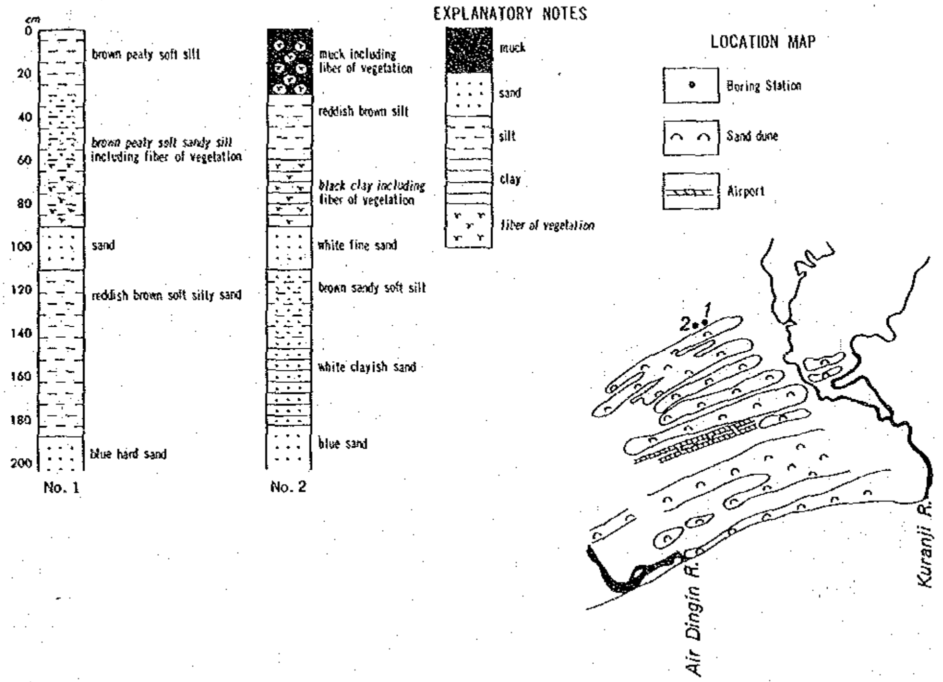
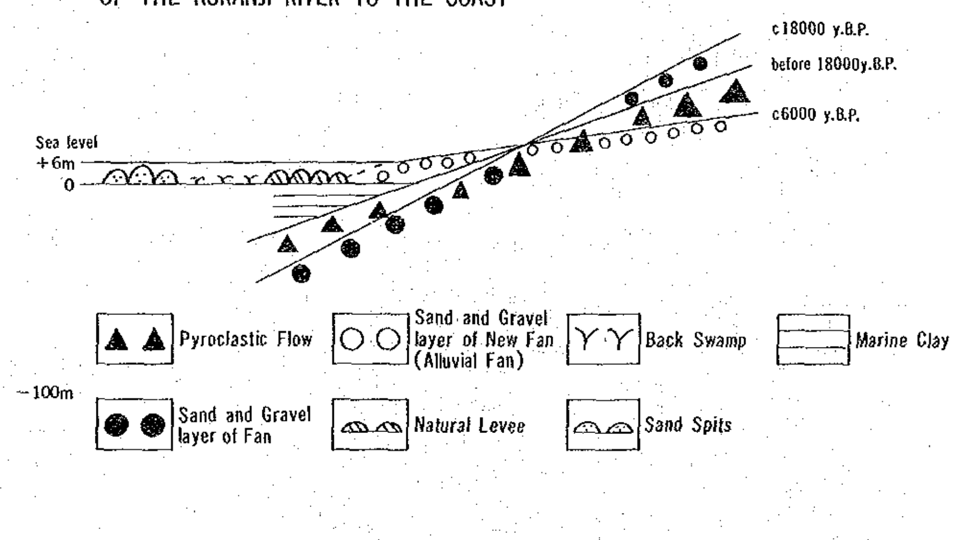


Fig. 4 GEOMORPHOLOGICAL CHANGE BETWEEN THE APEX OF THE KURANJI RIVER TO THE COAST



There is no fan along the left bank of the Arau River. The area of deposition by the Arau River is limited by big deposition of the Kuranji River. The small canyon with knick-points along the Arau River was formed by the deposition of the Kuranji River.

The features of the fluvial action of the three rivers will be discussed in the next chapter.

5. Comparative Study of the Fluvial Action of the Three Rivers —Arau, Kuranji and Air Dingin

There are distinct regional differences in the fluvial action of the three rivers of the Arau, Kuranji and Air Dingin.

Due to the push of the fan of the Kuranji River, the Arau River was narrowed near Barupiauan. There are several knick-points in the canyon. At these points stream flow is rapids (Fig. 5). There are big differences in fluvial action between the upper reaches and the lower reaches of the knick-points. The maximum diameter of the largest gravel is 85cm with a roundness of 6 in the upper part of the canyon, while the gravel becomes bigger in the canyon, about 210cm, and angular with a roundness of 5 (Fig. 6).

The river bed in the upper reaches of the canyon consists of andesite and granitic gravel. The ratio of the two species is 10:1. But there is no granitic gravel in the lower reaches. There is no granitic rock in the upper reaches of the Kuranji River. Furthermore, the river course of the upper reaches shows a braided stream. When we have a flood the flood waters overflow from the mainstream to the adjacent areas. The above mentioned facts show that the deposition of the upper reaches of the knick-points is big, but a considerable part of the sand and gravel is stopped by the knick-point in the canyon, and only smaller gravel is allowed to flow down via the knick-point. At the canyon big gravel is poured from both banks and stirred up from the river bed. Then the maximum diameter of the largest gravel is increased. But the volume of sand and gravel which flows down to the lower reaches is small (Fig. 7)

A topographic cross-section of the lower reach shows that the nearer to the river the land is, the lower it becomes. When we have a flood, flood water concentrates in the surrounding area to the mainstream. From a fluvial geomorphologic view point, in the case of the lower reaches of the Arau River, the state of flooding is moderate and deposition is the smallest among the three rivers. Therefore the location of Padang City is good.

In the case of the fan of the Kuranji River, there are many slightly hilly areas and many villages. The area is estimated as the natural levee on the fan or remenant of the fan, and the area is free from flooding. The fan of the Kuranji River is dissected especially in the upper part not only by the mainstream of the Kuranji but also by small streams on the fan. Furthermore, the lowering of river bed due to the existance of the Gunung Nago Weir and also excavation of the sand and gravel for construction work is recognized.

There are several streams on the fan. A small deposition is seen at the confluence point with the Flood Relief Channel. The volume of the sand and gravel which is transported by the small streams is small, because the sand and gravel is not transported from the upper reaches of the Kuranji River but from the fan.

In the case of the Air Dingin River, the erosion of the pyroclastic flow terrace and the fan is vivid. Due to the sand and gravel produced by erosion, a new alluvial fan has been formed between the pyroclastic flow and the sand-spits. A shifting of the river course is frequent in the alluvial fan.

Fig. 5 SKETCH OF THE KNICK-POINT AT BARUPIAUAN, ARAU RIVER

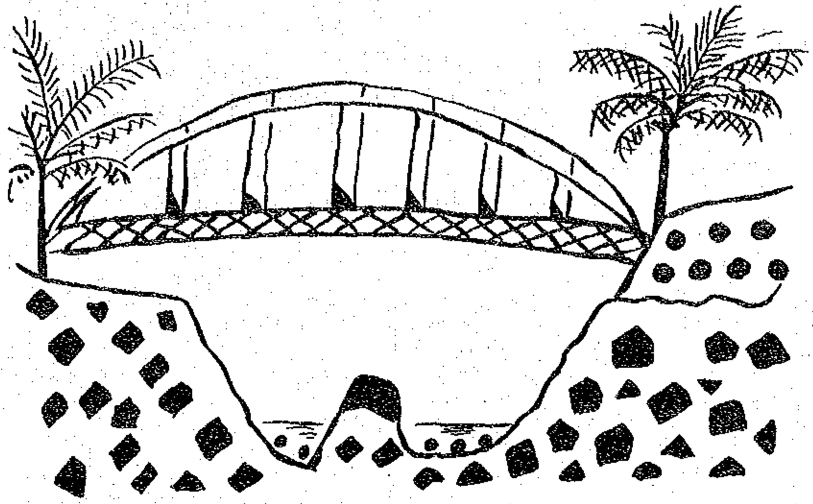
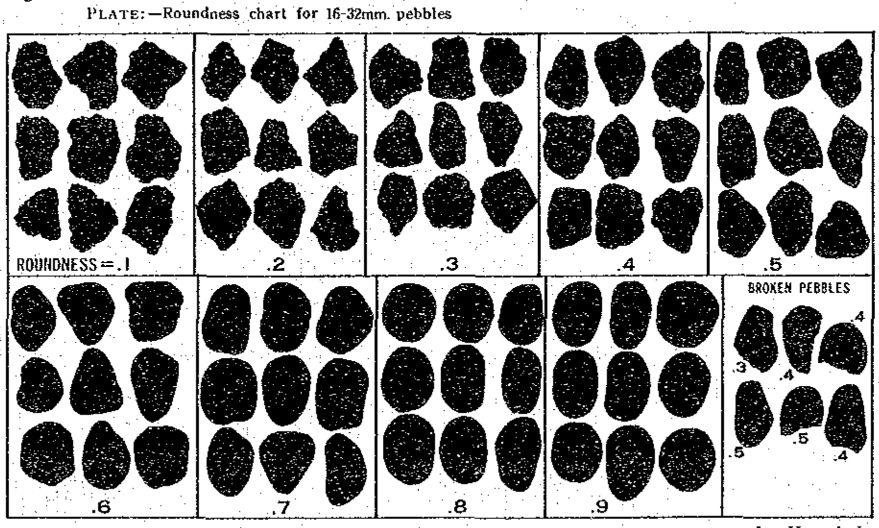


Fig. 6 PEBBLE IMAGES FOR VISUAL ROUNDNESS

PLATE:—Roundness chart for 16-32mm. pebbles

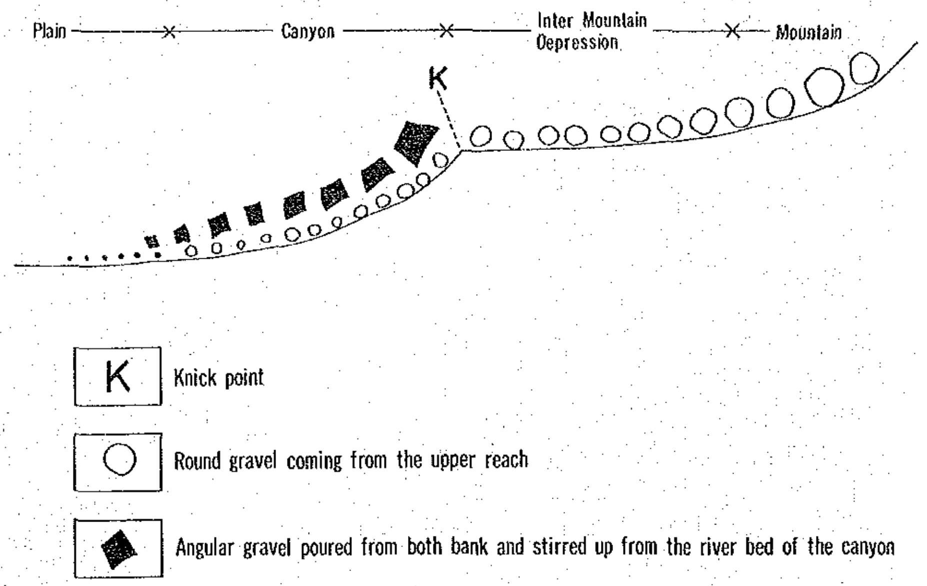


by Krumbein

6. Geomorphological Features of the Coast

Generally speaking, the coast line of the Padang Plain shows a straight line. But the left bank of the Arau River juts out about 500m, and the left bank of the Kuranji River also juts out about 300m into the open sea as a small cape. The former consists of hard rock and the latter, coral reef. Other parts of the coast line are straight or slightly curved and consists of sand.

Fig. 7 KNICK POINT AND CHANGE OF THE GRAVEL



Division of the Coast

The coastline is divided into several parts morphologically.

1) Arau River – Flood Relief Channel

The Area is surrounded by coastal embankments, and there are more than 30 jetties. They have been constructed since 1969. People living there said that the coastal line has retreated about 25m since 1969 to the present. Small depositions are seen at the southern part of each jetty.

2) Flood Relief Channel

There are several concrete blocks which were used for jetties in former days between the Flood Relief Channel and the Lolong River. The coast line is estimated to have retreated about 10m downward since 1940 from the location of the concrete blocks according to the story of the people living there.

The coast consists of sand almost entirely, but sometimes small gravel is seen. The gravel is not as flat as that seen in the coast generally but round. The gravel is andesite. This shows that the gravel was transported from the Kuranji River.

The slope of the coast is steep and, the height of the waves looks high. People living there said that high waves overflow the sand spits and flow down to the drainage canal which is located behind the sand spits. The houses located between the sand spits and the drainage canal are submerged 2 to 4 times in one year.

There are few sandy beaches between the Flood Relief Channel and the coral reef. There are many coconut palm trees, but some trees have died due to salt damage. Fisherman living there said that the coast have retreated about 20m since 1940 downward. The death of the palm tree is also related to coastal erosion.

3) Coral Reef

The left bank of the river mouth of the Kuranji is a sligthly hilly area. The area consists of coral reef and cover sand. The coral reef is not alive but a dead coral reef as has mentioned in the foregoing chapter. But a new coral reef is growing about 0,4km offshore. Fisherman are fishing the coral reef here.

There were swampy areas on the inland side of the coral reef covered by Nippa Palm. But during this past seven years the area has been changed as artificially filled-up fields.

4) Kuranji River — Air Dingin River

The coastline consists of sand. The width of the sandy coast is the biggest, about 300m, near the river mounth. If we compare the coast with the coast between the Flood Relief Channel and the Lolong River, the slope of the former is more gentle than that of the latter and the waves of the former are more moderate than that of the latter.

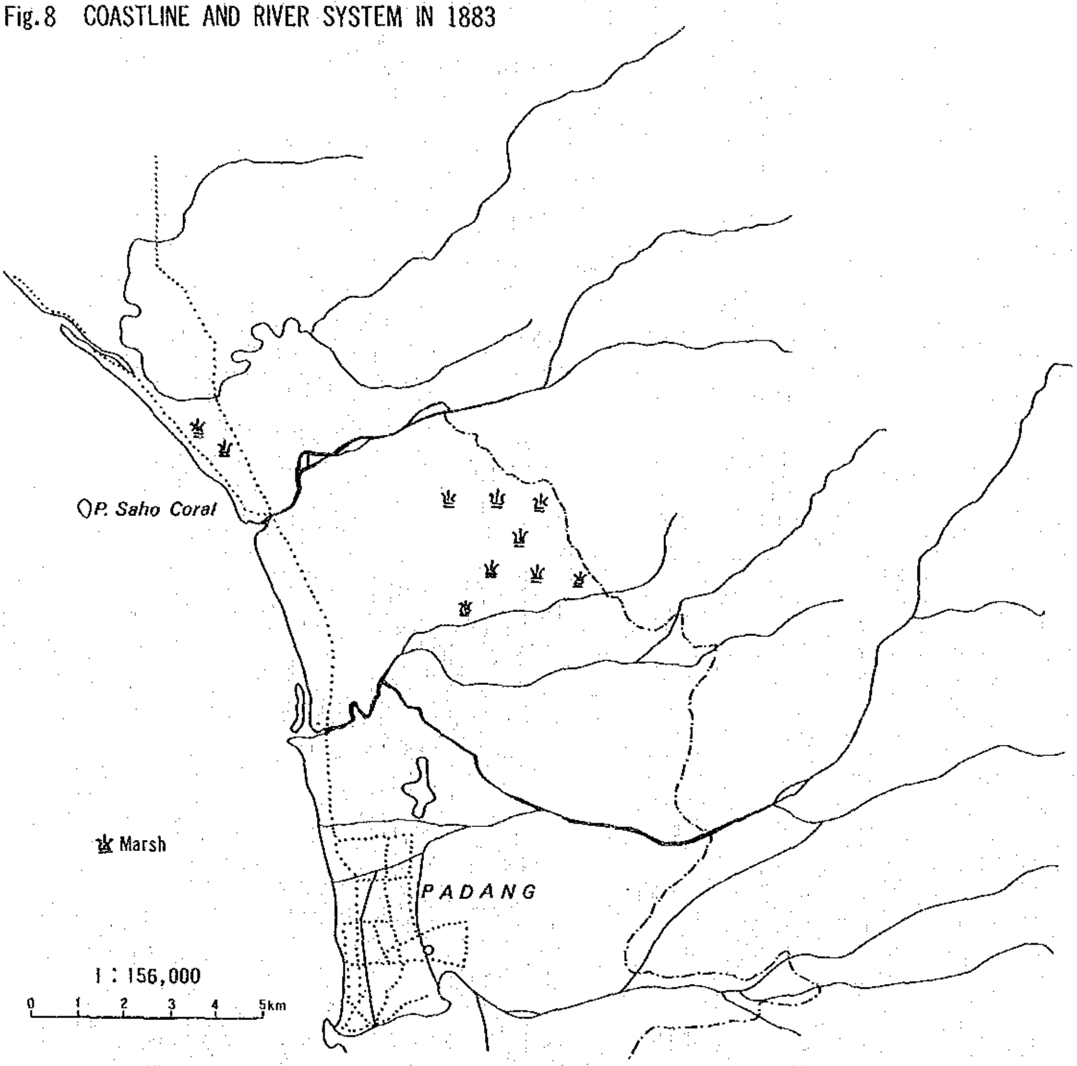
The writer found a map which was prepared by Van Eeen Ge deelte Van in 1883. The map shows that there was a sand bank at the right bank of the river mouth of the Kuranji River. At present, there is a narrow long back-marsh along the Baung River (Fig. 8). The sand bank in 1883 has grown and formed the present sandy beach and back marsh along the Baung River. By comparison of the map of 1883 with the present condition, the writer was able to recognize that coast has advanced about 200m.

People living there said that the coastline had retreated before 1967, but after that the coast has expanded and recovered about 13m.

5) Air Dingin River to North

The coast is sandy beach. There are many cusps along the coast. This shows that erosion is more predominant than deposition.

Fig.8 COASTLINE AND RIVER SYSTEM IN 1883



Van Eeen Ge deelte Van Sumatra's West Kust 1883 AMSTERDAM

7. Geomorphological Consideration of the Supply of Sand and its Movement Coastal Erosion

The sand of the coast is supplied from the rivers, transported by the littoral current and washed ashore by waves.

The width of the sandy beach is the biggest at the river mouth of the Kuranji. As has been mentioned above, the deposition by the Kuranji River is the biggest among the three rivers.

The main direction of the littoral current is estimated to be from north to south, Because the mouth of the Air Dingin River is winded to the south and there are small gravels coming from the Kuranji River between the Kuranji River and the Flood Relief Channel, in addition the deposition is seen at the southern side of each jetty.

Based on the map of 1883, we know that the Air Dingin River pours to the Indonesia Ocean with right angle. But the map of 1893 shows that the mouth of the Air Dingin River was winded to the south and joined with the mouth of the Kuranji River. The change has occurred due to the big deposition along the seacoast from the river mouth of the Kuranji to the North. After that the river mouth of the Air Dingin returned to the north and reached the present site.

Due to the coral reef the direction of the river mouth is winded slightly to the north. Therefore, after the pouring of the muddy river water into the open sea, the muddy water is dispersed from the mouth of the Kuranji River to the north. The writer made sure of the above-mentioned phenomenon not only by aerial photographs but by the color of the sea water. Namely, the color of the sea water in the northern part of the Kuranji shows a light brown color while a light blue color is recognized in the south. Live coral reefs located offshore from the river mouth of the Kuranji are situated in the blue-color sea. This shows that the sand and silt which were transported by the Kuranji River were mainly deposited on the northern coast from the river mouth.

Erosion is more predominant than deposition along the coast of the Padang Plain except for the coast between the Kuranji and Air Dingin Rivers.

One of the important reasons for the coastal erosion is related to the supply of sand coming from the three rivers. But as has been mentioned above the volume of sand and gravel which is transported from the upper reaches of the three rivers is not so big. The major part of the sand and gravel was supported by the bank erosion of the pyroclastic flow, the fan and natural levee in the plain. The volume is estimated not to be so big. Especially, the volume of the sand and gravel which is transported by the Arau River is small. And the direction of the river mouth of the Kuranji is winded to north by the existence of the coral reef.

Furthermore, weirs, dams and riverside embankments were constructed. These artificial works obstruct the flow of the sand and gravel which has been taken for construction work and a lowering of the river bed has occurred in recent years.

The writer estimated that the causes of coastal erosion are related to the above-mentioned natural conditions of the river and coast as well as artificial works.

8. Utilization of the Map

1) The map is useful to foretell the types of flooding in each geomorphological element. For example, in the case of the fan, deposition is big and change of river course is frequent while the water drains off well.

2) By a combination of geomorphological elements, you can estimate whether erosion is predominant or deposition is predominant in each river, and the type of flooding, i,e, overflowing or concentration type. For example, if you compare the Arau, Kuranji Rivers with regard to deposition, deposition of the Kuranji is bigger than that of the Arau River. Furthermore, you can estimate the causes of coastal erosion or deposition.

3) You can estimate where stable places or unstable places are by the map. For example, the river course in the alluvial fan is unstable, but that in a delta or natural levee is relatively stable. Utilizing the map, you can select a bridge site.

4) You can estimate the geomorphological formation process from the map.

5) There are close relationships between the state of the soil and the ground water situated near the ground surface.

6) You can use the map for city planning and land use. For example, coastal sand spits and natural levee areas are safe from flooding but back-swamps and deltas are dangerous.

7) There are close relationships between the area of liquefaction caused by earthquakes and geomorphology. You can estimate the areas in which liquefaction might occur. According to the experience in Japan, the lower part of the sand dunes and natural levees is a dangerous place.

(The map and the paper are written by Dr. Masahiko OYA)

References

Fumio TADA and Masahiko OYA (1959) The Flood-type and the Classification of the Topography, Proceeding of IGU Regional Conference in JAPAN 1957.

Masahiko OYA (1967) Geographical Study of Flooding Immediately Down-Sream From Pa-Mong in the Mekong River Basin, The Committee for Co-ordination of Investigations of the Lower Mekong Basin, ECAFE. Bangkok. THAILAND.

Masahiko OYA (1977) Comparative Study of the Fluvial Plain Based on the Geomorphological Land Classification, Geographical Review of JAPAN 50-1.

Masahiko OYA (1980) Multifunctional Use of Geomorphological Survey Maps in Identifying Flood-Stricken Areas and Land Types, National Geographer 15-2 Allahabad, INDIA.