IV. ISLAND STRUCTURES AND THEIR MODIFICATION

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Development of islet strata

The peripheral reef of Jaluit Atoll, like that of other atolls, is composed of rigid, wave-resistant skeletons of corals and coralline algae, with clastic particles or unbroken shells and skeletons of benthonic organisms partly or entirely filling cracks and interstices. In contrast, rocks that rest upon these reefs and that normally form the islets rising above them are very different structurally and texturally. Such rocks consist entirely of accumulations of detrital materials, ranging from sand to boulder size, which are cemented to varying degree. These rocks may or may not exhibit well-developed stratification. Bedding is poorly defined and inconspicuous where coarse material has been laid down in broad sheets or as mounds; it is prominent and in the form of cross-stratification where the normal sorting processes of a beach have been responsible for its development.

The forming of islands upon the peripheral reefs of atolls generally is attributed to the accumulation of detrital debris, at a particular stand of sea level, following initial development of a surface irregularity or nucleus for concentration. Should sea level rise suddenly and appreciably, a probable result would be rapid upward growth of reef-forming organisms so that even the former island area might be covered with the new reef rock; should sea level go down the island doubtless would be destroyed by subaerial processes of erosion. With a relatively constant position of sea level, however, an island may be expected to develop, within certain limits, as a result of geological processes operating under two types of conditions: (1) the normal, day by day processes of deposition and erosion resulting from waves, tides, longshore currents and other regular controls; (2) the occasional great storms which act violently and abruptly modify the environment.

To interpret correctly the history of any particular islet on an atoll, the processes operating under each of the two conditions cited above must be understood and appraised and criteria must be established for recognizing the deposits formed in each instance. Clearly, most islets are formed of deposits representing both normal and storm conditions, but the proportions attributed to each on any particular islet vary widely.

In general, the deposits of normal sediments on an islet consist of sand and small gravel with good sorting and well-developed cross-stratification. Constant reworking by waves and tides tends to remove the very fine materials (below sand size) and to separate fine gravel and sand into distinct layers. Because permanent accumulation of sediments is largely in the lee of the islands, such sediments continuously contribute to a leeward extension of beach deposits and therefore islets normally build in that direction.

Islet deposits developed during major storms, in contrast to those formed in normal times, consist dominantly of gravel, including much of boulder dimensions, that appears to be the product of mass or collective movement. They form ridges along the windward shores and sheet or blanket deposits across large parts of islet interiors. They may also form temporary ridges out on the reef flat. In general, these deposits are characterized by relatively poor sorting and rude stratification, but commonly by fair to good imbrication among flat gravels. Removal of sand-size and smaller particles through winnowing action is normal.

The past history of certain islets on Jaluit Atoll can be deduced in part through examination of sections both in natural exposures and in man-made wells and trenches. On the islet of Jaluit, at Jabor, for instance, exposures in a section (Figs. 14, 15B) across the northeastern part, immediately southwest of the inhabited area, show consolidated, cross-stratified lime sandstone and lime gravel, with laminae dipping lagoonward, only 350 feet from the present seaward margin of the islet as well as near the present lagoon margin. These once-buried remnants indicate the extent to which beach sands have migrated across the reef in this area during early history of the islet.

Also on Jabor, but in a narrow section about a mile farther southwest, a trench dug across the land almost to low tide level illustrates that here, on the other hand, little or no beach sand development is represented (Fig. 15A). This section shows that above typical reef rock in the bottom is a 3-foot layer of brown, well cemented conglomerate, apparently formed under storm conditions during an early stage in the development of this islet. White, poorly consolidated but otherwise similar gravel above apparently had a similar origin at some later date. Thus, in this part of the islet there is no evidence of rocks having been formed by the normal beach accumulation of fine sediments.

Studies on Mejatto Islet illustrate variations during early stages of development in relative contributions of the two types of deposits (normal and storm) similar to those described from Jabor (Figs. 14, 15C-D). The transport of materials towards and into the lagoon is evident from a comparison (cf. Fig. 16) of aerial photographs made prior to OPHELIA (in 1944) and afterwards (in 1958).

Modifications of islet strata resulting from typhoon

A principal objective of the present study has been to determine and record the effects of Typhoon OPHELIA on the geomorphic and structural features of islets on Jaluit Atoll. This has been accomplished by examining in detail, measuring, and plotting in cross-section available data for two islets -- Jabor and Mejatto -- known to have been especially hard hit and awash during the storm. Effects of the typhoon on these islets include both accretion and removal of material and an attempt is made to indicate the distribution and extent of these changes.

Sedimentary deposits, adding to the bulk of Jabor and Mejatto Islets and attributed to Typhoon OPHELIA (possibly also, in part, to the storms of 1957) consist of very slightly weathered or unweathered gravels ranging from pebble to boulder size with very little interstitial sand or other fine particles. They consist in part of material torn loose from the reef front.* Such fresh gravels are readily recognized by color, being uniformly white, in contrast to older gravels that are gray or brown either as a result of algal covering or of weathering in a soil zone. Imbrication is commonly developed among flat gravels, with surfaces dipping in the direction from which the storm waters advanced.

Based upon their geomorphic position, gravel accretions of the typhoon may be divided into three classes. These are (1) gravel tracts that locally form bars on the seaward parts of the reef, (2) shore ridges, referred to as ramparts by many geologists, and (3) gravel sheets or blanket deposits.

Gravel tracts were especially well developed on the reef flat seaward of Jabor Islet (Fig. 15A-B, Pl.I-a,-b), where for most of its length they formed a ridge 8 feet high and 45 to 60 feet wide; they were less well developed seaward of Mejatto Islet. In both places they contained abundant blocks and boulders from one to five feet in diameter, many of which were recently derived from the reef front as shown by their fresh, uneroded surfaces and by the types of coral represented. They had been transported landward as shown by sections across the ridge near Jabor where conspicuous imbrication of large slabs dipping seaward, constitutes the principal structure. At the time of examination, three months after Typhoon OPHELIA, gravel in these tracts had already migrated toward the islet a considerable distance, according to observations of Mackenzie and others who have been on the ground during that interval, and there seems little reason to doubt that normal wave processes will eventually carry them further back and add them to the seaward deposits of the islet.

Shore ridges, as exhibited on the seaward sides of Jabor and Mejatto Islets, are in all essential respects, except location, like the gravel ridges on the reef. They represent an ultimate in accumulation and piling up of coarse debris. They rise higher and contain larger boulders than other geomorphic forms on the islets and indicate the maximum storm concentration along the islet front. Structurally also they appear similar to the gravel ridges or the reef and probably are enlarged by material from these when landward migration has continued sufficiently.

The most significant additions, quantitatively, to the islets during Typhoon OPHELIA, are the blanket deposits of gravel, here termed gravel sheets. These extend as thin layers of white, little-weathered gravel across large parts of those islets that were inundated by storm waters and they appear to have been spread out and deposited in the manner of river flood or glacial outwash plains. Examples on Mejatto Islet (Fig. 16, 17) begin on the seaward side immediately lagoonward of the shore ridge or of scour channels and plunge holes as layers of loose gravel a few inches thick and in places they extend two-thirds or three-fourths of the distance across the islet. They end abruptly, forming a ledge or nearly vertical drop of two or three feet along a sinuous front.

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* This also is Banner's conclusion, see p. 76.

Texturally they are distinctive because of the absence of sand or other fine sediment as matrix. Structurally they form a single bed or layer, but commonly show imbrication of flat slabs within.

Gravel sheets spread over the islets contain particles that vary considerably in size from place to place as shown on Mejatto and Jabor but, in general, the particles in these sheets are considerably finer than gravels of the shore ridges and beach tracts. The gravel sheet appears to have been derived from at least three sources: (1) The outer reef area; (2) earlier shore ridges; and (3) reworking and redistribution of gravel of older sheets, with a winnowing away of soils and fine materials. It was not possible during the present study to determine the relative contributions from each of these sources. A significant observation, however, is that enough gravel was introduced from outside the islet in most parts of the sheet to raise appreciably the general island level in those places and to leave a new stratum of gravel as a record.

Although a considerable amount of sediment, nearly all coarse, was deposited on islets by the floodwaters developed during Typhoon OPHELIA, notable erosion also resulted from these waters. Evidence of such erosion is especially conspicuous in areas on the islets that apparently were occupied by relatively weak sediment adjacent to resistant surfaces. On both Jabor and Mejatto Islets, scour trenches several feet deep were cut into unconsolidated sand deposits landward from and parallel to beds of resistant beach rock that dip toward the sea (Fig. 17). On Mejatto many plunge holes were developed, one of them six feet deep, in weak deposits of sand to the lee of areas tightly bound by the root systems of trees (Fig. 17A-B). Thus, with the advance of water from seaward, a selective scouring developed in unprotected areas southwest of obstructions on the seaward sides of the islets.

Erosion also was considerable in areas bordering the lagoon shores of islets, especially between the margins of newly formed gravel sheets and resistant beach rock of the lagoon edge. In such areas water apparently concentrated in channels to scour out large plunge holes that have subsequently formed tidal pools (Fig. 15D).

A very large amount of fine sediment, especially of sand size, must have been removed from the islets of Jabor and Mejatto by flood waters of Typhoon OPHELIA. These fine sediments were winnowed out of the sandy gravel of the island and were largely stripped from former sand areas. At present the only significant sand areas exposed on these islets are in the bottoms and sides of deep scour channels and undercut areas around trees and beach rock. Some of the large amount of sand that apparently was once present, judging from remnants, now forms bars that extend out into the lagoon at various places; some of it constitutes submarine offshore bars (Fig. 14) formed by waves. The great bulk, however, presumably has been carried into the lagoon whose floor is now considered to have been raised appreciably.

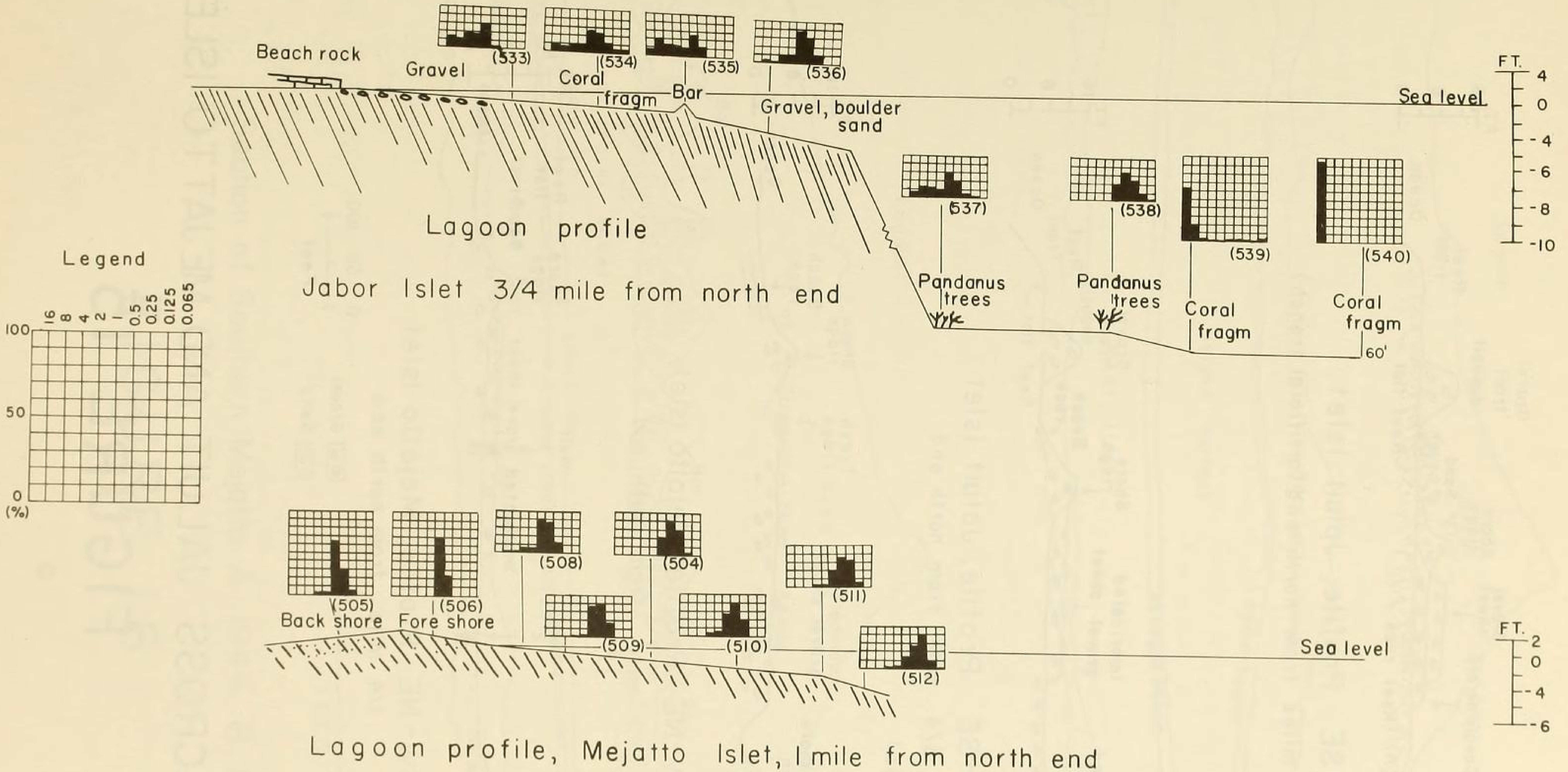
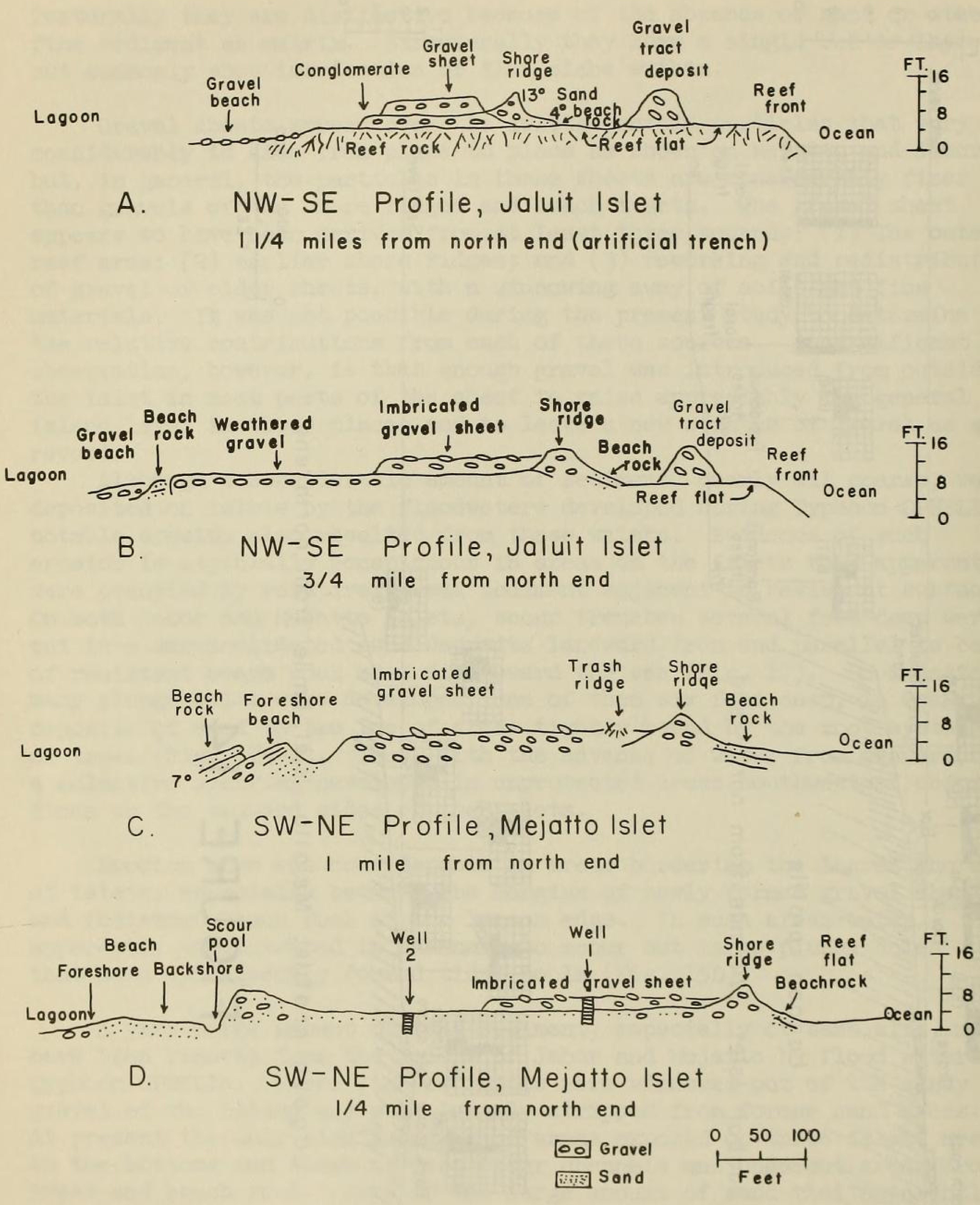
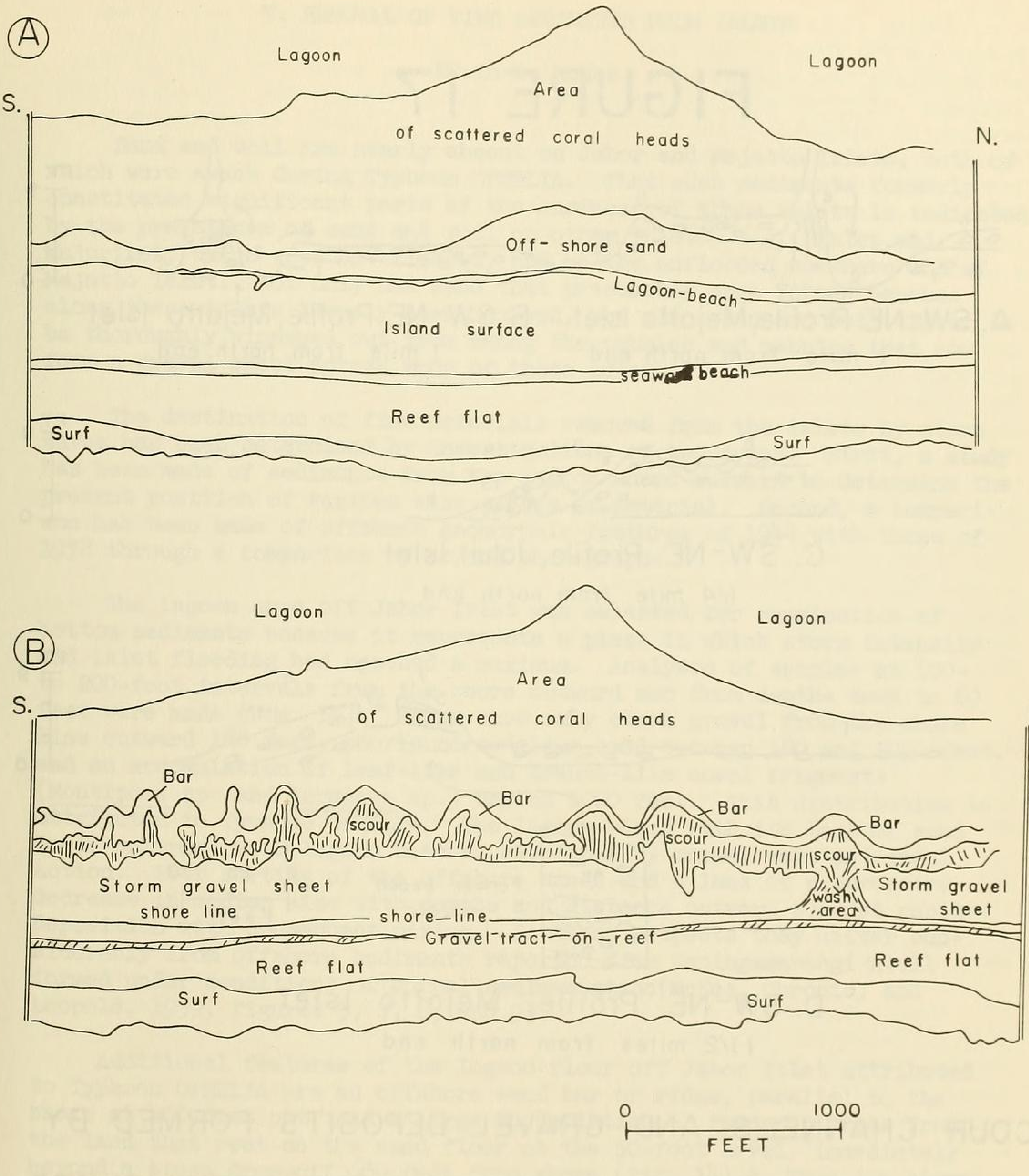

Legend
16
8
4
2
1
0.5
0.25
0.125
0.065
100
50
0
(%)
Beach rock
Gravel
(533)
Coral
fragm
(534)
Bar
(535)
(536)
Gravel, boulder
sand
Sea level
FT.
4
0
-4
-6
-8
-10
Lagoon profile
Jabor Islet 3/4 mile from north end
(537)
Pandanus
trees
(538)
Pandanus
trees
(539)
Coral
fragm
(540)
Coral
fragm
60'
(505)
Back shore
(506)
Fore shore
(508)
(504)
(509)
(510)
(511)
(512)
Sea level
FT.
2
0
-4
-6
Lagoon profile, Mejatto Islet, 1 mile from north end
0
100
200
FEET

FIGURE 14



SECTIONS ACROSS JALUIT AND MEJATTO ISLETS

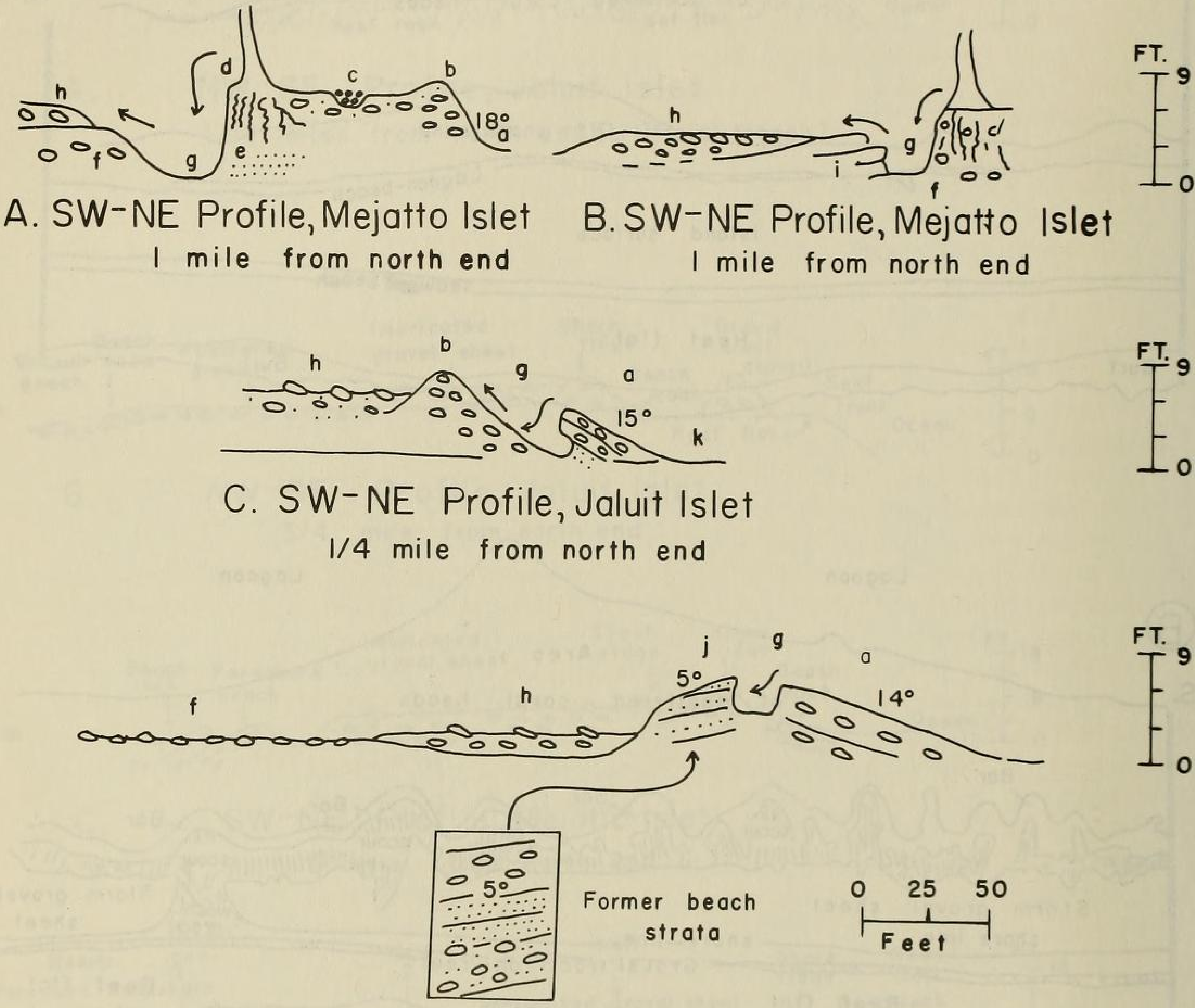
FIGURE 15



Section of Southern Mejatto A: 1944 B: 1958

FIGURE 16

FIGURE 17



A. SW-NE Profile, Mejatto Islet
1 mile from north end

B. SW-NE Profile, Mejatto Islet
1 mile from north end

C. SW-NE Profile, Jaluit Islet
1/4 mile from north end

D. SW-NE Profile, Mejatto Islet
1 1/2 miles from north end

SCOUR CHANNELS AND GRAVEL DEPOSITS FORMED BY TYPHOON OPHELIA ON JALUIT AND MEJATTO ISLETS

a. Beach rock
b. Gravel shore ridge
c. Debris, mostly logs, from typhoon
d. Roots of coconut tree
e. Unconsolidated sand
f. Weathered gravel, unconsolidated
g. Scour pit or scour trench from typhoon
h. Gravel sheet from typhoon
i Beds of conglomerate
j Sandstone, former beach
k Reef flat
↘ Direction of water movement

V. REMOVAL OF FINE SEDIMENTS FROM ISLETS

Edwin D. McKee

Sand and soil are nearly absent on Jabor and Mejatto Islets, both of which were awash during Typhoon OPHELIA. That such sediments formerly constituted significant parts of the surfaces of these islets is indicated by the prevalence of sand and soil on other islets, e.g. Pinlep and Majurirek, which were not flooded, and on the unflooded northern end of Mejatto Islet. Not only has sand that presumably once formed beaches along these islets largely been removed, but also sand and soil appear to be thoroughly winnowed out from among the cobbles and pebbles that now form a gravel sheet across much of these islets.

The destination of fine materials removed from the islets by storm waves has been determined by investigations of two types. First, a study has been made of sediments from the lagoon shore outward to determine the present position of various size-grades of material. Second, a comparison has been made of offshore geomorphic features of 1944 with those of 1958 through a comparison of aerial photographs.

The lagoon area off Jabor Islet was selected for examination of bottom sediments because it represents a place in which storm intensity and islet flooding had reached a maximum. Analyses of samples at 100- to 200-foot intervals from the shore outward and from depths down to 60 feet were made (Fig. 14). These show only coral gravel from the shore line outward 180 feet, poorly sorted lime-sand between 180 and 1000 feet, and an accumulation of leaf-like and branch-like coral fragments (Montipora sp. and Acropora sp.) beyond 1000 feet. This distribution is attributed to Typhoon OPHELIA. The lagoon beach with its lack of sand is in contrast with lagoon beaches developed by normal wave and tidal action. Poor sorting of the offshore sands and a lack of progressive decrease in median size with depths and distance outward suggest rapid deposition with consequent mixing. In those respects they differ considerably from offshore sediments reported from Kapingamarangi Atoll formed under conditions of normal sedimentation(McKee, Chronic, and Leopold, 1959, figures 5, 7, 8, and 9).

Additional features of the lagoon floor off Jabor Islet attributed to Typhoon OPHELIA are an offshore sand bar or ridge, parallel to the shore at 400 feet out, and a large accumulation of Pandanus trees from the land that rest on the sand floor at the 50-foot level, immediately beyond a steep drop-off 600 feet from shore (Fig. 14).* Thus the storm has left a record offshore consisting of poorly sorted fine sediments and land-derived materials which, if buried and preserved, will appear very different from the normal offshore deposits.

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* See Banner's remarks, pp. 77-78.

Pinlep and Majurirek Islets, where the typhoon effects were great but where flooding of the land did not develop as on Jabor, were also studied from the standpoint of lagoon sediments. Relatively little fine sediment was removed from these islets. Nevertheless, the offshore sands are poorly sorted (figure 18) as on Jabor, and seem to indicate a considerable amount of mixing as far out as samples were taken, 600 to 700 feet, and at depths as great as 15 to 25 feet. In contrast, lagoon beaches on these islets were formed of sand, analyses of which show good to fair sorting similar to that of beaches developed under normal conditions of reworking by waves and tides.

Constituents of offshore sand in the Jaluit Lagoon are shown by sample counts to consist largely of broken and worn pieces of coral, although mollusk shell fragments are also very common in all size grades. The tests of foraminifers, relatively uniform in size, make up more than 50 percent of the particles in the coarse-grain size, but are scarce in other size grades. Other contributions, including sea urchin spines and sections of Halimeda, are quantitatively unimportant. Comparison of these sediments with those accumulated at Kapingamarangi Atoll in similar locations but under normal conditions of waves and currents, suggest that the proportionately smaller amount of foraminifera in the very near-shore waters and their correspondingly greater numbers far out from shore at Jaluit are direct results of redistribution by the typhoon (McKee, Chronic, and Leopold, 1959). The relatively larger amount of coral debris may also be a result.

Studies of bottom sediments on seaward sides of islets on Jaluit Atoll were attempted for comparative purposes. On Jabor and Mejatto Islets sand was absent, probably having been removed by the storm waters that swept from these reef flats entirely across the islets. On Pinlep and Majurirek Islets, where storm effects were less intense, fine sediment of the reef flat was poorly sorted and relatively coarse, median diameters being greater than sand size (figure 18). The sediment was composed largely of coral fragments, contained some broken mollusk shells and Halimeda segments, but no foraminifers. Apparently most of the fine sand, if formerly present, had been removed.

Sand beaches are at present non-existent along much of the lagoon side of Jabor and Mejatto Islets. Aerial photographs taken since Typhoon OPHELIA reveal that a considerable area formerly occupied by beaches on these islets is now scoured to reef rock surface and sand deposits currently form loops, or bars in the offshore waters, each bar appearing as a half circle, convex outward. This pattern is especially well developed and forms a conspicuous feature along the middle part of Mejatto Islet (Fig. 16). Gentle lagoonward slopes and steeper shoreward sides on these bars, as seen in the photographs, are believed to result from gradual reworking of the sand masses by incoming waves off the lagoon.

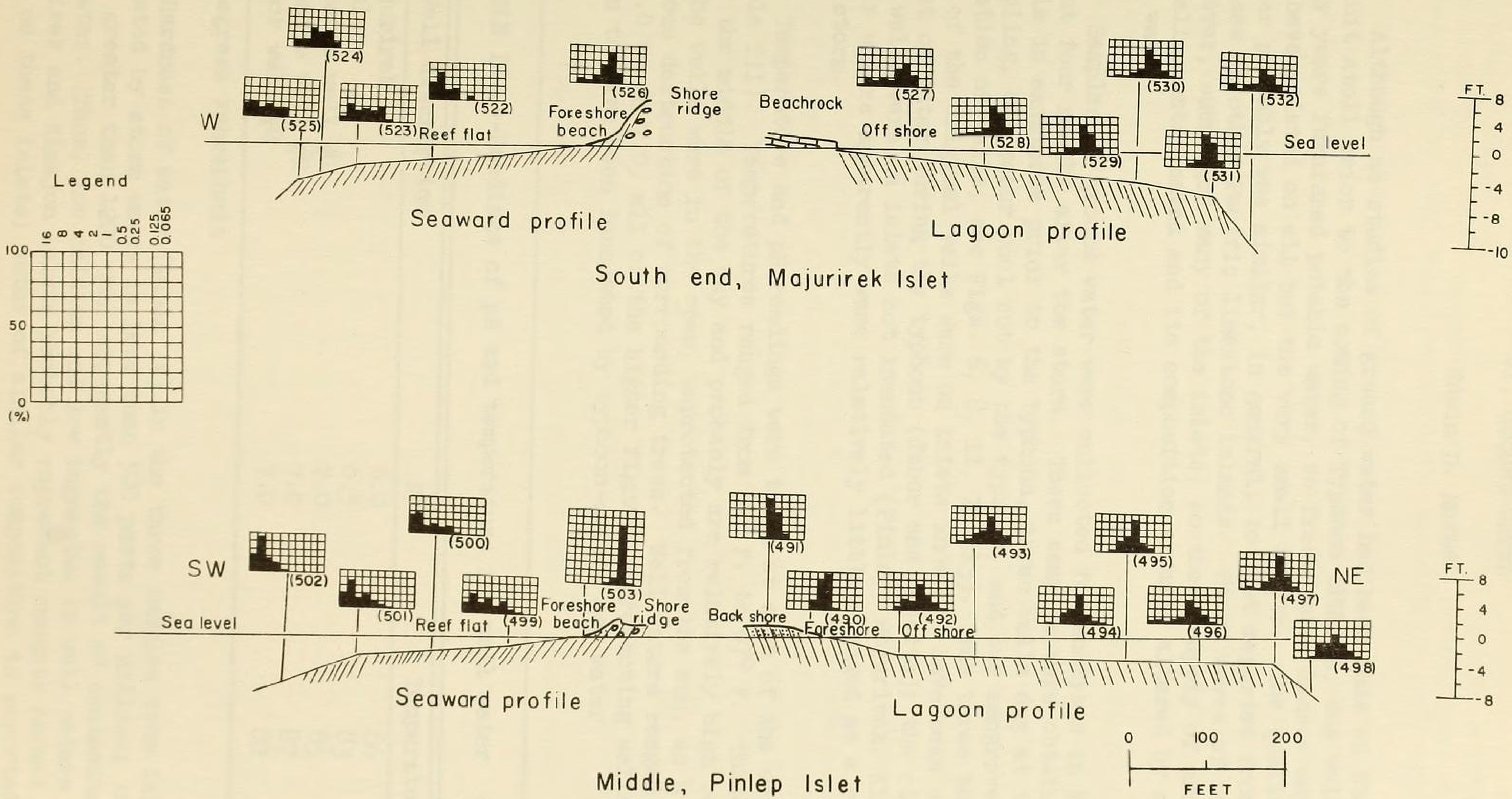
W
Seaward profile
Lagoon profile
South end, Majurirek Islet
Reef flat
Foreshore beach
Shore ridge
Beachrock
Off shore
Sea level
(524)
(525)
(523)
(522)
(526)
(527)
(528)
(529)
(530)
(531)
(532)
FT.
8
4
0
-4
-8
-10
Legend
16
8
4
2
1
0.5
0.25
0.125
0.065
100
50
0
(%)
SW
NE
Sea level
Reef flat
Foreshore beach
Shore ridge
Back shore
Foreshore
Off shore
(502)
(501)
(500)
(499)
(503)
(491)
(490)
(492)
(493)
(494)
(495)
(496)
(497)
(498)
Seaward profile
Lagoon profile
Middle, Pinlep Islet
0
100
200
FEET

FIGURE 18