

Table 1. HEAT FLOW MEASUREMENT ON THE REYKJANES RIDGE

| Station | Latitude (N) | Longitude (W) | Water depth (m) | Water temperature (°C) | No. of probes in sediment | Thermal gradient (10 ⁻³ °C/cm) | No. of conductivity measurements | Thermal conductivity (10 ⁻³ calories/cm s °C) | Heat flow (μcalories/cm ² s) |
|---------|--------------|---------------|-----------------|------------------------|---------------------------|---|----------------------------------|--|---|
| TR41-6 | 59° 37' | 28° 32' | 1,680 | 3.44 | 4 | 0.66 | 12 | 1.88 | 1.24 ± 0.28 S.D. |
| TR41-7 | 59° 44' | 28° 45' | 1,332 | 3.82 | 4 | 0.77 | 10 | 1.78 | 1.38 ± 0.15 |
| TR41-8 | 59° 47.5' | 28° 58' | 1,550 | 3.88 | 4 | 0.40 | 8 | 1.98 | 0.80 ± 0.06 |
| TR41-10 | 59° 52.5' | 29° 08' | 1,365 | 3.89 | 4 | 3.08 | 7 | 2.18 | 6.71 ± 0.98 |
| TR41-11 | 59° 58' | 29° 16' | 1,195 | 4.02 | 3 | 0.61 | 4 | 2.40 | 1.47 ± 1.00 |
| TR41-13 | 60° 02.5' | 29° 46' | 1,303 | 4.23 | 3 | 0.86 | 8 | 2.02 | 1.74 ± 0.43 |
| TR41-14 | 60° 07' | 29° 46' | 1,279 | 4.16 | 4 | 1.58 | 10 | 2.08 | 3.29 ± 0.23 |
| TR41-15 | 60° 09.5' | 29° 51' | 1,481 | 3.87 | 2 | 2.45 | 6 | 2.32 | 5.68 ± 0.43 |
| TR41-16 | 60° 12.5' | 30° 04.5' | 1,561 | 3.90 | 3 | 1.24 | 5 | 2.46 | 3.05 ± 0.82 |
| TR41-19 | 61° 35' | 27° 48' | 1,481 | 4.20 | 3 | 1.34 | 9 | 2.65 | 3.55 ± 0.37 |

The average of the present ten values on the crestral zone of the Reykjanes Ridge is 2.89 μcalories/cm² s. The heat flow of 3.55 μcalories/cm² s at station 19, located to the west of the crestral axis and about 200 km north-east of our profile, may belong to the north-western high heat flow zone. The location and value of this station suggest that the pattern observed along our profile may extend along the ridge.

In Fig. 3, the heat flow values are shown for comparison with the topography and the geomagnetic total force for profiles obtained by R/V Trident during the cruise traversing the ridge between the stations 6 and 16. The coincidence of the two peaks of high heat flow with the topographic depressions on both sides of the ridge crest and the number 2 anomalies of the magnetic field⁴ is striking. The causative relationships among these anomalies cannot, however, be concluded from a single traverse. More data in the vicinity of the area of present investigation will be

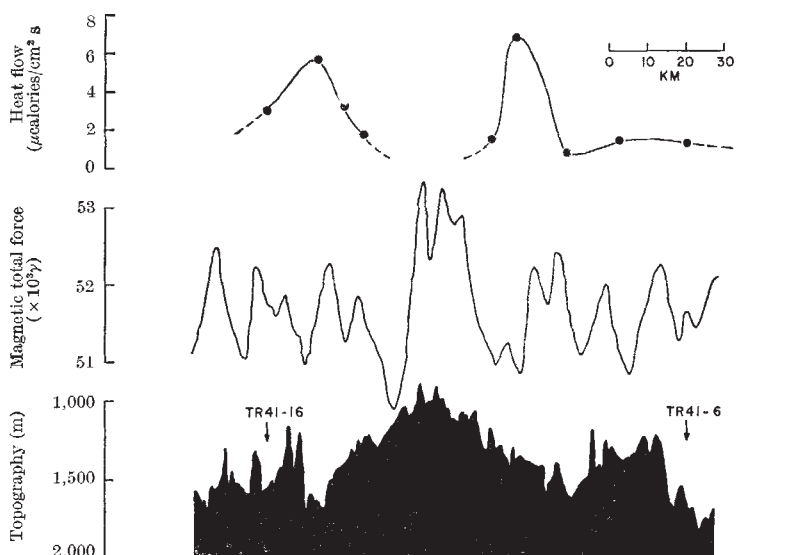


Fig. 3. Profiles of heat flow, topography and total force of the Earth's magnetic field across the crestral area of the Reykjanes Ridge near 60° N. Topography and magnetic data obtained by R/V Trident during the cruise traversing the ridge crest.

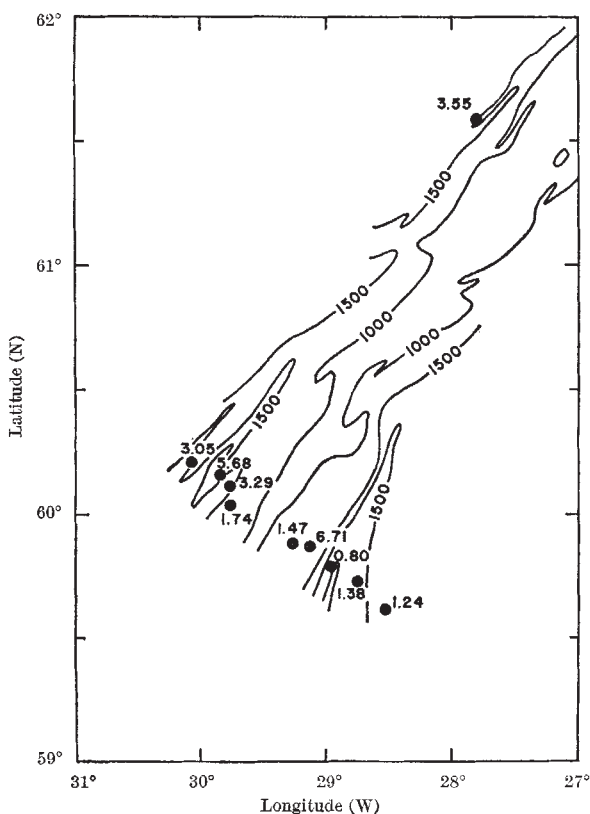


Fig. 2. Map showing location of heat flow stations and heat flow values (in μcalories/cm² s). Topographic contours (in metres) are based on the bathymetric data of this area⁵.

necessary to interpret the heat flow anomalies on the Reykjanes Ridge.

We thank Drs D. Krause and J.-G. Schilling and the crew of the R/V Trident of the University of Rhode Island for their help. Financial support was provided by the US Office of Naval Research.

KI-ITI HORAI
MARY CHESMAN
GENE SIMMONS

Department of Earth and Planetary Sciences, Massachusetts Institute of Technology, Room 54-314, Cambridge, Massachusetts.

Received October 10, 1969.

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Deep Sedimentary Basins proved in the Shetland-Hebridean Continental Shelf and Margin

A REGIONAL geophysical survey of the continental shelf and margin west of the Orkney and Shetland Isles was completed during cruises of RRV John Murray in 1967 and 1968. These surveys yielded about 9,000 km of continuous surface ship gravimeter and magnetometer

track across the shelf and margin, including ten seismic reflexion (sparker) traverses. This report gives a preliminary interpretation of the resulting Bouguer anomaly map (Fig. 1).

The regional rise in Bouguer anomaly across the shelf towards the continental margin is shown in Fig. 2. This is attributed to the thinning of the crust beneath the slope, from a continental type beneath the shelf to a thinner crust beneath the Shetland-Faroe channel, in quantitative agreement with the Airy hypothesis of isostasy. Superimposed on this WNW regional rise in Bouguer anomaly is the linear gravity "high" *A* and a series of gravity "lows" *C* to *G*. A further series of gravity "lows" occurs along the continental slope.

The NNE trending gravity "high" *A* is continuous for 250 km across the shelf. It also forms a belt of exceptionally large magnetic anomalies. Sparker and bathymetric profiles show that, for over 110 km of its length, the underlying crystalline basement rocks crop out on the seafloor. The maximum observed Bouguer anomaly of 94 mgal occurs 35 km WNW of Foula Island. The regional Bouguer anomaly associated with the continental margin is estimated as 50–60 mgal here, leaving a residual positive anomaly of 30–40 mgal for "high" *A*. The "high" could be explained by a thinner crust or by an exceptionally

large volume of basic igneous rocks. We prefer to attribute it to a belt of high density metamorphic rocks, of variable magnetic properties, similar to the granulites occurring in the Scourie district of Scotland. Such rocks may be upper crustal representatives of a type of rock usually occurring in the lower crust¹.

We restrict quantitative interpretation to profiles YY' across gravity "lows" *C* and *D* (Fig. 2) and XX' across "low" *E* on to "high" *A* (Fig. 3). The gravity, magnetic and sparker records show that these three gravity "lows" are caused by deep sedimentary basins. The adjacent "high" are caused by crystalline basement rocks occurring at relatively shallow depth. The residual negative anomalies along both profiles can only be explained satisfactorily by a basement/sediment density contrast of at least 0.3–0.4 g/cm³.

"Low" *C* can be interpreted as a basin 3.6 km deep for a density contrast of –0.4 g/cm³ or 4.6 km deep for –0.3 g/cm³. "Low" *D* requires 5.0 km of sediment for a density contrast of –0.4 g/cm³. The steep boundaries of the basins are probably faults, possibly formed as contemporaneous hinge-lines.

The Bouguer anomaly rises by 65 mgal between "low" *E* and "high" *A* (Fig. 3); the gradient is exceptionally steep. This anomaly is essentially caused by rapid

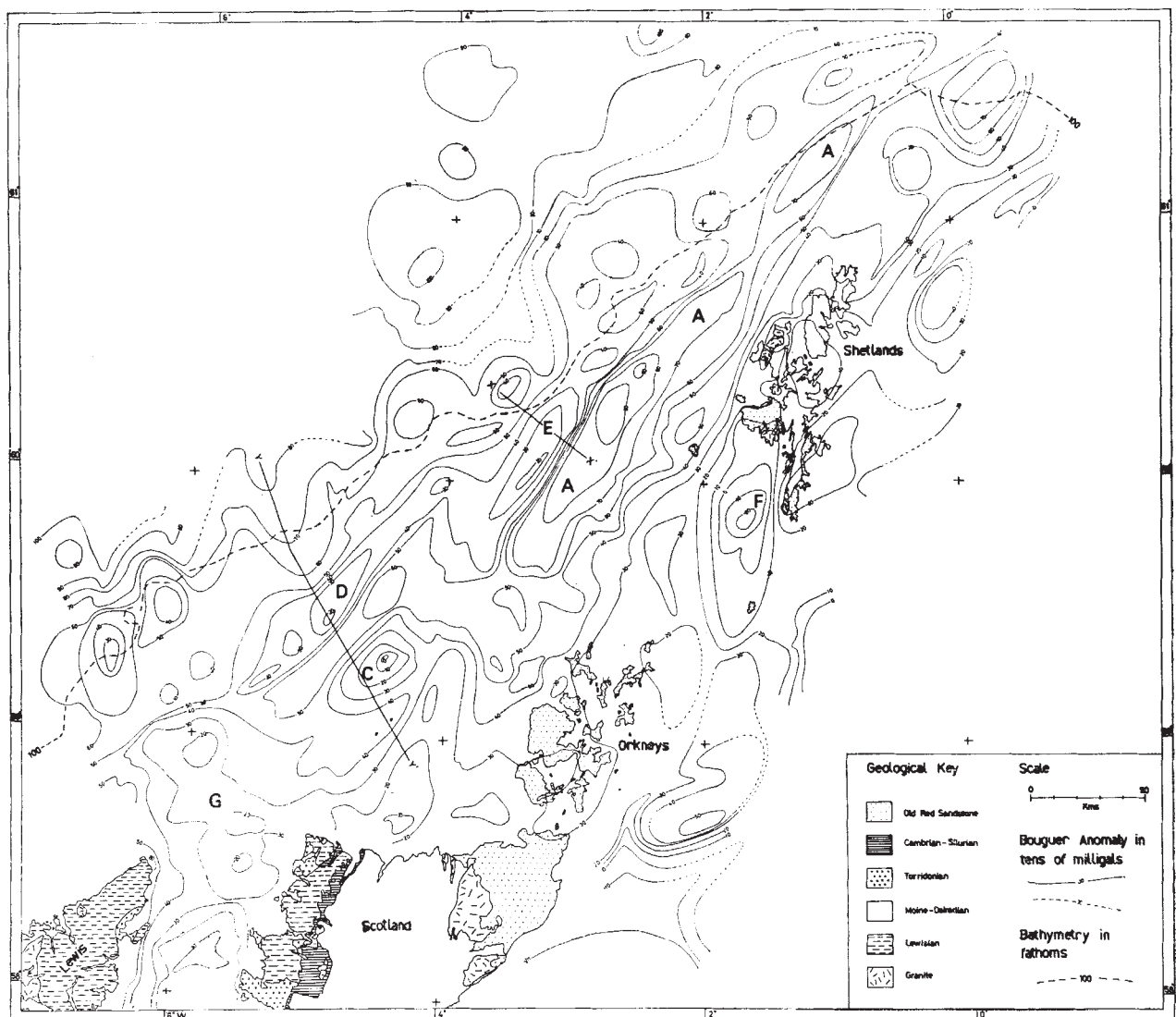


Fig. 1. Bouguer anomaly map of the Hebridean-Shetland shelf.

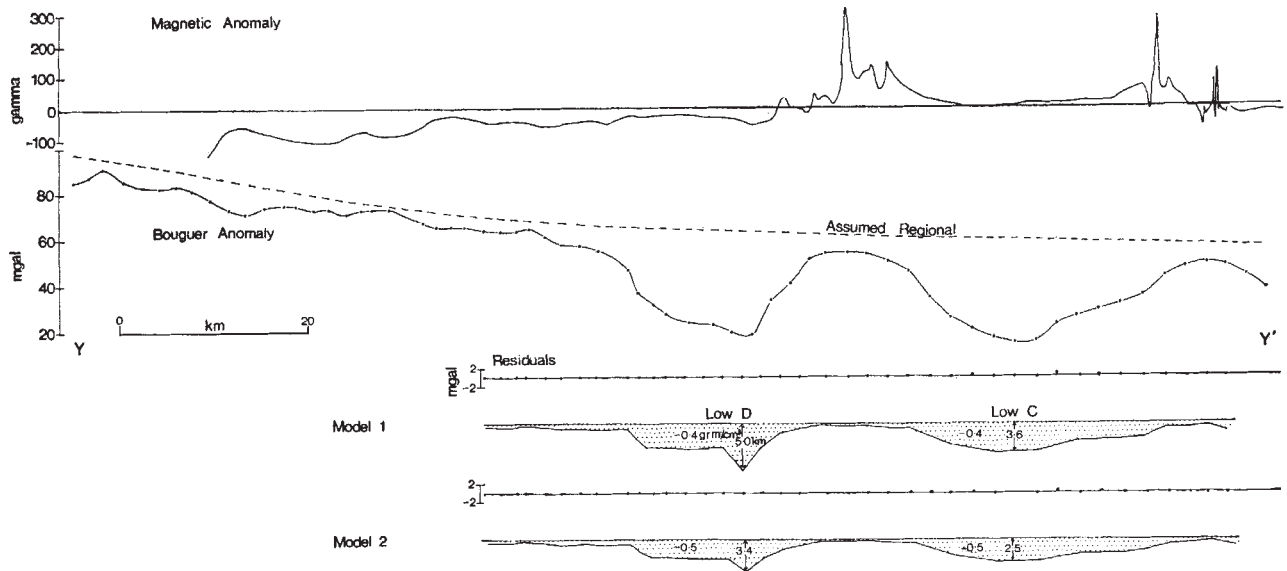


Fig. 2. Gravity and magnetic anomaly profile along the line YY' (Fig. 1). The models have been deduced for the assumed isostatic regional shown, for an assumed two-dimensional structure and for uniform density contrasts of -0.4 g/cm^3 and -0.5 g/cm^3 .

thickening of sediment from *A* towards *E*. The shape of the basin floor has been computed for density contrasts of -0.4 and -0.5 g/cm^3 for an assumed regional anomaly as shown. The steep eastern boundary of this deep basin must be faulted. Towards the west, the basin thins over a ridge of relatively shallow basement.

Two sparker profiles across the south end of "low" *E* show that the seaward dipping sediments forming the slope, when traced landwards, lie unconformably on south-easterly dipping sediments. Recent work² suggests that the slope sediments are Upper Cretaceous to Tertiary in age. Thus "low" *E* is predominantly caused by pre-Tertiary sediments. It is highly unlikely that Palaeozoic

sediments would have a sufficiently large density contrast with the basement, although they may occur beneath a thick Mesozoic succession. Thus the high density contrast needed to explain the steep gravity gradient between *A* and *E* can best be interpreted as a faulted contact between Mesozoic and Lewisian rocks.

Preliminary interpretation suggests that "low" *F* is caused partly by a southward extension of the Sandsting granite (Shetland Isles) and partly by Old Red Sandstone sediments. The composite "low" *G* which extends into the Minch is probably caused by sediments.

It has been suggested by previous workers that two major transcurrent faults cross the shelf region covered

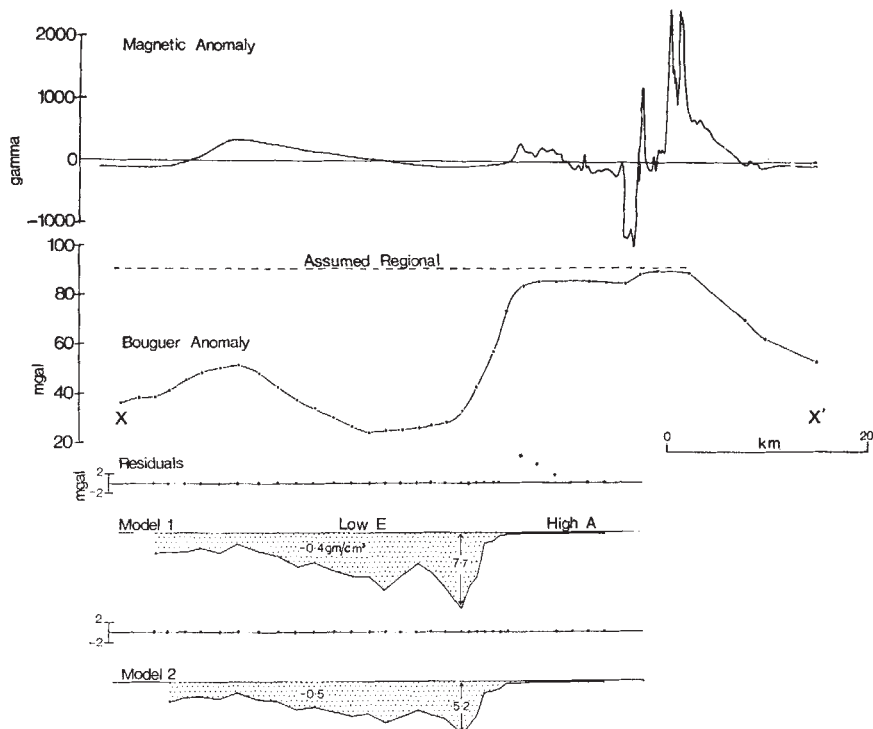


Fig. 3. Gravity and magnetic anomaly profile across "low" *E* and "high" *A* (Fig. 1, XX') showing interpretation as in Fig. 2.

by our surveys, namely the Great Glen fault³ and the Minch fault^{4,5}. Flinn³ suggested that the Great Glen fault passes through the Shetlands and reaches the continental margin. We find no evidence, however, for lateral displacement of gravity "high" A north of the Shetlands. We suggest that the Great Glen fault passes east of the Shetlands. This would also remove the need for a sharp change in direction of the fault line such as would not be expected for a transcurrent or transform fault.

Dearnley⁴ has suggested, on geological grounds, that the Minch basin is bounded on its NW margin by a transcurrent fault and Avery *et al.*⁵ have extended it in a NE direction across the shelf. Our evidence suggests, however, that the shelf is characterized by normal and not transcurrent faulting. The Minch fault is therefore interpreted as a normal fault which may extend NE to form the NW margin of Basin C. A further general implication of our surveys is that the continental slope of this region cuts gently across the tectonic grain as revealed by the gravity and magnetic anomaly trends.

Deep sedimentary basins can give the environment for source rock and reservoir rock in which economic quantities of oil and natural gas may be found. We anticipate that the newly discovered basins of the Hebridean-Shetland shelf may in future receive the detailed geological investigations now in progress in the North Sea and Irish Sea.

We thank the Natural Environment Research Council for financial support and for ship time on the RRV John Murray; we also thank Captain M. J. Perry and the officers and crew of the RRV John Murray and the technical staff and postgraduate students from the Durham Geology Department for their contributions to the work.

M. H. P. BOTT
A. B. WATTS

Department of Geology,
University of Durham.

Received October 27; revised November 26, 1969.

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Sublittoral Reef Phenomena of Aldabra

DURING phase 6 of the Royal Society expedition to Aldabra the sublittoral structure of the reef front was studied by means of one detailed reference transect (marked I in Fig. 1) and thirteen survey transects. All were levelled by SCUBA divers in the following way. Two divers holding the ends of a 10 m tape "leapfrogged" over each other in turn while swimming along a bearing and recorded depths at each fixed interval using wrist gauges. Transects 10 and 11 were levelled by diving from the boat at known distances from the reef front.

Near transects 4 to 8 were series of massive coral rock "bastions" each separated by sloping channels partly infilled from the landward end by coral sand and talus. The seaward peak of each main bastion was approximately 25 m below low water mark; the fronts of the bastions sloped steeply, some vertically, others undercut, to a maximum depth of 45 m. Several bastions had no definite peak, their

seaward face being rounded, suggesting that they were, or had been, subject to erosion. Although the bastions were too large to be accurately surveyed by free swimming divers¹, they were examined as follows. The diving team submerged opposite a fixed land mark to a depth at which the peaks of the bastions were clearly visible. Swimming at a fixed speed, one diver timed the "occurrence" of the bastions, while the other sketched the relevant features of each. Regular surfacing to allow time checks against fixed land marks helped to reduce the inaccuracies inherent in the method. Results for part of the series adjacent to transect 6 are given in Fig. 2. Transects 4 to 8 were all levelled down the gullies; the profiles of two of the bastions are shown in Fig. 2.

The survey has revealed that hermatypic corals are most abundant at depths between -10 and -25 m, although isolated colonies can be found from high water mark to 55 m deep. We found that the activity of the reef, assessed as areas supporting the growth of hermatypic coral, is correlated with Stoddart's classification of shore types according to exposure². This system, however, needs to be expanded, and we propose four categories based on a subjective estimate of exposure to wind and wave action derived from the position of the island in relation to the trade winds and meteorological data collected by the expedition. We shall discuss the four categories (Fig. 3) together with information about the relevant sublittoral reef phenomena.

The first type of shore (transects 4 to 9) is the most severely exposed, both reef ridge and reef flat are absent, no cliffs are present and the dissected reef rock slopes gently into the sea. The reef front slopes almost imperceptibly to a depth of 30 m, below which there is a marked break in the slope. There are no hermatypic corals, the substrate being composed of compacted coral sand and rhodoliths.

The second type of shore (transects 12 and 13) is less exposed, reef flats are present but not delimited by a marked ridge, the elevated reef rock slopes into the sea except at the head of pocket beaches where there are undercut cliffs. The reef front is characterized by large areas of dead coral which vary in extent. Sometimes the entire reef front consists of dead but intact "stagshorn" coral (transect 12); similar phenomena are reported from the Solomon Islands³. At the other extreme there are simply dead, eroded and partly concreted zones and patches (transect 13). These observations suggest that catastrophic events have caused massive kills.

The third type of shore (transects 4 to 9) is moderately exposed; the reef flat is wide, delimited by a marked ridge and exposed at most low tides, while cliffs undercut by solution are a constant feature of the coast. Hermatypic corals are abundant and the reef front is characterized by deep water bastions.

The fourth type of shore (transects 1 and 2) is the least exposed, with the widest type of reef flat and a distinct

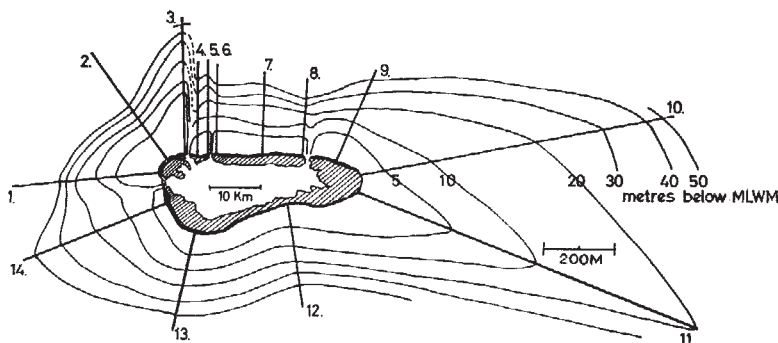


Fig. 1. Survey transects and approximate contours of the reef front. Note the difference between the scale of the island and the reef front. MLWM, Mean low water mark.