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Source: *Annals of the Association of American Geographers*, Vol. 49, No. 4 (Dec., 1959), pp. 345-360
Published by: Taylor & Francis, Ltd. on behalf of the Association of American Geographers
Stable URL: http://www.jstor.org/stable/2561510

ANNALS of the Association of American Geographers

Volume 49 | December 1959 | Number 4

LANDFORM-VEGETATION RELATIONSHIPS IN THE ATRATO DELTA

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THE delta of the Atrato River in northwestern Colombia exhibits physical features which permit recognition of recent changes in its landforms, hydrography, and vegetation. Vegetation in the delta is zoned in accordance with drainage conditions, salinity of water, soil type, and age of the land surface. Each of these factors has been subject to change as the delta accreted. However, there is a time lag between changes in these factors and vegetation change. For example, the natural levees contain a distinctive vegetation that retains its diagnostic characteristics long after the distributaries along which it was formed have ceased to function. Therefore, levees stranded in backswamps can be identified by their vegetation for many years after they have been abandoned by distributaries. The same holds true for point bars, mud flats, beaches, and backswamps. Since there is also a close agreement between extent of vegetation communities and landform units, the vegetation becomes an important key in the study of the physical changes that have occurred in the delta in the recent past.

This paper explains some of the ways in which the vegetation may be used to assist the geomorphologist in unravelling the details of the recent history of deltas as exemplified by the Atrato Delta. A vegetational approach to the study of deltaic development has been too little utilized by geomorphologists. It is hoped that this paper will focus attention on a valuable tool for the field investigation of landforms in deltas.

THE NATURAL SETTING OF THE DELTA

The delta of the Atrato River is located on the southwest side of the Gulf of Urabá (Darién) between latitude 7° 56′ N. and 8° 16′ N. The apex of the deltaic plain is located about twelve river miles downstream from the settlement of Sautatá where Caño Urabá, the first upstream distributary of the Atrato, departs for the sea (see Fig. 1). North of this point four main distributaries leave the river but each in turn bifurcates into two or more smaller distributaries. The major distributary arms are referred to locally as *caños*, while the smaller branches from them are called *bocas* (mouths). The Atrato has four main distributary systems and about twenty mouths.

The delta occupies a mangrove and palm zone in a climate that is transitional from rain forest to savanna. Insufficient data make it difficult to classify the climate of the delta. Observations of the monthly rainfall are available for the years 1931–39 inclusive, 1948, and 1952–54 inclusive. Temperature data are available for the years 1935–40, only. On the basis of this inadequate record it appears that about 8.25 percent of the rain for the year falls during the months of January, February, and March, the dry season. The mean annual rainfall is 72.33 inches. This contrasts greatly with the inland stations in the Atrato Valley where there is no dry season and the mean annual rainfall is in excess of 350 inches.

The delta forms a coastal lowland belt bounded on the south by an anticlinal uplift that extends from the mountains on the Panamanian border across the lower valley of the Atrato in the vicinity of Sautatá. On the west the lowland comprising the delta terminates against the mountainous mass along the bor-

[1] This paper is the result of field work supported by the Office of Naval Research, Geography Branch, Project NR 388-059, Contract Nonr-454(OO).

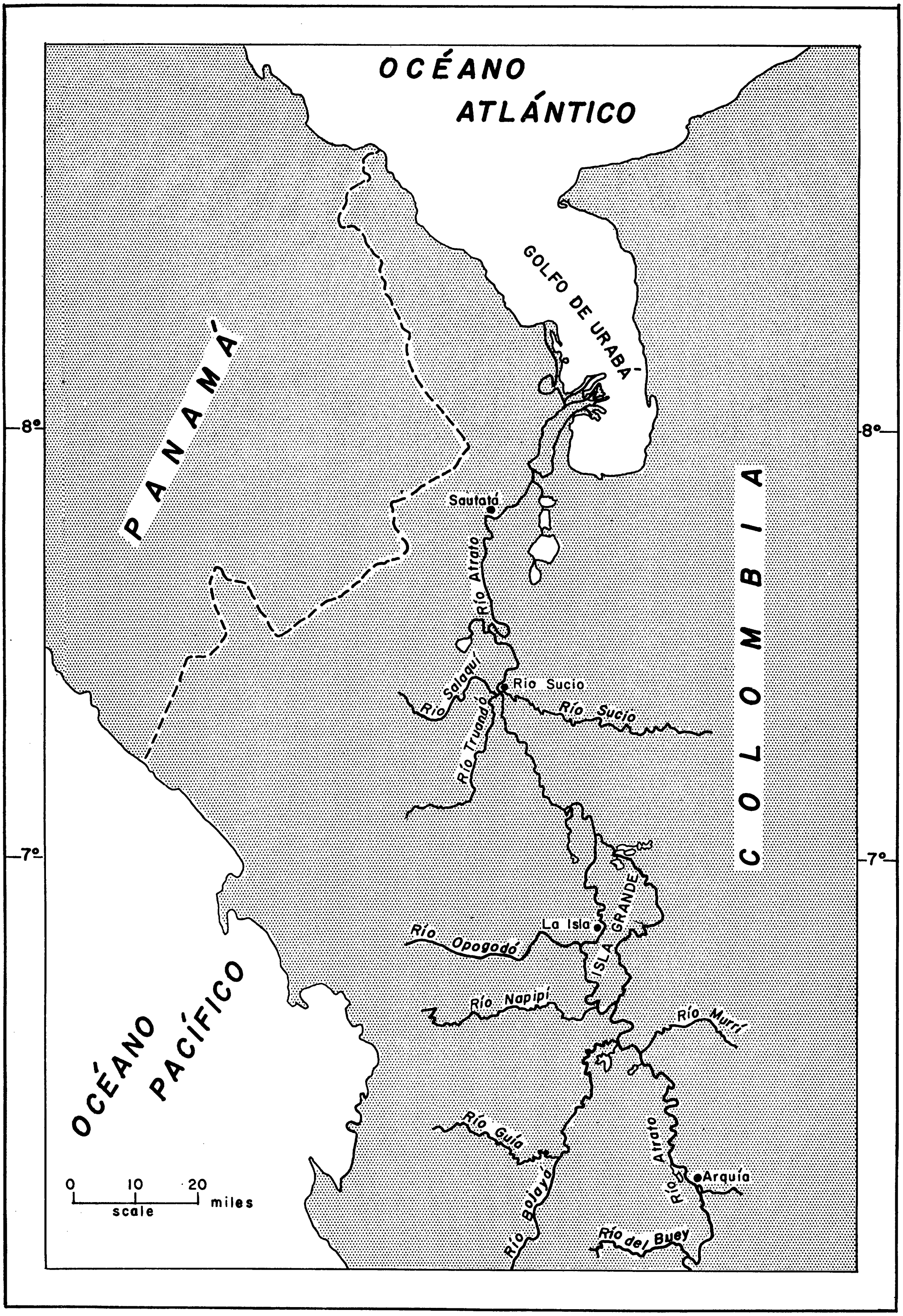

Fig. 1. Lower Atrato River.

der between Panamá and Colombia. Eastward the Gulf of Urabá separates the deltaic coast from the low hills of the mainland. The Gulf of Urabá is an incursion of the sea into the northern end of the Bolivar Geosyncline, and the delta forms an extension of the alluvial fill of the Atrato into the gulf.

South of the delta the swampy lowland of the Atrato Valley extends along a depression between the Cordillera Occidental on the east and the Serranía de Baudó on the west. The depression roughly follows the axis of the geosyncline. The Atrato receives large quantities of water from rainfall and run-off from the surrounding mountains. Consequently, its valley contains large, shallow lakes connected to one another and to the river by a maze of swamps and channels. The lakes are called *ciénagas* by the inhabitants of the valley. According to informants questioned in Quibdó, a town of the upper valley, rainfall is so evenly distributed in the upper valley throughout the year that these ciénagas show no seasonal fluctuations. Below Río Sucio it was observed in the field and confirmed by local inhabitants that the lakes are subject to fluctuations in size, shrinking appreciably during the dry season. During the summer rainy season when the writer visited the area, the ciénagas had coalesced forming one vast flooded swamp in the lower valley. However, even at this time there was considerable fluctuation in the position of the shorelines of ciénagas between rains. Ciénagas are connected to the Atrato by narrow channels across the natural levees. Soundings with a lead line thrown from a boat revealed that these connecting channels are frequently deeper than the ciénagas, which may indicate that they were formed by crevassing during floods. It was observed that ciénagas can be differentiated from other areas in the backswamps by the vegetation that grows in them. They contain low-growing aquatic plants, grasses, and vines in contrast to the swamp forest that covers the less completely inundated areas of backswamp.

PREVIOUS INVESTIGATIONS IN THE ATRATO VALLEY

The Atrato Valley has been an object of exploration since its discovery by Spaniards at the beginning of the 16th century. However, scientific investigation of the valley has been limited to the period since the middle of the 19th century when it became the proposed route of an interoceanic canal. During this period it has been visited by several expeditions with the object of assessing its value as a canal route. In addition several articles have been published containing references to the geological aspects of the valley. These latter papers contain the most accurate information available on the Atrato Valley.

The earliest scientific geography survey of the Atrato country was performed by J. C. Trautwine[2] who produced the first useful maps of the delta. He was followed by Lt. N. Micheler,[3] who made a detailed topographic survey of the Atrato and Truandó valleys in 1860. Lt. Frederick Collins[4] mapped and surveyed the Atrato and Napipí valleys in 1875, and Lucien N. B. Wyse[5] explored and mapped the southern part of the Isthmus of Darién and the Atrato Delta in 1876–77 in connection with a French scheme to construct an interoceanic canal. Wyse produced the most accurate map of the delta prior to the survey of the U.S.S. *Bushnell* in 1938.[6]

All of these surveys added significant details to the geographical knowledge of the Atrato lowland. However, they were mainly engineering surveys which paid little attention to the geomorphic aspects of the Atrato valley or delta. On the other hand they are useful to anyone interested in the geomorphology

[2] "Rough Notes of an Exploration for an Interoceanic Canal Route by way of the Rivers Atrato and San Juan in New Granada, South America," *Journal of the Franklin Institute*, Vol. LVII (1854), 145–54, 217–31, 289–99, 361–73; Vol. LVIII (1854), 1–11, 73–84, 145–55, 217–26, 289–99.

[3] "Report of Lt. N. Micheler. corps of topographical engineers, of his survey for an interoceanic ship canal near the Isthmus of Darién, via the Atrato and Truandó Rivers, called for by a resolution of the Senate June 5, 1860," *Senate Executive Document*, No. 9, Vol. 7, 36th cong., 2d sess., 1860–61 (Washington, 1861).

[4] "Report of the Survey of the Proposed Route of an Inter-oceanic Ship Canal by Way of the Atrato, Napipí, and Doguadó Rivers," *Senate Executive Document*, No. 75, 4th cong., 3d sess., June, 1875 Washington, 1879).

[5] "L'Exploration de L'Isthme du Darién en 1876–1877," *Bulletin de la Societé de Geographie* (Paris, 1877), 6th series, Vol. 14, pp. 561–80.

[6] Data gathered during the Bushnell survey are unpublished with the exception of the information which appears on H. O. Chart 5694. The US Navy Hydrographic Office made the complete results of the survey available to the writer.

because many soundings and other measurements were made, and conditions in the deltaic channels and over the river mouth bars were carefully described. The maps made by these surveyors are very useful in a study of changes that have taken place in the delta, since they record the positions of the shore line and distributaries at various times in the recent past.

The works of Hubach,[7] Troll,[8] and Nygren[9] have raised a basic question about the structural nature of the Atrato Valley. Hubach and Troll have maintained that the valley occupies the geosyncline as far as Sautatá. They see the lower part of the valley below Sautatá as a separate structural province unrelated to the geosyncline. Their work predates oil exploration in the valley. Therefore, they had to rely on surface geology, and were not familiar with subsurface conditions. Nygren, with access to subsurface geologic data, has shown very clearly that the Atrato Valley occupies the Bolívar Geosyncline throughout its length, and that the Miocene axis of the geosyncline is continued beneath the present valley and into the Gulf of Urabá. Nygren pictures the geosyncline as consisting of highs and basins. The ridge of basement rock that crosses the lower Atrato Valley in the vicinity of Sautatá is considered by him to be one of the highs.

THE ATRATO RIVER

According to all of the surveys cited above the Atrato is characterized by great fluctuations in volume in its lower course. At low water during the month of February at Río Sucio the depth of water in the channel is 50 to 55 feet,[10] while at high water in the summer floods it is 80 to 84 feet. No measurements of current speeds or discharge have ever been made in the Atrato, but estimates of current speeds at mean low water have been made for the main channel below Río Sucio.[11] The average of these estimates is three knots. The speed of the current is undoubtedly much higher during floods. The average width of the river between Río Sucio and Sautatá is about 1100 feet at mean low water and about 1500 feet at bank-full stage.[12]

The Atrato does not carry a suspended load proportionate to its volume. This may be stated on the basis of two observations: (1) the slow rate at which the delta advances in the Gulf of Urabá, and (2) the small size of the natural levees. An important factor governing the load of the river is the straining effect of the ciénagas. This was determined by measurements of load carried out in four ciénagas. A bucket attached to a strong rope line was used to dip water from various depths in the streams before they entered the ciénagas. Outflows from the ciénagas were similarly investigated and it was found that the water flowing out of ciénagas contained much less silt than that flowing into them. Every tributary entering the Atrato in its lower course must flow through these flooded backswamps before its waters enter the main stream. A large portion of the load of the tributaries is deposited in the ciénagas before reaching the Atrato.

The building of delta-like deposits in ciénagas, a process that appears to take place at a much greater rate during high water, is important in adding to the alluvial deposits of the Atrato Valley. Sizeable deltas were observed in the ciénagas investigated where the tributary streams enter them. Since there is little evidence in the form of cut-off meanders and abandoned channels that the Atrato has been a shifting stream wandering over its valley floor by developing numerous meander belts, the process of delta-building in the ciénagas has probably been a major way in which the alluvium of the lower valley has been deposited.

The Atrato, like other alluvial rivers flows in a valley characterized by natural levees, back-

[7] Enrique Hubach, "Apreciation de los proyectos de canal interoceanico por el Napipí y por el Truandó, segun puntos de vista geologicos," *Boletin de Minas y Petroleo,* Vol. III (1930), pp. 15–34; "Informe geologico de Urabá," *Boletin de Minas y Petroleo,* Vol. IV (1930), pp. 26–136.

[8] Carl Troll, "Die geologische Verkettung Süd- und Mittel-amerikas," *Mitteilungen der Geographischen Gesellschaft in München,* Vol. XXIII (1930), pp. 53–76.

[9] W. E. Nygren, "The Bolivar Geosyncline of Northwestern South America," *Bulletin of the American Association of Petroleum Geologists,* Vol. 34, part 2 (1950), pp. 1998–2006.

[10] Information on depths during the dry season is taken from an average of the reports of the various surveys, while the depth during the rainy season was measured by the writer by use of a regular navy sounding lead thrown by hand.

[11] *Special Report of the Governor of Panamá Canal on the Atrato–Truandó Canal Route* (Canal Zone, 1949), p. 4.

[12] *Ibid.,* p. 4.

swamps, and terraces. It differs from those rivers that flow through regions with less rainfall by having tributary deltas and more or less permanently flooded backswamps. The natural levees of the Atrato are also very interesting because of their small size. Compared with the levees of the Mississippi they are smaller than the difference in volume of the two rivers would indicate. This is partly caused by the relatively small load of the Atrato.

The Atrato might be classed as a meandering stream from Quibdó, a town of the upper valley, to the mouth of the Opogodó (see Fig. 1), since it presents an S-shaped channel pattern fashioned in alluvial materials in this portion of the stream, and is more or less free to shift the position of its channel and adjust the shape of its channel cross-section in accordance with local factors controlling meandering. Matthes[13] has isolated five variables, which seem to him to be basic factors controlling river meandering. These variables are: (1) valley slope, (2) bedload, (3) discharge, (4) bed-resistance, and (5) transverse oscillation. A river meanders when a state of equilibrium is reached in regard to these five factors. Any change in any one of them that tends to upset this equilibrium results in an inhibition of the meandering tendency.

In the lower Atrato three factors seem to be at least partly responsible for the lack of meandering: (1) change in valley slope, (2) change in the character of the bedload, and (3) change in the nature of the bank materials. The valley slope of the Atrato from Quibdó to Río Sucio is about one foot to the mile; below Río Sucio only six inches to the mile. If the valley slope is adjusted to meandering in the river above Río Sucio, as seems to be indicated by observation and measurement (made by the canal survey of the Governor of the Panamá Canal), a change in this slope in either direction (increase or decrease) would probably result in a change that tends to inhibit the meandering tendency. Samples of the bedload of the river were collected by the writer above and below Río Sucio and it was found that the bedload is of smaller grain size in the lower river. This reduction of grain size may have an inhibiting effect on meandering in the lower part of the river. Another and perhaps more important cause of reduced meandering below Río Sucio is the nature of the bank materials. Analysis of bank materials collected below Río Sucio indicates that clay of a very stiff consistency composes the banks. Bank materials collected by hand augering in the middle part of the river were composed of silts and fine sands. The more resistant bank materials of the lower river prevent the development of meanders. The one extreme bend in the lower course of the river is caused by a projection of the basement rock which outcrops in a hill at that point.

[13] G. H. Matthes, "Basic Aspects of Stream Meanders," *Transactions of the American Geophysical Union*, Vol. 22 (1941), p. 632.

THE GEOMORPHOLOGY OF THE ATRATO DELTA

Since the object of the field study was to investigate the geomorphology of the Atrato Delta much more detailed field work was performed there. Trimetrogon aerial photography of the delta on a scale of 1:30,000 was supplied by ONR, and these photos were used in the field. In addition to the photos, the field party was equipped with a Brunton compass, tape measure, shallow boring equipment capable of penetrating 60 feet below the surface, and a standard lead line for soundings both in the Gulf of Urabá and in the channels of the Atrato.

The apex of the deltaic plain of the Atrato is located where the Caño de Urabá or Léon bifurcates from the main stream. However, the present active delta, that part of the deltaic plain where sedimentation is now actively extending the delta seaward, is located at the gulf shore some 60 river miles to the north. At present the greatest portion of the discharge of the Atrato is entering the sea through El Roto mouth (see Fig. 2), and the major amount of delta-building is also taking place there. Though all caños are carrying some portion of the discharge, the delta is extending seaward very slowly everywhere except at El Roto (compare Figs. 2 and 3).

The Caño de Tarena, the main distributary of the Atrato until about 1898, is all but extinct today. It is being gradually filled with aquatic plants and becomes shallow very rapidly below El Roto. The velocity of the current flowing through it is quite feeble, and it is being invaded by the sea. Waves have

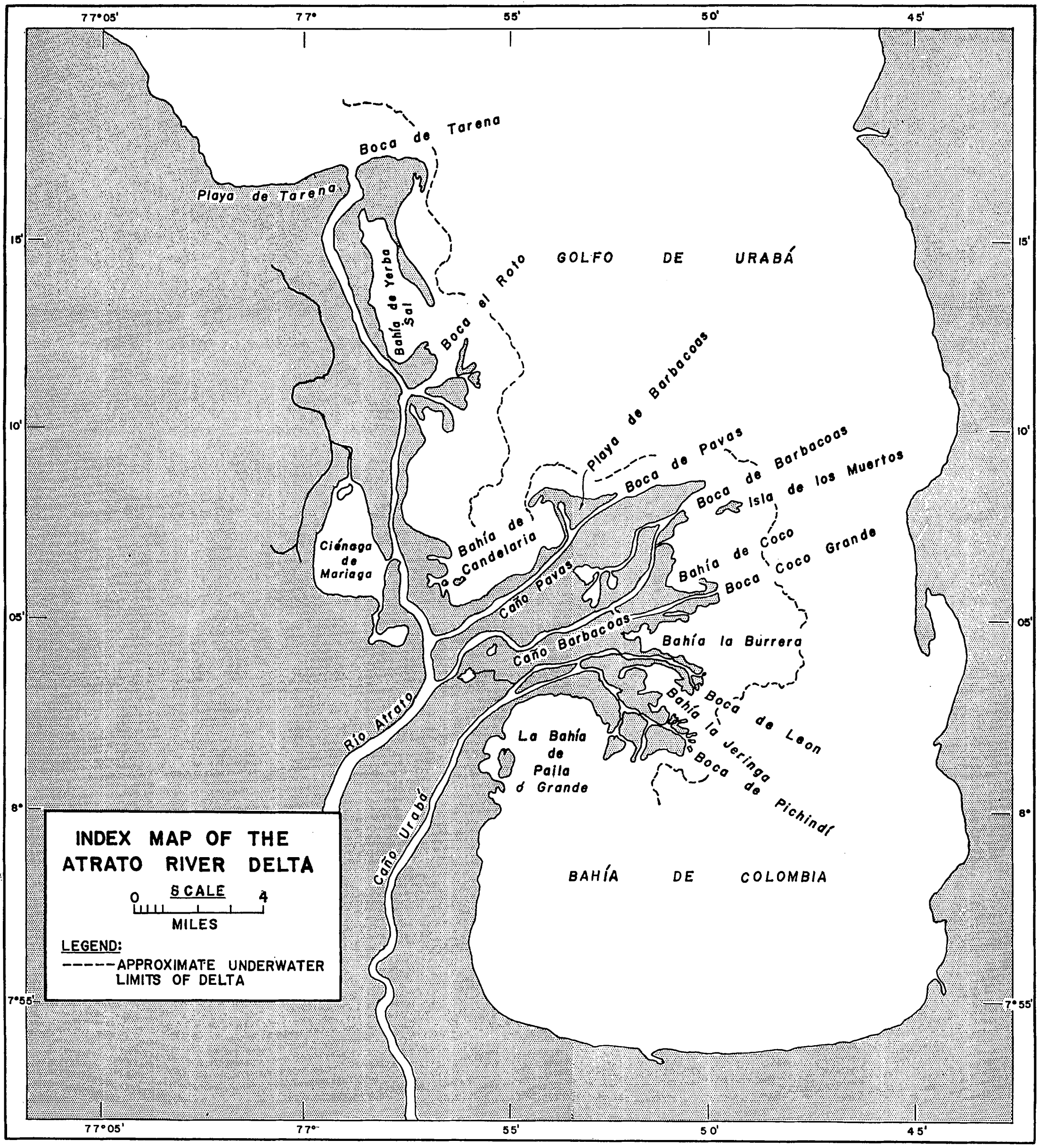

FIG. 2. The active delta of the Atrato. The limits of the active delta are Bahía de Yerba Sal on the north and Bahía Grande on the south.

greatly widened the Tarena mouth and are destroying the bars there.

The second most important portion of the discharge of the Atrato is flowing to the sea via Caño de Urabá at the mouths of which new land is accumulating more rapidly than any other place except El Roto (compare Figs. 2 and 3).

Of the other distributaries Barbacoas is carrying the least sediment, but about the same proportion of the discharge as Coco Grande. Very little new land is forming at the mouths of either of these distributaries, but Coco Grande has somewhat more than Barbacoas.

Landforms in the delta consist of new mud flats, natural levees, backswamp basins, point bars, round lakes, beach features, and flank depressions. The new mud flats are develop-

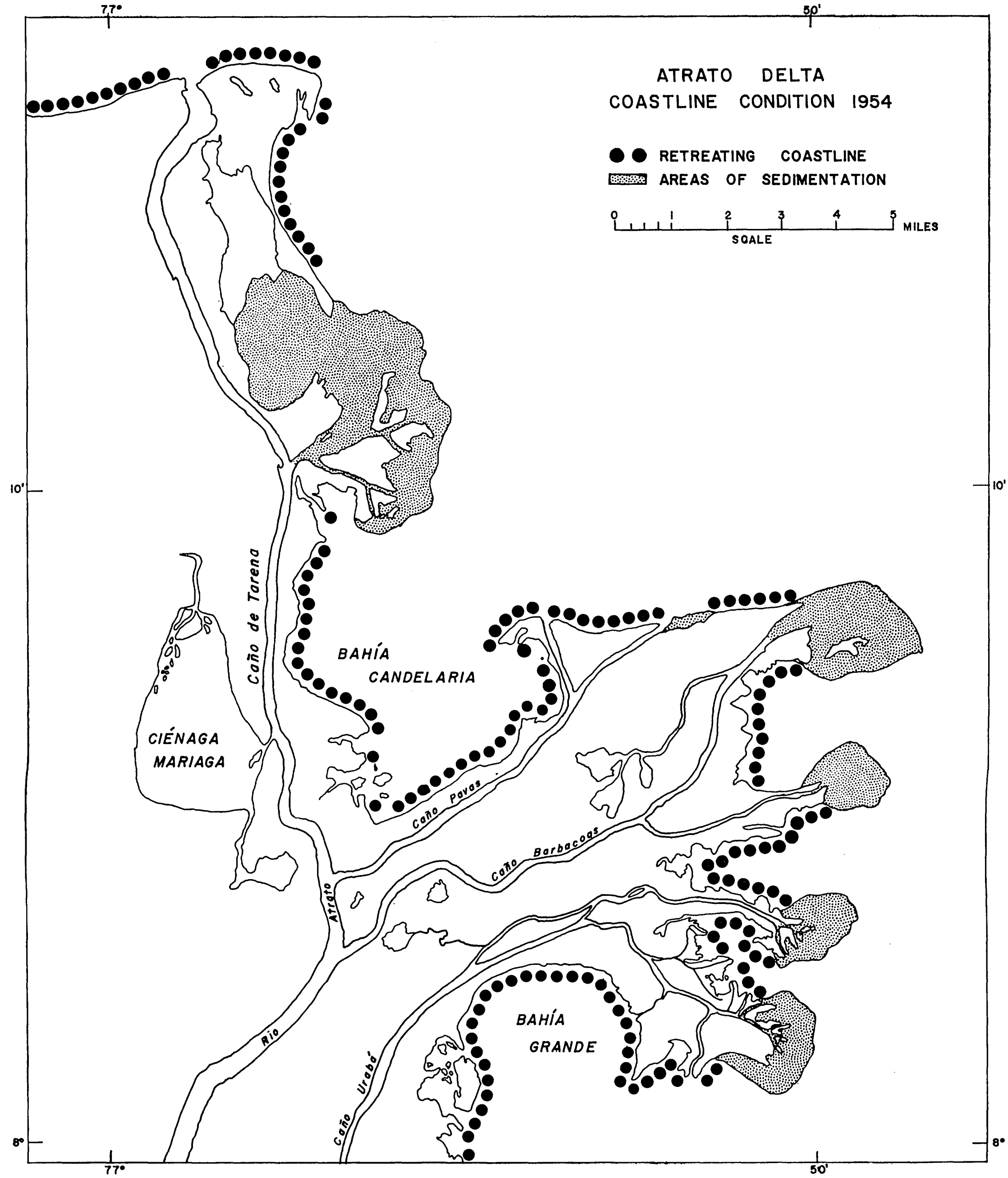

FIG. 3. Areas of active sedimentation and erosion in 1954. Note the greater size of the area to the north of Bahía de Candelaria.

ing around mouths where active deposition is taking place. These are very conspicuous features because they are devoid of vegetation in the early stages of their formation. Most of the new mud flats are located around El Roto mouth, where Bahía de Yerba Sal is being rapidly filled with Atrato sediment (see Figs. 2 and 3). The levee break that formed El Roto occurred in 1898, when wave erosion from the Gulf of Urabá so weakened the natural levee along Caño de Tarena that it would no longer hold against the current of the river in flood.

Since that time deposition around the new mouth has separated the Bahía de Yerba Sal from the gulf except for a narrow passage just north of El Roto (see Figs. 2 and 3).

The southern end of the Bahía de Yerba Sal was open to the Gulf in 1938 and contained three-fourth of a fathom of water (Fig. 2 illustrates conditions at that time). At present this opening is almost entirely closed by a bar that isolates Bahía de Yerba Sal from the Gulf of Urabá at low tide. Soundings along the one fathom line of 1938 made during the summer of 1954 showed only three feet of water in the southern part of the bay.

The natural levees of the delta are low banks that extend seaward along distributary channels gradually isolating portions of the sea that become bays. As long as a particular mouth is active these bays are filled with sediments by crevassing through the natural levees during floods. Once sedimentation ceases along the distributaries or becomes so reduced that it cannot keep pace with wave erosion from the gulf, the bays are enlarged by wave action and the shore is driven landward. Should one of these bays become a deep indentation in the coast, crevassing along the lower course of distributaries on either side of the bay may build a bar of sediment across the bay mouth. The bay then becomes a lake that gradually freshens, though it may maintain a connection with the sea for some time. The lake will gradually fill with sediment and organic matter, but this is a slow process.

The Ciénagas de Mantantugo, lakes between Caños Pavas and Barbacoas (see Fig. 2) were formed by the process described above. Another such round lake exists between Caños Barbacoas and Urabá that maintains a connection with Caño de Urabá (see Fig. 2). Still a third round lake occurs in the great bend of the Caño de Barbacoas that is not connected with any caño at present. These three lakes represent various stages in the process of lake formation. The Ciénagas de Mantantugo are the youngest of the three, the lake connected with Caño Urabá probably the next youngest because it is still connected with the caño, and the third lake is probably the oldest because it is completely isolated.

The entire delta appears to have been formed by the filling of bays between distributary arms in the manner described above. At present only one of the bays along the deltaic shoreline is filling, Bahía de Yerba Sal. All other bays are being enlarged by wave attack, a situation that will continue until another major break-through of the El Roto type occurs.

Small depressions exist on both sides of the main Atrato deposition, which until 1898 included the land between Pavas and Urabá mouths. South of Pichindí, Bahía Grande is a depressed area as in Bahía de Yerba Sal on the north (see Fig. 2). Borings to a depth of sixty feet were sunk around the shores of Bahía de Yerba Sal and they showed beach sands separated by silt accumulations throughout the whole depth of the borings. This indicates that there may have been some subsidence. Further evidence indicating possible subsidence can be found north of Bahía de Yerba Sal. Between the north end of the bay and the present shoreline north of the bay a series of stranded beach ridges are being encroached upon by the waters of the bay from their landward side. At the extreme northern end of the bay beach ridges may be seen under water. The depth of the water over these ridges was measured with a lead line and found to be 5 to 6 feet deep. Since there is no wave action in the bay, and probably hasn't been any since 1877 when it is first shown on maps as sheltered from the Gulf of Urabá by a sand spit, it was concluded that the drowned beach ridges are possible evidence of slow subsidence.

Subsidence is somewhat more apparent in the Bahía Grande area, since no sedimentation is taking place there as at the southern end of Bahía de Yerba Sal. The position of the one fathom line was determined by soundings along the entire extent of the delta shore during the summer of 1954. In Bahía Grande the one fathom line was found to be about 500 yards farther offshore than it was in 1938 when the Bushnell survey was made. Furthermore, there are many more islands in the unnamed island district along the southwest shore of the bay than there were in 1938. This might indicate nothing more than wave erosion if it were not for the fact that depths are slightly more than one fathom greater in the island district than they were in 1938.

Only two stretches of beach are found along the seaward face of the delta: the Playa de

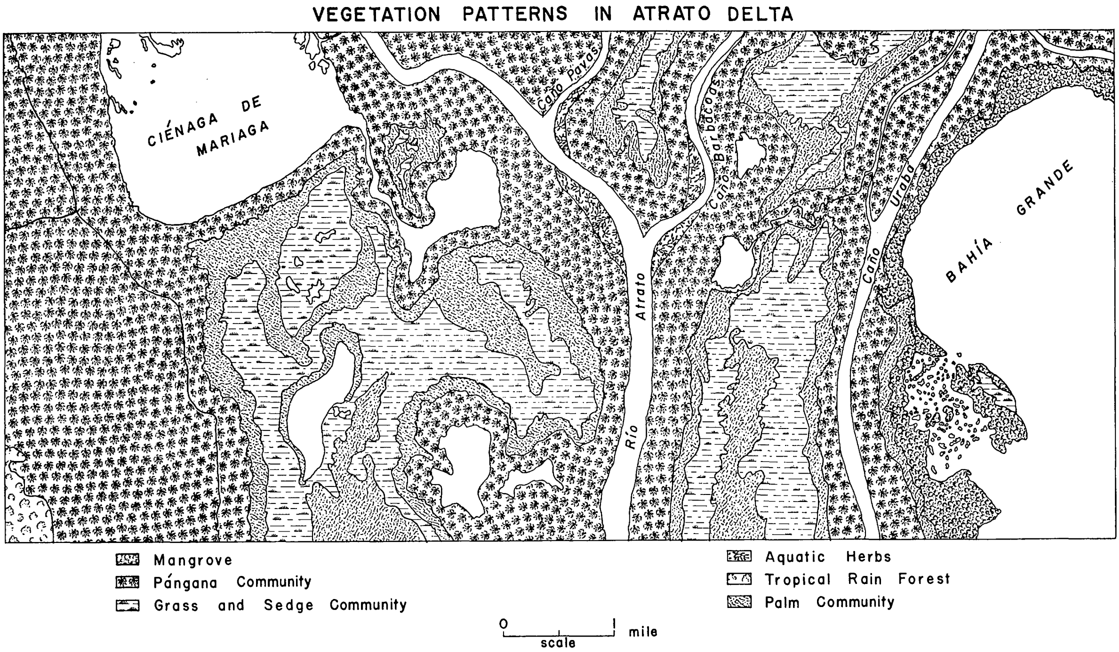

FIG. 4. The zonation of vegetation in the Atrato Delta. Note the association with landforms expressed by the proximity of the Pángana community to the distributaries and the location of the Palm and Grass and Sedge communities in the backswamps.

Barbacoas and the Playa de Tarena (see Fig. 2). Both of these beaches are narrow and flat and composed of very fine sand. They are located near river mouths where very fine sand is being discharged, and are also in places where the waves from the Gulf of Urabá and the open sea are free to break against the shore at a slight angle to the source of sand supply. The waves transport the sand along the shore for short distances by beach drifting and wave-formed longshore currents. Sand from Boca de Pavas has been thus spread along Playa de Barbacoas, and sand from Boca de Tarena and wave abrasion of the coast to the west has been similarly spread along Playa de Tarena. The rest of the deltaic shore is formed of mud, silt, or organic accumulations.

THE VEGETATION OF THE ATRATO DELTA[14]

The Atrato Delta contains four major vegetation types that serve to differentiate terrain types in the delta and are especially valuable as photo interpretation keys (see Fig. 4). The zone along the seashore within the tidal range is occupied by the mangrove plant community (Fig. 5). The principal plants of this community are *Rhizophora mangle* (mangle colorado), *Laguncularia racemosa* (mangle bobo), and *Muellera frutescens* (mangle humo). Mangle colorado and mangle bobo are trees 20 to 30 feet high forming conspicuous elements of the vegetation in the tidal zone, while mangle humo is a less conspicuous shrub or low tree with an almond-like seed and purple flower. The undergrowth of the mangrove zone is composed of *Pavonia racemosa* (marvilla), *Hibiscus tiliaceus* (marjagua de playa), *Drepanocarpus lunatus* (uña de gato), *Dalbergia ecastophyllum*, and *Rhabdadenia biflora.*

The natural levees are covered by a very distinctive vegetation. The dominant plants in the levee community are *Raphia taedigera* (pángana), *Pentaclethra macroloba* (capitancillo), and *Pachira aquatica* (saladero). The pángana is a palm with large, coarse, drooping fronds and is the most conspicuous tree of the delta (see Fig. 6). The capitancillo occurs less frequently along the levees, but is very striking in appearance. In the delta it is a tree that reaches 50 feet in height

[14] The identification of plants collected by the writer was done at the Instituto de Ciencias Naturales, Bogotá, Colombia, through the courtesy of Dr. Armand Dugand, director.

FIG. 5. *Rhizophora mangle* along the shore of Bahía de la Jeringa.

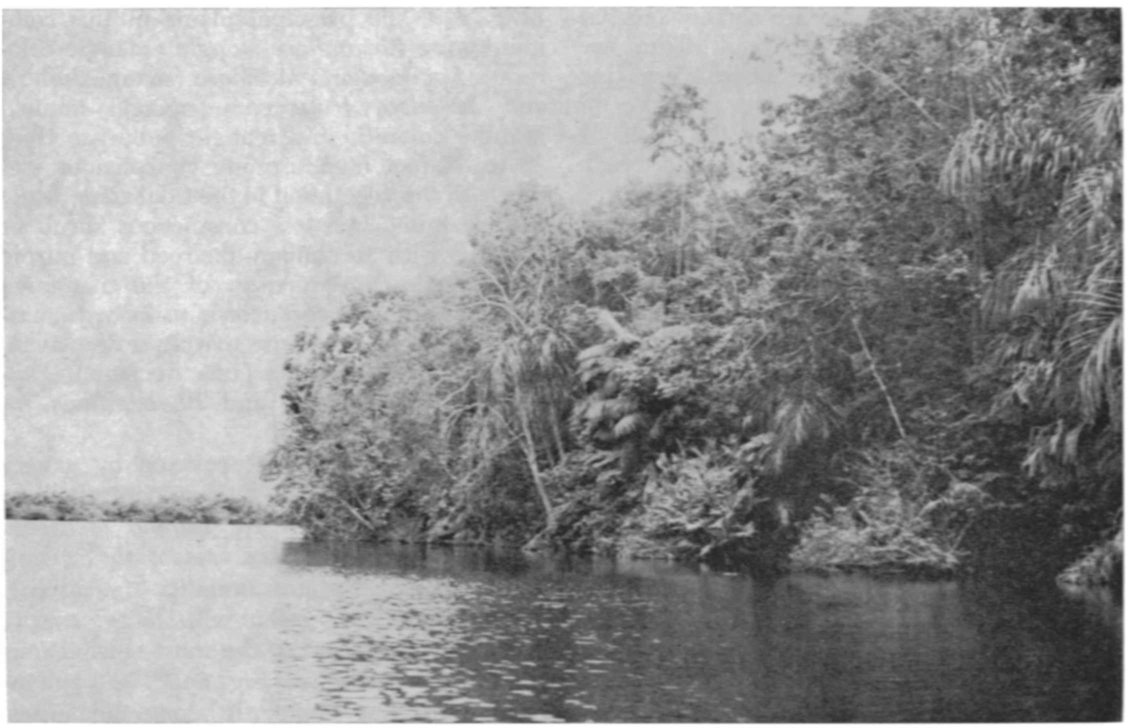

FIG. 6. Pángana community along Caño de Barbacoas. The palm in the center with the coarse fronds is *Raphia taedigera*.

FIG. 7. Cabeza de negro palm of the palm community.

and has large elongate white flowers, and small, lacy, light-green leaves. It is a member of the family Leguminosae and belongs to that section of the family usually designated as Mimosaceae. When the tree is not in flower it resembles the familiar mimosa. The saladero is a tree 30 to 50 feet high in the delta, but elsewhere in South America it reaches somewhat greater heights and is popularly referred to as the Guinea chestnut. Its flowers with their long, showy stamens make this a most conspicuous tree. There are many other plants on the levees in the undergrowth but it is the trees described above that give the levees their special vegetative character.

Between the caños or brazos in the zone of filled ciénagas two plant communities are especially prominent. In the area farthest removed from the stream channels, where the round lakes are found, grasses and spiny shrubs are the dominants of what will hereafter be called the grass and sedge community. Surrounding this low growth and separating it from the pángana community is a belt of higher growth composed of several palms and shrubs hereafter called the palm community. The major palms of this community are *Phytelephas Seemannii* (cabeza de negro; see Fig. 7), *Ammandra decasperma* (cabecita), *Euterpe rhodoxyla* (naidí), and *Mauritiella* sp. (quitasol). A very distinctive element in this community is the giant aroid *Montrichardia aborescens* (arracacha). The palm community occupies a zone that is transitional between levee and backswamp basin. The palms and ferns of this community occupy the lower backslopes of levees and the margins of the basins. Palms such as cabeza de negro, quitasol, and naidí occur on the lower backslopes, and ferns (*Acrostichum*) are more numerous at the basin margins. The zone of maximum water-logging is occupied by aquatic herbs, grasses, and sedges of the grass and sedge community. In the quiet, stagnant water of the interior ciénagas the aquatic herbs become established. They gradually choke the swamps and lakes, which soon fill with organic debris forming a peaty muck. This muck functions as a soil on which grasses and sedges can gain a foothold. The whole marshy area then becomes an area of low growth, which it remains unless again

FIG. 8. Grass and sedge community. The light colored area in foreground is *Cyperus gigantea* and darker areas are *Scleria* and *Paspalum*.

invaded by silt. The grass and sedge community is composed mainly of the grasses *Paspalum* (chuscal) and *Scleria* (cortadera), which dominate the partially filled ciénagas (see Fig. 8). In addition to the grasses the large sedge *Cyperus gigantea* is frequently encountered. The flowers of this plant are borne in spikelets which are assembled in heads creating a puffed or crowned appearance (see Fig. 8). This sedge is commonly referred to as the cattail and attracts attention because of its twelve-foot height and puffy crown. Scattered clumps of quitasol and naidí are found within the grass and sedge community wherever remnant natural levees along former distributaries are found.

In addition to the four basic plant communities described the delta contains two of lesser importance—the aquatic community of the point bars and the beach community. The point bar community is composed of aquatics and other plants with a low growth habit that form a mat in streams as soon as the current deteriorates along channels in the process of abandonment. These plants begin to take over the point bar side of bends when the main thread of current in a distributary channel shifts to a more easily traversed course because of accretion along the channel side of the bar.

The principal plants in the point bar community are: *Eichornia azurea* (no me olvide), a close relative of the water hyacinth, *Limnanthemum humboldtianum* (hoya de raya), a member of the water-lily family that is usually called "floating-heart" in English, *Cydistra aequinoctialis* or *Bignonia aequinoctialis*, a low-growing vine with showy pink flowers, *Sagittaria lancifolia* (cabeza de flecha), an aquatic herb with tuberous or knotted roots, *Cimbosema* sp., an aquatic plant that occurs infrequently, and *Montrichardia aborescens* (arracacha; see Fig. 9). The principal chokers of degenerate caños are *Eichornia*, *Limnanthemum*, and *Sagittaria* all of which propagate very rapidly in still, quiet water.

The beach community is composed of low shrubs, vines, and creepers, chief among which are *Hibiscus tiliaceus* (mahoe), a shrub with yellow flowers and leaves similar to the linden, *Hibiscus bifurcatus*, a shrub with a deli-

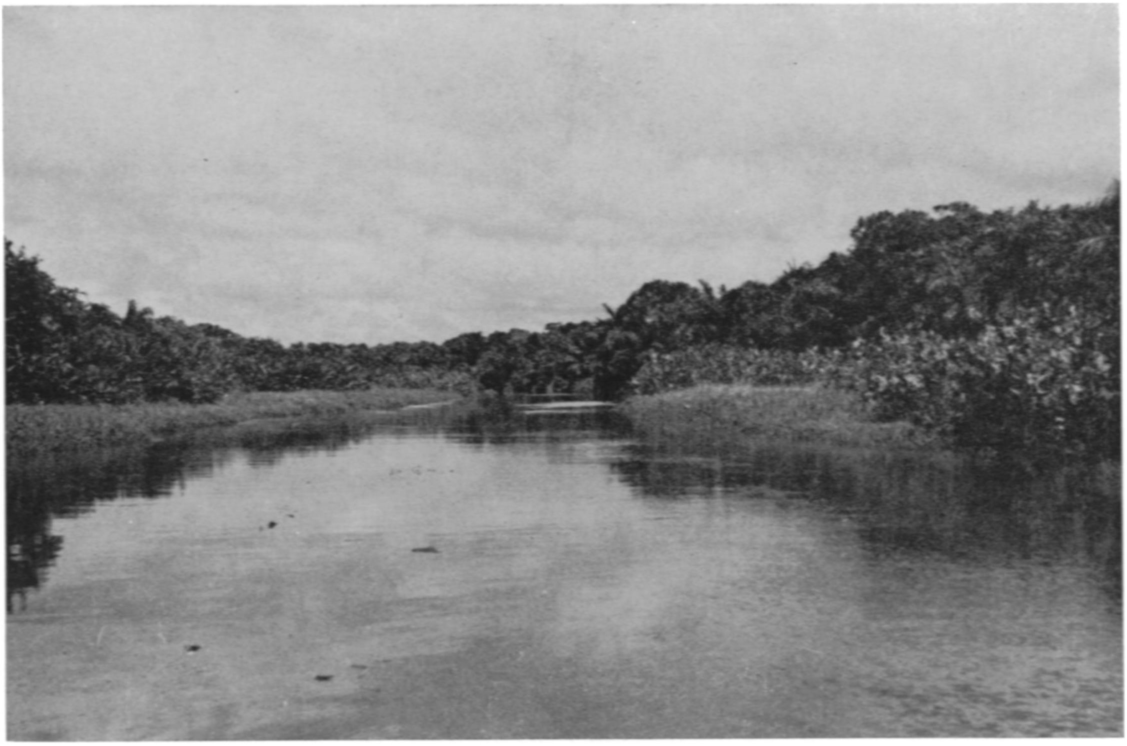

FIG. 9. Aquatic herbs on the point bar (light-colored low growth on right). Large leafy plants on right are arracacha, and high growth in background on the natural levee is *Raphia taedigera*.

cate violet flower, *Entada gigas*, a low climbing plant of the family Mimosaceae, *Canavalia rosea*, an herb with a large flat woody pod with bean-like seeds, *Cordia macrostachya*, a climbing shrub belonging to the family Boraginaceae, *Rhabdadenia biflora*, low shrubs of the family Apocynaceae also found in the mangrove, *Wedelia brasiliensis*, a creeping herb of the family Compositae, and *Ipomoea Pes-caprae*, a creeping vine of the morning glory family.

The beach community is restricted to two short, narrow beaches. The longest is Playa de Tarena (see Figs. 2 and 10) which is slightly over five miles long extending along the northern shore of the delta. The shorter beach is Playa de Barbacoas extending for about 3.2 miles between Boca de Barbacoas and the entrance to Bahía de Candelaria (see Fig. 2). The flora is decidedly richer along Playa de Tarena than along Playa de Barbacoas, partly because it is a wider, steeper beach having better drainage, and partly because Playa de Barbacoas is littered with decaying organic matter discharged by the river and deposited on shore by waves (see Fig. 11). The reworking of this organic material by the waves has produced beach features similar to those in sand.

Each of these communities forms a pattern that stands out clearly on aerial photographs (see Fig. 4 prepared from aerial photographs). These patterns and the differences in color tone and height of the plant assemblages greatly facilitate mapping of plant communities. The mangrove is darker than the other trees of the delta and confined to the narrow tidal zone along the shore. The natural levee growth is higher than the mangrove, lighter in color, separated from the mangrove by narrow strips of lighter, shorter vegetation, and possesses a coarser texture than the mangrove because of the dominance of the pángana with its large, drooping fronds. The trees of the palm community are lower than the levee or mangrove trees and have an uneven texture caused by the mixture of plants of different heights and colors that compose the palm community. The grass and sedge community is lighter in color and shorter than any of the

FIG. 10. View looking west along Tarena Beach. The beach community is to the left and man is 66 inches tall. The dark spots near the water line are palm stumps truncated by wave erosion.

other types and occurs in the most inland positions in the delta. It also tends to assume rounded patterns interrupted here and there by patches of the palm community. The pattern of this association has been determined by the shape of the round lakes it has choked.

THE RELATIONSHIP BETWEEN VEGETATION AND LAND FORMS

The chief significance of the vegetation of the Atrato Delta to the alluvial morphologist is its value as an indicator of terrain types. Everywhere mangrove occupies the mud flats of the tidal zone, the pángana community clothes the levees, the point bar assemblage marks areas of stagnant or weakly circulating fresh water, and the grass and sedge and palm communities occur in the backswamps.

The mangrove can also be used to determine the relative age of mud flats. It is never the first stage in the plant succession on a new flat, but is preceded by two other stages. The first community established on a new flat is composed of grasses and herbs, and it is followed by aquatic, salt tolerant herbs that occupy the flats during the second stage of the succession. The mangrove is the third community to occupy the flats and does not become established until the flat has been built well above low tide sea level. Thus flats occupied by the mangrove are older than those colonized by herbs and grasses. Bare flats are youngest of all.

Plant growth on the levees is largely controlled by drainage and soil texture. The trees that thrive on the levees have more exacting requirements in soil and drainage than either the mangrove or the backswamp plants. The texture of the levee soils is coarser, insuring better soil drainage and aeration. Since the levees are narrow and restricted the pángana and its associates form narrow strips along the streams. Other vegetation replaces this community where the slope is less and the soil denser.

Interruptions of the pángana vegetation by low growth in narrow strips at right angles to the principal caños indicates crevassing. The vegetation of the levees tends to persist long after distributaries have ceased activity.

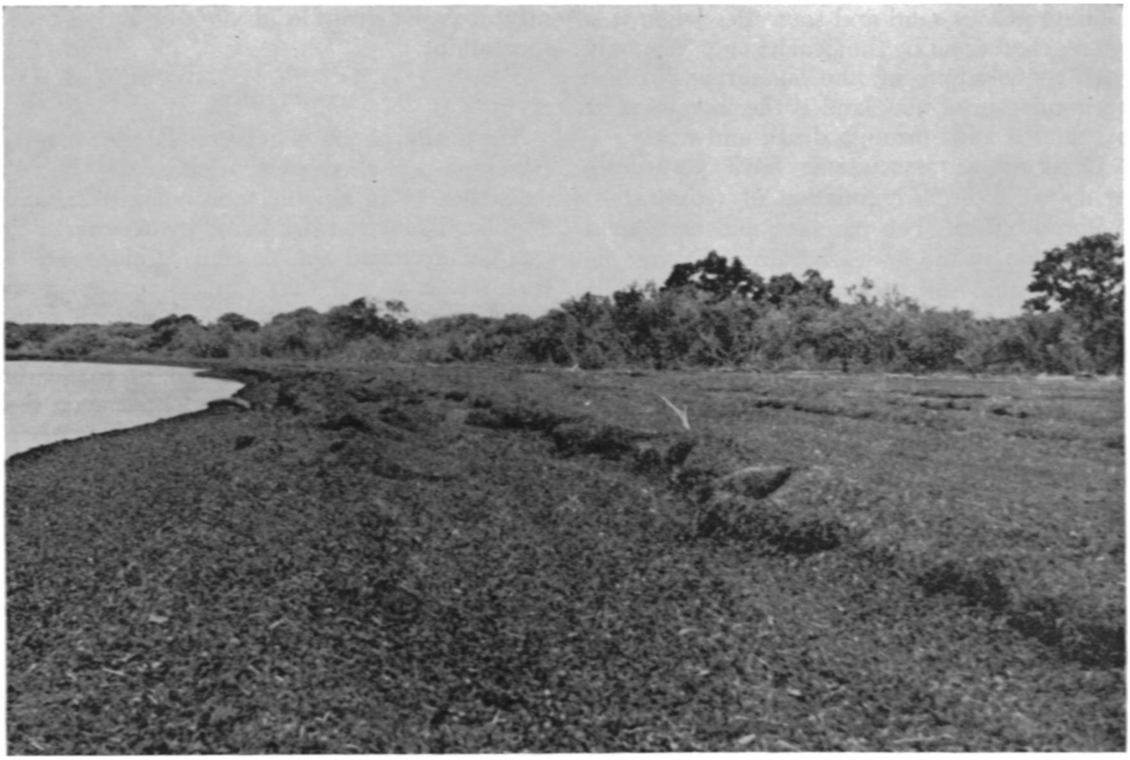

FIG. 11. A section of the Barbacoas beach showing wave modification of organic matter. Note tidal nip and other features usually found in sand beaches.

Throughout the backswamps stranded levee ridges bearing the typical pángana vegetation mark the course of former distributaries. The relative ages of these inactive levees can be estimated from the condition of the vegetation. When the levee ceases to receive sediment from regular floods erosion begins, the soil texture becomes finer, and subsoil and surface drainage begin to change. This causes the gradual deterioration of the levee vegetation, and other plants begin to replace it. A comparison of the state of the vegetation on the various abandoned levees permits estimates of the relative age of the ridges. If soil borings are made through the levee material and used in conjunction with the study of the vegetation it is possible to make even more accurate estimates of the relative age of distributaries. As the levees are reduced in height during their deterioration the plants of the palm community occupy them, and when the ridges are reduced to the level of the backswamp the grass and sedge community replaces the palms and ferns. Therefore, levee remnants surrounded by palms and ferns are younger than those surrounded by grasses and sedges. Using this technique it was determined that caños Coco Grande and Barbacoas are oldest, Urabá intermediate in age, and Tarena and El Roto youngest.

VEGETATION AND SEDIMENTARY ACCUMULATIONS

The claim is often made that vegetation assists in the formation of deltas by catching and holding sediment. There is little evidence to support this contention in the Atrato Delta. Each plant community of the delta must have a certain type of terrain before it can thrive.

The mangrove has been especially misrepresented as a sediment accumulator. It is unnecessary to go further than a study of the plant succession on new mud flats to prove that this plant is not an effective accumulator of sediment. Mangrove does not precede the appearance of new land along the deltaic seashore, but colonizes flats only after they have risen above low tide level. Furthermore, the mangrove has no part in the accumulation of sand along beaches because it cannot long tolerate porous sand and soon dies when it is encroached upon by the beach zone. The only real contribution of the mangrove to the accumulation of new land is the increment of material it adds through death and decay.

Other plant associations have very little to do with the accumulation of sedimentary material either. The pángana and associated plants live on the levees because of favorable drainage and soil texture. Levees must exist before the pángana community can become established. The same may be said of the intermediate community with the possible exception of the arracacha which is often found in river bank locations in very dense stands. Its stems are so close together that they trap small amounts of sediment, but the amount is so small that it adds very little to the formation of the bank. Many of the secondary plants of the grass and sedge community are aquatics that trap very little sediment. Plants that have root systems capable of catching and holding appreciable amounts of sediment do not become established in the interior of the backswamps until the ciénagas and caños become choked by dead vegetation and sediment. Furthermore the interior community does not grow in an area of active sedimentation.

CONCLUSION

The study of the vegetation–landform relationships of a tropical delta can be of assistance to an alluvial morphologist in field studies. The writer has found by experience in the Guianas and the eastern Orinoco Delta that this is a tool that can be applied with equal effectiveness elsewhere in tropical lowlands. The recent sediments along the Guiana Coast show the same zonation of plants in relationship to terrain types. There even the different species of mangrove are zoned in accordance with very slight changes in terrain type. In the eastern Orinoco Delta vegetation patterns very similar to those in the Atrato Delta have been observed, and the causes of these patterns seem to be the same as in the Atrato Delta. An appreciation of the relationship between vegetation and landforms in these tropical lowland areas greatly facilitates mapping of landforms, assists in the reconstruction of the most recent shifts of distributaries, and facilitates recognition of the forms of the land surface both in the field and on aerial photographs.