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# Geomorphology of Aldabra Atoll

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[Plates 2 to 9]

## 1. Regional setting

Aldabra Atoll (latitude 9° 24′ S, longitude 46° 20′ E) is situated 420 km northwest of Madagascar and 640 km from the East African mainland, in the southwest Indian Ocean (figure 1). It forms one of a group of slightly elevated coral reefs to the north of Madagascar, and is thus distinguished from the sea-level coral reefs of the Farquhar group, the Amirantes, and the central Indian Ocean. The raised reefs of Aldabra, Assumption, Cosmoledo and Astove are situated on the summits of mountains approximately 4000 m high, rising from a fairly flat sea floor between 4000 and 4300 m deep. Aldabra and Assumption cap two neighbouring peaks, which are distinct at depths shallower than 2500 m, and Cosmoledo and Astove another pair, distinct above the 2000 m level (figure 2). The general bottom topography round these islands is based on surveys by H.M.S. *Owen* in 1962. More detailed surveys have been made of Aldabra itself, by H.M.S. *Owen* in 1962 and H.M.S. *Vidal* in 1967, and these soundings are contoured in figure 3.

The deep sea floor from which these island mountains rise forms a basin bounded to the west by the African coast, to the south by Madagascar and the Comoros, and to the east by the Farquhar, Amirantes, and Seychelles–Mascarene Ridge. The bathymetry of this western Indian Ocean area (figure 4) has been studied by Fisher, Johnson & Heezen (1967) and by Fisher, Engel & Hilde (1968). Farther north the basin between the African mainland and the Seychelles Bank has been shown to contain thick sequences of sedimentary rocks and to have a normal crustal structure (Francis, Davies & Hill 1966). The Seychelles–Mascarene Ridge, limiting this basin to the east, appears to be of complex structure. The Seychelles Bank itself is underlain by late Pre-Cambrian granite, which emerges to form the main islands (Baker & Miller 1963; Matthews & Davies 1966). Matthews believes, from geophysical evidence, that similar rocks, with later basic dikes, are found between the Seychelles Bank and the Saya de Malha Bank, and again underlying Cargados Carajos Shoals near the southern end of the Ridge. The Saya de Malha Bank, near the middle of the Seychelles–Mascarene Ridge, is thought to consist of volcanic rocks capped with coral (Shor & Pollard 1963). The islands of Mauritius, Réunion and Rodriguez, at the southern end of the Ridge, are volcanic: radiometric dates of up to 1.54 Ma have been reported for basalts from Rodriguez (McDougall, Upton & Wadsworth 1965).

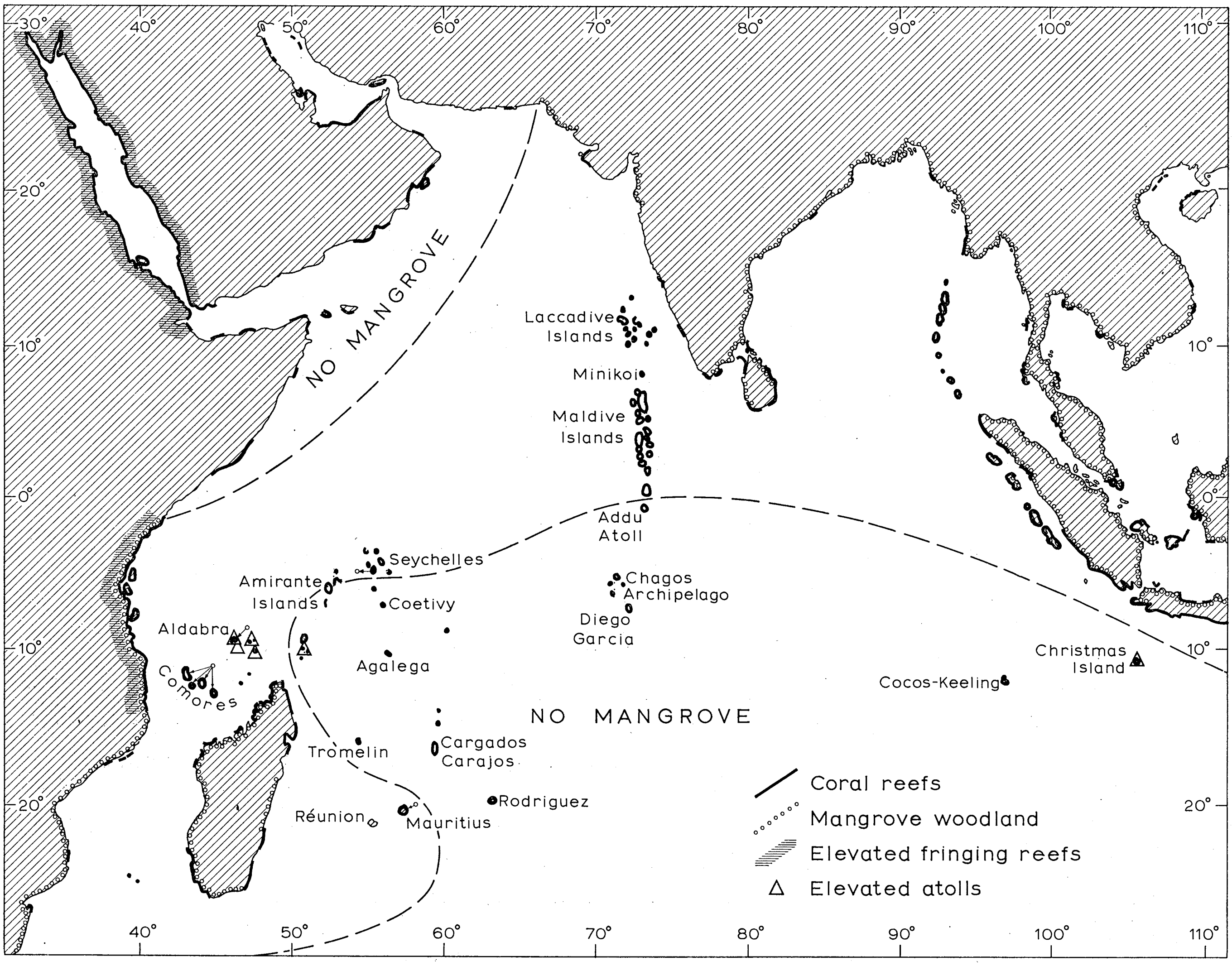

FIGURE 1. Indian Ocean coral reefs and islands, after Stoddart (1969*a*).

The Amirantes Ridge and Trench extend southwards from the western end of the Seychelles Bank. The Ridge probably consists of a coral capping, less than 1 km thick, overlying a basaltic volcanic arc (Matthews & Davies 1966). Little is known of the crustal structure between the Amirantes and the north coast of Madagascar. The isolated nature and considerable relief of the mounts of the Aldabra group, together with the existence of recent volcanoes in the Comoros and massive Tertiary and Quaternary volcanism in Madagascar, suggests a volcanic basement at undetermined depth beneath the islands. Unpublished geophysical work on Aldabra by Matthews and Loncarevic (D. H. Matthews, personal communication) supports this interpretation. Further evidence comes from the dredging of volcanic rocks from two places in the southwest Indian Ocean. First, fragmental basalts, similar to rocks from Madagascar, associated with Foraminifera of probably Eocene–Oligocene (but possibly as old as Upper Cretaceous) age, have been dredged from the slopes of Providence, 480 km east of Aldabra, at a depth of 1360 m (Wiseman 1936). Secondly, basalts dredged from 2400 to 2700 m in the middle Amirantes give K–Ar ages of 82 ± 16 Ma indicating a Middle or Late Cretaceous (or possibly as late as Eocene) age (Fisher *et al.* 1968). This development of volcanic topography presumably took place

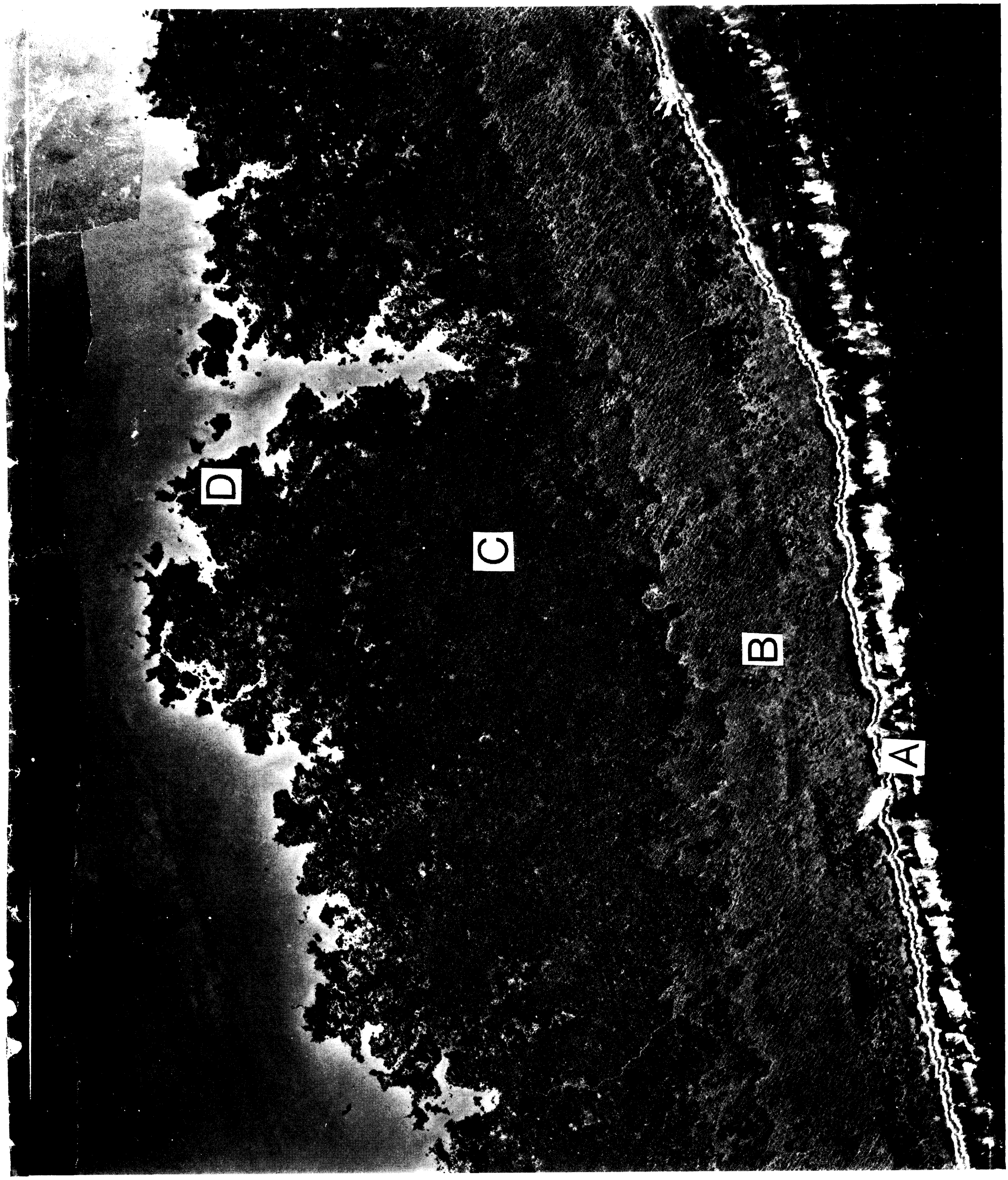

FIGURE 13. South Island from the air, showing (A) the dune at Entreboy and the narrow seaward perched beach; (B) high coastal champignon with low scrub; (C) low champignon with dense scrub of *Pemphis* and *Mystroxylon*; (D) lagoonward mangrove fringe.

Figure 14. The South Island platin from the air, showing (A) dunes at Cinq Cases and the narrow seaward perched beach; (B) high coastal champignon, without vegetation; (C) platin with open woodland and numerous pools; (D) the bare inland fringe of the mangroves, with scattered trees of *Lumnitzera* and *Avicennia*; (E) the mangroves of Bras Takamaka.

FIGURE 15. Main and West Channels from the air.

FIGURE 16. East Channel from the air. Figures 13–16 are reproduced by permission of the Commissioner of the British Indian Ocean Territory. (Crown copyright reserved.)

after the main lineaments of the southwest Indian Ocean, particularly the relative positions of Madagascar and the Seychelles, had been formed.

Interpretation of geophysical data, mainly from the northwest Indian Ocean, in terms of migration of the continental blocks from the mid-ocean ridge, has suggested to Pichon (1968; Pichon & Heirtzler 1968) that the topography of the Madagascar–East Africa area was substantially similar in the Eocene to that of today, with the Seychelles, Maldives and Chagos still in the process of migrating northeastwards to their present positions.

These data together suggest that volcanism began north of Madagascar in late Cretaceous or Eocene times, and continued in places into the Quaternary, contemporary with extensive volcanism on mainland Madagascar (Battistini 1965*a*). There is no information on the date of cessation of active volcanism on islands of the Aldabra group, or of the initiation of reef growth. As in the Pacific, it may be useful to dredge on the summits of guyots in the Mozambique Channel, as well as on the slopes of Aldabra, preparatory to further geophysical work on Aldabra, including possible deep boring.

Apart from the granitic and volcanic islands and the elevated reefs of the Aldabra group, the islands of the western Indian Ocean are mainly sand cays of reef debris on sea-level coral reefs. Baker (1963) has described the geology of many of them. Royal Society parties from Aldabra have visited Assumption, Cosmoledo, Astove, Farquhar, and several of the Amirantes, and their results will appear separately (Stoddart, ed., 1970).

## 2. Topography of Aldabra

The slightly elevated atoll of Aldabra is elongated east–west, with a maximum length of 34 km and a maximum width of 14.5 km. Its total area, bounded by the edge of the peripheral intertidal reef flat, is 365 km$^2$, and of this, land occupies 155 km$^2$. The land rim consists of four main islands, varying in width from 0.25 to 5 km and averaging about 2 km:

| | | | |
|---|---|---|---|
| South Island | 110 km$^2$ | Polymnie | 1.8 km$^2$ |
| Middle Island | 26.4 km$^2$ | Picard or West Island | 9.3 km$^2$ |

West Island and Polymnie are separated by a gap 600 m wide containing Main Channel, a steep-sided channel 300 m wide and 18 to 22 m deep at its entrance. Middle and South Islands are separated by the narrower East Channel. West Channels, between West and South Islands, are shallow gaps of recent origin eroded through a narrow sector of the land rim. Channel characteristics are considered in § 7(*b*).

In addition to the main islands, there are numbers of smaller islands within the lagoon, mostly close to the land rim and often connected to it at low water. These lagoon islands are concentrated along the south shore of Middle Island and along the eastern lagoon shore of South Island. Within the lagoon itself there are two larger islands: Ile Esprit (0.34 km$^2$), with the small adjacent Ile Sylvestre, in the west, and Ile Michel (0.4 km$^2$) in the east.

The main features of the surface geomorphology of Aldabra have been described by Fryer (1911, pp. 401–405), when the local terms *champignon* and *platin* entered the reef literature. Fryer used champignon for deeply pitted and irregular solution-fretted reef rock, and platin for smooth surfaced pavement-like cemented limestones. The distinction between these two types oversimplifies the morphological variation on Aldabra (Stoddart & Wright 1967, p. 19), but is nevertheless useful as a first approximation. Champignon so defined occupies the greater part of West Island, Polymnie and Middle Island, together with most of South Island from

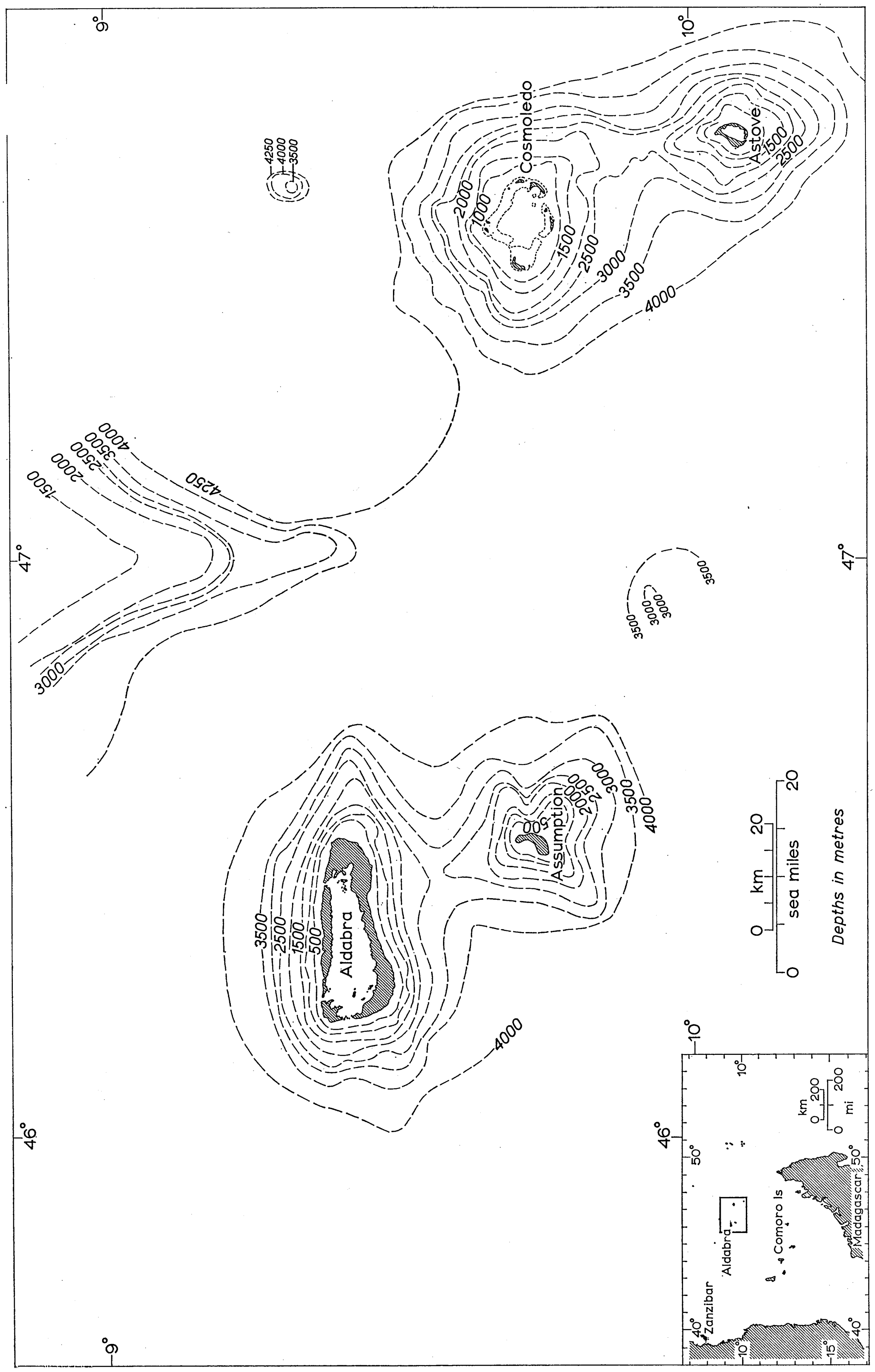

FIGURE 2. Aldabra Group: bathymetry.

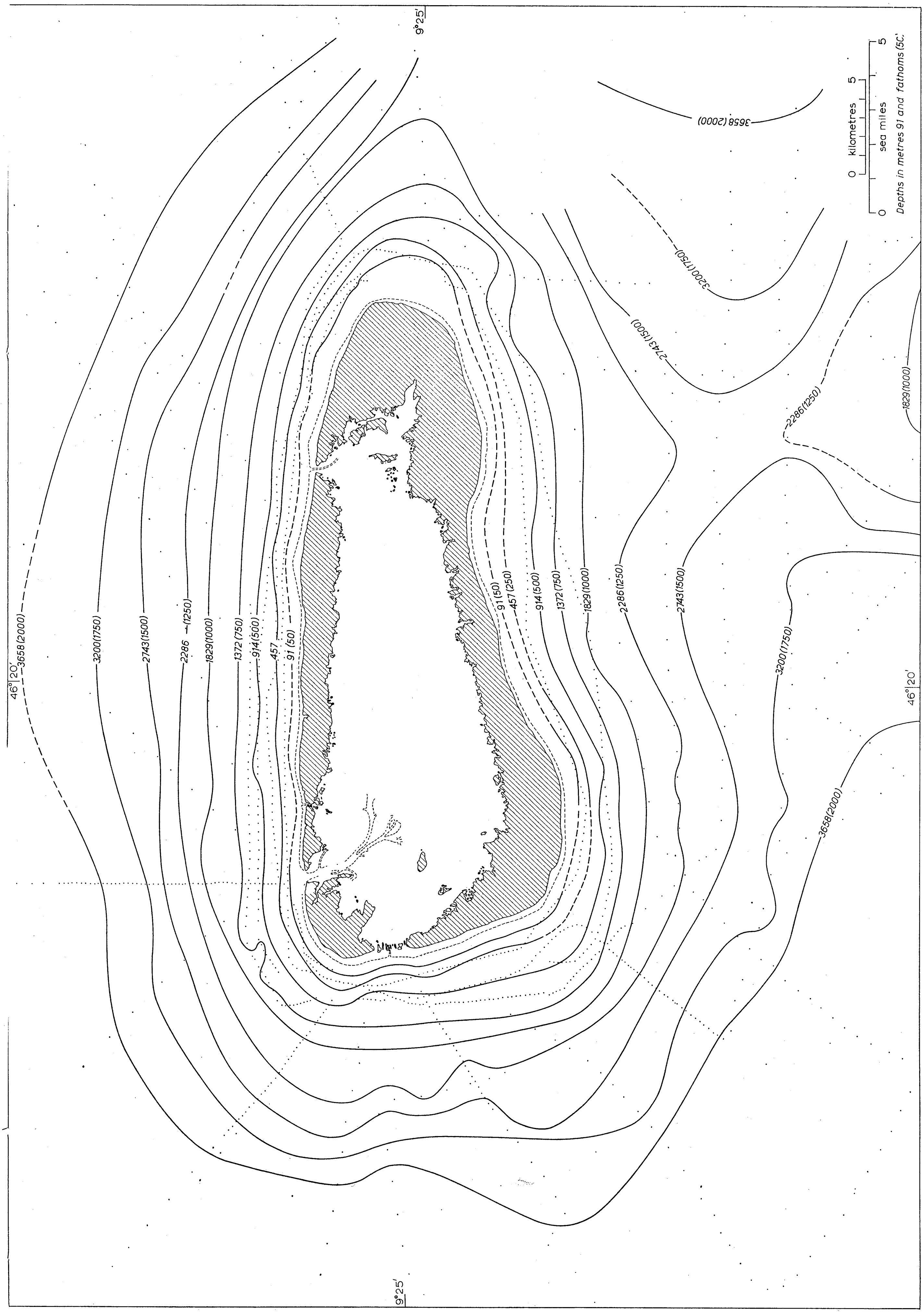

FIGURE 3. Aldabra: bathymetry.

FIGURE 4. Southwest Indian Ocean: bathymetry.
After Fisher, Johnson & Heezen (1967) and Fisher, Engel & Hilde (1968).

West Channels to approximately 2.5 km east of Dune Jean-Louis (figure 21, plate 6). It forms a zone several hundred metres wide round the eastern end of South Island, and near East Channel occupies the whole width of South Island. Platin, apart from small areas near the Settlement on West Island, occupies most of the eastern end of South Island, from Takamaka towards East Channel (figure 14, plate 3). It covers a total area of about 36 km$^2$, 28 % of the dry land area (excluding mangrove), or one-quarter of the total land area of the atoll. Champignon forms the higher part of the atoll rim, generally rising to 3 to 4.5 m above sea-level, though large areas near lagoon coasts stand at less than 2 m elevation; platin ranges from approximately 1 to 3 m above sea-level. Because of the deep dissection of the champignon there is little surface water and the water table lies at depths of up to several metres below the ground surface. On the dimpled platin surface, however, drainage is inhibited by the formation of a surface crust, and permanent or semi-permanent pools are common. The largest of these, Bassin Flamant (3905, 7905), has a dry season diameter of about 300 m, but this and other pools increase markedly in size during wet weather.

On the basis of spatial distribution, surface form and lithology, Fryer (1911, pp. 405–407) concluded that champignon is a surface formed on elevated reef-framework with many corals, and platin a surface developed on lower, finer clastic back-reef deposits. Fryer himself noted difficulties in this interpretation, which was expanded to include the effects of different porcesses, notably salt-water and freshwater solution, in an earlier treatment of the geomorphic development of Aldabra (Stoddart & Wright 1967, pp. 22–24).

Because of the nature of the surface, density of the vegetation, and lack of detailed survey, the topography of Aldabra is inadequately known. Surveyed sections on several islands, together with observations of surface form, allow a more detailed interpretation of Aldabra topography.

While the cliffs round the seaward coast of Aldabra rise to 3.5 to 4.5 m above the level of the intertidal reef flat or platform, this is not the maximum altitude of raised rock on the atoll rim. Sections levelled between Settlement and Anse Var on West Island (figure 6) show a coastal terrace 50 to 75 m wide inland from the cliff top, and 3 to 6 m above datum (defined as the level of the intertidal platform at the foot of the cliffs). Inland from this terrace the surface rises steeply to a ridge 30 to 80 m wide and up to 7.5 m above datum, before falling on the lagoonward side of the ridge to a low champignon zone. Density of vegetation prevented levelling across this, but much of it probably lies at about 1 to 2 m above datum. The ridge is a constant feature around the seaward coast of Aldabra, though its detailed surface morphology differs so widely that the homology of the feature is not at first apparent. Sections levelled across South Island (figure 7), for example, show a coastal terrace at about 4 m which is much wider than on West Island (140 to 280 m, compared with 50 to 75 m), and a ridge which is much more dissected and also wider (250 to 350 m) than that on West Island. The maximum elevation of the South Island ridge, 8 m, is the same as that on West Island; erosional residuals above the general surface also reach this level. Lagoonward of the ridge the surface is low-lying and cavernous, and stands at 0 to 2.5 m above datum. Similar coastal terraces and ridges have been noted on Middle Island (figure 8) and Polymnie. The highest point on solid rock so far levelled on Aldabra (8.2 m) is the summit of Ile Esprit, in the lagoon (§5 (*c*)).

The forms so far described are all solid rock features. Coastal depositional features, including beaches, perched beaches and dunes, are considered in §6. Dunes on the south coast of Aldabra reach up to 18 m above sea level at Dune d'Messe and Dune Jean-Louis.

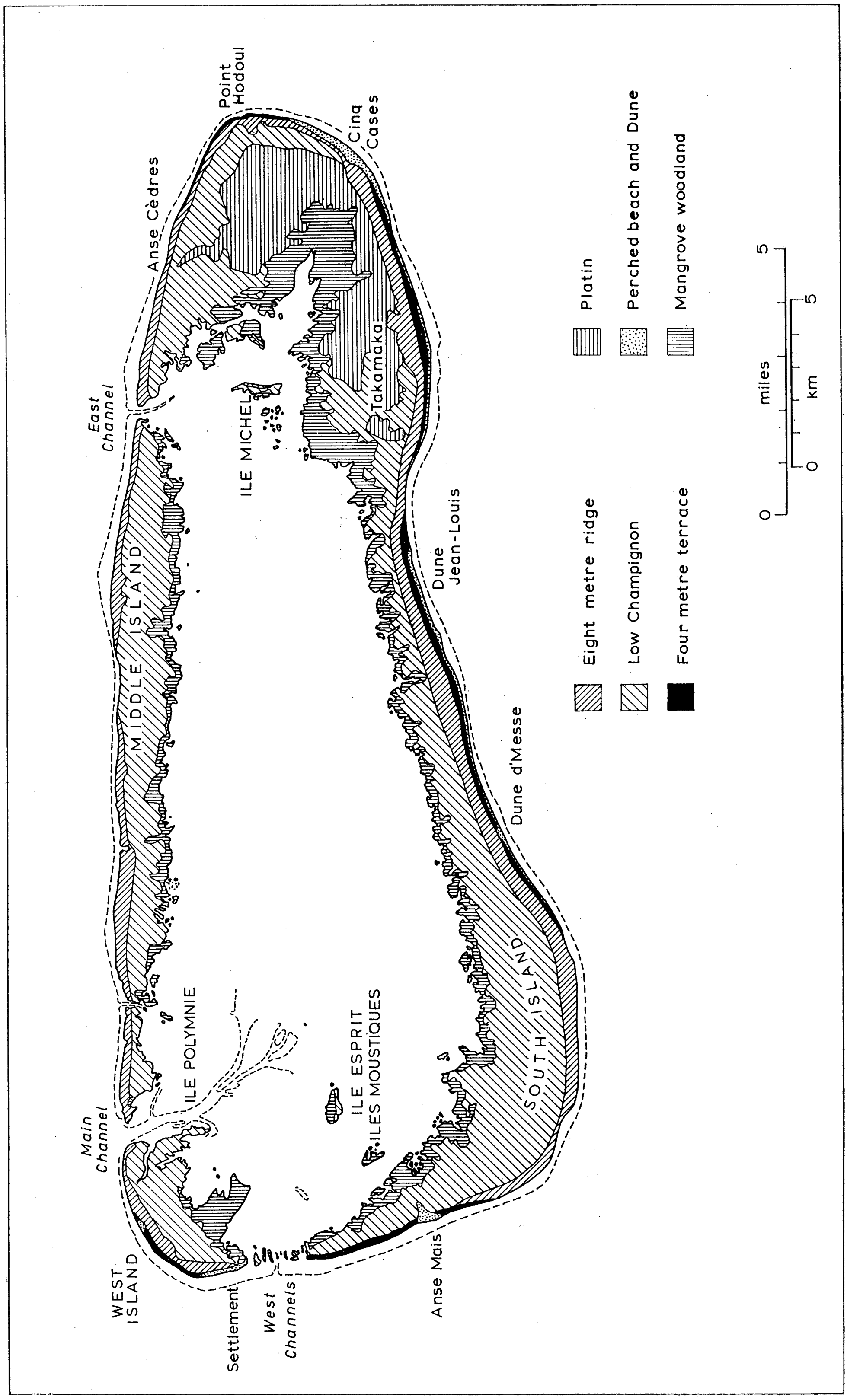

FIGURE 5. Aldabra: topography.

Interpretation of the 8 m ridge and 4 m terrace on the land rim requires further consideration of (*a*) geology and (*b*) detailed surface morphology.

## 3. GEOLOGY

The presence of massive corals in the position of growth in the raised limestones, particularly in the cliff faces of the north coast, led Fryer to conclude that Aldabra had been formed by simple elevation of a coral atoll: the atoll's peripheral reef formed the higher champignon, the back-reef deposits the lower platin. In this view the morphology of Aldabra is the result of relatively minor solutional modification of a reef topography formed before the elevation of the atoll.

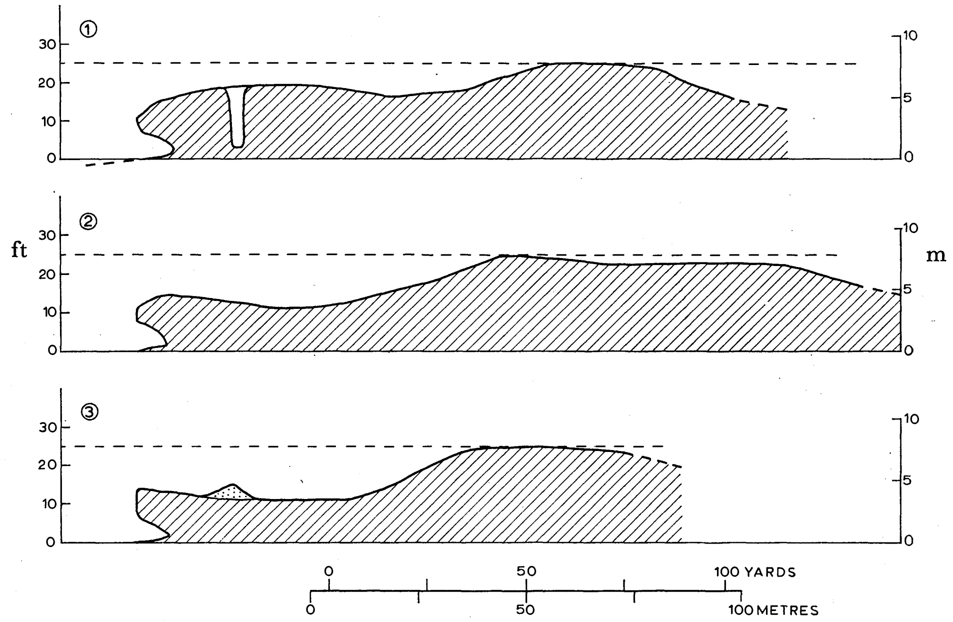

FIGURE 6. West Island: levelled sections near Anse Var.

The main limestone on Aldabra, forming the foundation of exposed land, is at outcrop a dense reef limestone which has been much recrystallized, and at least in surface samples is often almost structureless. Large corals are found in this limestone, but they are tightly cemented and much altered by solution. This Lower Limestone varies in lithology as a result of facies changes in the original reef environment, but because of its degree of alteration it has not been studied in detail.

A second, younger reef limestone has also been recognized (figures 17, 18 and 19, plate 6), particularly in more protected situations on islands within lagoon channels. This Upper Limestone is much less altered than the Lower Limestone: it is easily disaggregated, and contained fossils are well preserved, in some cases retaining colour banding. Corals collected from the Upper Limestone at Polymnie (1065, 1230) include *Heliopora* (dominant), *Acropora* cf. *palifera*, *Goniastrea* sp. and *Favia* sp.; from an island in West Channels (6100, 8600) *Acropora* cf. *formosa* and *Galaxea*; and from West Island south of Settlement (5750, 9250) *Goniastrea* sp. and *Galaxea clavus*. The molluscan fauna of the Upper Limestone is better known than the coral fauna. Taylor has identified the following species from Polymnie (1065, 1230): *Tridacna maxima*, *Barbatia fusca*, *Spondylus hystrix*, *Perigylpta puerpera*, *Trachycardium flavum*, *Chama imbricata*,

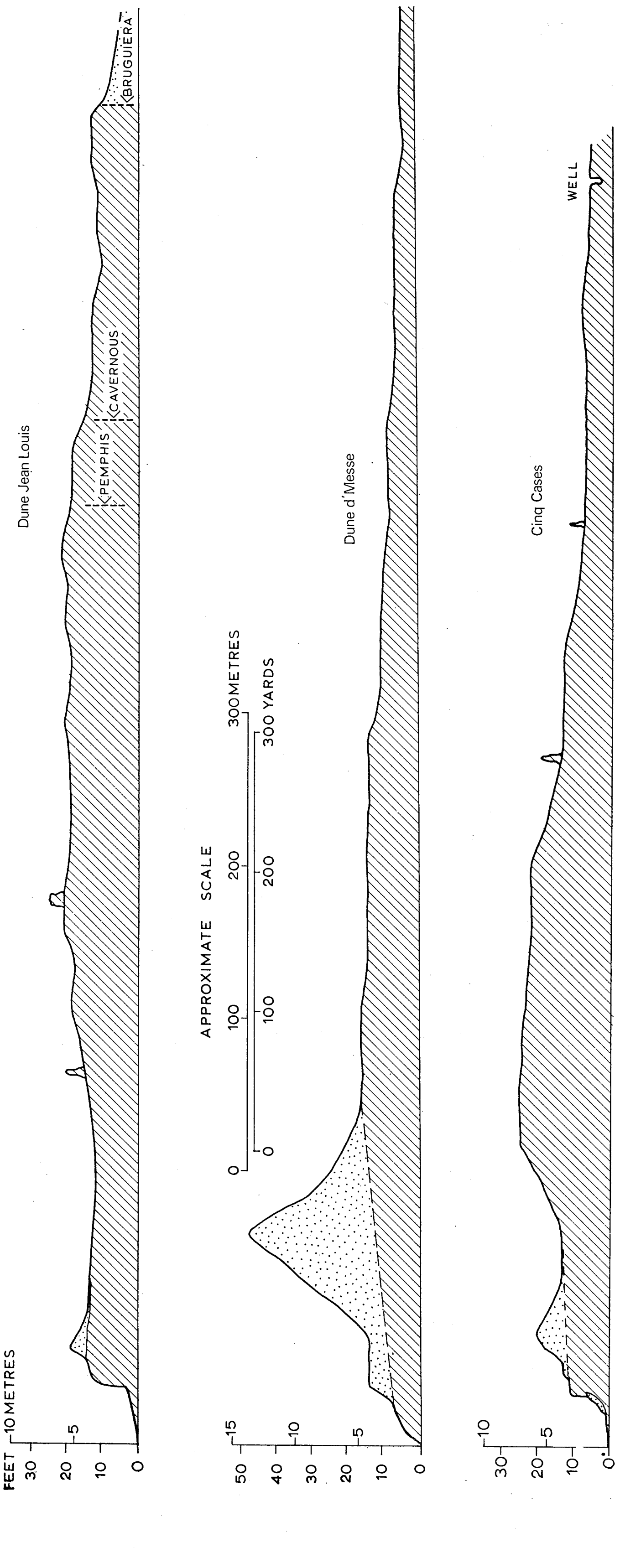

Figure 7(*a*)

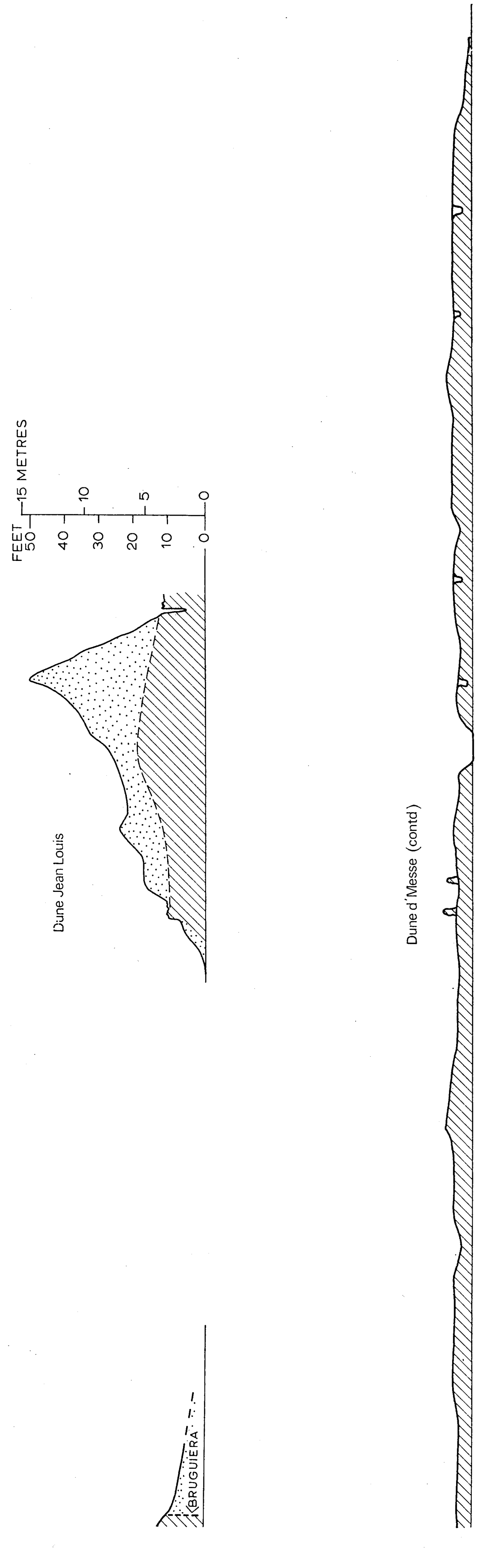

Figure 7(*b*)

Figure 7. South Island: levelled sections at Dune d'Messe, Dune Jean-Louis and Cinq Cases.

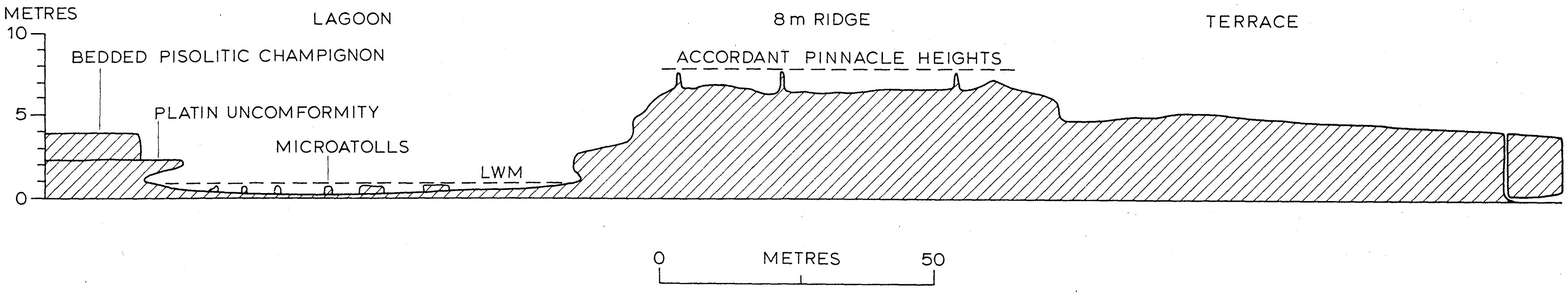

Figure 8. Middle Island: levelled section at Passe Houareau.

*Scutarcopagia scobinata*, *Cerithium echinatum*, *Cymatium nicobaricum*, *Cypraea staphylaea*, *Chlamys coruscans*, *Turbo setosus*, *Cypraea talpa*, *Bursa bufo*, *B. granularis*, and many others. On West Island (5750, 9250) he records *Barbatia fusca*, *Turbo argyrostomus*, *Trochus flosculus*, *Cerithium echinatum*, *Spondylus hystrix*, *Columbella turturina*, *Coralliophilia* sp., *Trapezium oblongum*, and *Cypraea isabella*. Much of the fauna of the Upper Limestone consists of species commonly occurring in the Indian Ocean today, and many species are found living round Aldabra. Certain species, however, including species of *Semele* and *Ostrea*, have a present-day range which does not extend to the western Indian Ocean, and others have not been found living at Aldabra.

Coral mounds, presumably of Upper Limestone age, are conspicuous on some small islets within channels. These contain much *Lobophyllia* and many *Fungia*. The fungiid *Herpolitha limax*, found in sandy facies on one of these islets, has yet to be found on the modern reefs.

In places the reef corals of the Upper Limestone are overlain by sandy sediments, as at Passe Femme and Anse Cèdre Polymnie; at the latter location *Codakia tigerina* shells 12 cm long occur prolifically in life position. In other areas they are overlain by fine-grained lagoonal limestones with small *Porites* heads and abundant *Galaxea*, *Barbatia*, *Turbo* cf. *cornutus* and *Trochus* cf. *maculatus*. Mounds of young limesands overlie a reef limestone at 0.45 m above high-water springs within the lagoon at Passe Gionnet. These contain such sand-burrowing molluscs as *Cerithium asper*, *Fragum fragum*, *Timoclea marica* and *Terebra affinis*, all common in sandy substrates in channel areas today.

No detailed picture can yet be constructed of facies variations within these reef limestones. Farrow has found wedges of comminuted talus and comminuted material filling gaps between coral heads at intervals along the south coast from Dune Jean-Louis to Point Hodoul. In the west at Anse Mais he found a coarser conglomeratic talus associated with the Lower Limestone. Boulders in this conglomerate bear *Tridacna maxima* in life position, and lenses of finer comminuted material overlying this conglomerate carry numerous horizontally alined disarticulated *Tridacna* valves. An occasional hint of bedding is seen, with WSW dips of 2°. Much steeper dips, possibly in aeolianite, have been seen between Anse Coco and Anse Tambalico, south of Anse Mais, but have not yet been investigated.

Correlation between these reef units and deposits formed in back-reef and lagoonal environments can at present only be tentative. Three main lagoonal deposits can be recognized:

(*a*) *Algal porcellanites*. Indurated algal limestones breaking with a conchoidal fracture are found extensively round the present-day lagoon, always appearing beneath a plane of

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## DESCRIPTION OF PLATE 6

FIGURE 17. The Upper Limestone, here composed largely of plates of *Heliopora*, at Anse Cèdre Polymnie.

FIGURE 18. The Upper Limestone on cliff tops at Anse Gale, South Island (6550, 5250).

FIGURE 19. Undercut island inside Passe Femme, West Channels, showing a knoll of Upper Limestone age unconformably overlying Lower Limestones.

FIGURE 20. Exposed cliffs north of Point Hodoul, with pinnacled champignon on the cliff edge and a basal algal platform.

FIGURE 21. Pinnacled high champignon falling to densely vegetated low champignon north of Grand Trimeau.

FIGURE 22. Rough champignon with rounded ridges on the high coastal ridge at Dune d'Messe. The photograph was taken shortly after a light rain shower.

FIGURES 23, 24. Tower karst in lagoonal calcarenites on Ile Esprit. The vertical relief is 5 to 6 m.

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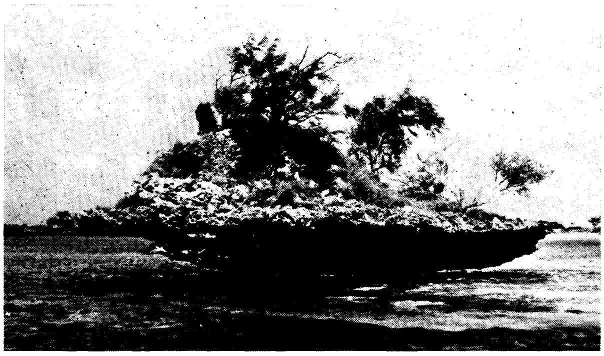

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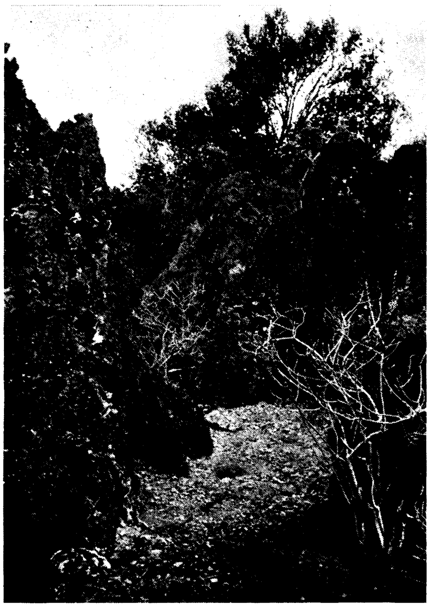

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FIGURES 17 to 24. For legends see facing page.

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Figures 25 to 32. For legends see facing page.

unconformity which resembles an old platin surface. This unconformity is well seen at Passe Mili, Passe Femme, and islets in La Gigi, West Channels, at Ilots Chalen, and at East Channel (figure 19, plate 6). The surface underlies the Upper Limestone already described. The relation between this surface and the main platin of the Takamaka–Cinq Cases area has not been established. The algal porcellanites may be indurated equivalents of the algal nodules now forming on the lagoon floor, as at Ilot Marquoix, East Channel.

(*b*) *Shallow water calcarenites.* Wide areas of the Takamaka–Cinq Cases platin are in lagoonal facies, often sandy, with a sand-inhabiting fauna. Large numbers of *Strombus*, *Fragum fragum*, *Conus* and *Polinices* weather out of the platin surface around Bassin Frégates, and *Polinices* is also abundant at the Cinq Cases landing. In other regions, for example, from Anse Owen to Point Tanguin, Main Channel, this facies is full of small *Codakia* cf. *punctata*, *Ctena divergens*, and where rather sandy large *Trachycardium elongatum*.

(*c*) *Shelly limestones.* Molluscs are often sufficiently abundant in these sandy lagoonal beds to form a tough shelly limestone when indurated. *Scissulina* and *Fragum* limestones are found over large areas of the South Island platin. Shelly lagoonal limestones are also found on Ile Esprit (§5(*c*)).

These back-reef or lagoonal deposits frequently contain corals, in some cases large hemispherical colonies now transected by the ground surface, elsewhere branching *Acropora* cf. *formosa*, fragments of which commonly weather out and lie loosely on the ground surface.

In addition to the two main reef limestones and associated deposits, Taylor has also found shells of *Chama imbricata* at both Polymnie (1065, 1230) and West Island (5750, 9250), cemented to the Upper Limestone, well above present high-water springs. *Chama* is a species not usually found higher than the lowest eulittoral, and thus indicates a third distinct period of marine deposition.

A wide variety of lithified solution-hole deposits is also found on Aldabra, and these deposits may be compared with those now accumulating in present-day holes and pools. Many modern holes, especially larger holes in champignon which are subject to tidal inundation, contain a brown, poorly sorted clayey fill (figure 29, plate 7). Some of these holes are large enough for small tidal drainage systems to develop, though tidal filling occurs through underground rather than direct connexion with the sea. Smaller potholes have similar deposits, often including

### Description of plate 7

Figure 25. Freshwater pool on the platin northwest of Cinq Cases. In the background there is a spur of the high coastal champignon.

Figure 26. Dry platin north of Cinq Cases, occasionally flooded with fresh water. Note the basally notched residual.

Figure 27. Small-scale solution pans on the platin surface near Frigate Pool, south of Anse Cèdres. Note the small notched residuals with a height of about 10 cm. The ground vegetation is *Fimbristylis spathacea.*

Figure 28. Mammillated surface on the margins of a temporary pool, formed by the deposition of tufaceous limestones, near Croix Blanc.

Figure 29. Platin covered with loose slabs, south of Anse Cèdres.

Figure 30. Large tidal solution hole in champignon west of Point Hodoul. Some of the pipe-limestone residuals in this hole contain fossil tortoise bones.

Figure 31. Residual of brown pipe-limestone, fluted by rainwater corrosion, south of Bassin Flamant.

Figure 32. Exposed coastal cliffs at Cinq Cases, topped by a perched beach. Note the pinnacled upper cliff, and the presence of a notched and dissected shelf at about neap tide level at the cliff foot.

fallen fragments of limestone; they are characteristically inhabited by *Cardisoma*. Tortoises may fall into such holes and die. Lithified brown pipe-limestones are found in many places, in modern solution holes, as residual pillars on platin and less frequently on champignon, and on some lagoon islets. In some cases, these brown limestones, which are not phosphatic, contain abundant tortoise bones. Other types of pipe fill include breccias and less commonly oolites. The latter have presumably been formed by wave-swirling in potholes: they are found at East Channel and Ile Esprit.

Depositional features are also associated with several of the platin pools, especially those in dimpled topography which fluctuate widely in size. The margins of some are surrounded by a mammillate surface of banded tufaceous deposits, forming a zone a few metres in width (figure 28, plate 7). These tufas presumably reflect seasonal variation in pool size. The main deposits associated with dry pool areas are, however, unconsolidated silts and sands, yellow to white in colour, with larger mollusc and other fragments. These unconsolidated sediments are subject to continuous post-depositional disturbance by burrowing infauna and by wallowing tortoises.

The relations between geologic units and the main features of atoll topography have not been conclusively established. On the west side of Aldabra the Upper Limestone forms a wedge, thickening seaward, overlying massive Lower Limestone, at the edge of the 4 m terrace. Upper Limestone is not found on the slopes or summit of the 8 m ridge. On West Island, near Anse Var, the ridge crest is formed of fine-grained back-reef or lagoonal deposits with thin-walled mollusc shells of lagoonal facies. Whether the ridge topography was formed during a period of reef growth in Lower Limestone times, or whether it has been substantially modified by marine erosion during Upper Limestone times, will be considered in § 9; first it is necessary to consider the diverse surface forms resulting from erosional and depositional processes now acting on the raised limestones.

## 4. SURFACE MORPHOLOGY

Fryer's distinction between champignon and platin, though useful in surface description, clearly oversimplifies the range of surface forms present on the elevated limestones. While the relation between the two types of surface and different limestone lithologies has been at least partially confirmed, it has also been found that linking series of forms can be described, and situations distinguished where a platin surface is being transformed into champignon and vice versa. Divergent conclusions on the respective roles of lithology, geomorphic history and present process in the formation of the present surfaces can be to some extent resolved by the adoption of a more precise descriptive terminology and the more detailed specification at different scale levels of the topography of each surface type. Although the terms champignon and platin are thus ambiguous and imprecise, they are nevertheless embedded in local usage and are valuable in botanical and zoological work: indeed the terms have been used interchangeably for biological as well as geomorphic features, and this has added to confusion. For these reasons, the following descriptive analysis of surface forms on the raised limestones (partly based on Fosberg (1969)) makes use of the two traditional categories. It is suggested that a third term, *pavé*, used on other western Indian Ocean raised limestone islands (Stoddart, ed., 1970) be adopted for a surface with many of the morphological characteristics of platin, but lying at a greater elevation.

### (*a*) *Champignon*

Three types of champignon may be distinguished, differing in degree of dissection, elevation, and location.

(1) The most intricate dissection of the limestone, forming a fretted surface with exceedingly sharp points and edges and rasp-like surfaces, is found on the edges of cliffs, particularly on exposed coasts (figure 20, plate 6), in low-lying areas bordering the lagoon, and round the margins of some inland depressions. The size of the pinnacles and depressions is partly a function of the thickness of limestone above sea-level (3 to 4 m on seaward and 1 to 2 m on lagoon coasts). On the lagoon margins and round inland depressions the main erosional process appears to be tidal inundation; on the seaward coast drenching by salt spray is more important. Total relief may be several metres, with deeper pits reaching the salt-water table.

(2) A champignon with similar large-scale dissection features of pits and pinnacles, with sharp points and edges, but without the intricate fine dissection and rasp-like surfaces, is found over large areas away from the coast (figure 21, plate 6). These areas are not subject to tidal inundation or to excessive salt spray, and are generally too rough to be accessible to tortoises.

(3) Champignon of rather lower relief, though still very rough, with points and edges generally not very sharp, rounded off or worn down (figure 22, plate 6). These areas support large tortoise populations, which may have worn down the edges and points by the rubbing of their plastrons over long periods.

### (*b*) *Pavé*

(4) Pavé is applied to large areas of a rough limestone with a relief of only a few decimetres, usually not more than 0.5 m, with points and edges rubbed dull, without abundant pinnacles or deep pits, and with shallow flat-bottomed solution pans. Pockets or depressions contain deposits of fine silt or marl. Long sharp ridges up to 20 to 25 cm high are found on this surface probably representing case-hardened cracks, as they often have a groove on top. A type area of pavé on Aldabra, resembling some of the flatter pavé on Astove, is found on the surface of the 8 m ridge south of Anse Var, West Island. The surface of the 8 m ridge at Takamaka is likewise hummocky and irregular but smooth: deep holes and loose blocks do not disguise the solid character of the surface.

### (*c*) *Platin*

(5) Surfaces of lower relief, with wide shallow depressions, in which the main surface forms are solution pools, often with undercut rims, and with perfectly smooth floors, often with a thin chalky deposit, represent the extreme form of Fryer's platin (figure 27, plate 7). The slopes of sides and of residuals in these solution pools form sharp angles with the floor. The smaller solution pools are comparable with the features termed pans in type 4, above. In places the pool floors coalesce to form extensive smooth pavements, with only occasional projections or rims. Adjacent pools may be at rather different levels, however, forming a step-like topography. The ground surface may be intersected by long straight cracks.

(6) Extensive areas with only minor relief, up to several decimetres, not very rough, frequently including large or small examples of types 4 and 5, with stack-like erosion remnants (see § 5*a*, *b*). Shallow depressions are filled with fine silt or marl, with a very flat surface.

(7) Extensive areas of minor relief, up to several decimetres, not very rough, but covered with flat slabs of limestone, lying loose, the slabs up to 10 cm thick and 1 m or more across (figure 29, plate 7). The slabs may in places entirely cover the ground surface.

### (*d*) *Other types*

(8) Irregular surface with rounded ridges and a local relief of less than 0.5 m. There are occasional higher blocks, sometimes loose and perched. Solution pans are common, and often located on the tops of broad low pillars. Surface slabs and solution holes are rare.

(9) Scoriaceous surface of dark brittle sponge-textured rock with an irregular surface profile; deeper solution holes are rare. This scoriaceous surface often stands at a higher level (up to 1 m) than adjacent platin. It is often more densely wooded than the platin, and dark brown humic soil accumulates in some holes.

Other categories of surface and specific landform features can be distinguished, including depositional forms, but these nine types cover the main surface forms on the raised limestones and could be made the basis of a morphological map. In contrast to the mainly lithological control of form suggested by Fryer (1911) and the lithology/process control suggested by Stoddart & Wright (1967), Fosberg (1969) has proposed that these forms are genetically related. In his analysis pinnacled champignon is developed by salt-water solution soon after emergence. Relief is dulled when rainwater solution becomes dominant, and cavities which fail to drain gradually develop flat floors and expand laterally, while those that do drain enlarge to form pits and hollows. Spalling of slabs takes place, presumably as a result of thermal stress, on roughly levelled surfaces. Such a process of platin formation is clearly not irreversible, for in many places horizontal platin is being converted into deeply pitted champignon. How far the erosional modification of champignon would be capable of developing the area of platin on Aldabra will depend on the rate of solution, the time available since emergence, and on whether development has been continuous or interrupted.

Although smooth surfaces may be formed by solution of champignon, there is some evidence that the larger platin areas of Aldabra, especially in the Takamaka–Cinq Cases area, are associated with back-reef or lagoonal deposits, as Fryer supposed. Good sections are lacking, but in solution holes 2 m deep at Bassin Cabri, West Island, the top 0.45 to 0.6 m below the platin surface consists of a structureless massive limestone, much altered by solution and in places pinnacled, overlying bedded calcarenites with a lagoonward dip of 1 to 2° conformable with the surface. The massive limestone may be a weathering crust, and the flat-lying surface result from the bedded nature of the lagoonal deposits and their permeability when uplifted. Evidence has already been summarized in §3 for the existence of recent marine deposits of lagoonal facies in the Takamaka–Cinq Cases area, where the topography also resembles that of the modern lagoon floor.

Type (2) champignon, as developed on Ile Esprit, is strikingly similar to erosion forms in the Emanuel and Napier Ranges of the Fitzroy Basin, Western Australia (Jennings & Sweeting 1963, plates 4 and 5). Features in both areas are developed on massively bedded back-reef calcarenites, though in the Australian case the rocks are of Devonian age. The present mean annual rainfall of the two areas is the same (670 mm), and in each case severe storms falling on 3 or 4 days each year account for half the total annual rainfall. In both cases the landforms have probably developed as a result of rainwater corrosion.

## 5. Additional evidence of polycyclic development

In addition to the main evidence of sea-level fluctuations given by the 8 m ridge and 4 m terrace on Aldabra, and by the Lower Limestone, Upper Limestone, and post-Upper Limestone *Chama* shells, several minor features serve as additional evidence of polycyclic development.

### (*a*) *Reef-rock residuals*

Reef-rock residuals are common on the more deeply and intricately eroded sectors of the land rim. In the sections levelled on South Island (figure 7), residual pillars stand up to 1.5 m above the level of the ridge crest (bringing the maximum height to 8 m), whereas residuals on the lower surface lagoonward are accordant with the present general ridge level. To what extent the pinnacles on the lower surface are residual remnants of a higher one, or are inherited from individual coral stacks on a reef surface it is impossible at present to say: the limestone composing them is thoroughly recrystallized, and fossils cannot be detected in hand specimens.

### (*b*) *Pipe-limestone residuals*

Larger solution holes in the present champignon, especially those which contain tidally fluctuating water bodies, have deposits of yellow or brown mud on their floors, in contrast to superficial platin pools, such as Bassin Flamant, which have a layer of light-coloured silt or marl from 1 to 2 cm to more than 1 m thick. At several places on the platin, especially between Cinq Cases and Bassin Flamant, there are steep-sided residuals of a brown limestone standing 1 to 2 m above the platin level, and in some cases 2 to 3 m in diameter (figure 31, plate 7). These brown limestone residuals are fluted by rainwater on their sides, and often slightly undercut at their bases, as though by solution in a shallow water-body. If the brown limestones of these residuals did in fact originate as pipe-limestones, then clearly the platin must have a longer and more complex history than envisaged by Fryer, and must have developed from a higher pot-holed surface. Information on the distribution of these residuals on the platin is inadequate, but they appear to be more common close to the lagoonward edge of the 8 m terrace; it is possible that the deposits formed in holes in the 8 m surface, and have been exposed by subsequent lateral erosion of its margins during Upper Limestone and later times. Similar brown pipe-limestones have been described from elevated reefs in the British Solomon Islands (Stoddart 1969*b*, *c*).

Many of the pipe-limestone residuals contain fossil tortoise bones. In a large pool immediately inland from the 8 m ridge at Point Hodoul (figure 30, plate 7), it is clear that the accumulation of brown sediments and their lithification has been a discontinuous process. Two periods of pipe-fill are present in this basin: the present unconsolidated sediments, subject to tidal inundation, and residual pillars standing up to 1 m above the present fill surface, consisting of lithified yellow-brown limestone with abundant tortoise bones. These bones are weathering out of the residuals and are being incorporated into the more recent sediments. The first period of sedimentation and tortoise bone accumulation was thus interrupted and followed by an interval when the fill became lithified and dissected, before infilling was renewed. This sequence, which has important implications for the antiquity of *Geochelone* on Aldabra, may be linked to eustatic sea-level changes, the dissection of the older fill taking place during a low sea-level and the renewed filling during the Recent sea-level stand.

### (c) *Ile Esprit*

The anomalous character of Ile Esprit, in the western lagoon, was recognized by Fryer. Here a complex topography of pinnacles and depressions with a vertical relief of up to 6 m resembles in miniature a tropical Kegelkarst (figures 23 and 24, plate 6). The summit ridge on Esprit, which is little dissected and rises to 8.5 m, is capped by an oolitic calcarenite, with a dark brown matrix and containing streaks of banded phosphate. The calcarenite is only slightly phosphatized and in places has traces of horizontal bedding. A breccia at a lower level contains cobbles of the oolite, with pebbles of dark brown-black phosphate, and of reef limestone. At the east end of the island, blocks in the breccia reach a maximum diameter of 2 m. The underlying limestone surface is deeply dissected, with tall pinnacles and deep, flat-floored solution holes. Two facies can be distinguished: a lower shelly limestone and an upper white calcilutite. Molluscs found in the lower shelly limestone on the southeast coast of Esprit include, in approximate order of abundance, species of *Natica*, *Conus*, *Glycymeris*, *Cardium*, turreted gastropods including *Terebra* and *Terebralia*, small *Arca*, and large *Tellina*. This is clearly a sand-flat community: *Terebralia palustris*, which is common, is at present confined to the lagoon on Aldabra, and is associated with the mangrove fringe. The calcilutite, an indurated, fine-grained white mud, is noticeably less fossiliferous than the shelly limestones, but a small *Cerithium* is distinctive. Shells in this sequence are poorly preserved, and most of the aragonite is leached out. The limestone is penetrated by solution pipes with phosphatic brown filling; larger pipes are filled with a brown-matrixed breccia, and in some cases with oolites. The composition of two solution-pipe fillings, determined by X-ray fluorescence spectrometry, is shown in table 1.

TABLE 1. COMPOSITION OF SOLUTION-PIPE FILLS, DETERMINED BY X-RAY FLUORESCENCE SPECTROMETRY

(1) Dark brown cobbles in oolitic fill, southeastern Ile Esprit. (2) Sparsely oolitic fill, with tortoise bones, Middle Camp, Passe Houareau

| | (1) % | (2) % | | (1) % | (2) % |
|---|---|---|---|---|---|
| MgO | 1.90 | 2.20 | $SiO_2$ | n.d. | n.d. |
| $K_2O$ | 0.03 | 0.05 | CaO | 56.30 | 56.44 |
| $Fe_2O_3$ | 0.40 | 0.64 | $Al_2O_3$ | 0.24 | 1.28 |
| MnO | 0.00 | 0.00 | $P_2O_5$ | 39.70 | 3.50 |
| $TiO_2$ | 0.01 | 0.09 | loss on ignition | — | 34.20 |

The Esprit succession clearly records a complex history when sea-level stood higher than at present. Two alternative interpretations may be suggested. Either the extreme champignon developed at a time of high sea-level, the breccia resulting from collapse under high-energy wave conditions, and the summit oolitic calcarenite formed on a fairly high-energy littoral. Or the summit calcarenites are cave deposits, and the breccia results from cave collapse. In both cases a sea-level at least 10 m higher than the present is indicated. No correlations have yet been established between Esprit and the main atoll rim, and because of major differences in facies it will be difficult to do so. Presumably the island owes its preservation to its location near the watershed between Main Channel and West Channels lagoon drainage systems.

## 6. Coastal morphology

### (a) *Seaward coasts*

The land rim is surrounded on its seaward side by an intertidal or slightly subtidal platform, which is narrowest (down to 100 m) on the east or windward side, averages 180 to 280 m in width along the north and south coasts, and reaches 460 m on the sheltered west coast. The intertidal platform is an erosion feature formed of planed reef rock, with a thin, discontinuous cover of sand, gravel and cobbles, patchily covered with algae (including encrusting calcareous algae) and marine phanerogams (Price, this volume, p. 123): it is not a primary reef flat formed by contemporary reef growth. Baker (1963, p. 110) has argued that the platform is a growth feature since if it were erosional it would be widest in more exposed locations. The erosion processes, however, are solutional and biological, rather than abrasional, and hence less directly dependent on wave energy. Baker's second argument, that the platform must be a growth feature because it continues into the channel entrances, does not follow, for solution can be effective there even though abrasion cannot. The planed-rock platform could not be formed by reef growth at its present level, nor are corals common on it, except in unusually deep areas. Fryer (1911, pp. 413–414) suggested an erosional origin, and this is accepted here. Detailed erosion forms on the platform, including channels and ridges normal to the shore, and scour holes, show that erosion is continuing.

The seaward edge of the platform is marked by an intermittent boulder zone on the windward side, but there is no algal ridge, in contrast to reefs of the central Indian Ocean and the Seychelles (Stoddart 1966, p. 17; Taylor 1968; Stoddart & Taylor, eds. 1970). On the leeward side of the atoll, between Anse Mais and Anse Var, bars of mobile sand are common on the outer half of the flat, and there is a low reef-edge boulder zone at the Settlement. Taylor (this volume, p. 173) has studied biological zonation on the intertidal platforms in detail.

The inner margin of the intertidal platform is generally formed by retreating limestone cliffs of variable height and morphology. Five distinct types can be recognized.

(1) The cliffs in the very high energy environment of Point Hodoul are 4 to 5 m high, deeply fretted by salt-spray solution, especially at lower levels, and with a more scoriaceous, less pinnacled surface at higher levels (figure 20, plate 6). The intertidal platform is deeper and narrower here than elsewhere. At the foot of the cliff there is an algal platform less than 3 m wide, with rimmed pools. Similar cliffs with algal benches have been described on exposed elevated reefs in the Marianas (Cloud 1959; Emery 1962) and the Solomon Islands (Stoddart 1969*b*). There are no beaches.

(2) Cliffs on the south coast of South Island, between Cinq Cases and Dune Blanc, also on the windward side of the atoll, face a wider intertidal flat than the Hodoul cliffs, and the cliff profile is more ramp-like (figure 32, plate 7). Again there is a distinction between a lower fretted pinnacle zone and a higher scoriaceous zone; depressions between pinnacles at higher levels broaden to form flat-floored pools mostly less than 0.5 m in diameter but exceptionally up to 1 m. There is no algal terrace with rimmed pools at the foot of the cliff, but instead a persistent ledge with a notch at its outer edge. The ledge lies at approximately the level of low-water neaps, and may result from the effectiveness of solution processes at this height; it is less than 2 m wide and 1 m high. The ledge is found at the foot of small spurs on the cliff face; between the spurs there may be deep scour holes, often extending across the flat as scour channels.

Beaches at interruptions in the cliff are rare, though in places, as at Cinq Cases, the lower part of the cliff may be covered with a lens of sand. On top of the cliffs, however, is a continuous perched beach, generally 1 to 2.5 m thick and 10 to 80 m wide (figure 33, plate 8). The beach consists of coarse sand with some gravel; its seaward slope is bare and covered by swash at equinoctial springs; the landward slope is vegetated, mainly with the grasses *Sporobolus* and *Sclerodactylon.* In several places the perched beach develops into large isolated dunes up to 18 m above sea-level, as at Grand Trimeau, Dune d'Messe, and in the Dune Jean-Louis complex (figures 34 and 35, plate 8).

Although the perched beach is only reached by the sea during storms and at the equinoxes, it is normally drenched with spray at high tides throughout the Trade Wind season (April to December). At several places, for example at Grand Trimeau and between Dune Jean-Louis and Anse du Bois, beach-rock is forming on the seaward face of the beach and over the cliff-top surface to seaward. This is an unusually high level for the formation of what is normally an intertidal deposit.

The perched beach is continuous on the south coast from Point Hodoul to Dune Blanc, except for a section between Anse du Bois and Point Lion, where the coast trends more nearly parallel with the Southeast Trades. Here the coast is steeply cliffed and undercut, and vegetation advances close to the cliff edge. Elsewhere the perched beach is interrupted only south of Point Hodoul (approximately 4060, 8200), where there is a gap several hundred metres wide, covered with poorly sorted coral boulders and rubble. The ends of the beach on either side of this zone are abrupt. The gap in the beach and the associated deposits were probably formed by a hurricane crossing the coast from the east; the storm may also have been responsible for the widespread death of near-coastal vegetation in the Cinq Cases area. These features were present in September 1966, before the hurricane of that year.

(3) Sea conditions are less extreme on the north coasts of Polymnie and Middle Island, and the South Island coast between East Channel and Point Hodoul and between Anse du Bois and Point Lion, and the dominant process is solutional. The cliff face is deeply undercut by an intertidal notch (figure 36, plate 8). This has an amplitude at its mouth of not less than 2 m; the deeper notches commonly extend back under the cliff for 15 m, and in some cases up to 20 m. The floors of the notches slope seaward, and are polished, furrowed or potholed; the roofs are irregular, with micro-erosion and depositional features. Discontinuous sand and cobble beaches may form within the deeper notches, and in some places are characteristically blue in colour from their *Heliopora* content. Above the notch the cliff face rises vertically for 2 to 3 m, and at the curve-over to the land surface it is intricately dissected into pinnacles and solution holes. At low-water springs the notch is completely dry, at high-water springs the sea reaches and may cover its upper lip. Blowholes are common on cliffed coasts of this type, and are often marked by conical mounds of the leaves of marine phanerogams mixed with sand and gravel; these mounds may be several metres in diameter.

While the notch-forming process is clearly solutional and biological rather than mechanical, and similar to that described in the Red Sea by Macfadyen (1930) and Guilcher (1955), the undercutting frequently leads to failure and collapse of sections of the cliff face. In plan, the recession process forms micro-headlands and bays, but the outline is surprisingly regular and outlying residual stacks are not common.

Immediately at the foot of the cliff, between the notch and the intertidal platform, there is often a linear depression, up to 1 m deeper than the general platform surface. This is probably partly excavated by mechanical erosion at high water, as well as by solution.

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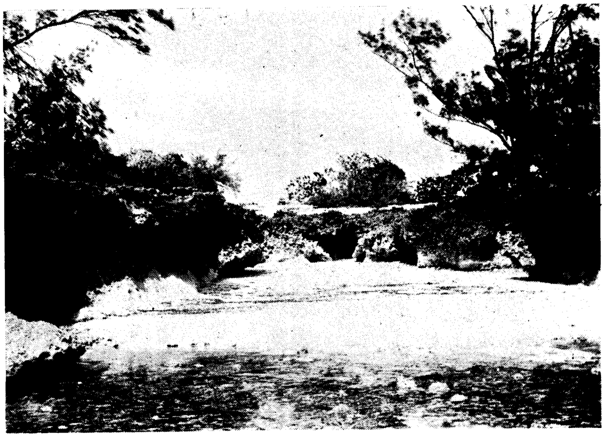

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Figure 33. The south coast perched beach, covered with *Sclerodactylon* (foreground) and *Sporobolus*, east of Anse Takamaka.

Figure 34. Vegetated dunes at Dune Jean-Louis, with *Tournefortia argentea* and a turf of *Sporobolus virginicus*.

Figure 35. Bare eroding dunes with a sparse turf of *Sporobolus virginicus* at Dune Jean-Louis.

Figure 36. Undercut lee coast cliffs at Anse Var, West Island.

Figure 37. Beach at Anse Cèdres, with beach-rock. The photograph was taken at mid-tide, and the cliff notch is almost submerged.

Figure 38. Small pocket beach (anse) in leeward cliffs north of Anse Cèdres. Note the perched beach above the cliff.

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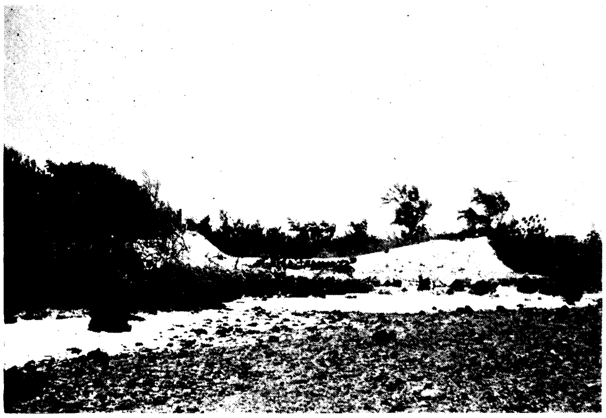

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FIGURE 39. High vertical cliffs formed by fracturing and collapse of the limestone between Le Renfin and Point aux Vaqua, South Island.

FIGURE 40. Massive bedded beach-rock at Ile Magnan, West Channels.

FIGURE 41. Small dunes at the southern point of West Island, on Passe Femme. At high tide the sea reaches the top of the cliff.

FIGURE 42. Delicately notched cliffs on a lagoon shore, on South Island inside Passe Houareau.

FIGURE 43. Mangrove woodland of *Avicennia* within the lagoon on the south coast of Ile Esprit.

Beaches are found, but rarely, on type 3 coasts. In places uneven cliff retreat has formed small coves with pocket beaches (figure 38, plate 8), locally known as *anses* (the 'lances' of Fryer 1911, p. 402). At Anse Cèdres, for example, the beach is less than 100 m long, has a 10° slope, and is 45 m wide at low water. Similar pocket beaches are found at Anse Malabar and Anse Var. Several of these beaches have beachrock at intertidal levels (Anse Var, Anse Cèdres). The rock is a bedded calcarenite with seaward dip of 5 to 10°, lying at intertidal levels (figure 37, plate 8). Its upper surface is usually fluted and potholed by erosion, but it is clearly of Recent origin, related to the present sea-level stand. The cement bonding the grains is aragonite, as shown by staining tests. In addition to the pocket beaches, there is an intermittent perched beach, thinner, narrower and less continuous than on the south coast.

(4) An unusual cliff form is found on the southwest coast of South Island between Anse Coco and Le Renfin (figure 39, plate 9). Here the coast is protected from the Trades, and deep intertidal notching has led to massive cliff collapse. The coast has retreated so far that the 4 m terrace has been destroyed and the cliffs are now cutting into the 8 m ridge. Vertical fresh cliff faces, with little undercutting, are found up to 5.5 m high, with the land surface at the cliff top commonly 7 to 7.3 m above sea level (datum is very approximate here, because of roughness of the water inshore). These are the highest cliffs on Aldabra. Blocks are collapsing by fracturing of the surface parallel to the cliff edge. Because of the rapidity of retreat the usual fretting and champignon formation are absent from the cliff edge, which simply abruptly terminates a smooth pavé surface.

(5) On the leeward coast, between Settlement on West Island and Anse Mais on South Island, the limestone rim is unusually low and the cliffs are poorly developed. In places, as on West Island north of West Channels, there are vertical cliffs up to 4 m high with basal notches up to 2 m high and 10 m deep. Farther south the limestone outcrops to form low headlands with basal Lower Limestone and tapering wedges of Upper Limestone with no pronounced intertidal notching. The inland limestone surface in this sector varies from 2.5 to 4 m above datum, and that of the Upper Limestone on the headlands up to 3.5 m at Anse Badamier.

Beaches are common along this sector of coast. The beach on the west coast of West Island, 1.3 km long, is the longest beach on the atoll; it has a maximum height of 4.5 m above the reef flat. The beach itself is approximately 30 m wide at low water; massive seaward-dipping beachrock outcrops on its lower half. This beachrock is also Recent, with aragonite cement. The sand ridge back of the beach crest is generally 30 to 50 m wide. At the south end of West Island, in Passe Femme, there are several low dunes, up to 5 m high, on a low limestone surface; the dunes are undergoing fairly rapid erosion (figure 41, plate 9).

South of West Channels the beaches are less continuous on account of the limestone headlands. There is a perched beach on top of the cliffs, up to 2 m thick, reaching 4 to 4.5 m above datum. Exposed beachrock is less common south of West Channels. In West Channels the land rim has been breached and the seaward coast is formed by low cliffs. Beaches were formerly present here, for a coarse conglomeratic beachrock is found in massive beds on the seaward side of Ilot Yangue, partly blocking adjacent channels. This beachrock incorporates tabular fragments of earlier beachrock, which was probably broken by storms. A sample of *Tridacna squamosa* from this beachrock has yielded radiocarbon dates of 385 ± 95 and 280 ± 115 a.

### (*b*) *Lagoon coasts*

The lagoon shores of Aldabra are formed either by undercut limestones (figure 42, plate 9) or by mangrove communities (figure 43, plate 9); the latter are described by Macnae (this volume, p. 237). The undercut cliffs differ from those of medium-energy seaward coasts (type 3) mainly in their lower total height and more intricate dissection. The vertical amplitude of the solution notch is similar (2 to 2.5 m) near the entrances to channels, but decreases within the lagoon (down to 0.5 m) as tidal range decreases. The vertical face above the notch is also lower, ranging from 0.3 m or more in the mouths of channels to zero within the lagoon. It is so low, especially on residual islets, that the cliff may be completely submerged during high-water springs. The deep delicate notching of the cliffs is striking, and in many cases has isolated small islands and stacks. These are more common in calmer waters at the east end of the lagoon: at the west end, which is exposed to short steep seas during the Trades, many of the residuals are broken and collapsed. The width of the platform resulting from cliff recession is variable but may reach 50 m; it is generally a bare smooth surface, with grooves normal to the shore and occasional residuals. At lower levels it is covered with lagoonal deposits, mainly poorly sorted sands and gravels; landward it may be patchily covered with small beach deposits.

Active recession has isolated many stacks, some of which have surface dimensions several times as large as the pillar on which they rest: it is to these that the term 'champignon' (mushroom rock) originally referred. Undercut islands are well seen in both Main and East Channels, along the north shore of South Island, and particularly in West Channels. Where the Upper Limestone is absent, the surface of these islets may be horizontal at approximately the level of high water equinoctial springs; where the Upper Limestone is present the islets characteristically have a hummocky hour-glass shaped appearance.

Both Wharton (1883) and Fryer (1911) drew attention to the possible role of mangroves in the retreat of lagoon shores at Aldabra, both by mechanical and chemical action. Mollusc shells in mangrove mud are usually deeply etched and eroded, presumably by chemical action, and Wharton's suggestion needs further study.

## 7. SUBMARINE MORPHOLOGY

Discussion of shallow submarine geomorphic features and their bearing on the Recent history of Aldabra may be considered in terms of seaward slopes, lagoon channels, and lagoon floor.

### (*a*) *Seaward slopes*

The deeper submarine topography of Aldabra has been discussed in §1; we are now concerned with slopes within the normally accepted range (*ca.* 150 m) of Pleistocene sea-level falls. The upper slopes of Aldabra are not well known, except for a detailed survey of the northwest coast from Anse Badamier to Main Channel, carried out by H.M.S. *Vidal* in 1967, supplemented by a survey from Anse Badamier to Anse Mais by H.M.S. *Owen* in 1962 (figure 9).

Below 200 m the submarine slopes at this northwest corner have a fairly uniform gradient of approximately 18° between 1000 and 2000 m, and of 10° between 2000 and 4000 m. Above 200 m the main facets shown by bathymetric data are as follows:

(1) Emerged land rim, maximum elevation + 8 m, width generally less than 1 km.

(2) Intertidal reef flat or platform, exposed at low-water springs, width in this area 200 to 450 m.

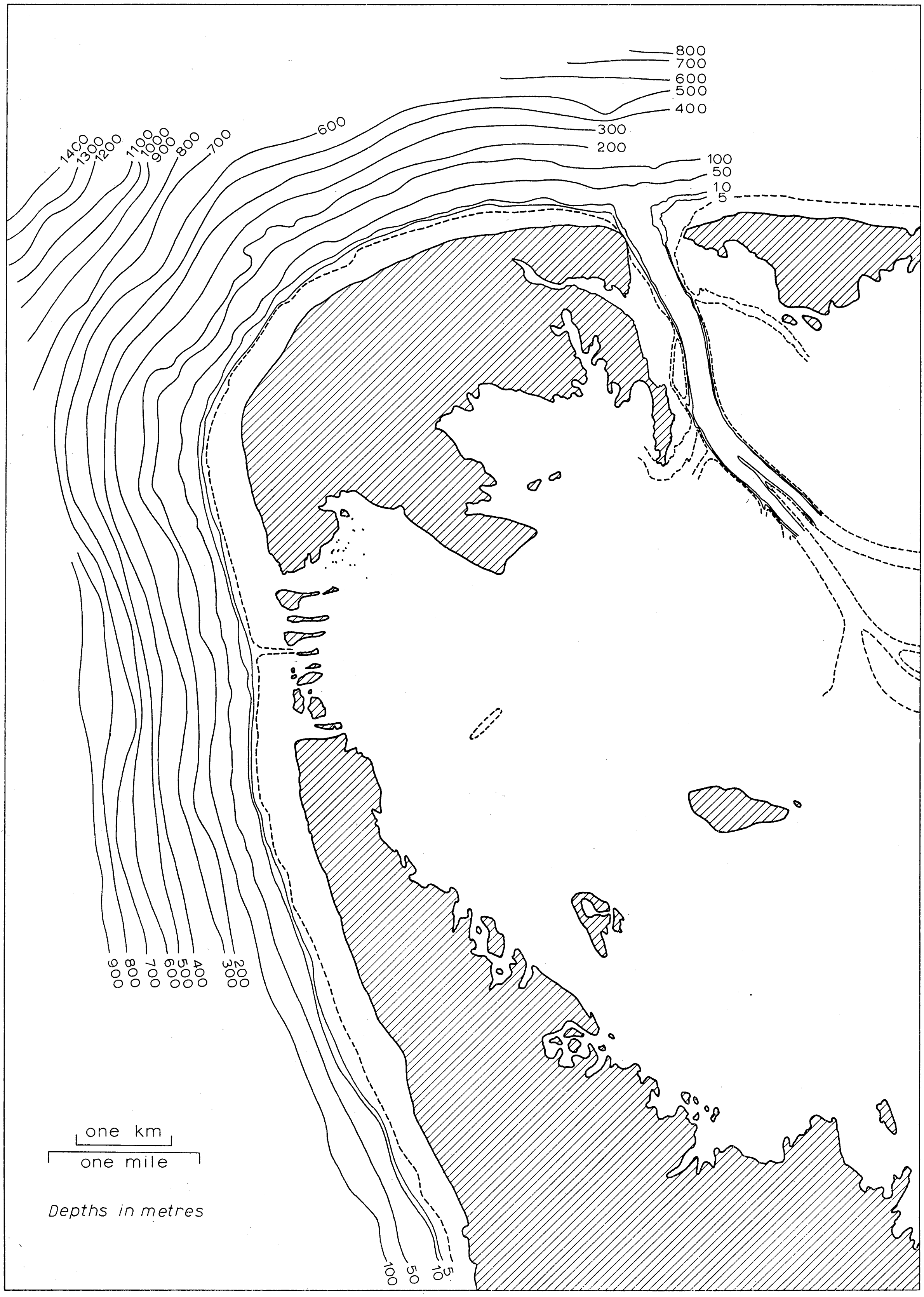

FIGURE 9. Northwest coast: bathymetry.

(3) Reef-front shelf, depth at outer edge 10 m, mean width 125 m, mean slope 4° 30′. Travis (1959, p. 163) has described a reef-front shelf with outer edge at 21 m, with furrows 0.6 m wide and 0.3 m deep.

(4) Fore-reef slope, depth 10 to 35 m, mean width 50 m, mean slope 25 to 30°.

(5) Fore-reef slope, depth 35 to 90 m, mean width 200 m, mean slope 15°

(6) Deep slopes below 90 m depth, mean slope decreasing to 10° down to 1000 m.

It is possible, though perhaps unlikely, that the slopes below 90 m are mainly volcanic constructional slopes, and those above are formed from reef deposits. If this is the case, the 15° slope between 35 and 90 m may be a fore-reef talus, and the succession of shallower facets may be erosional and constructional features underlain by reef limestone. The reef-front shelf with outer edge at 10 m is of interest because of the identification in other parts of the world of platforms at depths of 14 to 18 m. In the Bahamas, Marshall and Tuamotu Islands such reef-front platforms have been interpreted as erosional features dating from a lower sea-level; alternatively they may be equilibrium forms adjusted to the wave energy now expended on them, resulting from an adjustment between marine abrasion and coral growth. In the latter case the depth of such terraces would be a function of wave energy and would be expected to vary systematically round an atoll. If the feature is inherited from a Pleistocene low sea-level stand it is more likely to be horizontal.

A less detailed survey of the upper slopes has been made at the eastern end of Aldabra, between Anse Cèdres and Cinq Cases, by H.M.S. *Owen* in 1962 (figure 10). Profiles from these bathymetric data show the existence of a shelf, mostly deeper than 10 m, with its outer edge at 25 to 30 m, varying in width from 1 to 3.6 km. The slope of this shelf varies from about ¼° to 1½°. Travis (1959, p. 163) has described the surface of this shelf as formed of bare limestone with algae. Between depths of 25 and 80 m mean slopes range from 2 to 8° over a width of 400 to 1100 m, and steepen further below 80 m.

The submarine slopes at Point Hodoul do not therefore correlate well with levels at West Island, the shelf at the former having an edge depth of 25 m and at the latter of 10 m. Hodoul is much more exposed to present wave action than West Island, and a 10 m level at the former could have been destroyed by erosion. Alternatively the terraces at different heights may represent equilibrium forms which are deeper in more exposed and shallower in more protected situations. Without the discovery of such diagnostic forms as submerged caves, notches and intertidal beachrock, the significance of these features must remain in doubt.

### (*b*) *Lagoon channels*

The Aldabra lagoon is drained by two main channels, Main Channel (Grande Passe) and East Channel (Passe Houareau); by a smaller but deep channel, Passe Gionnet, between Polymnie and Middle Island; and by the shallow but eroding complex of channels through the atoll rim at West Channels.

Main Channel (figure 16, plate 5) consists of a branching network of deep channels extending for 6 km into the lagoon. Sediment distribution patterns on air photographs and observation of tidal streams suggest that Main Channel drains approximately 60% of the lagoon area. Assuming the mean depth at high springs of this drainage area to be 2 m, the total tributary drainage volume of Main Channel would be approximately $240 \times 10^6$ m$^3$. With a cross-sectional area in the Main Channel of 5000 to 6000 m$^2$, this volume of water could pass through the channel during ebb or flood of a semidiurnal tide if velocities of 3 m s$^{-1}$ (6 knots) are maintained throughout. Tidal stream measurements by H.M.S. *Vidal* show that such velocites are reached at the peak of ebb tides only, and it is likely that the residence time of some water within the lagoon may be comparatively long.

Main Channel has been surveyed in detail by H.M.S. *Owen* in 1962 and H.M.S. *Vidal* in 1967 (figure 11). Figure 11 also shows a series of transverse profiles drawn from the bathymetric data, and figure 12 longitudinal profiles from the same source. The main channel is steep-sided and flat-floored; the sides are in places overhanging. The floor has a fairly constant maximum depth of rather more than 20 m for 3 km from its mouth. Greatest depths of up to 27 m are found in scoured and overdeepened sections distant from the mouth. Lagoonward the channels shoal slightly, especially at bifurcations, but depths of 10 m are found almost to the heads of the tributaries. Tributary channels, as distinct from bifurcations in the main channel, are not accordant with the main channel: the main tributary, south of Polymnie, is generally less than 5 m deep, compared with 20 m in the main channel. At the heads of tributaries the channels become less incised and broaden into fields of growing coral.

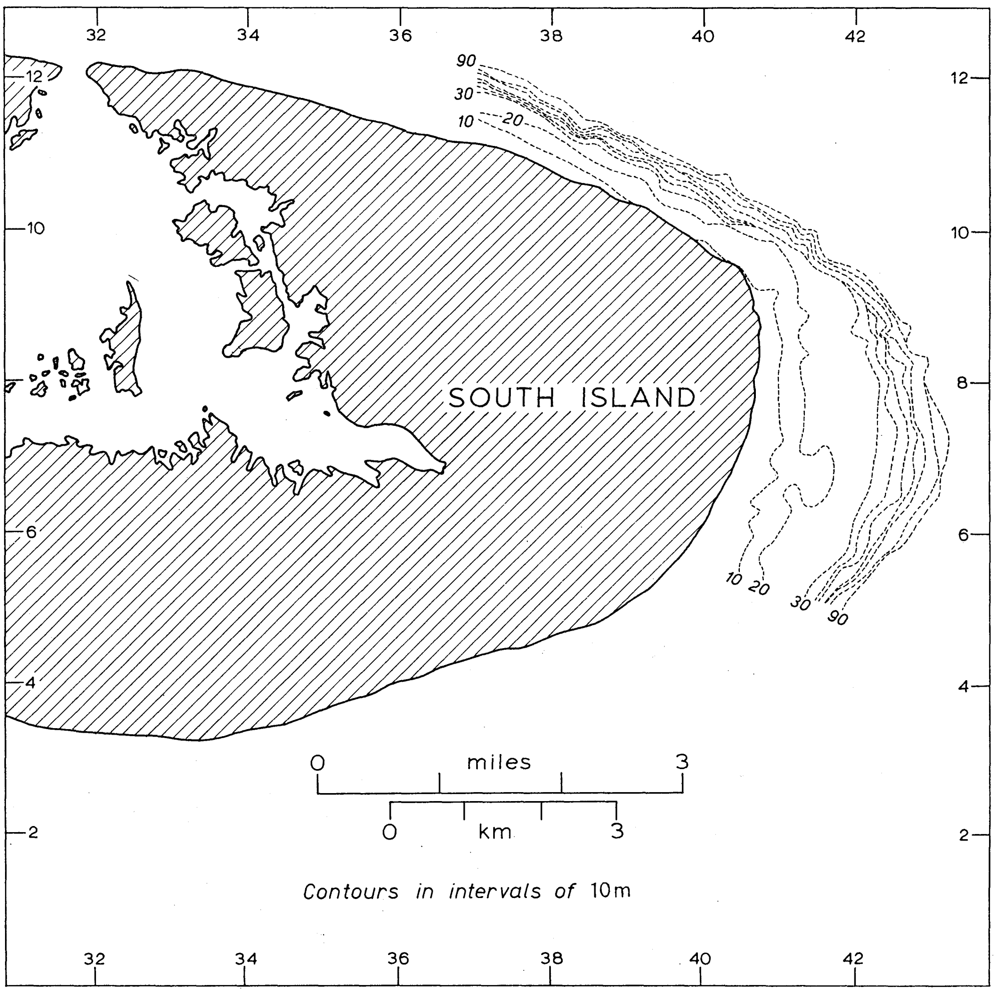

FIGURE 10. Point Hodoul: bathymetry.

The flat floor of the main channel at about 20 m may be either (i) an equilibrium or still deepening form resulting from solution during present tidal discharge, or (ii) inherited from

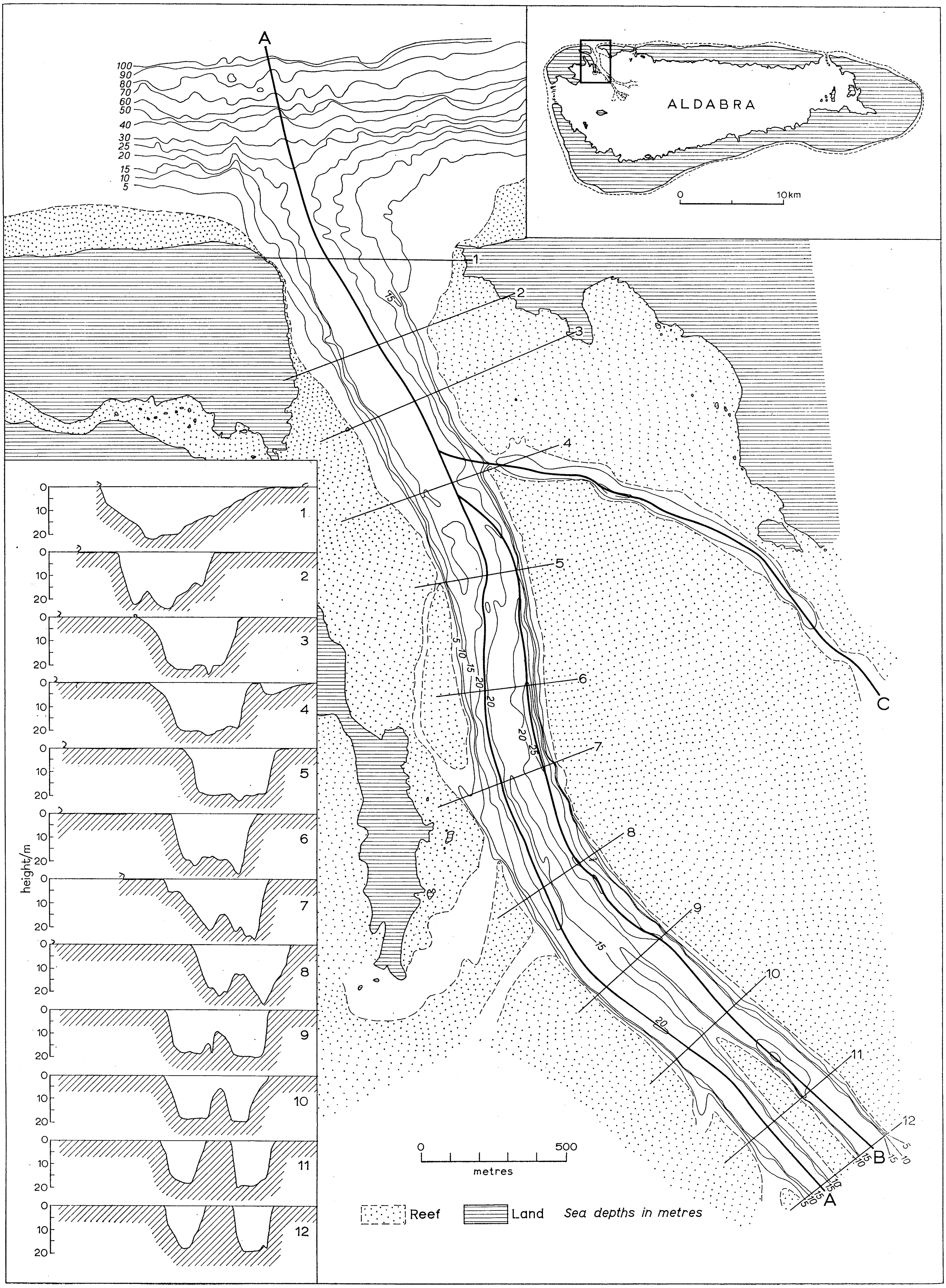

FIGURE 11. Main Channel: bathymetry and cross-sections.

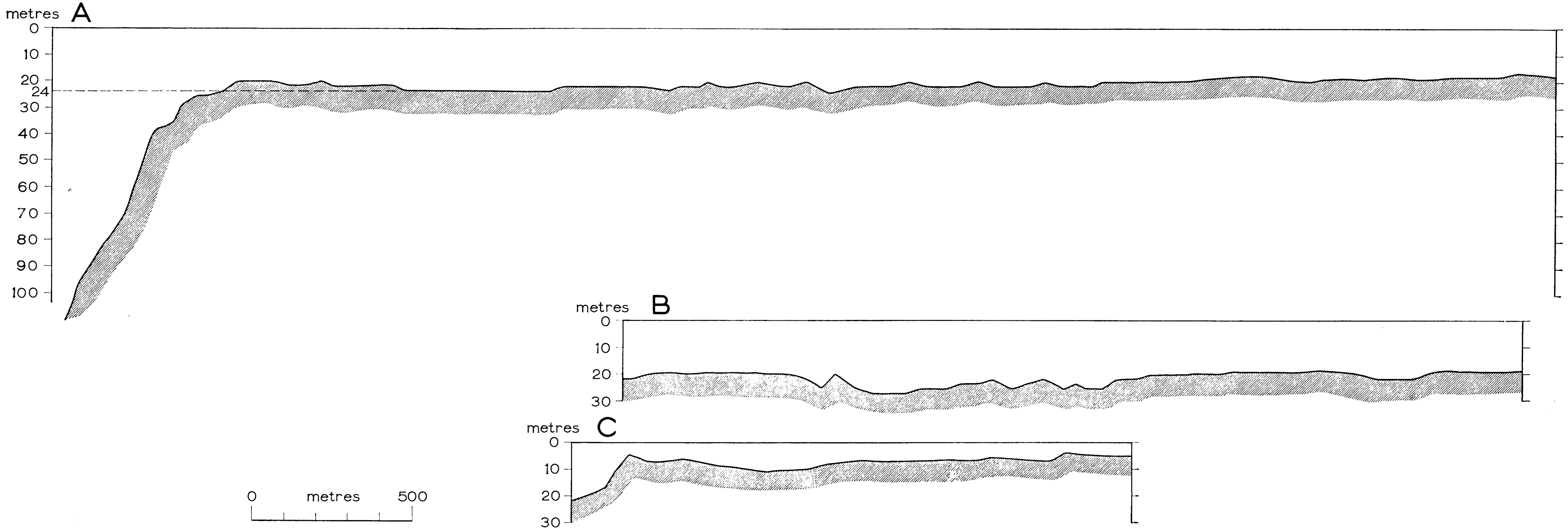

FIGURE 12. Main Channel: longitudinal profiles.

a low-level stillstand of the sea when subaerial drainage systems may have been in operation. The second explanation is unlikely: (*a*) there is no reason why an integrated surface drainage system should have formed on permeable limestones when the sea was lower, (*b*) the amount of discharge required to form a fluvial system of this type would be unlikely, and (*c*) the longitudinal profiles and discordant tributary junctions are unlike those of fluvial systems. The 20 m level does not correlate with the terraces on the adjacent seaward slopes of West Island, though it could be linked with the 20 to 25 m terrace at Point Hodoul. It is more likely that the form of Main Channel is adjusted to present tidal discharge.

This interpretation is supported by inspection of the other channels, none of which has, however, been surveyed in detail. All have smaller tributary areas and discharges than Main Channel, and also smaller depths. East Channel (figure 16, plate 5), draining about 11 % of the lagoon, has maximum depths of about 15 m; Passe Gionnet, draining only one-tenth the area of East Channel, has soundings of less than 9 m. Of West Channels (figure 15, plate 4), all are shallow passes which do not dissect the intertidal platform (except locally) and which are wadable at low water, except for one deeper channel, Passe du Bois, which is eroding into the flat from seaward. This has a maximum depth of 5 m.

### (*c*) *Lagoon floor*

The topography of the lagoon floor is very inadequately known, largely because no land bench marks related to an atoll tidal datum have yet been established round it. Normal sounding methods are inappropriate because of the high tidal range and complex lag effects within the lagoon. In the course of sediment sampling, Taylor has established that the lagoon is rock floored, and that sediment cover is thin except in the vicinity of channels. In most of the central lagoon sediment is insufficiently thick to cover the underlying rock. At the southern margin of the lagoon the floor is pitted, with numerous depressions 1 m in diameter filled with fine sediment. The rest of the lagoon floor is fairly uniformly flat and smooth, with only minor local pitting.

Probably no part of the lagoon, except the channels, is deeper than 5 m at equinoctial springs. This is unusually shallow for an atoll lagoon of this size, even allowing for an extra minimum additional water depth of 10 m indicated by features on the atoll rim. The width of the lagoon varies from 6 to 10 km; it is improbable that a surface so wide has been formed by processes of cliff retreat now in operation on the lagoon margins. Work on the chemistry of lagoon and channel waters should throw light on the processes now in operation. The absence of major solution features on the lagoon floor, comparable to the 'blue holes' of the Bahamas and certain Caribbean reefs, is very striking, and the flatness of the lagoon floor also contrasts with the karst forms one would expect to have developed during the presumed late-Pleistocene emergence of the atoll. Much of the present lagoon floor topography is in fact comparable to that of the broad platin area north of Cinq Cases.

## 8. CHRONOLOGY, PROCESS RATES, AND CLIMATIC CHANGE

Before attempting to combine the available information on geology and geomorphology of Aldabra in a reconstruction of the history of the atoll, it is necessary to consider questions of absolute chronology, the rates of operation of present-day processes, and the possibility of climatic as well as sea-level change.

### (*a*) *Chronology*

Because of the wide lateral facies variations in the raised limestones and the present lack of island-wide stratigraphic correlations, the chronological framework of the exposed limestones is still uncertain.

Samples were taken from Ilot Emile in West Channels, where the present intertidal notch is cut in massive Lower Limestone, and above the notch, forming the capping of the island, is a horizon of Upper Limestone, with much stagshorn *Acropora*. Weathering out of the Lower Limestone, in the roof of the notch, are large valves of a giant clam, *Tridacna* sp., which is not found living in the modern Aldabra reefs. This large clam is apparently absent from the Upper Limestone, where a smaller clam, *Tridacna* (*Chlamytrachea*) *squamosa*, is common. Valves of a large *Tridacna* are fairly common elsewhere on Aldabra, particularly on the platin north of Cinq Cases. They have been collected from Point Hodoul, Bassin Flamant, Cinq Cases, Dune Jean-Louis, the ridge inland from Anse Var, Anse Cèdre Brissant, and Point Tanguin. The largest specimens have valves up to 1 m wide, with a mass of almost 100 kg; they were free-living forms in rocks of lagoonal facies.

Two samples of the giant *Tridacna* from the Lower Limestone at Ilot Emile (061, 085), one from Point Tanguin (099, 103), one from the large solution hole at Point Hodoul (401, 092), and one from the platin surface north of Cinq Cases (390, 068) gave carbon-14 ages in excess of 39.9 ka. Whether all the giant *Tridacna* are of the same age, and whether those from the West Channels Lower Limestone are stratigraphically equivalent to those from the Anse Var ridge and the Cinq Cases platin, has yet to be established, though a sample from Dune Jean-Louis (265, 038), dated at 26.95 ± 0.9 ka, suggests that the relationships may not be simple.

The Upper Limestone at Ilot Emile contains abundant *T. squamosa*, and this is common on the surface, in the position of growth or as loose valves, over much of the champignon surface, including the sides of the 8 m ridge at Cinq Cases and Point Hodoul. One sample from Ilot Emile (061, 085), from the surface, also gave a carbon-14 age greater than 39.9 ka. Two samples from the Upper Limestone on Ile Polymnie (106, 123) gave ages of $38.8 \pm ^{3.7}_{2.8}$ and $37 \pm ^{2.9}_{2.2}$ ka, respectively. A further sample from the surface inland from Anse Cèdres (365, 105) gave an age of $34.9 \pm ^{2.2}_{1.8}$ ka, one from the platin at Cinq Cases (395, 057) an age of 34.3 ± 1.9 ka, and one from the side of a gap in the 8 m ridge at Point Hodoul (403, 093) an age of 28.7 ± 0.95 ka.

The valves of *Chama imbricata* cemented to the Upper Limestone at West Island have not yet been dated. More dates on *Tridacna* material are awaited. In spite of the difficulties inherent in the method and the material, it is likely that absolute age determinations will be of great value in working out the geological succession on Aldabra. It has not yet been possible to obtain carbon-14 dates on collagen from fossil tortoise bones found in brown pipe-limestone deposits, because of their highly mineralized state and the consequent need for extremely large samples.

### (*b*) *Process rates*

No measurements have yet been made of rates of operation of erosional processes on the Aldabra limestones. Measurements from raised limestones in other parts of the world, often under different climatic conditions, are of doubtful relevance in the Aldabra case, except to suggest orders of magnitude involved.

Hodgkin (1964) found rates of solution in intertidal notches to average 1 mm $a^{-1}$. Such rates on Aldabra would be sufficient to cut notches of the depths now found during the present stillstand of the sea, but would not be adequate to account for the formation of intertidal flats several hundred metres wide in the time presumed available in the Holocene. Nor could such rates account for the origin of the lagoon in terms of marginal cliff recession.

There is little information on rates of operation of areal erosion processes. It is possible to make approximate estimates of possible erosion on Aldabra, however, making assumptions about rainfall and duration. If rainfall over the past 120 ka is assumed to have been 0.65 m $a^{-1}$, the total amount would have been $78 \times 10^3$ $m^3/m^2$. Assuming 75 % evaporation or transpiration, the remaining $20 \times 10^3$ $m^3/m^2$ would be capable of dissolving 800 kg calcite at 25°C and atmospheric $CO_2$ pressure, if saturation is achieved. Assuming a calcite density of 1.35 g $cm^{-3}$, this is equivalent to 0.6 $m^3/m^2$ or 0.6 m vertical loss over 120 ka. Similar calculations have been made for wetter Bermuda, and have thrown doubt on the interpretation of Bermuda as a late Pleistocene karst (Land, Mackenzie & Gould 1967), and also in Florida by Ginsburg (1953).

The calculation takes no account of variations in facies and mineralogy in the Aldabra limestones, and the assumption of constant rainfall since the last Interglacial is almost certainly false. It does, however, suggest a difference of two orders of magnitude between marine and subaerial erosion rates. This needs to be substantiated by measurements of processes now in operation.

### (c) *Climatic change*

Evidence for climatic change at Aldabra is at present tenuous. Many of the platin pools on South Island have clearly been larger in the past than they are now (figure 26, plate 7). Features such as notched marginal cliffs and pool-floor sediments show that in some cases pools were formerly 0.6 to 1 m deeper than at present, and many times their present area. If weather conditions since 1966 have been representative of climate of recent decades, the total rainfall of about 0.65 m $a^{-1}$ is inadequate to fill these larger pools, in spite of the seasonal and episodic nature of the rainfall. Hence higher rainfall, lower evaporation, or both, are indicated, though the magnitudes involved will not be known without detailed topographic surveys of the pools. It is possible that they are still filled in occasional years of exceptionally heavy rainfall: the presence of freshwater molluscs, including *Bulinus* (though mostly dead), in dry sediments and on rocky residuals in pool areas suggests that the last such period may have been quite recent.

Alternatively, it is possible that longer term climatic fluctuations are indicated, and this is possibly supported by apparent fluctuations in tortoise numbers since *ca.* 1880 (Stoddart 1968, p. 479). Fryer found few tortoises in 1905, and it may be that the present high population built up from low late-nineteenth century levels during favourable years between 1910 and 1950, when rainfall may have been higher, and that conditions are now drier once more. There is some evidence from the vegetation (presence of only mature trees on the dunes, lack of regeneration) for this view, though there are no instrumental records or even casual observations from 1910 to 1950 to support it. Climatic records from other Indian Ocean islands, where available, also show no evidence of such variations.

The larger question of climatic changes during the Pleistocene cannot now be discussed. Presumably Aldabra would be affected by latitudinal variations in the Trades, and it may have experienced one or more 'pluvial' periods. Pollen analysis of sediments from deeper pools and holes may help to suggest such changes through the vegetation record, but post-depositional disturbance of these sediments may have been so great that reconstruction is not possible. It is likely that more information on climatic change will be obtained from northern Madagascar, the Comoros and the African coast than from Aldabra and other similar islands.

## 9. Evolution of Aldabra

### (*a*) *Age of the main reef limestones*

Bathymetric and geophysical evidence for the western Indian Ocean indicates that Aldabra and neighbouring islands consist of coral caps on volcanic mountains which may date back to late Cretaceous or early Tertiary times. The date of initiation of coral growth is unknown.

The surface limestones on Aldabra consist of two major units: an older Lower Limestone and a younger Upper Limestone. Radiocarbon ages on *Tridacna* shells from the Lower Limestone are in excess of 39.9 ka. Dates from the younger limestone range from 26.95 to more than 39.9 ka. The surface limestones at Aldabra, forming the land rim, are probably of late Pleistocene age. The age of the Upper Limestone is anomalous, in that world sea-levels are generally considered to have been low at this time: they thus indicate either a revision of the eustatic curve, a consistent error in the material dated, or local movement of Aldabra. Revision of the eustatic curve is not entirely to be ruled out (Milliman & Emery 1968), for similar dates on raised limestones have been reported elsewhere in the coral seas; on the other hand, the form of neighbouring atolls, such as Astove and Cosmoledo, suggests the occurrence of local independent movements, including tilting. It has yet to be determined whether the Aldabra emergence is eustatic, tectonic, or both.

Data from other Indian Ocean coral reefs is relevant here. Carbon-14 ages for elevated reefs in the Red Sea are all greater than 30 ka (Nesteroff 1959; Berry, Whiteman & Bell 1966). Uranium-series dates have been obtained by Veeh (1965) for elevated fringing reefs on Mahé and Praslin, Seychelles, and on Gabriel Island, Mauritius, at 9, 6 and 2 m above sea-level, respectively, of 140, 140 and 160 ka, These ages are in broad agreement with others from the Pacific Ocean, suggesting reef growth during the last Interglacial and subsequent emergence.

Raised reefs are also found in Madagascar, especially on the west coast: two reef limestones of different elevations and ages can be distinguished in both north (Guilcher 1956; Battistini 1965*a*) and south Madagascar (Battistini 1964). Each reef is associated with overlying dunes, and the whole sequence is assigned to the Madagascan Aepyornian (Quaternary *sensu lato*). The higher older reef, varying in elevation from below present sea level to 16 m above it, and the overlying Grande Dune are dated as Tatsimian, and the lower reef, at about 3 m, and Petite Dune, as Karimbolian by Battistini (1964). The Karimbolian has been correlated in terms of elevation with the Ouljian of northwest Africa, and thus with the Mediterranean sequence. There followed a regression after the formation of the Karimbolian reef (corresponding to the last glaciation?), and finally a transgression corresponding to the Flandrian. The Madagascar sequence is important in spite of being dated entirely in local terms, for it has been correlated with a sequence on Europa Island in the Mozambique Channel (Battistini 1965*b*, 1966). Europa is raised atoll 6 km in diameter, which repeats in miniature many of the features of Aldabra, particularly the occurrence of champignon and platin on the atoll rim, and of a central lagoon. Unlike Aldabra only a single limestone has been found on Europa. Battistini correlates it by age and appearance with the Madagascar Karimbolian or last interglacial. It would, therefore, correlate with the raised reefs of Seychelles and Mauritius dated by Veeh. Battistini interprets the lagoon and peripheral platin of Europa as the primary lagoon of a Karimbolian atoll, but believes that the Flandrian transgression may have temporarily submerged the platin.

The reef sequence of the East African coast has not been studied in detail. At Bamburi, near

Mombasa, reef deposits extend from +26 to −59 m; at Mombasa a platform is cut into the raised reef at 9 to 12 m above sea level, with a less prominent terrace at 3 to 4.5 m (Caswell 1953). These levels are similar to those of the 8 m ridge and 4 m terrace at Aldabra, but the Mombasa levels are not constant along the Kenya coast (Thompson 1956; Williams 1962). On grounds of time available for reef growth and supposed correspondence with European levels, Caswell dates the main reef growth as 'Second Interpluvial' (post-Kamasian, or (?) Mindel-Riss), and the 9 to 12 m terrace as 'Third Interpluvial' (post-Kanjeran, or (?) Riss-Würm). There are, however, no absolute dates, and the identification of pluvials in East Africa and their correlation with the European glacial sequence has not survived detailed re-examination by Bishop (1962) and Flint (1959). Caswell's suggested age for the 9 to 12 m level at Mombasa is not inconsistent with the inferences already made for the Seychelles, Mauritian and Madagascan reefs.

### (*b*) *Problem of Holocene sea-level*

In none of the western Indian Ocean reefs so far described has a reef similar to the Aldabra Upper Limestone reef of 34–39 ka been described. Conversely, there is as yet no firm evidence for Holocene high stands of the sea at Aldabra, though if these occurred they would have inundated large areas of platin. Evidence for such Holocene high levels in the western Indian Ocean is of two types: (*a*) dated reef deposits above present sea-level; (*b*) multiple tidal notching of limestone cliffs, in some cases radiometrically dated. At Aldabra it is possible that *Chama* shells cemented to the Upper Limestone and low level fossiliferous calcarenites of the kind found at Passe Gionnet may have been formed during the Holocene.

Carbon-14 dates on elevated reefs in the western Indian Ocean have been obtained as follows:

| | | |
|---|---|---|
| Ceylon | reef at 0.6 to 1 m | 2990 ± 220 a (Shepard 1963) |
| South Madagascar | reef at 0.5 to 0.6 m | 860 ± 100 a (Battistini 1963) |
| Gulf of Aqaba | 'shoreline' | 4770 ± 140 a (Friedman 1965) |

Elevated or multiple notches on limestone cliffs are absent from Aldabra, and also from other southwest Indian Ocean islands, including Cosmoledo, Astove, Assumption and Europa, but are present in the Red Sea (Guilcher 1955) and in both south and north Madagascar. Battistini (1964) has found notches at present sea-level, 0.4 to 0.6 m, 1 to 1.3 m, and 2.3 to 2.5 m. These apparently correlate with Red Sea levels. Shells from the 1 to 1.3 m notch give radiocarbon dates of 2250 ± 420 a.

If the Holocene sea-levels indicated by the raised reefs and notches are eustatic, which has yet to be firmly established, then their absence from Aldabra requires explanation. With the possibility of continuing local movement at Aldabra, as well as sea-level changes, correlation or dating of deposits by height alone will be dangerous. More work is needed at Aldabra on deposits which may post-date the Upper Limestone.

### (*c*) *Major relief of Aldabra*

The oldest and highest part of Aldabra is formed by the 8 m ridge, the extent of which is shown rather schematically in figure 5. The Upper Limestone where found lies at lower levels on the edge of the 4 m terrace seaward of this ridge, and the 4 m terrace itself may be an erosion flat developed at the time of formation of the Upper Limestone. The terrace may be compared in width with the present intertidal platform, for example at Cinq Cases, and it is tempting to see in the steep seaward slopes of the 8 m ridge homologues of the present seaward cliffs. No tidally notched cliffs have been found on the 8 m ridge face, but notches are also absent from the present cliffs on the south coast of the atoll. If the 8 m face in the Cinq Cases area was formerly a sea cliff, it would presumably have been ramplike and irregular, like the present cliff, with possibly a low-water neaps bench and notch. There are traces of such a possible low-water neaps bench in places at the foot of the 8 m ridge face near Cinq Cases.

Under this interpretation the 8 m ridge has undergone considerable erosion, at least on its seaward side, and is not an original constructional feature in its present form. The ridge at Anse Var, for example, consists largely of back-reef or lagoonal deposits, and the reef framework on the seaward side has presumably been eroded away. Further evidence of erosion on the seaward side of the 8 m ridge is given by residual pillars of brown pipe-limestone near the present cliff top. One of these near Cinq Cases protrudes through perched beach deposits 31 m from the edge of the seaward cliff and 85 m seaward of the 8 m ridge: it is filled with tightly cemented tortoise bones in a brown matrix. Reef limestone with solution holes in which this pipe deposit formed clearly stood higher on the 4 m terrace than it does now. We conclude that the relief of the present 8 m ridge is not entirely depositional. Gaps in the ridge east of Cinq Cases have flat floors at the 4 m level: they may be original reef gaps from 8 m times, reoccupied by the 4 m sea, or they may have been eroded by the 4 m sea at the time of the deposition of the Upper Limestone.

### (*d*) *Development of surface features*

The surface of the 8 m ridge on the leeward side of the atoll consists of pavé, a fairly smooth, locally irregular surface with some solution pans and occasional deep potholes. On the windward side of the atoll, the pavé surface has largely disappeared and has been partially replaced by an irregular pinnacled champignon, with accordant pinnacle heights and patches of surviving pavé.

The surface of the 4 m terrace, especially near its edge, consists of champignon with solution holes, some of which are blowholes. The surface is more irregular than that of the pavé on the leeward 8 m ridge, presumably because, on West Island, the pavé surface is formed on backreef facies, whereas the 4 m surface is on coral facies.

The area lagoonward of the 8 m ridge is difficult to interpret. There is some evidence of an old sea cliff on the lagoonward as well as the seaward side of the 8 m ridge. This is well seen at the south end of West Island, where the dissected limestone ridge reaches a height of only 5.3 m, before falling abruptly, in places by a vertical clifflet 1.5 m high, to a horizontal platin surface at 3 m above datum. This platin surface now forms a strip as little as 10 m wide: it is being dissected by deep potholes and fissures advancing from the lagoon, from a salt-water table 2.5 to 3 m below its surface, to form an extreme champignon. Close to the platin remnant this champignon has accordant pinnacle levels; within 100 m this regularity has become less apparent. It is difficult to explain the pattern except by changes in groundwater relations. The 3 m platin surface *may* correlate with the cutting of the 4 m seaward terrace and deposition of the Upper Limestone: with the fall in sea-level to the present, a wave of retrogressive solutional erosion was initiated at the lagoon margin and has advanced rapidly toward the old shoreline through former lagoon floor deposits. It is of course possible that the 3 m platin is of different age from the 4 m terrace. Whether the platin level on West Island correlates with the main platin surface on South Island, and whether it is possible to distinguish a lagoonward sea cliff on the much more eroded 8 m ridge on South Island, have not yet been satisfactorily determined. The general similarity between present lagoon floor topography and that of the main platin surface, and the presence of basally notched residuals on the platin, both suggest a former inundation by the sea. Why the Takamaka–Cinq Cases platin has escaped the wave of retrogressive champignon formation now active on West Island, and which may possibly already have destroyed platin surfaces on the lagoon side of South Island between Dunes d'Messe and Jean-Louis, remains unknown, though the destruction of platin by opening of joints and formation of sinkholes near Cinq Cases is certainly beginning.

This interpretation of the development of surface forms, while clearly only a first approximation, raises certain stratigraphic problems which cannot at present be settled. One of the most important is the fact that in West Channels giant *Tridacna* are found in the Lower Limestone and *T. squamosa* in the Upper, whereas giant *Tridacna* are widespread on the South Island platin, which was presumably inundated in Upper Limestone times. It must also be emphasized that topographic control is everywhere inadequate on Aldabra, and that detailed interpretation must await the production of large-scale topographic and geological maps.

This interpretation probably also pays inadequate attention to the way in which present surface features are being altered by erosion, and particularly to the stages in the transformation of champignon to flat-lying platin. Fosberg (1969) has indicated genetic stages in this sequence. It will be difficult to assess the relative importance of such transformation until data are available on rates of solution: figures so far calculated, while clearly highly approximate, suggest that subaerial solution processes may be quantitatively inadequate, over the probably available time span, to form the major features of Aldabra geomorphology, in particular the regional distinction between champignon, pavé and platin, while possibly capable of local modification.

Observation of surface forms suggests also that the processes of development of champignon may be diverse. On littoral champignon, where the pinnacled limestone was first observed and the term applied, solution appears to be mainly by salt spray acting from above. In cases where platin is being converted to champignon, however, the main solution is taking place from below. The platin surface is largely a self-sealing case-hardened surface of low permeability. Deposits below the surface crust are less strongly lithified, and it is likely that much solution takes place in fresh, brackish and even salt water at the water table, which is commonly 1 to 4 m below the ground surface. The first stage in the conversion of platin to champignon is often the appearance of surface fracturing caused by collapse over water-table caverns: such fractures once formed rapidly enlarge into chasms and holes, down which surface water and rainwater can percolate. Scoriaceous rather than pinnacled champignon develops on the edges of these features. Further investigation is needed on cavernosity, both in champignon and under apparently undissected platin, and on the hydrology and chemistry of water at the water table.

Carbon-14 age determinations were made by Isotopes Inc. of New Jersey. We thank Mr R. Sotiriov for analysing the solution-pipe fills using the X-ray fluorescence spectrometer at the Department of Geology, University of Hull.

Figures 2, 3, 9, 10, 11 and 12 are reproduced from, or based on, original British Admiralty surveys and charts with the sanction of H.M. Stationery Office and of the Hydrographer of the Navy.

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FIGURE 13. South Island from the air, showing (A) the dune at Entreboy and the narrow seaward perched beach; (B) high coastal champignon with low scrub; (C) low champignon with dense scrub of *Pemphis* and *Mystroxylon*; (D) lagoonward mangrove fringe.

FIGURE 14. The South Island platin from the air, showing (A) dunes at Cinq Cases and the narrow seaward perched beach; (B) high coastal champignon, without vegetation; (C) platin with open woodland and numerous pools; (D) the bare inland fringe of the mangroves, with scattered trees of *Lumnitzera* and *Avicennia*; (E) the mangroves of Bras Takamaka.

FIGURE 15. Main and West Channels from the air.

FIGURE 16. East Channel from the air. Figures 13–16 are reproduced by permission of the Commissioner of the British Indian Ocean Territory. (Crown copyright reserved.)

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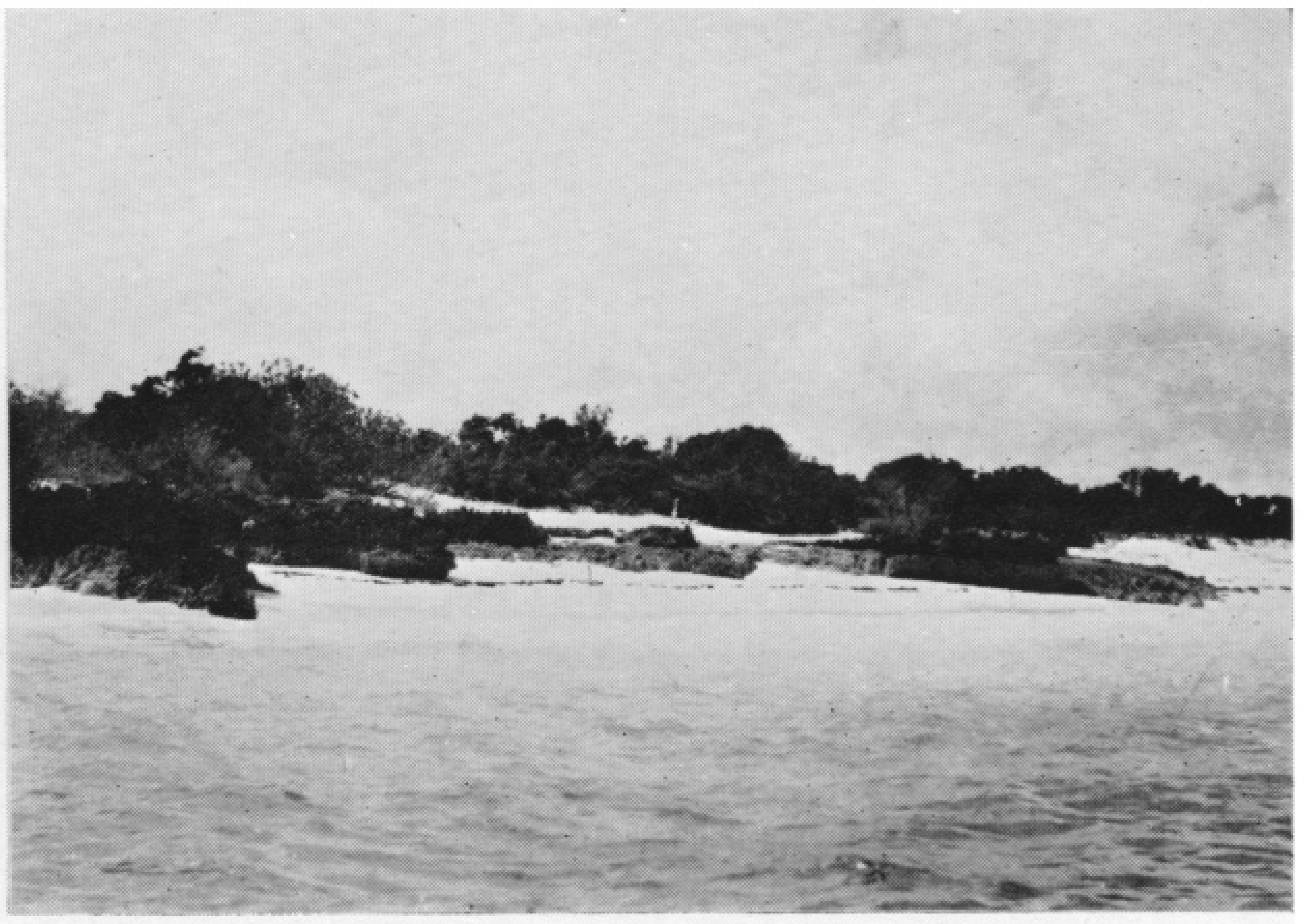

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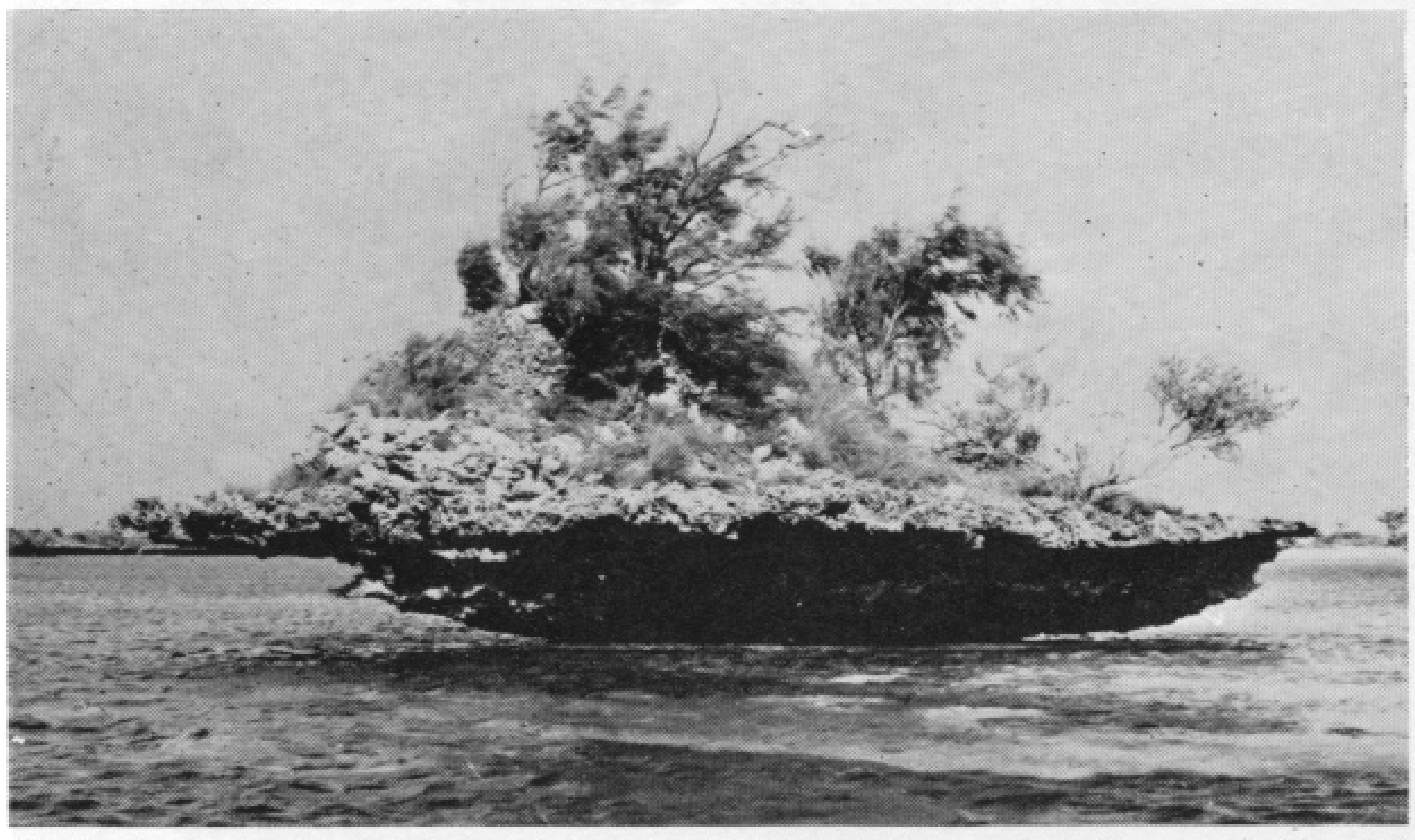

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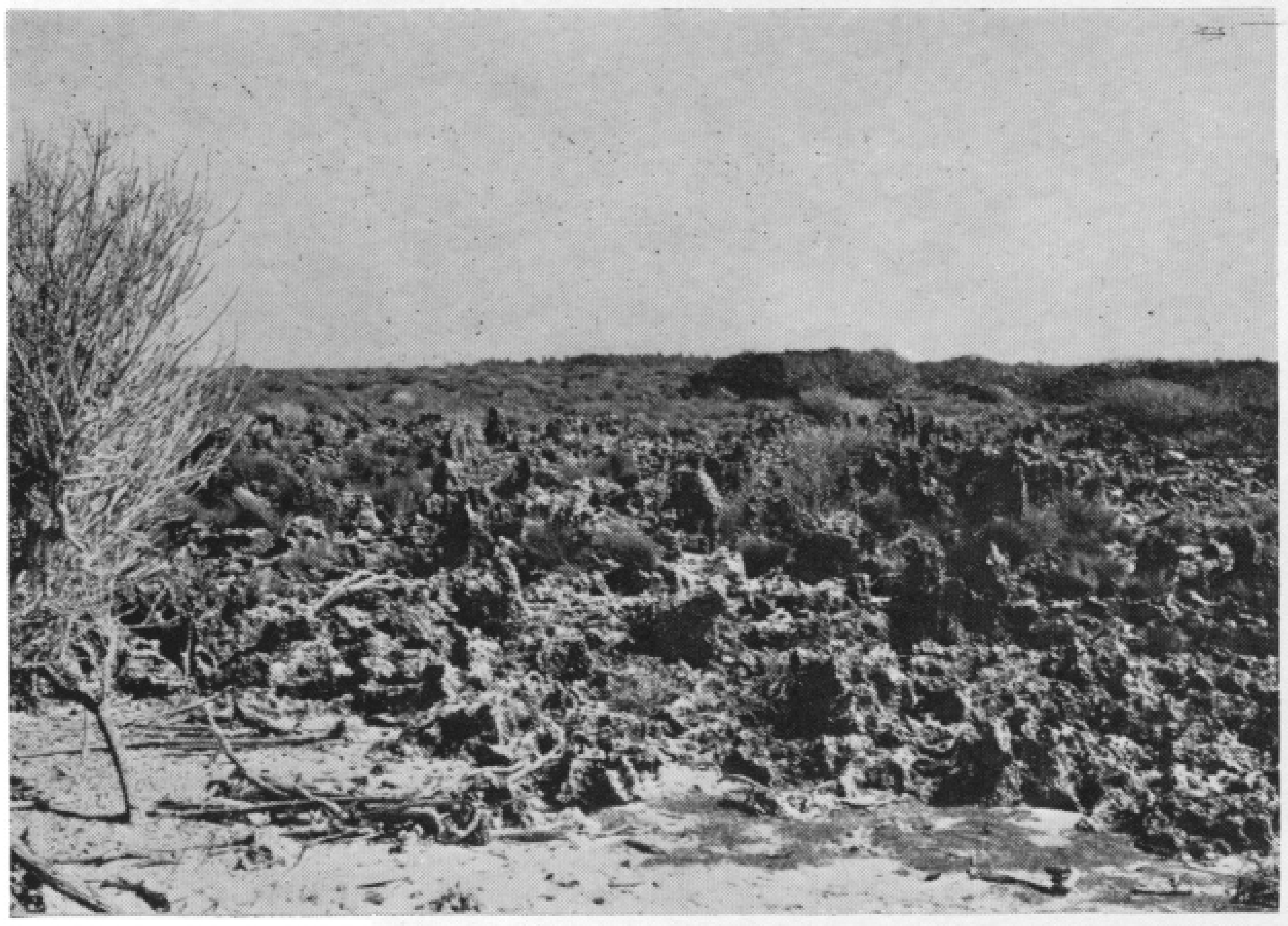

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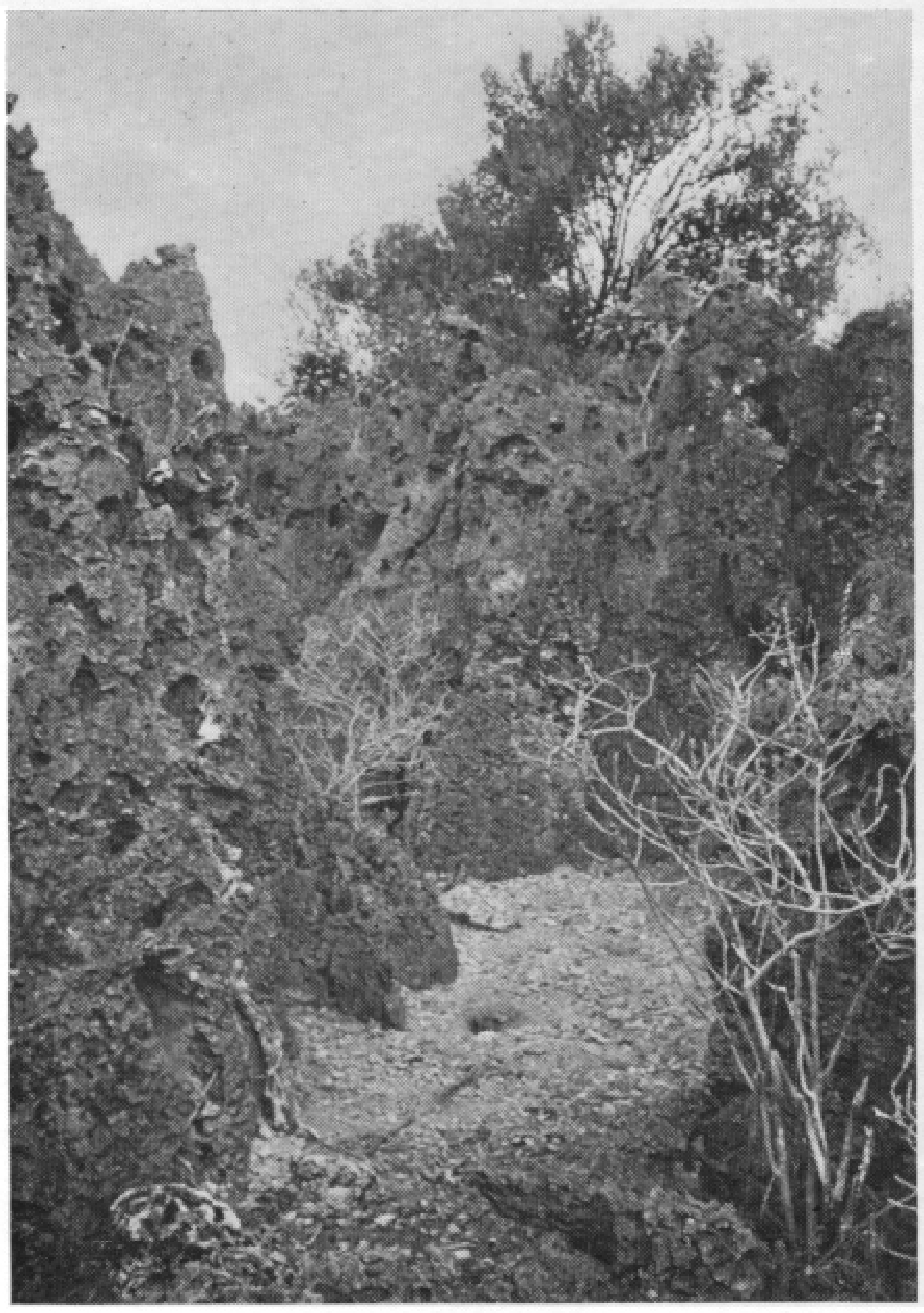

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Figures 17 to 24. For legends see facing page.

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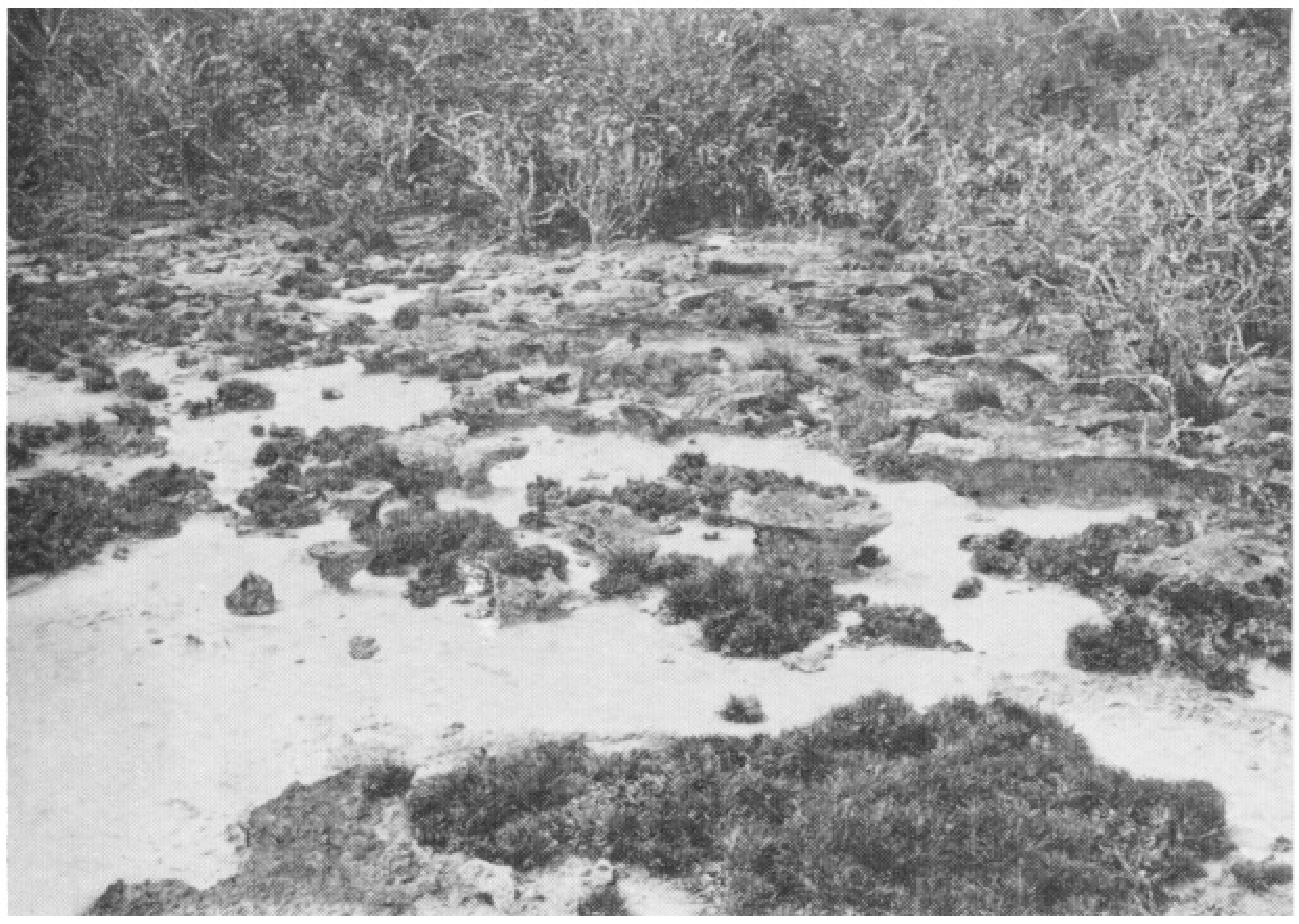

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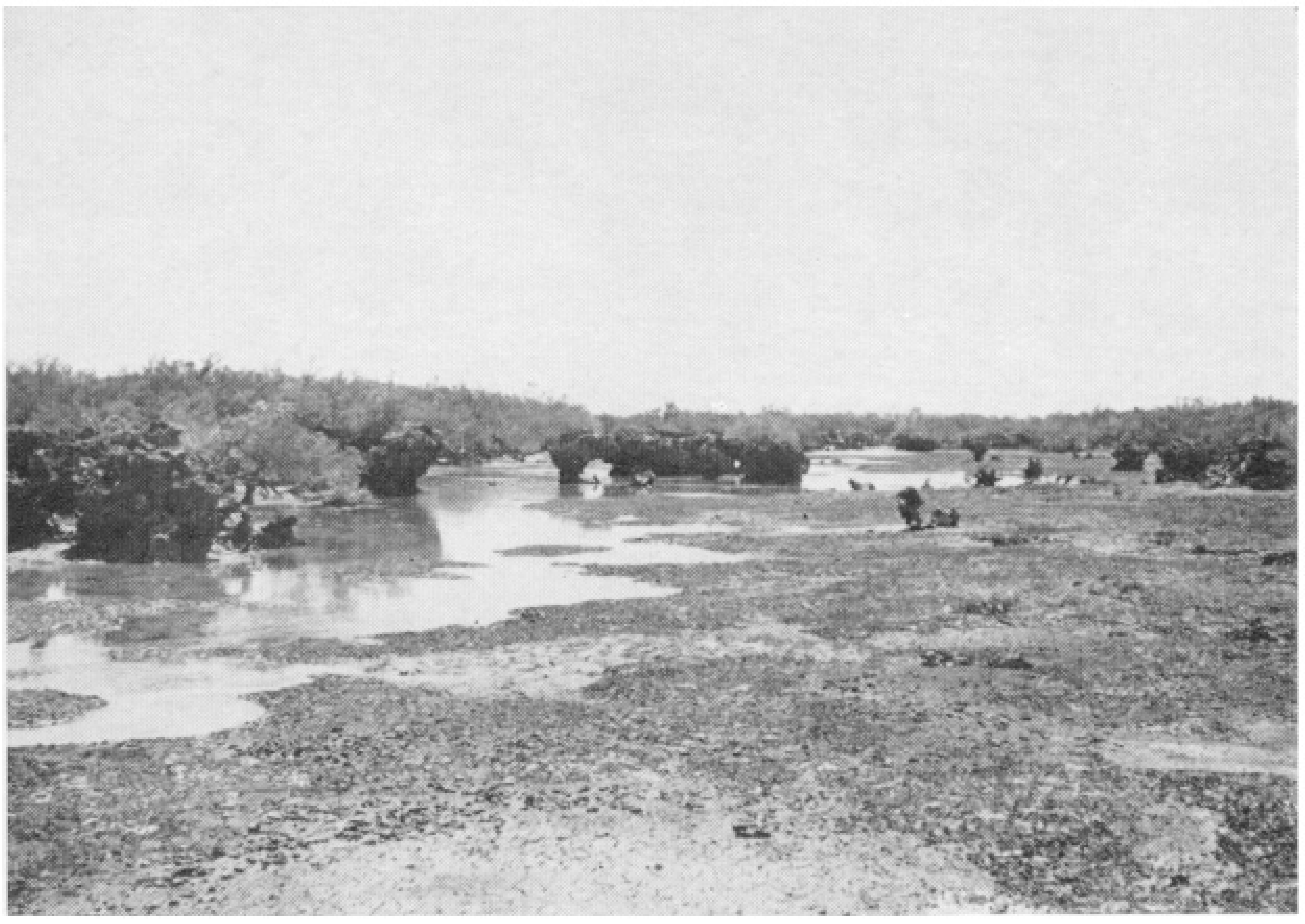

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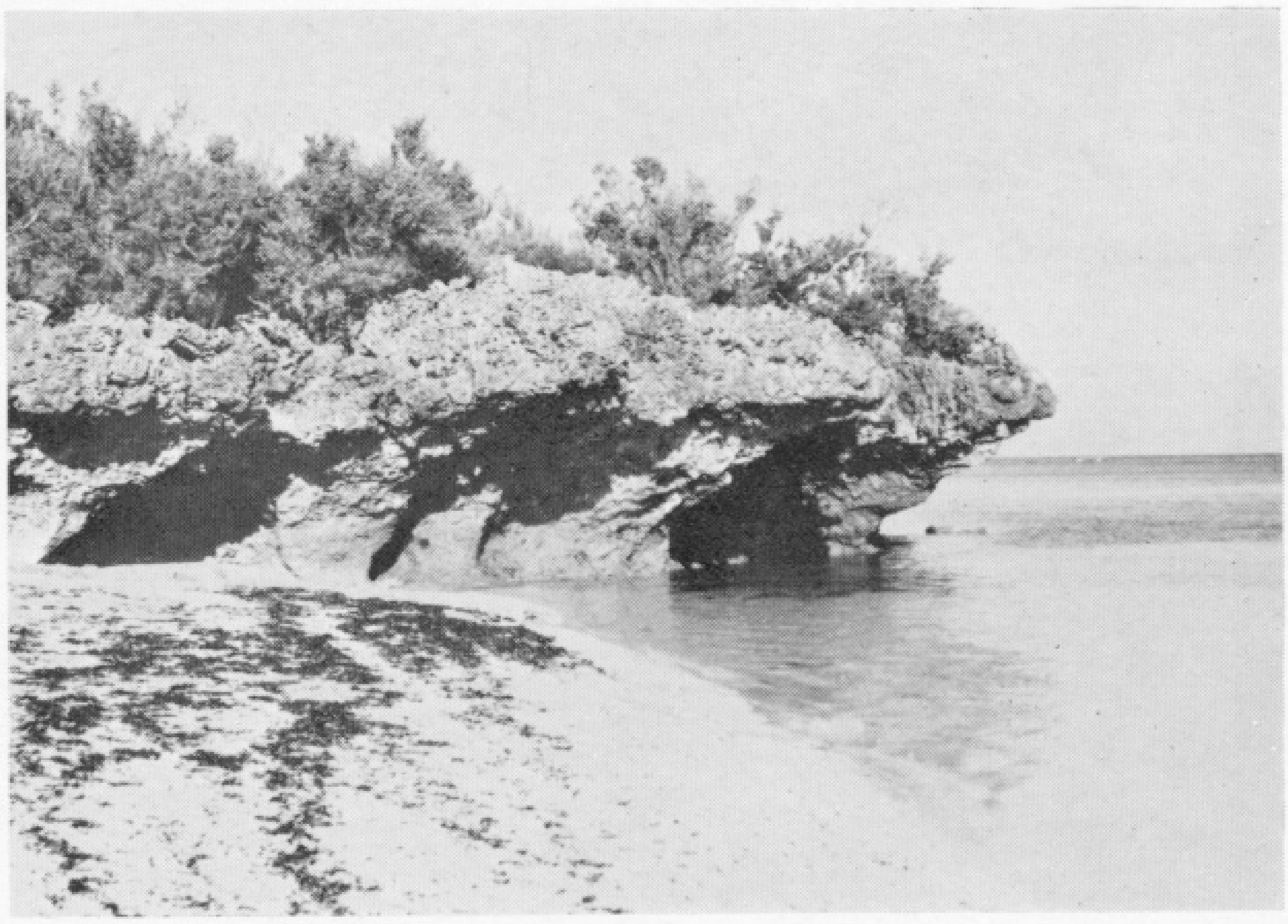

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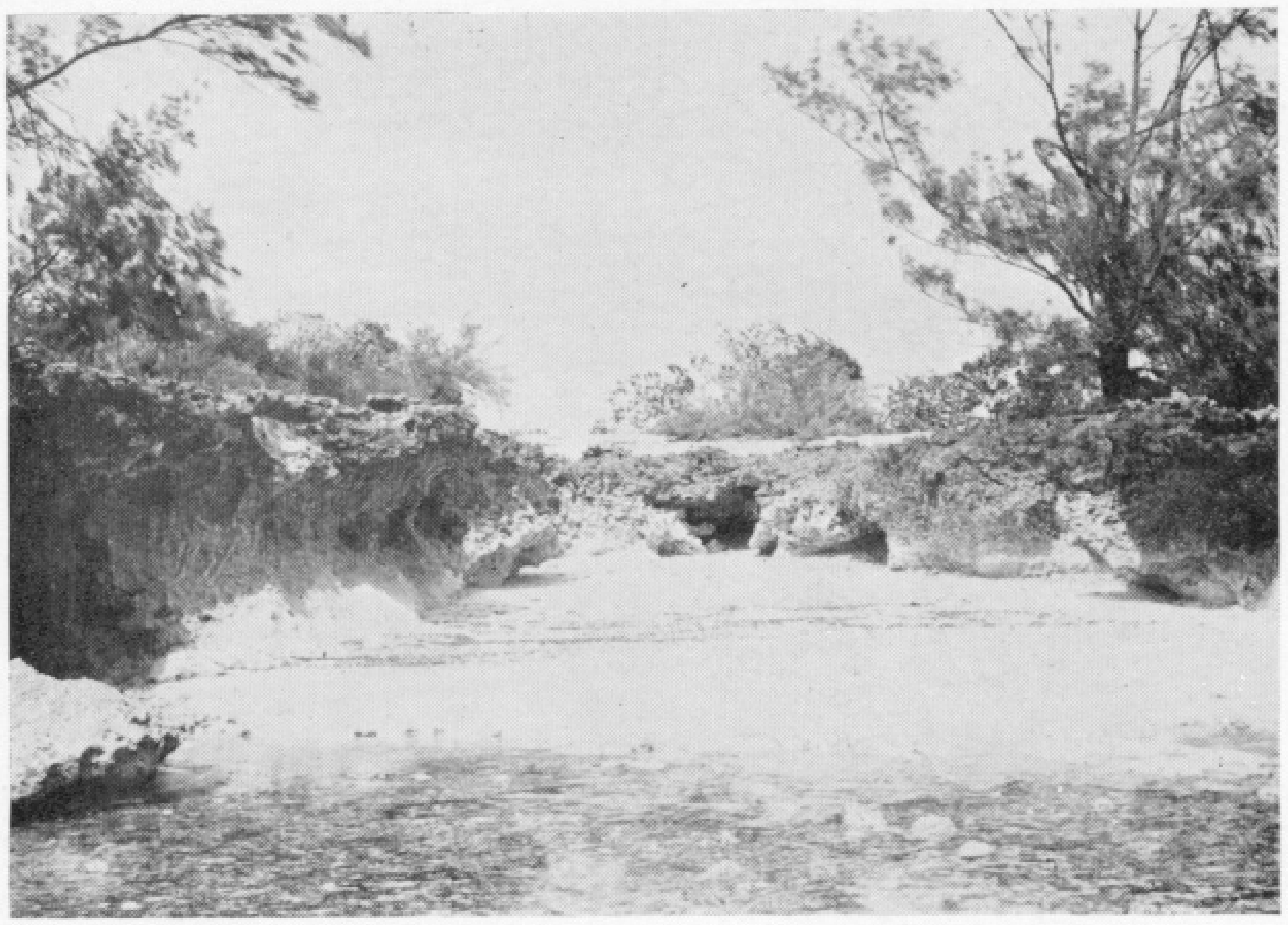

FIGURE 33. The south coast perched beach, covered with *Sclerodactylon* (foreground) and *Sporobolus*, east of Anse Takamaka.

FIGURE 34. Vegetated dunes at Dune Jean-Louis, with *Tournefortia argentea* and a turf of *Sporobolus virginicus*.

FIGURE 35. Bare eroding dunes with a sparse turf of *Sporobolus virginicus* at Dune Jean-Louis.

FIGURE 36. Undercut lee coast cliffs at Anse Var, West Island.

FIGURE 37. Beach at Anse Cèdres, with beach-rock. The photograph was taken at mid-tide, and the cliff notch is almost submerged.

FIGURE 38. Small pocket beach (anse) in leeward cliffs north of Anse Cèdres. Note the perched beach above the cliff.

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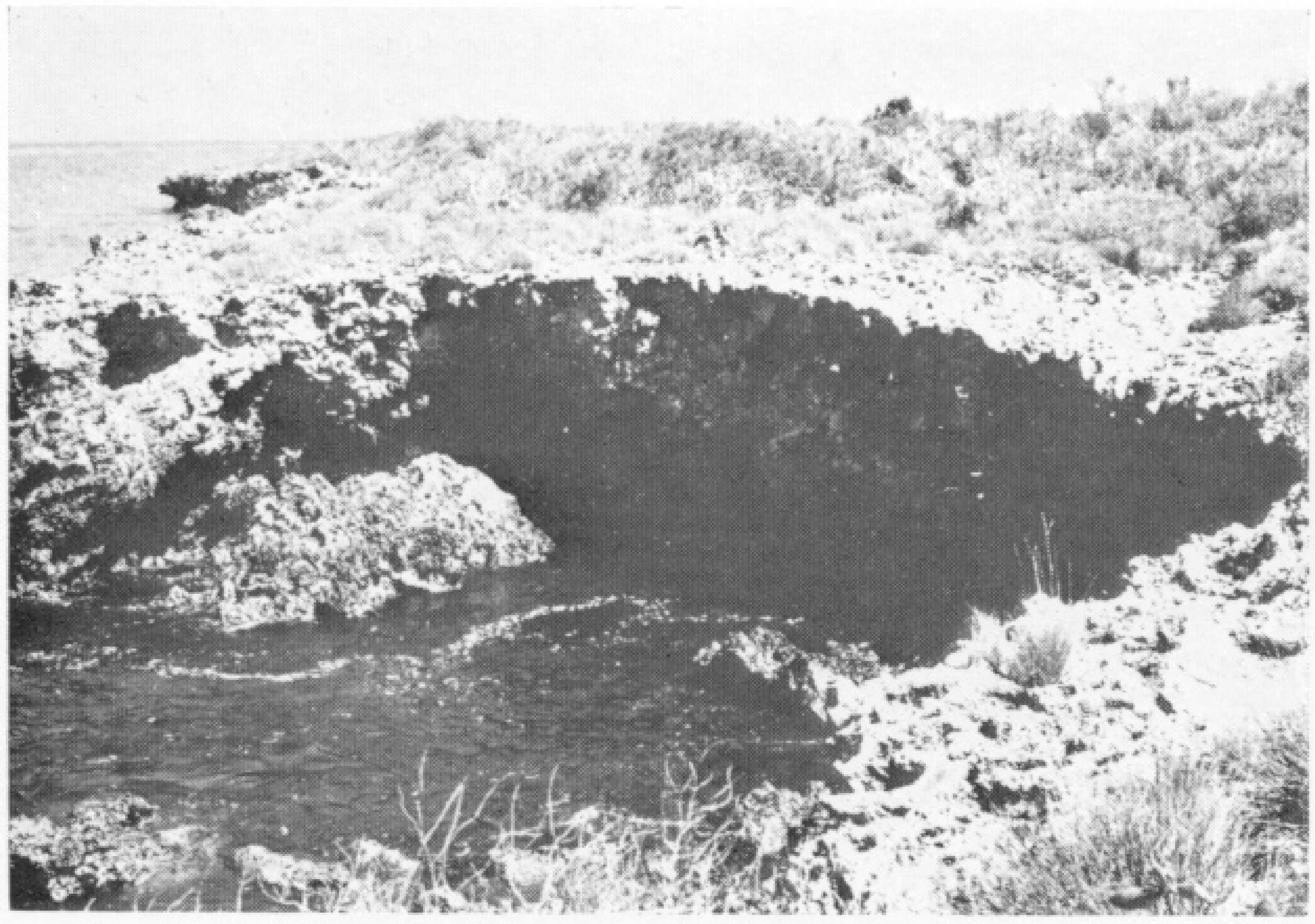

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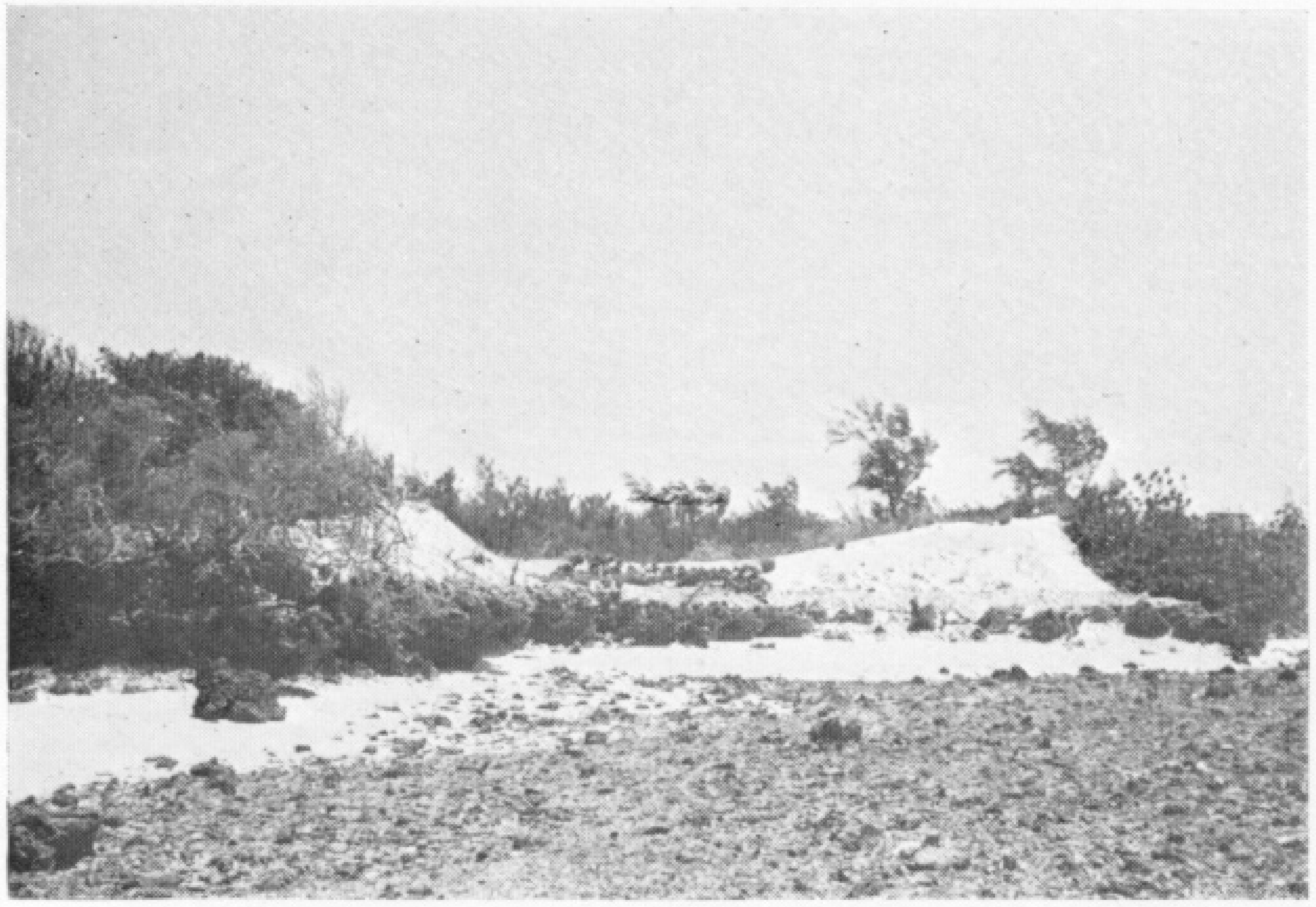

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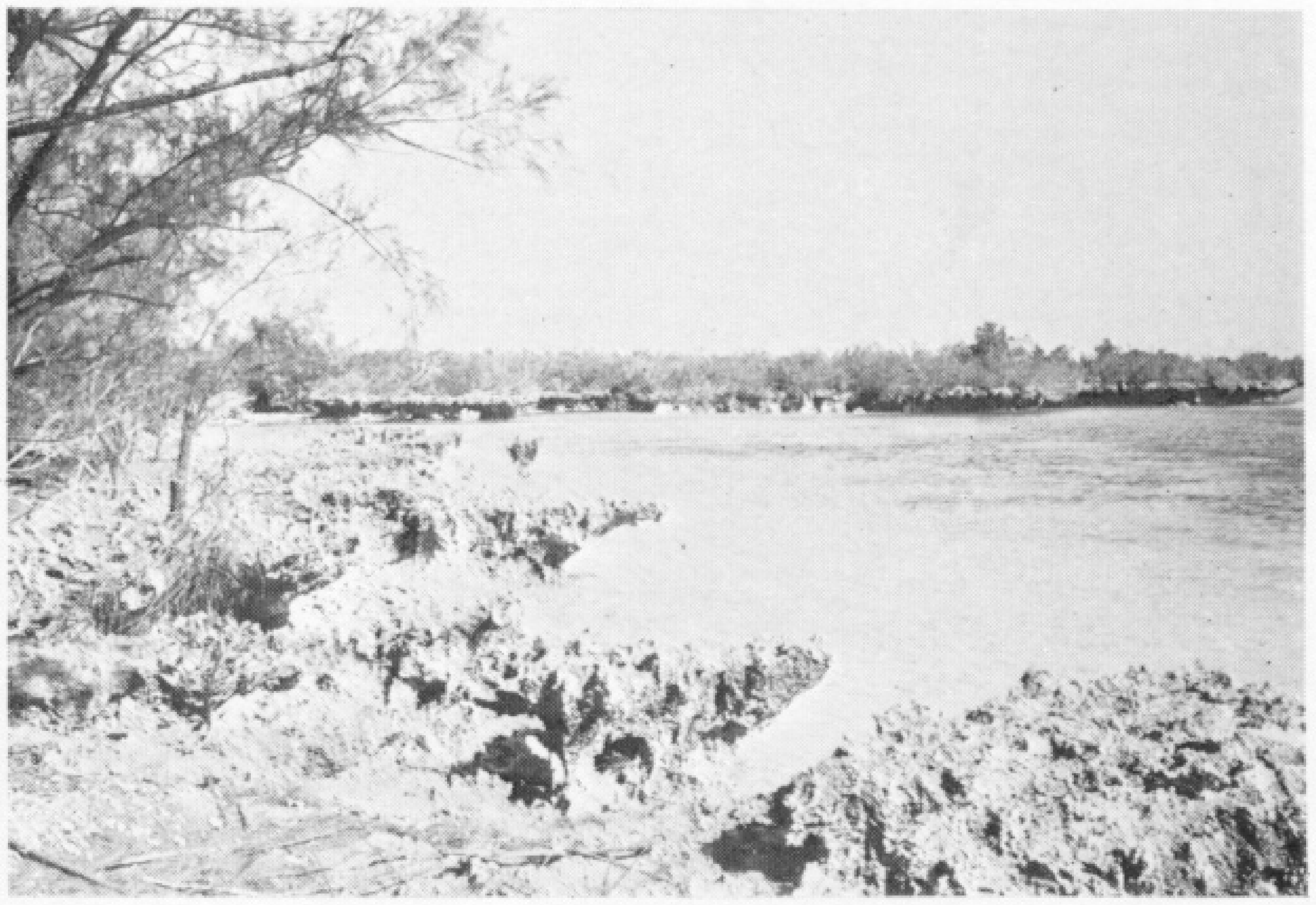

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FIGURE 39. High vertical cliffs formed by fracturing and collapse of the limestone between Le Renfin and Point aux Vaqua, South Island.

FIGURE 40. Massive bedded beach-rock at Ile Magnan, West Channels.

FIGURE 41. Small dunes at the southern point of West Island, on Passe Femme. At high tide the sea reaches the top of the cliff.

FIGURE 42. Delicately notched cliffs on a lagoon shore, on South Island inside Passe Houareau.

FIGURE 43. Mangrove woodland of *Avicennia* within the lagoon on the south coast of Ile Esprit.