PART II: OTHER FEATURES

by F. R. Fosberg

Soils

The loose sediments piled above high-tide level on atoll islets are composed almost entirely of clastic limestone debris, mostly of organic origin and varying in size from the finest silt-size particles to enormous boulders many tons in weight (pl. 23B). This material is remarkably uniform in chemical nature but diverse in biological origin, comprising skeletons and fragments of skeletons of such lime-secreting organisms as corals, Foraminifera, mollusks, echinoids, and calcareous red and green algae, as well as all sizes of fragments of limestone consisting of such skeletons cemented together by recrystallized calcareous and phosphatic materials (pls. 28-31, 33). These are mixed in varied proportions without a regular pattern of distribution. The texture range is extremely wide and the range in sorting is far wider than that described above for the beach materials. They are irregularly stratified (pl. 25C), the strata mostly representing stages or events in the deposition of the material. There seems to be little regularity about the vertical or areal arrangement of different grades and mixtures of these sediments, although in general the lagoon sides of the islets are more likely to be sandy in texture, and the seaward sides are more often of coarse material (pls. 21-23). The sampling, unfortunately, scarcely represents the coarser range of these sediments. Previous descriptions of similar material have been given by Sollas and others (1904), David and Sweet (1904), Cloud (1952), Newell (1954a, 1954b, 1956), Fosberg (1954), Tercinier (1955), Schlanger and Brookhart (1955), McKee (1956, 1958), and Fosberg and others (1956).

The loose, unconsolidated materials on the atolls are the parent materials of the majority of the soils developed.

The soils on the islets fall into five principal types (Stone, 1951a; Fosberg, 1954):

1. Essentially unaltered sands and gravels.
2. Stony and very stony areas.
3. Shioya series.
4. Arno Atoll series.
5. Jemo series.

These are described in detail in Part IV.

Drainage

The material of the islets is generally so porous that drainage by percolation down through the ground is perfect and almost instantaneous. There is no running surface water, except during typhoons or tsunamis, when great sea waves may sweep across the islets. Normally there is no standing surface water except where depressions or taro pits extend down to below the maximum water table. An exception to this occurs on islets subjected to intensive military traffic, such as Kwajalein. Here the surface layers become so compacted and, apparently, so cemented as to become more or less impervious. Water puddles may stand in such areas as long as 24 hours after heavy rains.

Vegetation

Most of the original vegetation of the northern Marshall Islands has been replaced by coconut plantations. This is especially true on the larger islets. Only on Taongi (Pokak) (pl. 24A, B), Bikar, and Wotho Atolls was it possible to study considerable areas of apparently undisturbed vegetation; on Lae, Ujae, Ujelang, and Kwajalein Atolls smaller areas were studied (see Fosberg, 1953, 1955; Fosberg and others, 1956). As extensive reports on the vegetation are to be published elsewhere only a brief summary need be given here.

The coconut plantations (pl. 24C, D) range in density from almost complete cover in more moist areas to quite sparse in the dry northernmost atolls. The ground cover under the trees ranges from grass and other herbs to a thick tangle of bushes, vines, and trees, depending on the climate and on how diligently the weeds are kept cleared.

On the seaward sides of most islets a belt of thick scrub and scrub forest (pl. 2A) is left to protect the coconut trees from excessive wind and salt spray. On the windward side this tends to be very dense and to slope gradually to the beach. On more sheltered sides this belt tends to be narrower, taller, less dense, and with a more abrupt slope to the beach, both because trees grow closer to the beach and because shrubs and trees are less stunted by wind and salt spray.

On smaller islets, and on areas left undisturbed on larger ones, there are several types of forest--pure stands of giant soft-wooded _Pisonia_ trees (pl. 25), of fantastic _Pandanus_, of umbrella-like _Ochrosia_, or mixed stands of these and several hardwood species. These forests commonly have dense canopies and little undergrowth. Around the edges a dense scrub fringe gives an appearance of impenetrability.

On sand spits, bars, and narrow places on islets a sparse scrub of pioneer species (pls. 26, 27) is found, grading into forest.

On very small or very rocky islets the woody vegetation may be low and dense, or of irregularly scattered trees and shrubs with patches of sparse bunchgrass and thin low scrub; rock flats may be completely bare of vegetation. Such aspects become more and more predominant as one goes northward in the Marshall Islands, until they characterize almost the entire vegetation of arid Taongi (Pokak) Atoll (pl. 24A, B).

Principal reef-forming animals and plants

Corals, by J. W. Wells

The reef building corals of the Marshall Islands include 52 genera of the Scleractinia, 2 genera of the Alcyonaria (Heliopora and Tubipora), and 1 hydrozoan genus (Millepora). The skeletons of all these are aragonitic, analyses showing $CaCO_3$, 98.05-99.71 percent; $MgCO_3$, 0.09-1.11 percent; and minute amounts of SiO_2, $(Al,Fe)_2O_3$, and traces of $CaSO_4$ and $Ca_3(PO_4)_2$. The texture of the skeleton ranges from porous or spongy in such rapidly growing forms as Acropora, Porites, and Montipora to relatively dense and solid in such relatively slow growers as Favia, Pocillopora, and Heliopora.

The protean scleractinian genus Acropora, with a bewildering array of species (298 named, but less than one-third valid), is easily the dominant coral everywhere on the Indo-Pacific reefs except in regions geographically peripheral to the reef zone. Judging from its frequency in reef rock and loose debris, it accounts in many places for three-quarters or even more of the mass. Locally, according to ecological controls, Acropora may be quantitatively secondary to a few other genera: on algal ridges to windward, Pocillopora commonly is almost the only scleractinian, followed by the hydrozoan Millepora. Behind the ridge, Acropora is dominant over those parts of the reef flat that do not "dry" at ordinary low tide. On many Indo-Pacific reef flats, but only rarely in the Marshall Islands, branching Montipora may be locally abundant even to virtual exclusion of other corals. Near shore, especially where the substratum is of shifting loose debris, Acropora diminishes and dominance is assumed by species of Porites or the alcyonarian "blue coral" Heliopora. Lagoon reefs are easily dominated to considerable depths by Acropora, except close to the shore. On Marshall Islands reefs the overall order of quantitative importance appears to be: Acropora, Porites, Pocillopora, and Heliopora, with Montipora, Astreopora, the faviid genera (as Favia, Favites, Platygyra, Goniastrea, Leptastrea, Cyphastrea, and Plesiastrea), and all others much in the minority.

Foraminifera, by Ruth Todd

Four species of Foraminifera are the chief representatives of this group of animals found in the sediments and soils of the northern Marshall Islands:

Calcarina spengleri (Gmelin)
Amphistegina madagascariensis D'Orbigny
Marginopora vertebralis Blainville
Homotrema rubrum (Lamarck)

In certain of the sands the four together comprise the bulk of the material and, in some places, Calcarina spengleri (Gmelin) alone accounts for most of it.

The entire skeletons of these four genera are composed of calcite. All are rather thick-walled forms with numerous interior chambers and consequently they are more resistant to abrasion on the beaches than are the smaller, thinner-walled and more fragile specimens of Foraminifera that comprise the remainder of the large foraminiferal fauna of the Marshall Islands.

So far as is known at present, Calcarina spengleri (Gmelin) lives only on the reef flat (Cushman, Todd, and Post, 1954, p. 364). Marginopora vertebralis Blainville lives both on the reef flat and in water of shallow to moderate depths inside and outside the atoll. The larger, thicker and more robust forms of this species are presumed to have lived on the reef flat or in shallow water. Homotrema rubrum (Lamarck) is an encrustation that occurs both on the reef flat and in water of probably only shallow depth.

Amphistegina madagascariensis D'Orbigny probably does not actually live on the reef at all, although it is found there in small quantities. Elsewhere, it is very abundant. It probably lives both inside and outside the atolls from shallow to moderate depths, with larger and thicker-walled specimens (such as those in the samples listed below) originating in the shallower parts of the lagoons.

Table 1 records the distribution of these major species in three groups of samples. Samples in (a) with mainly fresh and unworn specimens, indicate little transport from their place of origin; in (b) with worn and some polished specimens, indicate long transport and (or) prolonged abrasion; and in (c), with corroded specimens, may indicate attack by acid solutions.

Algae, by M. S. Doty

In tropical seas certain algae are major accumulators of the material that becomes deposited as calcareous sediment or rock to form the atolls and islands around and on igneous rock bases (Ladd and others, 1953). These algae dominate the atoll reefs and much of the lagoon bottom area. A readily available illustrated resume of these algae has been published by Johnson (1954). Fragments of algae broken from the reef patches and atoll reef edges by wave action or the browsing activities of such animals as the parrot fishes (Scaridae) or surgeon fishes (Acanthuridae) may wash into the lagoon where they contribute to its filling or accumulate as islands on reef tops. Calcareous algae, when ingested by animals such as these fishes, are defecated largely as fine sediment.

Quantitative relationships of four major constituents of present-day reefs are given in table 2. Among the red algae three or four genera are most conspicuous on the reefs of today, Porolithon, Goniolithon, Jania, and Amphiroa.

Table 1.--Foraminifera in various types of terrestrial sediments on atolls in the northern Marshall Islands

Analyst: Ruth Todd

(a) Samples containing fresh (unworn) Foraminifera

Foraminifera	14	18	53	57	60	75	76	92	105	112	126	129	139	156	253	275
Marginopora vertebralis	X	X	X	X	X	X	X	X	...	X	X	...	X	X	X	X
Amphistegina madagascariensis	X	X	X	...	X	X	X	X	...	...	X	...	X	...	X	X
Calcarina spengleri	...	...	X	X	X	X	X	...	X	X	X	X	X	...	X	X
Homotrema rubrum	...	...	...	...	X	...	...	X	...	X	X	...	...	X	X	...

(b) Samples containing worn Foraminifera

	22	25	29	34	36	44	70	72	96	104	110	115	116	120	122	132	150	166	251	254	255
Marginopora vertebralis	X	X	X	...	...	...	...	...	X	X	X	...	...	X	...	...	...	X	...	...	...
Amphistegina madagascariensis	X	X	...	X	...	...	X	...	X	X	X	X	X	X	X	X	X	X	X	...	...
Calcarina spengleri	X	X	X	X	X	X	X	X	...	X	X	X	...	X	X	X	X	...	...	X	X
Homotrema rubrum	X	...	...	...	...	X	X	...	...	X	...	X	...	...	...	X	...	X	...	...	X
							1/ p	p			p			p					p	p	p

(c) Samples containing corroded Foraminifera

	21	23	28	71	100	102	114
Marginopora vertebralis	...	...	X	...	X	X	X
Amphistegina madagascariensis	X	X	...	...	...	X	X
Calcarina spengleri	X	X	X	X	X	X	X

1/ polished specimens.

The genus Porolithon is the builder of sea edges of reefs, it is perhaps the principal organism making up the pink stony crusts and heads that may coalesce to form the buttresses and ridges of the reef margin. These buttresses and overhangs are, on occasion, broken off by storms and deposited inland or on the reef flat, often as huge and conspicuous reef boulders. Smaller fragments make up much of the island gravels and sand grains. It is to be noted that some of the huge chunks broken from the reef edge by storms become lodged in the grooves between the marginal reef buttresses and there, after being overgrown, contribute to the roofing-over of the inward ends of the grooves. In the central Pacific the material seen in such areas, often as a pink pavement, is perhaps 90 percent Porolithon onkodes.*/

Goniolithon, another of the lime-producing genera, is a dendritically branched alga of the more inward reef flats and passes between atoll islands. It does not form large detrital pieces, being friable, and is most notably a sand producer. Jania and Amphiroa are flexible jointed coralline algae that form patches of branches a few centimeters high and a millimeter or so in diameter. Upon breaking loose from their site of growth on the reef flats they die, and the soft parts of the joints decay leaving calcareous sediment or sand. This red algal detrital material around Johnston Island (Emery 1956, p. 1511) may be the principal lagoon-filling sediment. In many places a green alga, Halimeda, is the principal constituent of the sand that builds the islands, as in the Caribbean and Bermuda, or one of the principal constituents of lagoon sediments, as in the northern Marshall Islands atolls (Emery and others 1954, p. 58). Halimeda is composed of branches that are made up of heavily calcified, flat, waferlike segments. These segments persist as sand grains of a rather coarse kind after the death of the plant. While Halimeda does grow on reef flats, especially the broader and what we feel to be the older reef flats, it grows most conspicuously in the lagoons where it may densely cover the sides of the lagoon reefs and reef patches and form meadows on the shallower bottoms.

The chemical composition of these algae is shown on table 3. Further studies of chemical composition are reported by Clarke and Wheeler (1917), Lemoine (1911, p. 38-43), and Johnson (1954). The high magnesium content of the red algae is to be noted. This may be one of the sources of the dolomitizing magnesium salts in atoll areas. Whereas there are theories that certain phosphorites have arisen under marine conditions upon decay of marine organisms, from the very white color of young fossil material and the low P_2O_5 content, it is unlikely that these marine algae play such a role. Little is yet known of the biomass of these rocklike organisms. From the chemical analyses it is clear that they are mostly inorganic and thus could be regarded as mostly nonliving.

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*/ The oft-referred-to genus Lithothamnion is, virtually, not to be found on reef surfaces.

Table 2. - Quantitative relationships of the four major constituents of reefs

Constituents	Pearl and Hermes Reef [1]	Southeastern Florida [2]	Bahamas [2]	Murray Islands Australia [1]
Algae, calcareous	48.5	25.1	18.0	42.5
Mollusk	17.8	17.5	12.2	15.2
Coral, madreporarian	16.6	9.3	8.2	34.6
Foraminifera	6.3	9.0	17.3	4.1
Total (percent)	89.2	60.9	55.7	96.4
Constituent ratios				
Algae/coral	2.92	2.70	2.20	1.23
Algae/mollusk	2.72	1.43	1.47	2.79
Algae/Foraminifera	7.70	2.80	1.04	10.03
Mollusk/Foraminifera	2.82	1.94	.71	3.71
Mollusk/coral	1.07	1.88	1.49	.44
Coral/Foraminifera	2.64	1.01	.47	8.44

[1] Data from T. W. Vaughan, 1917.
[2] Data from Thorp, 1936, p. 52.

The results of Odum and Odum (1955) indicated that there is uniform concentration of chlorophyll (equivalent to between 0.05 and 0.10 gm/cm of Codium edule, dry weight) over the reef surface regardless of substratum, whether it be coralline crust, animal coral, or detrital. Sargent and Austin (1949) and Odum and Odum (1955) have shown that there may grow and be deposited as much as 1.4 to 1.6 cm of material per year over a reef surface. Under more ideal conditions growth may be much faster. For all practical purposes, reef surfaces are generally in equilibrium with as much material being removed by erosion as is deposited by the living organisms. Thus this increase of about 1.5 cm per year times the area involved can be used as a figure for calculating a maximum amount of material depositable as clastics that could become soil.

Table 3.--Partial chemical composition of some sediment-forming red algae as percent of dry weight

Sources: Clarke and Wheeler, 1917; Lemoine, 1911; Johnson, 1954

Algal species	CO_2 in ashed samples 1/	CO_2 in samples not ignited 1/	Organic matter	Moisture in air-dried samples	SiO_2	R_2O_3	CaO	MgO	SO_3	P_2O_5	SrO	Total
Porolithon onkodes	...	37.5	2/ 12.9	1.34	Tr	Tr	33.3	7.49	.68	1	1.03	94.2
	...	35.3	2/ 12.9	1.40	do.	do.	32.7	7.16	2.32	1	1.21	93.0
Porolithon gardneri	3.43	36.8	12.7	.67	do.	do.	34.0	7.64	1.03	.25	1.10	94.2
	2.96	37.4	11.8	.68	do.	do.	34.3	7.62	.28	.38	1.18	93.6
Porolithon aequinoctiale	3.27	28.2	21.5	1.72	do.	do.	31.9	8.62	2.05	1	.97	96.0
	2.88	28.4	21.0	1.54	do.	do.	31.9	8.46	1.84	1	1.10	94.2

1/ Determined by HCl titration. 2/ Loss in weight to 550° C.

Note: These percentages should not total 100 percent, as all the constituents were not determined. The figures for CO_2 in ashed samples should not be included in totals.

Legends of plates

Plate 23. Miscellaneous deposits.
- A. Dunes on sand spit, south end of Enajelar islet, east side of Ailuk Atoll.
- B. Large boulder in interior of Kamwome islet, Taongi (Pokak) Atoll, apparently carried some hundred meters inland by storm waves.
- C. Mass of pumice pebbles on surface of ground, interior of south extension of Ebbetyu (Ebeju) islet, Ujae Atoll.
- D. Top of broad boulder ridge, apparently piled up by typhoon, Utirik islet, Utirik Atoll.

Photos by Fosberg.

Plate 24. Types of vegetation on islets.
- A. Lepturus grassland with shrubs of Sida fallax and scattered trees of Messerschmidia argentea, boulder covered with guano, on Shioya soil series, Kamwome islet, Taongi (Pokak) Atoll.
- B. Sparse, half-dead Messerschmidia woodland on cobble flats, Kamwome islet, Taongi (Pokak) Atoll.
- C. Coconut grove with thick undergrowth on cleared, disturbed Jemo soil, Jemo island.
- D. Grassy opening in coconut grove on Shioya soil, Jemo island.

Photos by Fosberg.

Plate 25. Pisonia forest and forest soil.
- A. Giant Pisonia grandis tree, Ebbetyu (Ebeju) islet, Ujae Atoll.
- B. Pisonia forest with grassy ground cover, Jemo island.
- C. Soil test pit in Pisonia forest on Bikar islet, Bikar Atoll, showing buried hardpan layer of Jemo soil series.
- D. Pisonia forest, Bikar islet, Bikar Atoll, showing dark humus layer on the surface of the ground, Jemo soil series.

Photos by Fosberg.

Plate 26. Shore and sand-flat vegetation.
- A. Mixed forest on stony soil, Bokerok islet, Ujae Atoll. Wave-cast log, probably Douglas fir from northwest America, in foreground.
- B. Scrub forest of Pemphis acidula on rock platform surface, Jabwe islet, Ailuk Atoll.
- C. Well-developed fringe of Scaevola scrub at top of gravel beach, leeward side, Kalo islet, Ujelang Atoll.
- D. Darkening of bare coral sand by crust of blue-green algae, open areas on west end of Lae islet, Lae Atoll. This crust may contribute to the nitrogen supply of the soil.

Photos by Fosberg.

Plate 27. Pioneer vegetation.

A. Low shrubs of Pemphis acidula on denuded rock platform surface, Jabanngit islet, Ailuk Atoll.

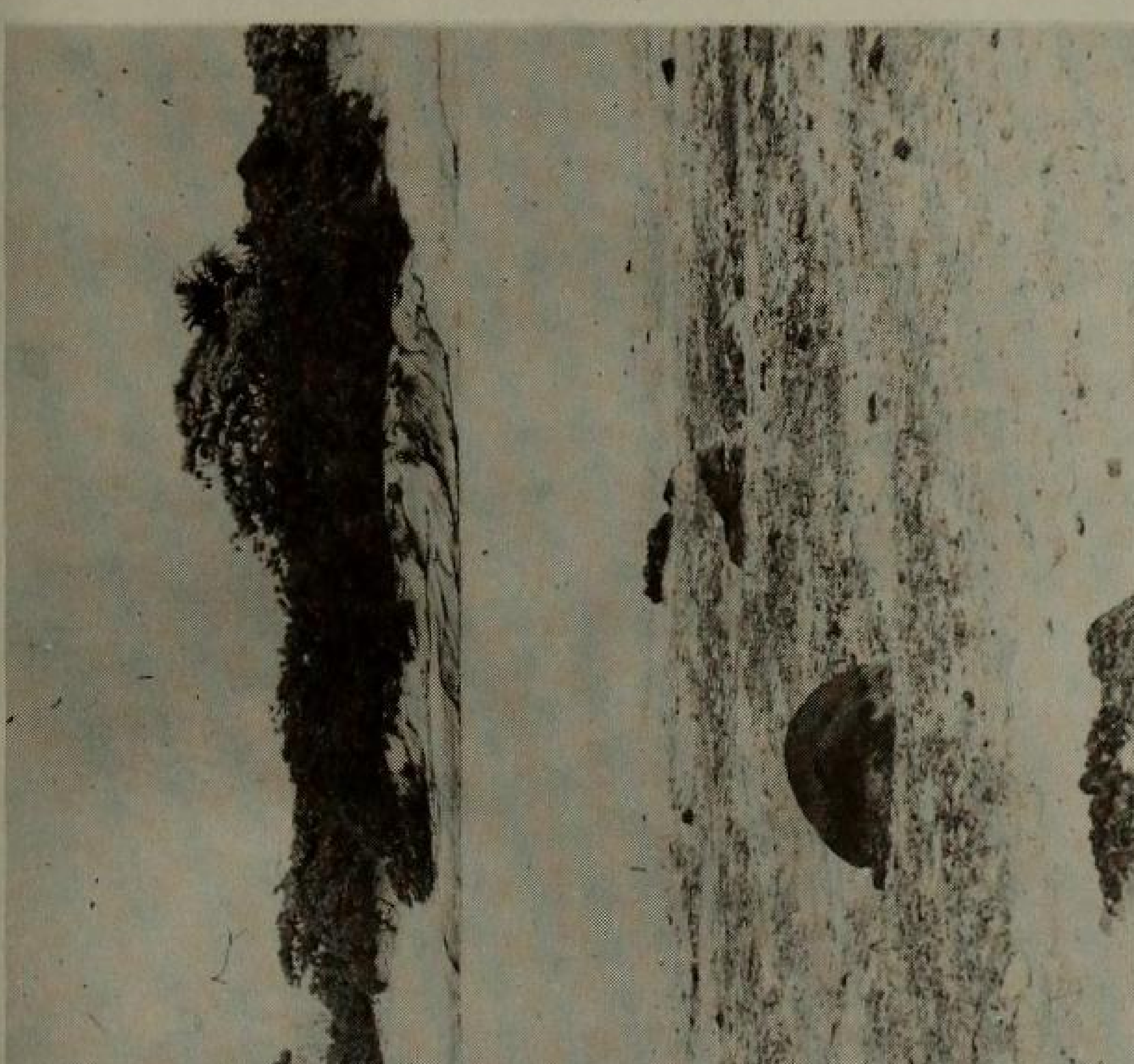
B. Young Scaevola and Messerschmidia plants colonizing gravel bar on south reef of Lae Atoll.

C. Scaevola and Messerschmidia colonizing gravel flat on Kabben islet, Wotho Atoll.

D. Young Scaevola plants colonizing upper part of gravel beach, lagoon side of Bwdije (Breje) islet, Taongi(Pokak) Atoll.

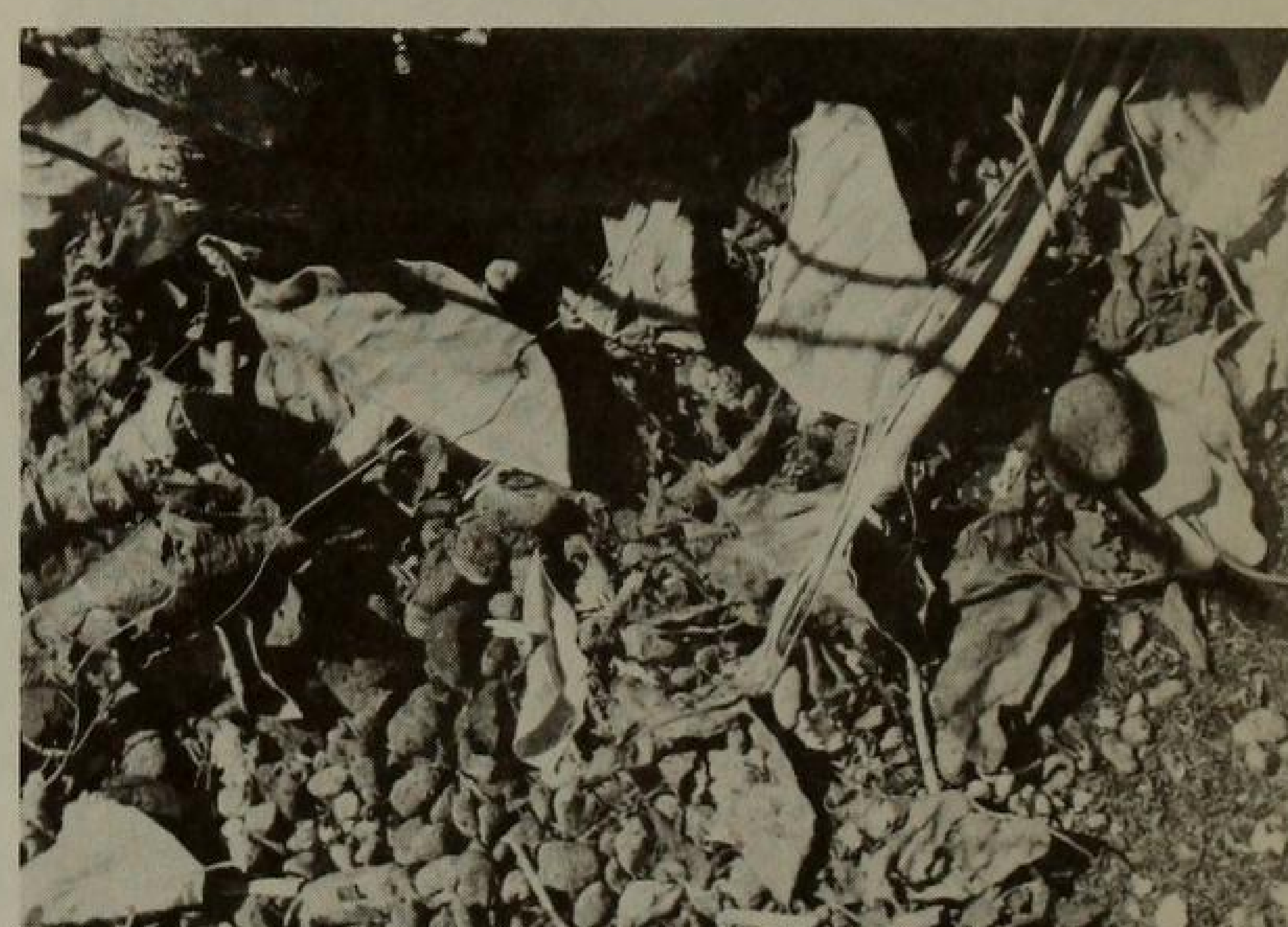
Photos by Fosberg.

Plate 23



A

B



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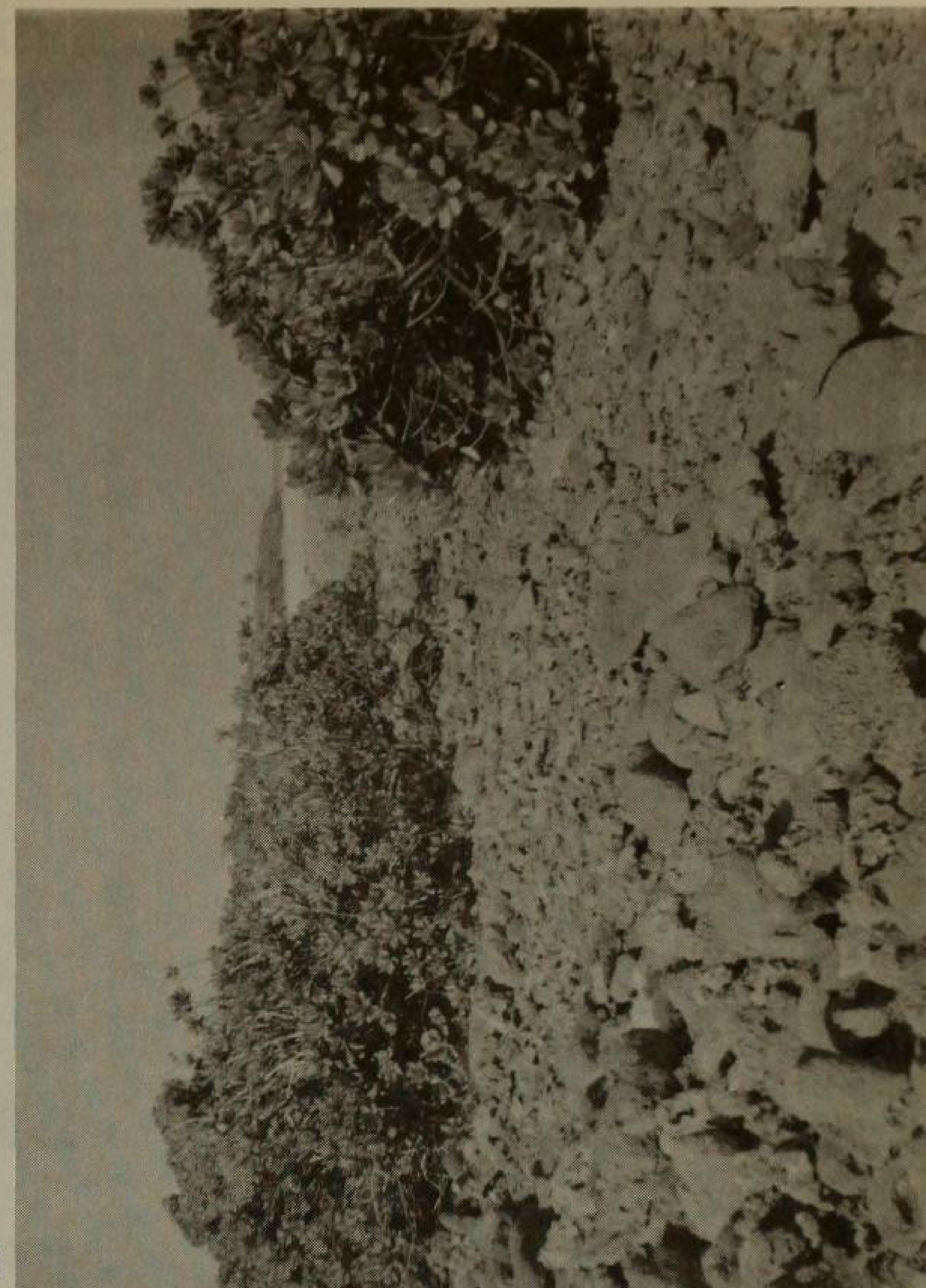
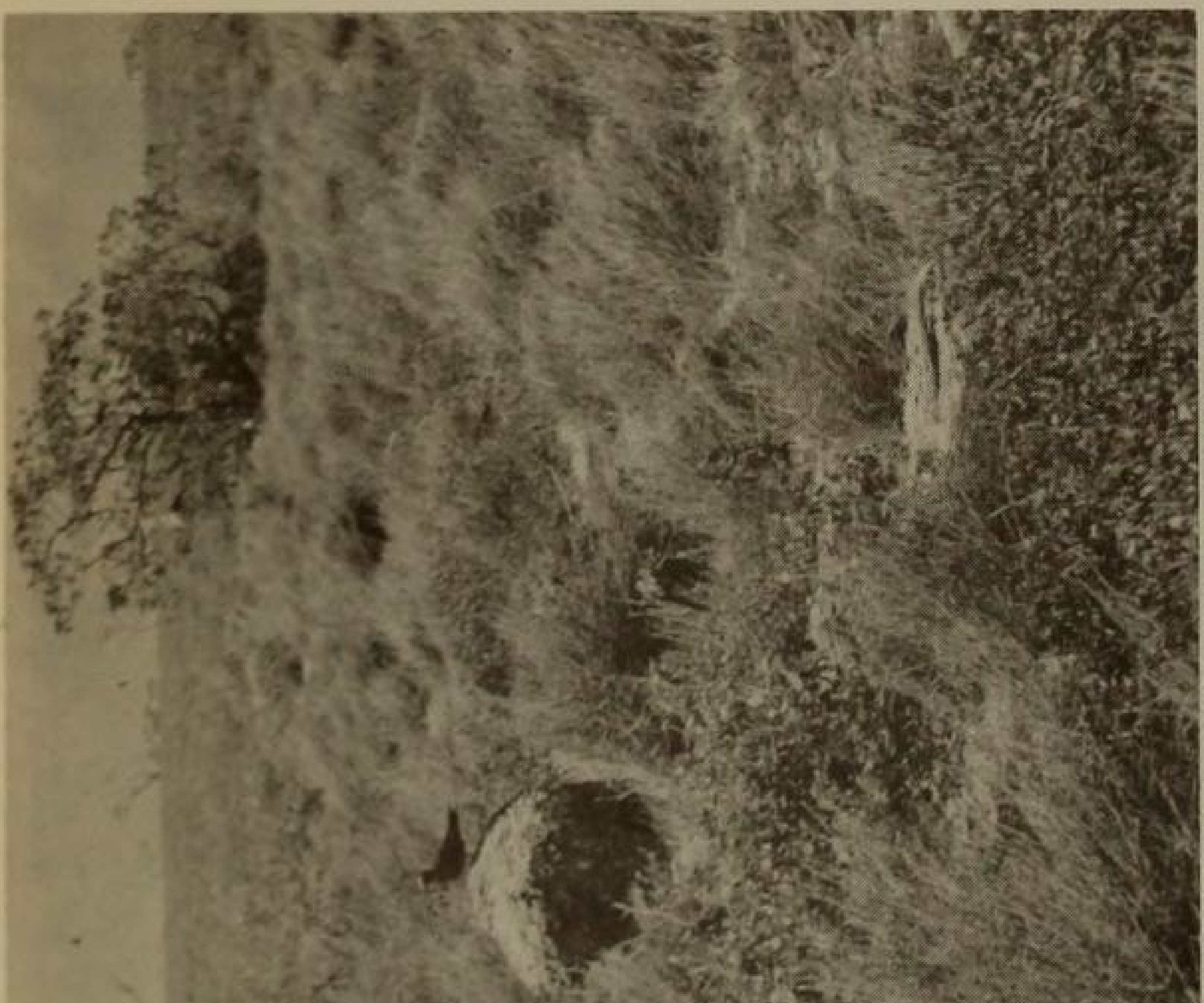


D

Plate 24



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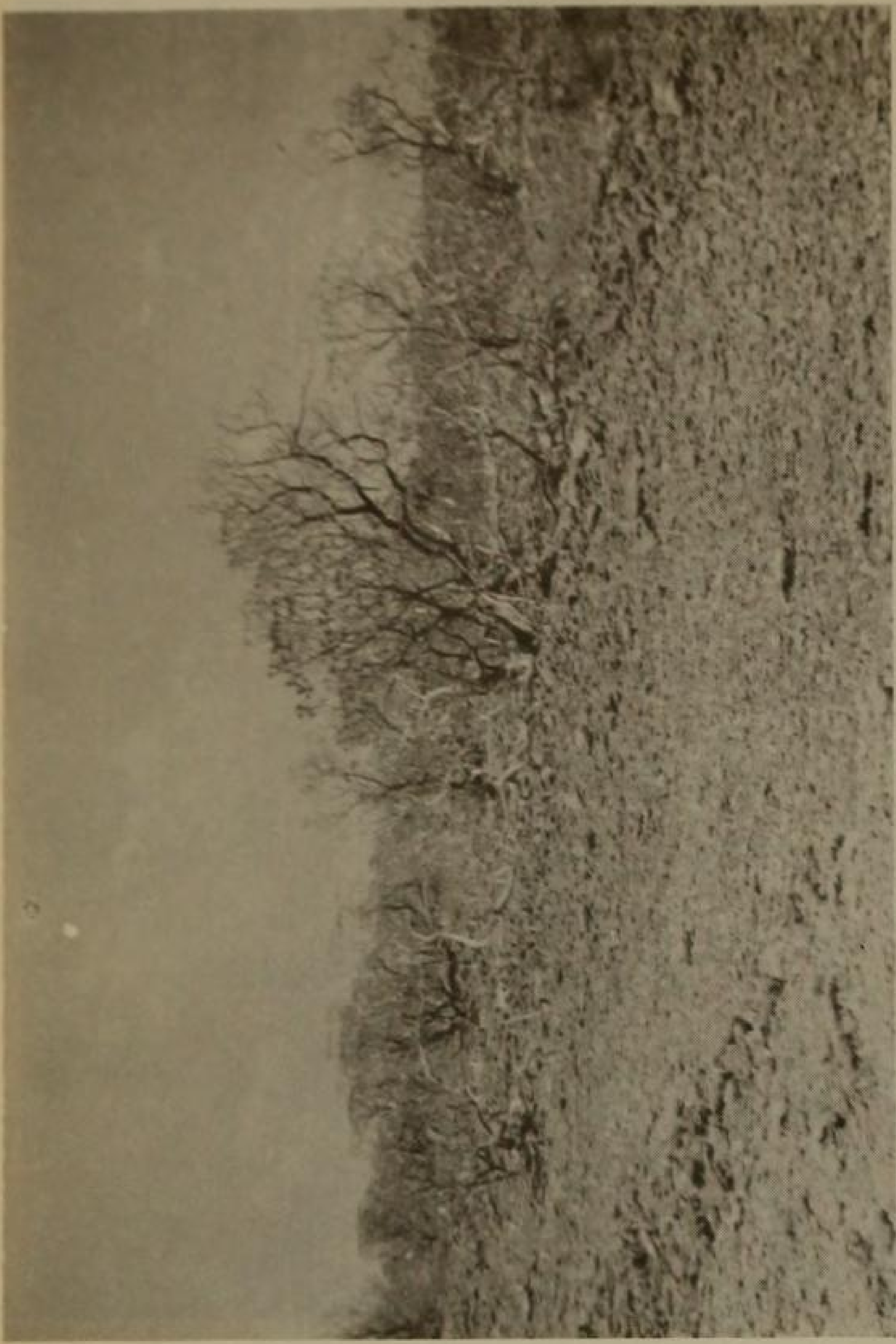

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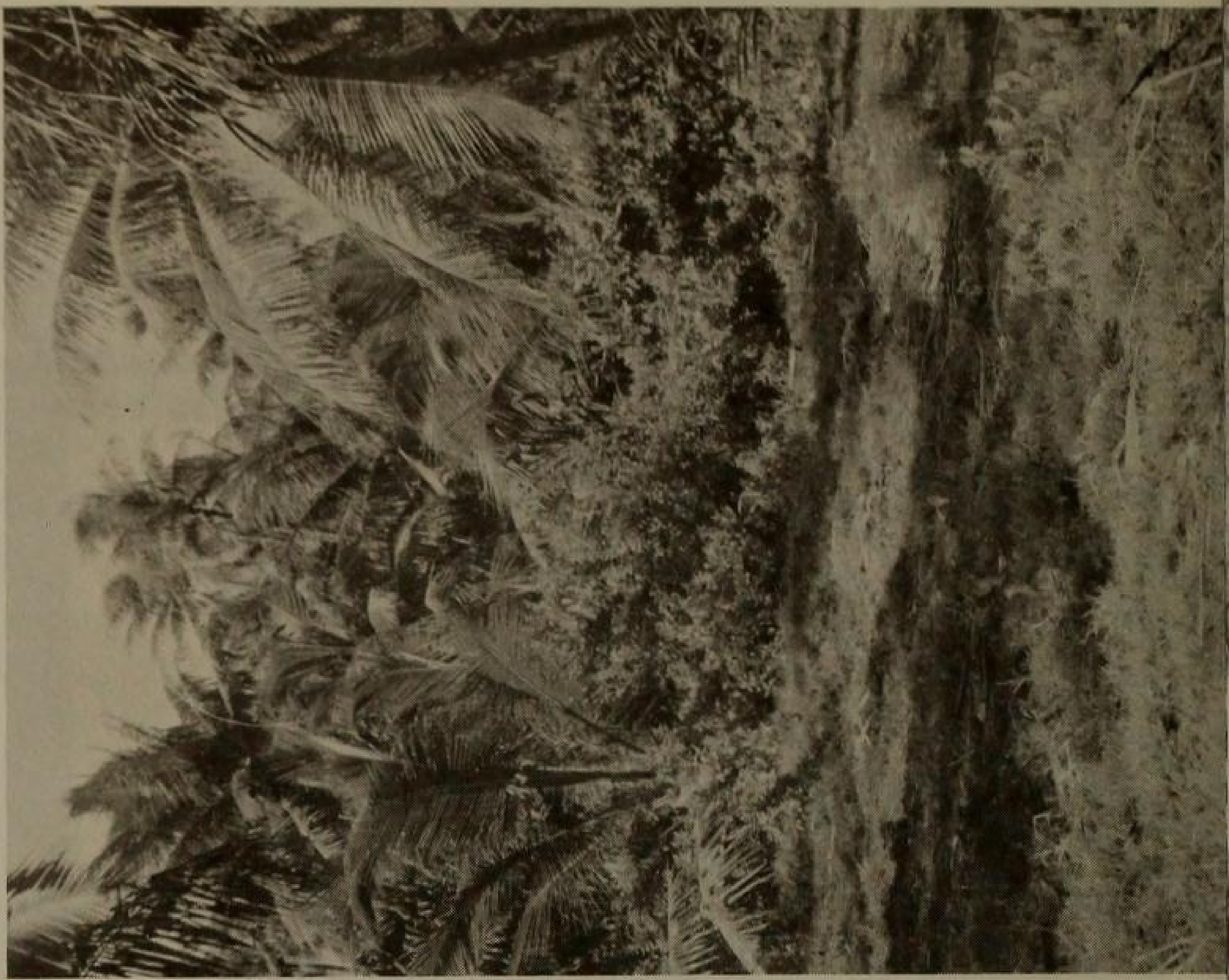
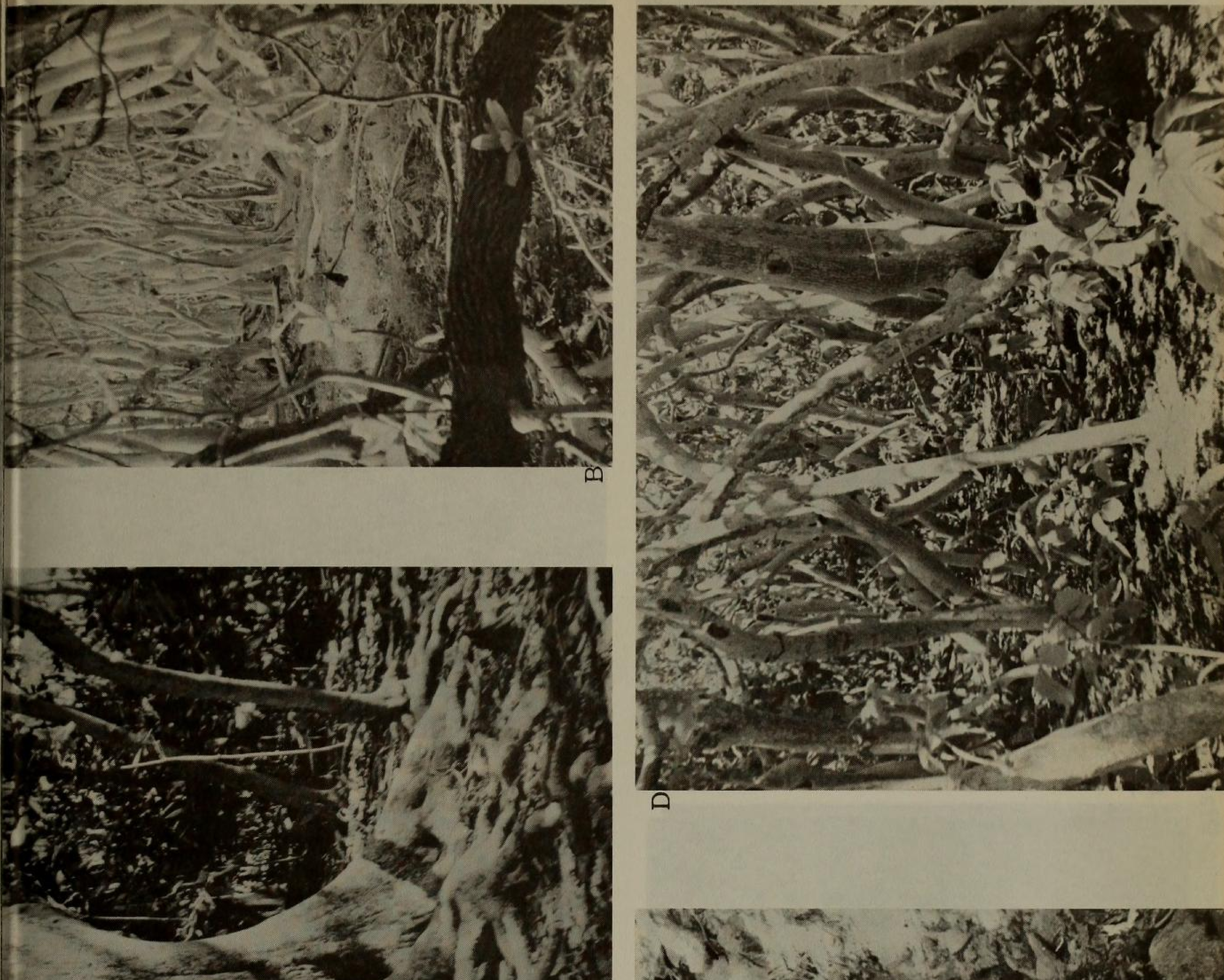
C



D

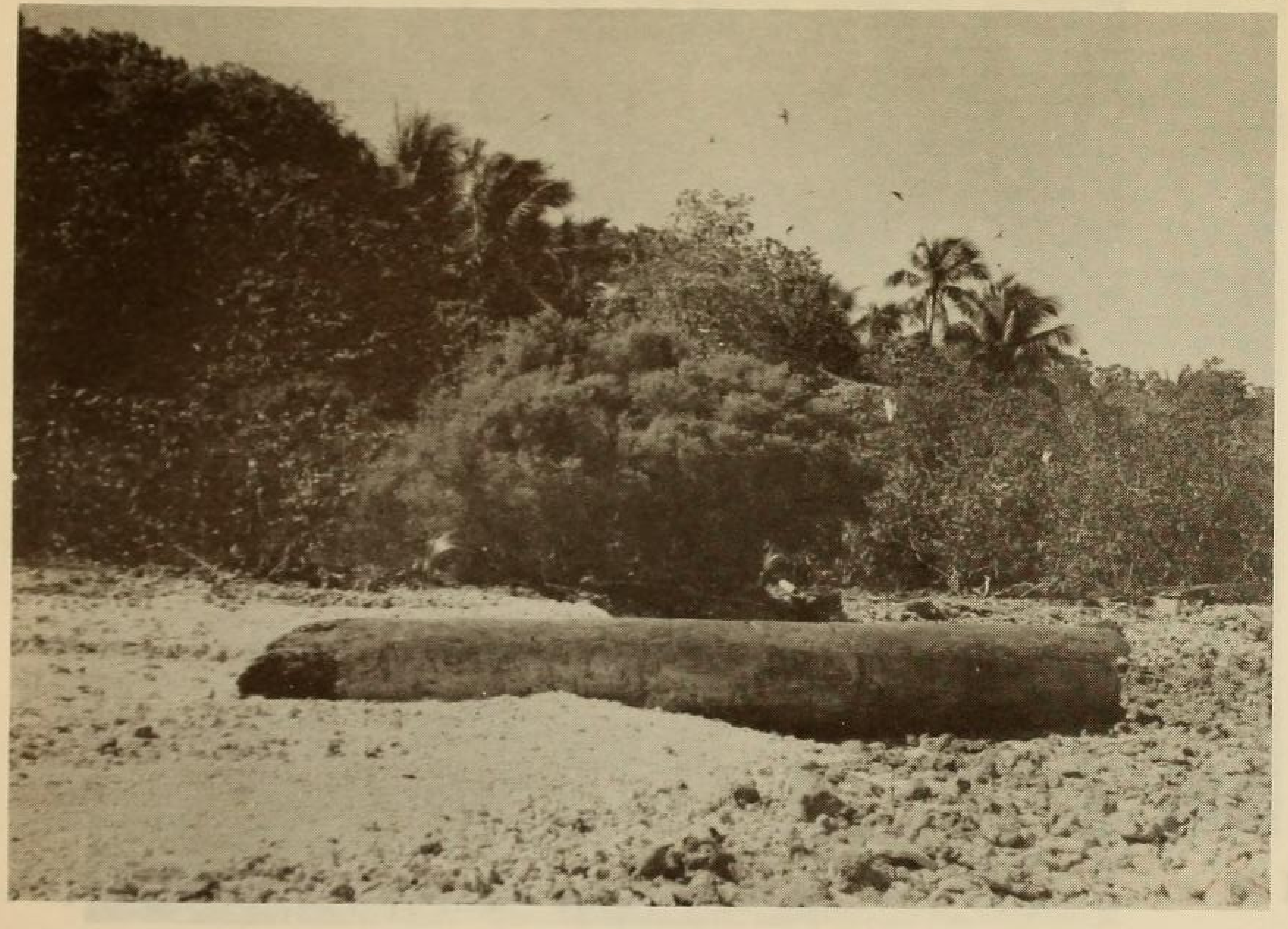
Plate 25



A B C D

Plate 26

A ←



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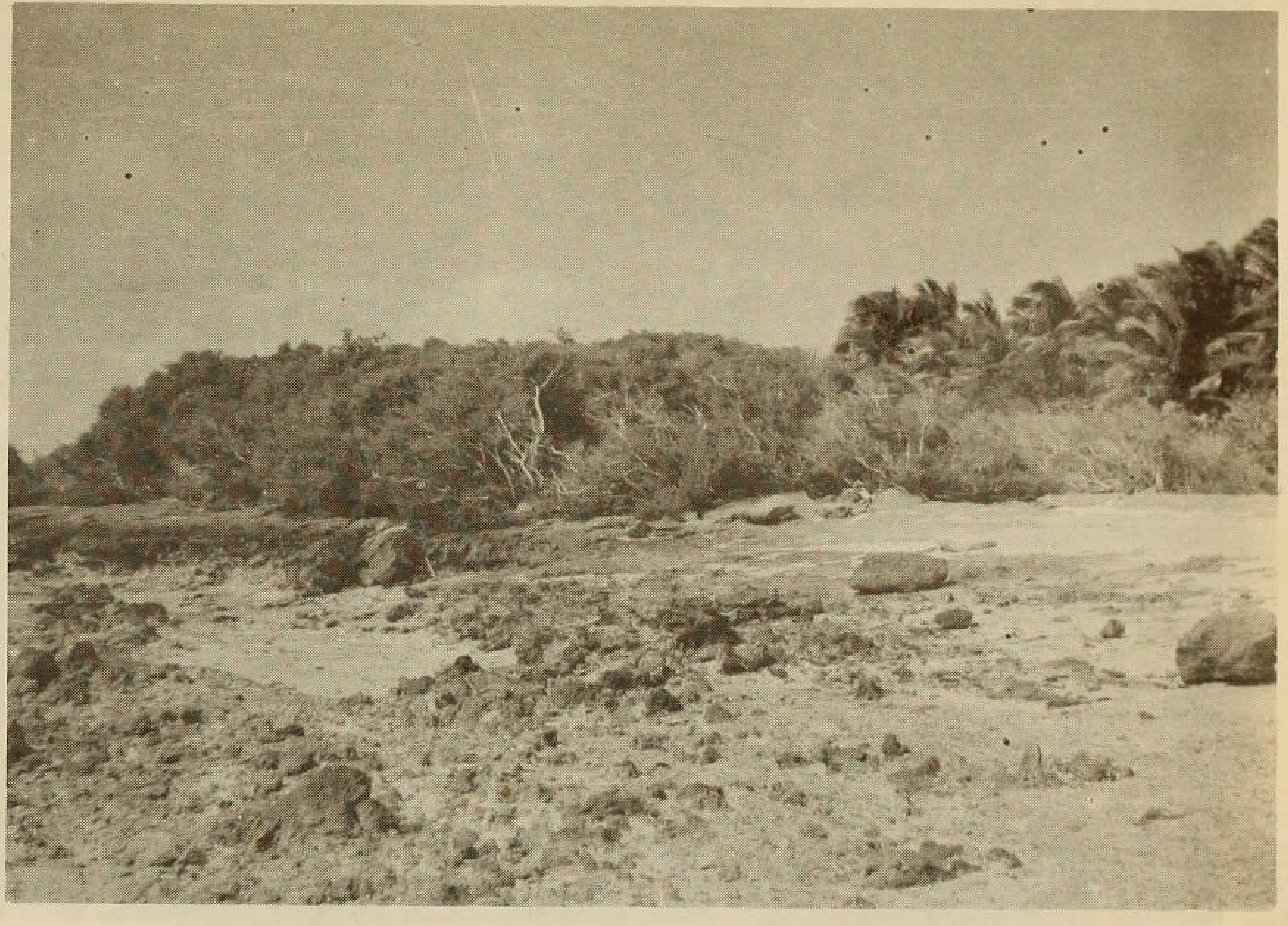

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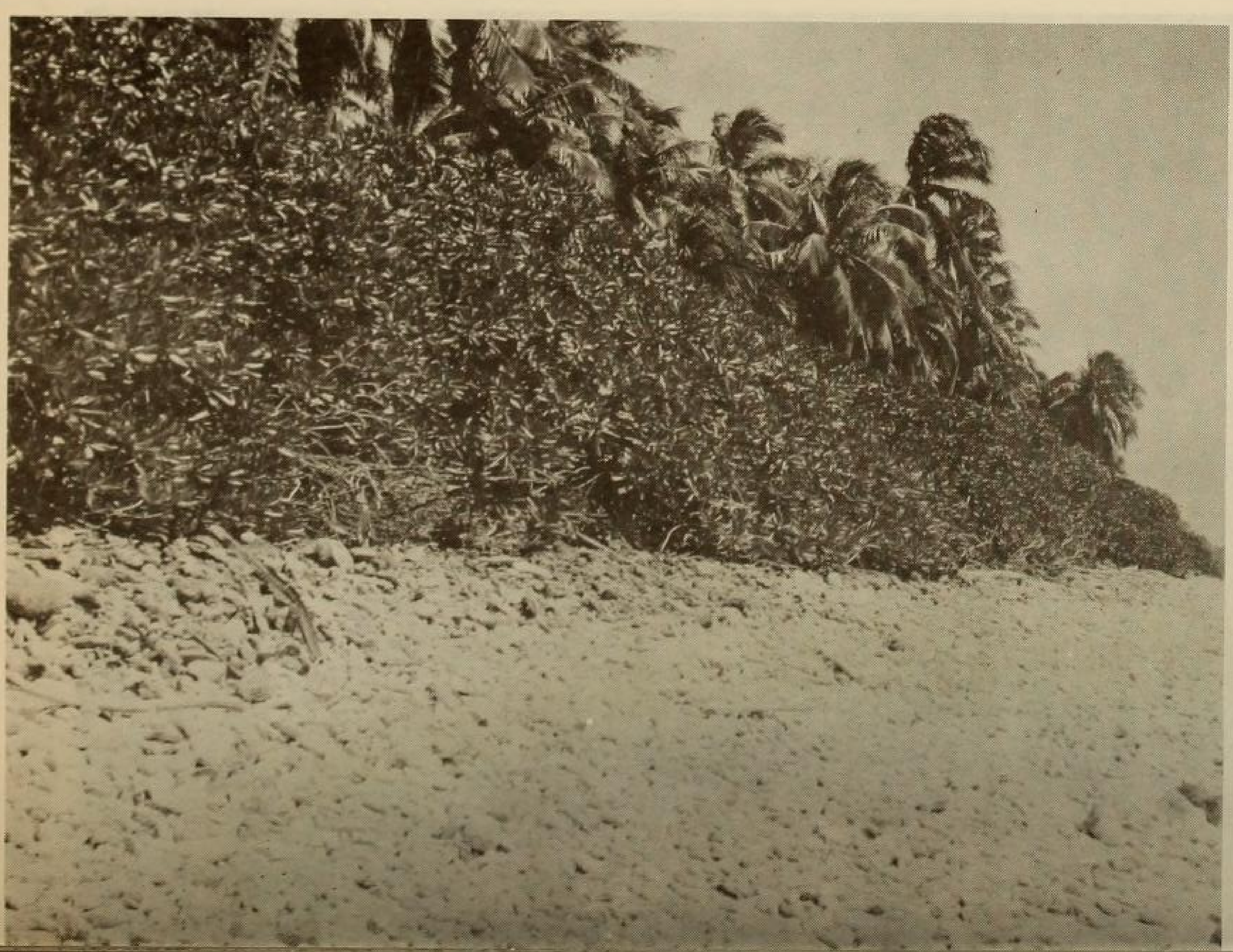

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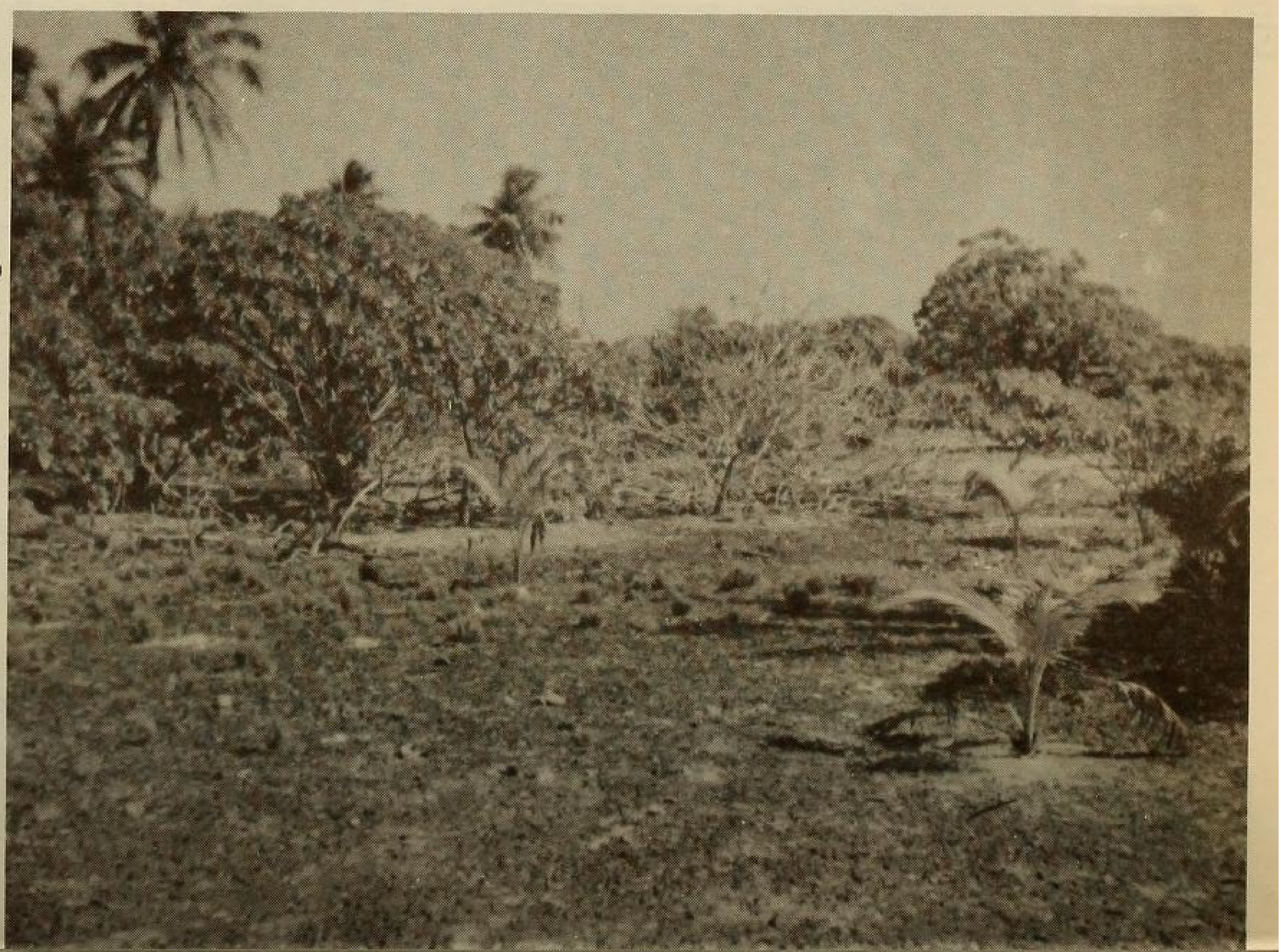

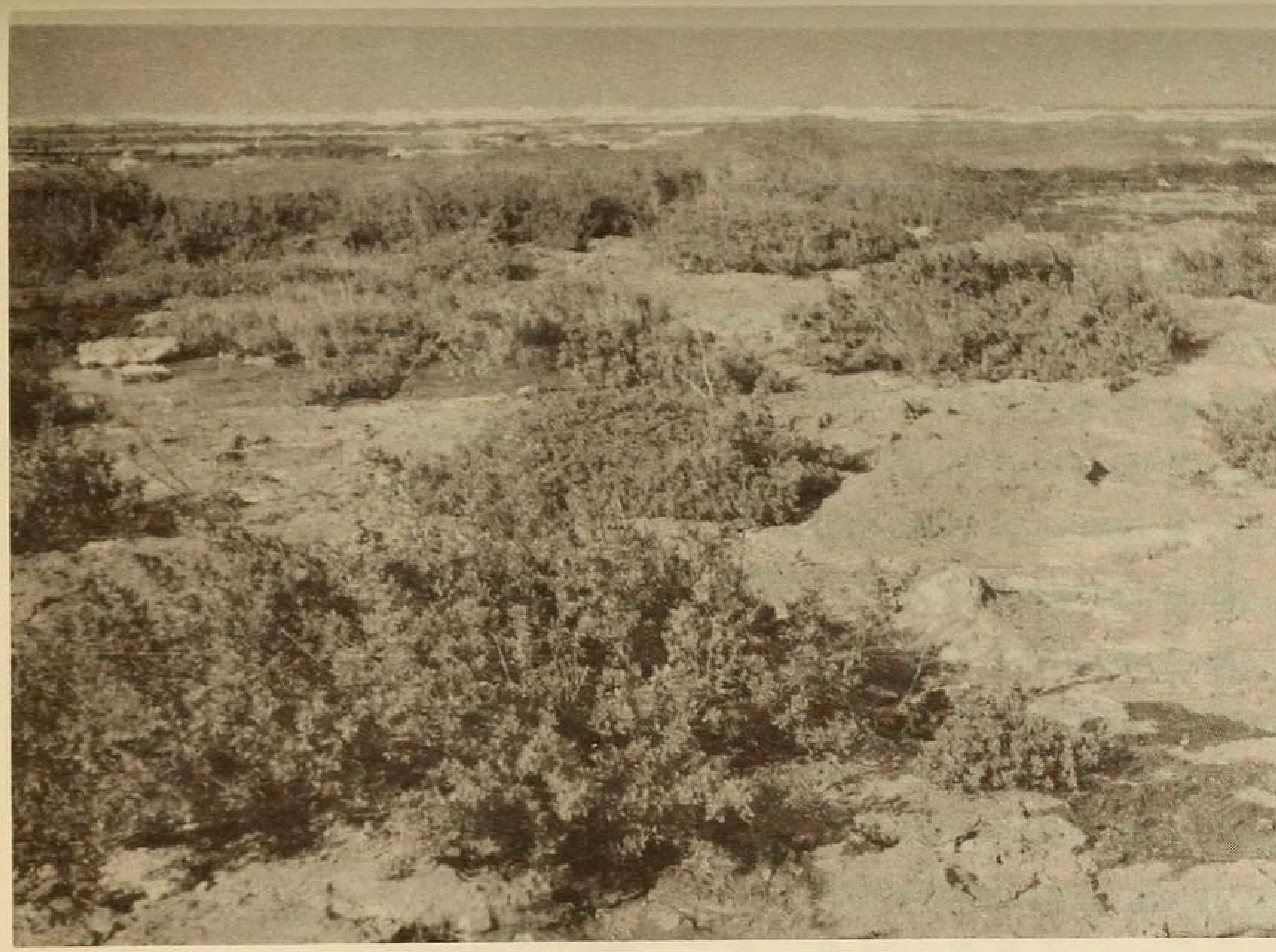

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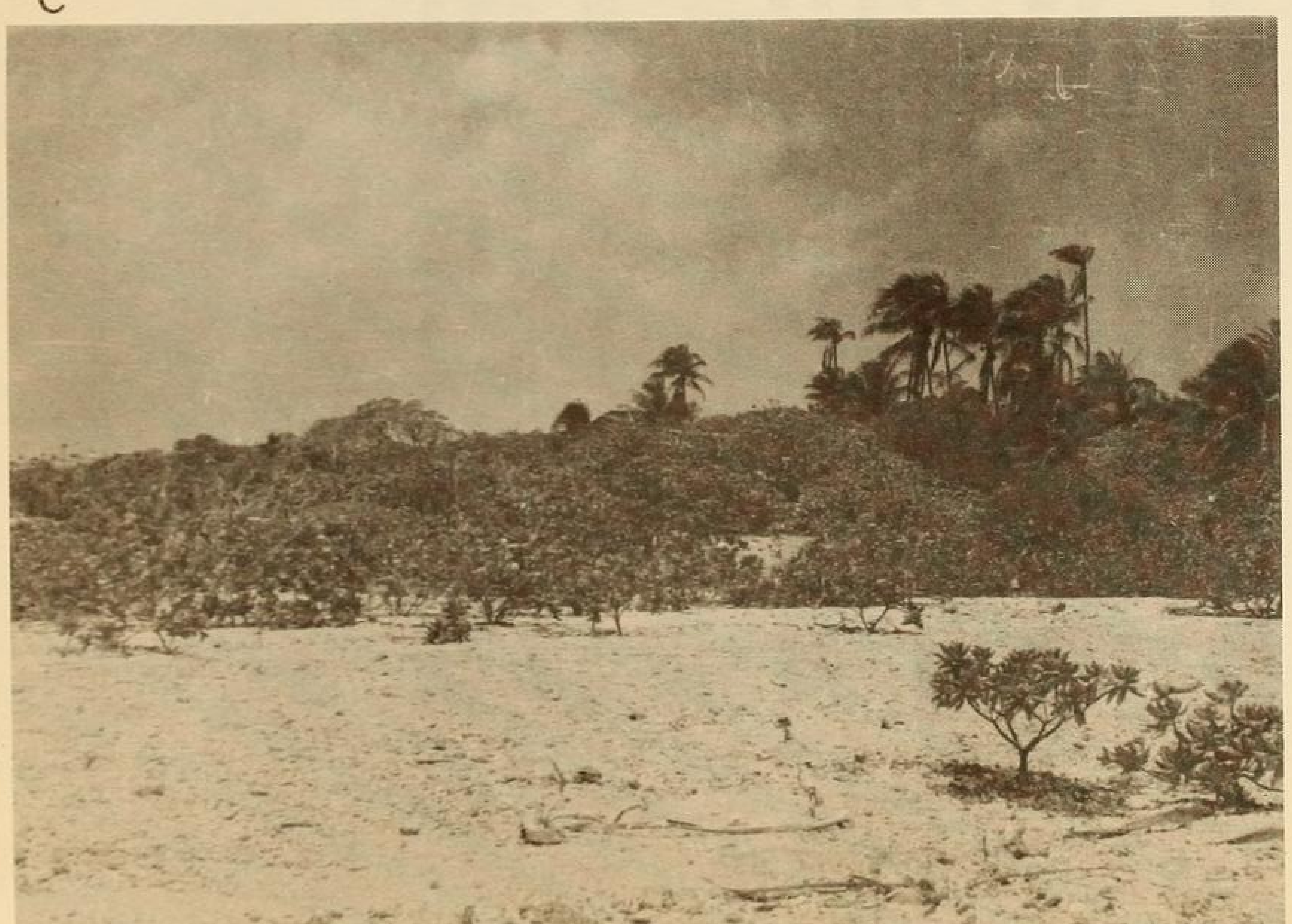

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