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SUBSURFACE SOLUTION UNCONFORMITIES AT HERON ISLAND, GREAT BARRIER REEF

by

P.J. Davies

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SUMMARY

Geophysical studies at Heron Island indicate a marked planar resistivity contrast at a depth of 20 m over the length of the island. The Heron Island borehole indicates a marked mineralogic change at this depth. The zone 0-20 m is composed of calcareous sands, in the main uncemented, largely aragonitic, and showing very little recrystallization of aragonite to calcite. Below the 20-m mark, and extending down to 25 m, a zone occurs which is characterized by alteration of aragonite to calcite, development of mouldic porosity, and the precipitation of calcite. Part of the zone is brown stained. These characters are identical with those defining subaereally formed solution surfaces at Eniwetok. The 20-m surface at Heron Island is interpreted in a similar manner. Two deeper surfaces are also indicated in the borehole. All therefore probably represent major marine regressions in the Capricorn area. An attempt has been made to correlate these with eustatic features in the southern Great Barrier Reef.

A surface comparable with the Heron Island 20-m surface is seen at Michaelmas Cay, 700 km to the north. It occurs at a depth of 27 m.

FOREWORD

This record formed the basis of a paper read by the author at the International Symposium on Coral Reefs held on board the M/V Marco Polo in Great Barrier Reef waters, June 1973. It will be published in the Proceedings of the symposium. The research was carried out while the author was working at the University of Queensland.

INTRODUCTION

It is the purpose of this short note to report the presence of a number of possible unconformities within the subsurface at Heron Island, Great Barrier Reef, and to discuss their significance in terms of their environmental interpretation, age, and relationship to reported sea level changes within the Capricorn area. Much of the evidence put forward is the author's own interpretation of previously published and unpublished data.

Heron Island forms part of the Capricorn Reefs, which occur in the southern Great Barrier Reef Province (Fig. 1). The general bathymetry of this part of the Tasman Sea is shown in Figure 2. Four boreholes have been drilled in the area, two by Gulf Oil, one by Humble Barrier Reef at Wreck Island, and one by the Great Barrier Reef Committee at Heron Island (Fig. 1). It is the Heron Island Borehole which forms the basis of the present work. Core and cuttings recovery in the top 210 m of the other boreholes is either poor or non existent.

GENERAL BATHYMETRY

The general bathymetry of the southern Great Barrier Reef Province is shown in Figure 2. The following topographic features are important; Kern, Wreck, and Cato Reefs form part of the north-trending Tasmantid Sea Mount Chain (Krause, 1967). To the west of this lies the Cato Trough, which rises gently westwards to form the Marion Plateau (Gardner, 1970, Marshall 1972). This is a gently sloping platform between 200 and 600 m. Saumarez Reefs occur on top of a bank rising from the floor of the Marion Plateau. West of the Marion Plateau, the sea floor rises up a short and sometimes steep slope to the Swain Reefs at the outer edge of the continental shelf. The Swain Reefs are separated from the Capricorn/Bunker Reefs by the Capricorn Channel.

THE HERON ISLAND BOREHOLE

Previous work

In 1934 the Great Barrier Reef Committee financed the drilling of a borehole at Heron Island. This was described by Richards & Hill (1942). Reproduction of the drilling log for this hole is not possible, but a condensed version of the original description is shown in Figure 3A. Basically, the borehole shows a sequence of calcareous sands, in situ reef rock, foraminiferal and quartz sands, and lime muds. The drill bottomed at a depth of 220 m. Maxwell (1962) redescribed the borehole and generalized the succession into three groups- (a) shallow reef rock; (b) intermediate reef rock, and (c) subreef sands (Fig. 3B).

Richards & Hill (1942) considered that the whole of the sequence at Heron Island was post Pleistocene age, because none of the fauna showed the effects of the Pleistocene ice ages. Lloyd (1968) concluded that Recent and Pleistocene sediments were represented in the top 133 m, and these rested with marked unconformity on the Miocene at this depth. Palmieri (1971) also recognized a Pleistocene part of the section, but identified a Pliocene sequence between 197-133 m, indicating that no unconformity exists between Pleistocene and Miocene. Both authors agree that a large part of the section is Pleistocene. The Heron Island borehole sequence must therefore provide some evidence of the changing sea levels within the Pleistocene of the Capricorn area (Maxwell 1968, 1969, 1971; Veeh & Veevers 1970; Marshall, 1972).

Reinterpretation

During an initial examination of the borehole data, the writer was impressed by constant references to solution, brown staining, and calcite cementation. Systematic notes were made of the occurrence of these features together with the distribution of aragonite, high magnesium calcite, lithological variations, as well as interpretative comments regarding conditions of deposition. The results of this study are shown in Figure 4, and are summarized below.

1. Aragonite cementation occurs in the beach zone, i.e. in beachrock. This has been verified by the recent work of Davies & Kinsey (1973).

2. Below this layer of surface cementation, 20 m of calcareous sands plus reefal limestones occur. These are uncemented, largely composed of aragonite and high magnesian calcite, and exhibit very little recrystallization of aragonite to calcite. It is therefore concluded that the top 20 m represents a stable environment in which very few visible changes have occurred in the sediments since burial. The top 20 m is called Zone 1 in Figure 4.

3. A zone of marked solution occurs at about the 20 m level, this extending down to 24 m. This solution zone also pinpoints the entry of calcite cementation. The effects of solution and calcite cementation decrease downwards to the 36-m level, where solution is patchy, and little cementation is visible. The middle of this depth range is characterized by brown staining of the sediments, owing to a higher percentage of oxides and organic

material than in unstained zones. The depth range 20-36 m is termed Zone 2 in Figure 4.

4. At least two further zones can be tentatively identified below the 36 m level. These are -

(a) Zone 3a, 36-75 m - characterized by detrital sediments overlying reefal sediments; strong solution and much calcite cementation, poorly lithified at the base; and brown stained areas. It should be noted however, that the brown stained areas extend outside the zone into the one below. This may indicate that this zone has been affected by oxidation processes on more than one occasion. Zone 3b, 75-96 m. Composed essentially of reefal limestones, strongly brown stained zones, intensive solution, and much calcite cementation.

(b) Zone 4, 96-140 m - characterized by detrital sediments at the top. Strong to very strong solution zones give way downwards to patchy and very little solution, similarly distinct brown stained zones given way downwards into completely unstained areas. Some aragonite occurs in the sediments at depth.

Schlanger (1963) described subsurface solution unconformities in the boreholes from Eniwetok and Bikini. Leached zones characterized by fossil moulds, overlain by unaltered sediments, and separated from them by sharp boundaries, were found in all the boreholes studied. The upper surfaces of the leached zones form solution unconformities. The leached rocks grade down into unaltered sediments through transition zones, which are brown-stained owing to the presence of organic matter. Below the transition zone, lime muds often occur. The solution unconformities at Bikini and Eniwetok represent evidence of subaerial erosion.

A striking resemblance exists between the descriptions from Bikini, Eniwetok and Heron Island. It is therefore tempting to postulate that the 20 m, 36 m, 96 m, and 140 m levels represent subsurface solution unconformities underlying Heron Island, although data from a single borehole provides insufficient evidence for firm conclusions to be drawn. The situation is partly resolved by the results of resistivity experiments conducted on Heron Island by Hall (pers. comm.). They are briefly reported below with full permission of this worker.

RESISTIVITY EXPERIMENTS

Resistivity depth soundings at 20-minute intervals during rising and falling tides along a current base above the highwater mark were made for three days on Heron Island. A Schlumberger electrode configuration was laid out with a total spread of 301 m. A seismic geophone cable was used as a current base. Six pairs of aluminium foil electrodes were buried at spacings of 297 m, 243 m, 189 m, 135 m, and 81 m. Current was provided by two 12 volt accumulators, and measured with a standard test meter, and potential differences were measured with a null voltmeter. Mean resistivities for the period of each of the three days observations are plotted logarithmically as depth sounding curves in Figure 5. Ignoring graph A in Figure 5, curve matching points conclusivly to the existence of two layers within the depth interval sounded, the upper layer of resistivity 0.95 ohm metres and 20-25 m thick, above a medium of resistivity 1.5 ohm-metres.

It can be seen from the above that a well defined surface occurs at a depth of approximately 20-25 m below Heron Island. The present writer concludes that the surface described is the surface identified in the borehole. It is concluded that a well defined surface occurs 20-25 m below Heron Island. This is likely to be the top of a solution unconformity, which probably formed after the emergence of the area, with concomitant solution and reprecipitation of carbonates. The solution unconformity therefore represents a regression, the extent of which may be broadly gauged from the extent of the solution zone. A similar origin is suggested for the deeper solution zones, although the precise depth and range of the zones cannot be stated with as much precision.

The correlation of the Heron Island sequence with the three other boreholes in the Capricorn area is not possible because of the very poor recovery of sediment from the top 150 m, and also because the data for the Wreck Island bore are in no way as comprehensive as for the Heron Island bore. Correlation within the Capricorn area is therefore difficult. However, the excellent des cription by Richards & Hill (1942) of the borehole at Michaelmas Cay, in the Northern Great Barrier Reef Province shows that marked solution and cementation occur below the 28-m level. Above this level, aragonite and high magnesium calcite predominate as the basic mineral assemblage, while foraminifera tests still retain their colour. A major disconformity therefore occurs in the subsurface at Michaelmas Cay, at approximately the same order of depth as at Heron Island. The two areas are 732 km apart. If the solution unconformity is the result of exposure after marine regression, then it must have been a major event, and likely to be global. Evidence for eustatic sea level changes is abundant in the Capricorn area. These are examined in order that a possible age for the 20-m solution surface can be postulated.

EUSTATIC EVENTS IN THE CAPRICORN AREA

Maxwell (1968, 1969, 1971), Veeh & Veevers (1970), and Marshall (1972) have described submarine terraces of eustatic origin in the Capricorn area. A synthesis of this data together with unpublished BMR data is shown in Figure 6. The radiocarbon dates published for some of these surfaces reported by Maxwell (1971), Veeh & Veevers (1970), Cook & Polach (1973) and Cook (pers. comm.) are shown in the same diagram. It should be noted that marine terraces correlate with postulated solution unconformities at the 35 m and 96 m levels, and possibly at the 18 m level.

As the Pleistocene to Recent sequence at Heron Island is represented by only 150 m, and as marked eustatic features are recognized within the Capricorn area, it is likely that major unconformities occur within the borehole sequence. The 13 600-17 000-year date for the 150-175 m level reported by Veeh & Veevers (1973) cannot therefore be a realistic age for this depth in the borehole. Marshall (1972) suggests that subsidence associated with faulting may have occurred along the continental slope. An analysis of Maxwell's data (1968, 1971) also indicates a complex picture. Maxwell (1968) suggests that a major transgression occurs from 150-28 m, followed by a major regression to 58 m, and a gradual transgression to above present sea level. The 18-m marine terrace formed during a stillstand within the last major transgression. It is suggested that this sequence of events occurred during the past 17 000 years. However, Maxwell (1971) states that no major regression occurred from 28-58 m, this being replaced by a much shorter regression from 28-35 m, and dated as between 11-9000 years B.P. The 18-m terrace once again formed as a stillstand during the transgression to present day sea level.

It can be seen from the above that the correlation of possible solution unconformities with Maxwell's data (1968, 1969, 1971) is difficult. The 20-m borehole features represent a prominent solution surface, suggesting regression. No marked regressional feature is reported by Maxwell (op. cit.) at this depth. Instead, a stillstand feature is reported at 18 m. If this correlates with the 20-m borehole surface, then the interpretation placed on one or the other is incorrect. One further possibility is that the 20-m solution surface correlates with the 28-m eustatic feature, and that this formed at an earlier date than that suggested by Maxwell (1968, 1971). The possible correlation of the 20-m Heron Island surface with the first subsurface unconformity at Michaelmas Cay, lends some credence to this possibility.

The situation is further complicated when comparison is made between the 20-m to 35-m subsurface unconformities and the world eustatic curve of Morner (1971) shown in Figure 7. Morner's curve indicates a slight regression at the 18 m depth which occurs at 11 000 years B.P. No major features are seen at 28 m to 35 m in the time range 17 000-11 000 years B.P. However, in the time range 70-75 000 years B.P., the curve shown as a major regression to 35 m, a transgression to 28 m, and a further regression. It is apparent therefore that the eustatic features fit better into Morner's global curve at the 70-75 000 year level than at the 11-9000 year level. This is especially true of the 35-m surface.

CONCLUSIONS

1. Marked solution, mineralogic alteration, marked cementation, and the presence of brown stained areas within the Heron Island borehole have allowed the delineation of at least four zones within the borehole sequence. The boundaries of these zones at 20 m, 35 m, 75 m, 96 m, and 140 m, may form solution unconformities, similar to those described at Eniwetok. These unconformities are interpreted as being due to marine regression. A feature, identical to the 20-m unconformity at Heron Island, but at a depth of 28 m, is seen in the Michaelmas Cay borehole.

2. The subsurface solution unconformities correlate with submarine eustatic features at similar depths, i.e. 18 m, 28 m, and 35 m. The ages of these features are not precisely known. The 20-m subsurface unconformity may be 11-9000 years old. It is possible however, that the solution surfaces at 20 m and 35 m may both be 70-75 000 years old. Drilling and radiometric dating is required to substantiate these claims. However, it is expected that major unconformities will be proven within the Pleistocene sequence of the Great Barrier Reef Province.

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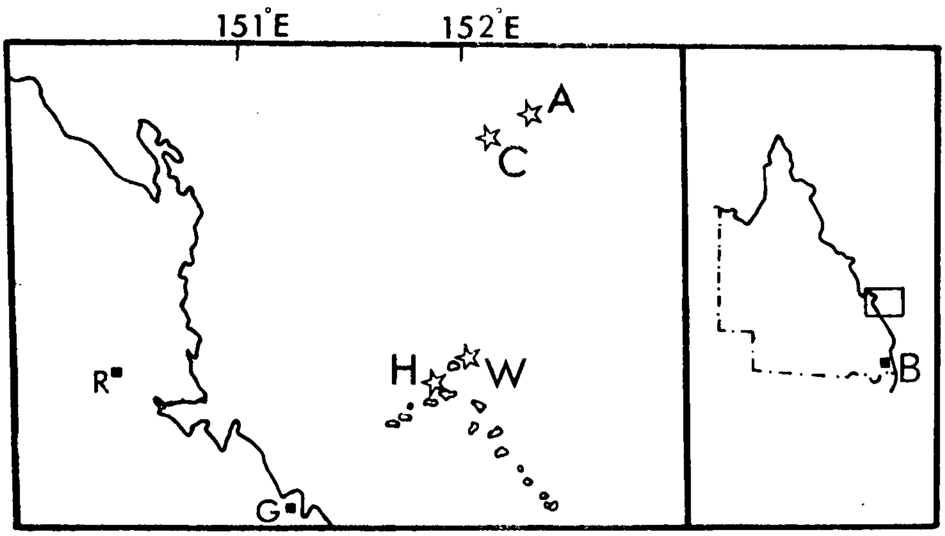

Fig. I. The position of the Capricorn and Bunker Reefs.
Starred localities are borehole sites —
H = Heron Island, W = Wreck Reef, C = Capricorn No. I.,
A = Aquarius No. I., R = Rockhampton, B = Brisbane,
G = Gladstone.

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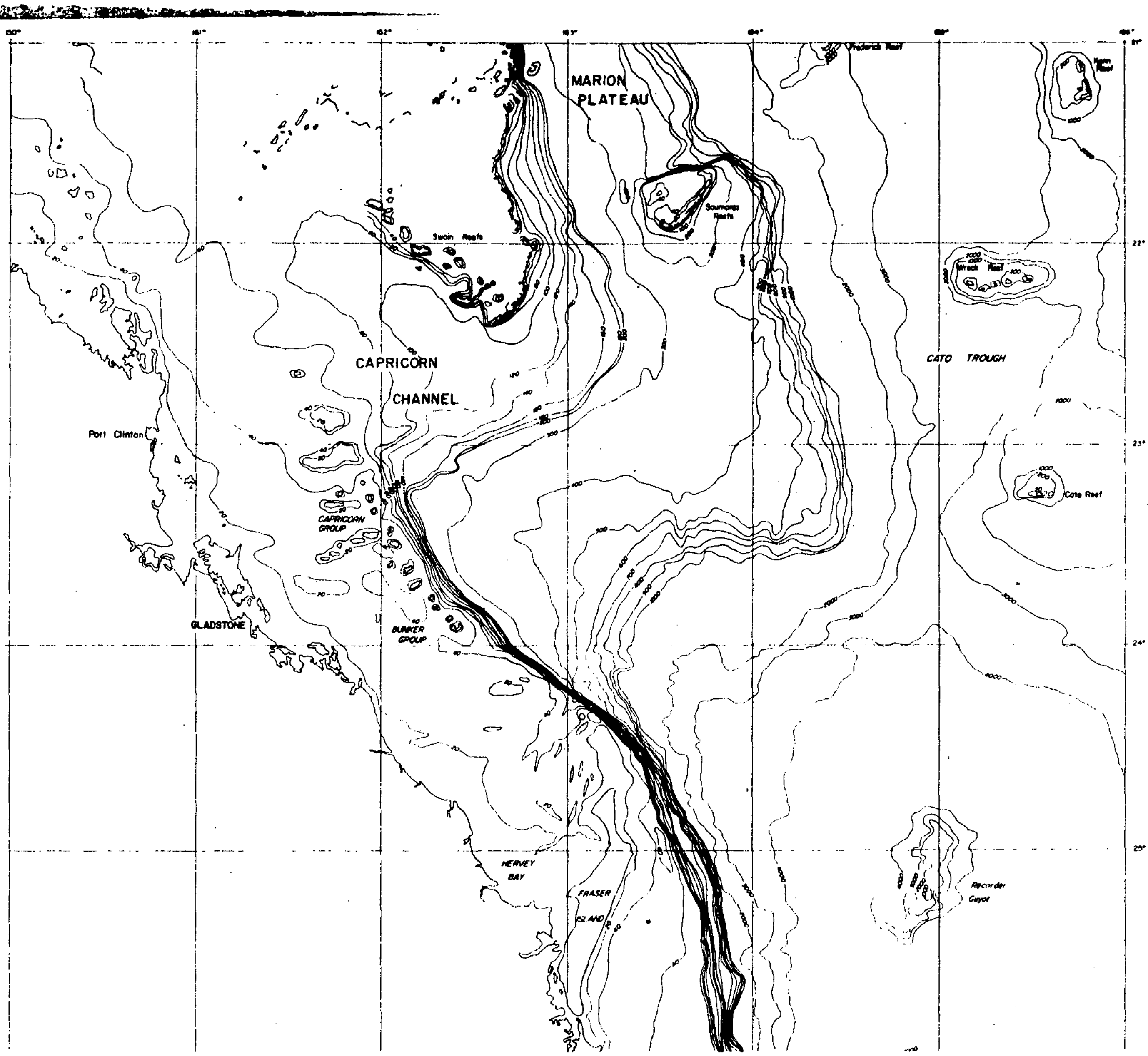

Fig.2. General bathymetric features of the Southern Great Barrier Reef Province. (After Marshall, 1972

A–A = Tasmantid Sea Mount Chain D – D = Capricorn. Channel

B–B = Marion Plateau E – E = Capricorn – Bunker High

C–C = Swain High

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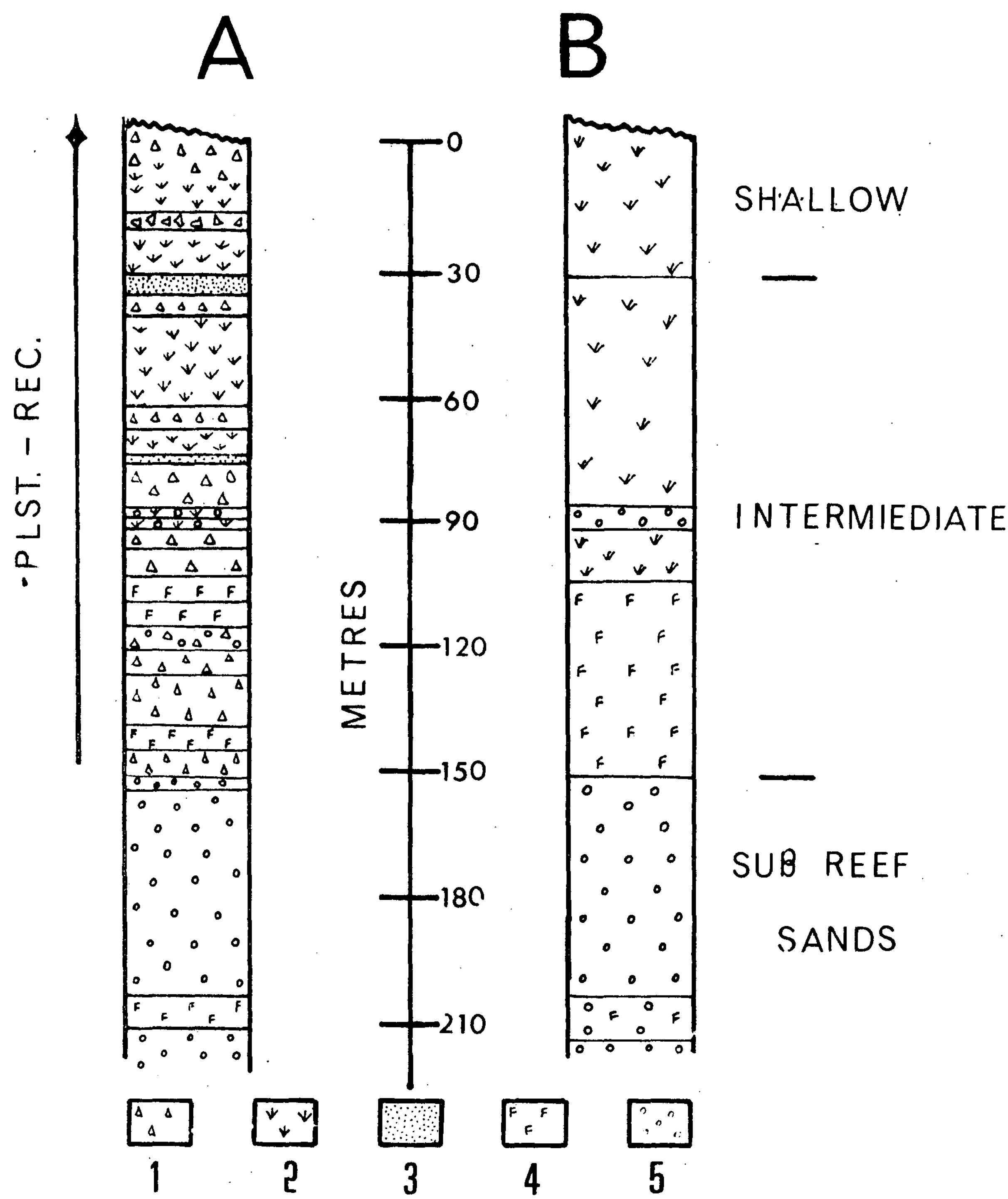

Fig. 3. Lithological variation seen in the Heron Island Borehole.
A After Richards and Hill (1942), B After Maxwell (1962)

1. = Carbonate sands
2 = Reef Limestone
3 = Carbonate mud
4 = Foraminiferal sands
5 = Quartz sands

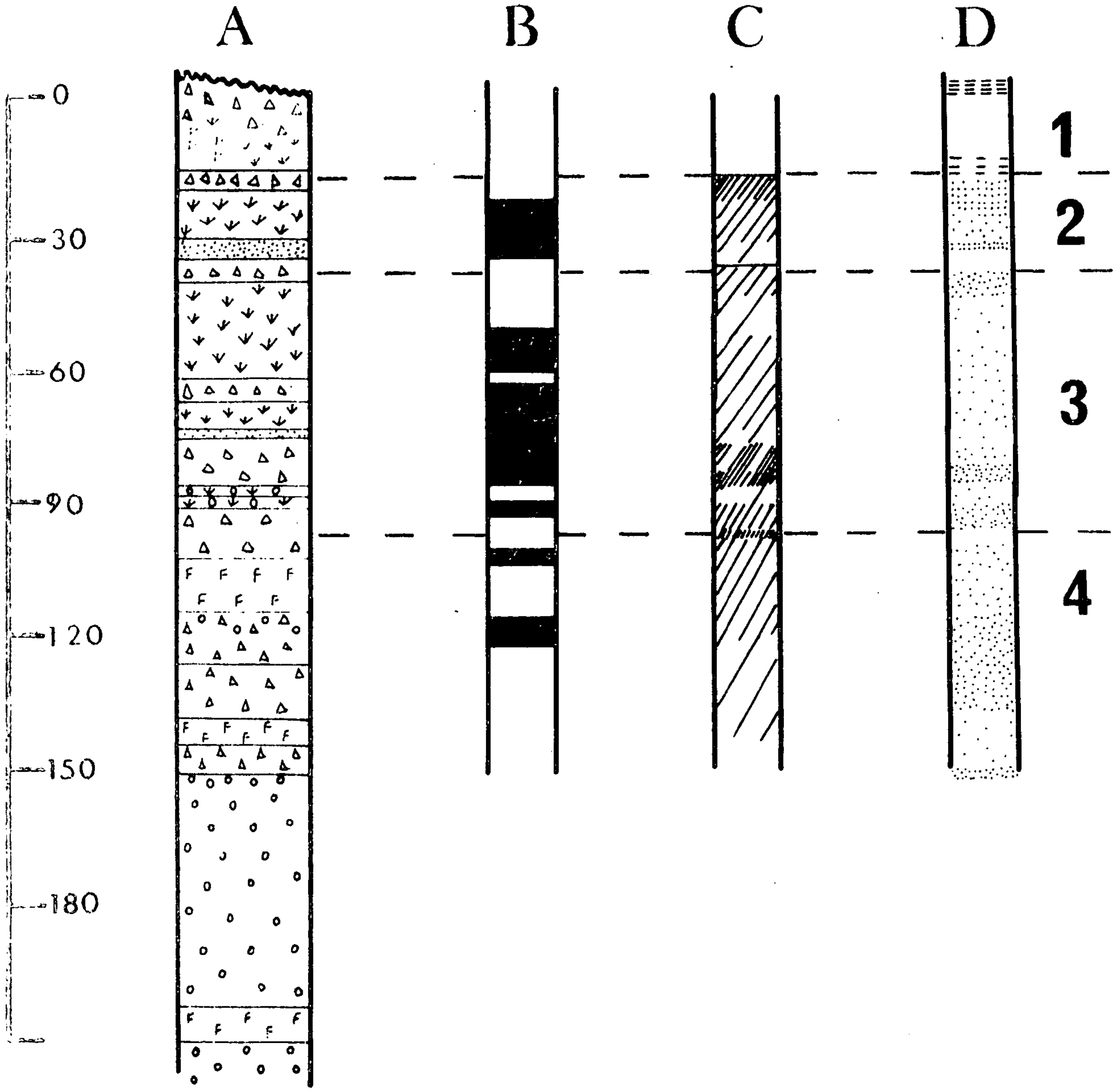

Fig.4. Re-interpretation of the Heron Island Borehole Data.

A – Lithological interpretation — shading as in Figure 3.
B – Position of Brown Stained zones
C – Intensity of solution zones shown by density of diagonal shading.
D. – Intensity of calcite cementation shown by density of dot shading. Horizontal bars in zone 1 represents aragonite cement.

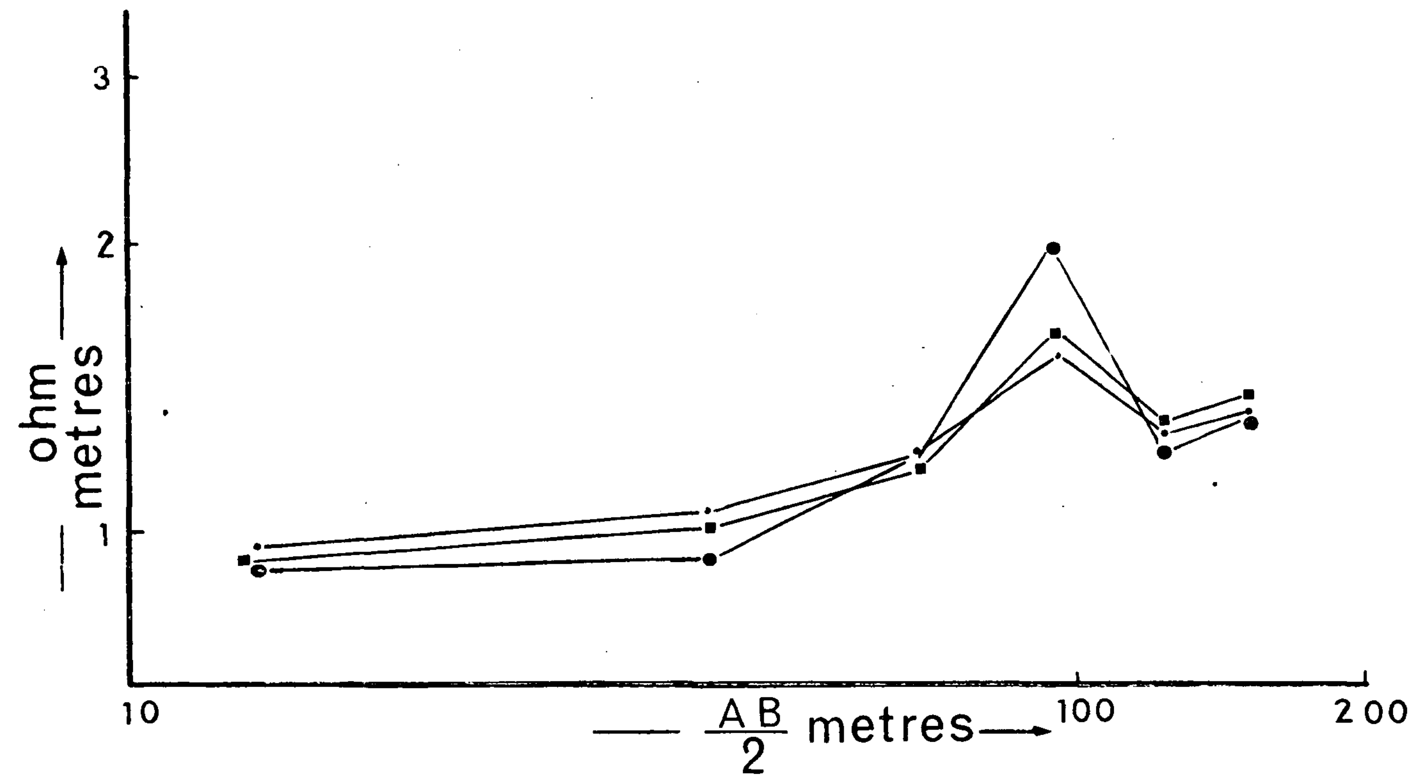

Fig. 5. Mean resistivity measurements over three days of observations, plotted as depth sounding curves. (After Hall, pers. comm.)

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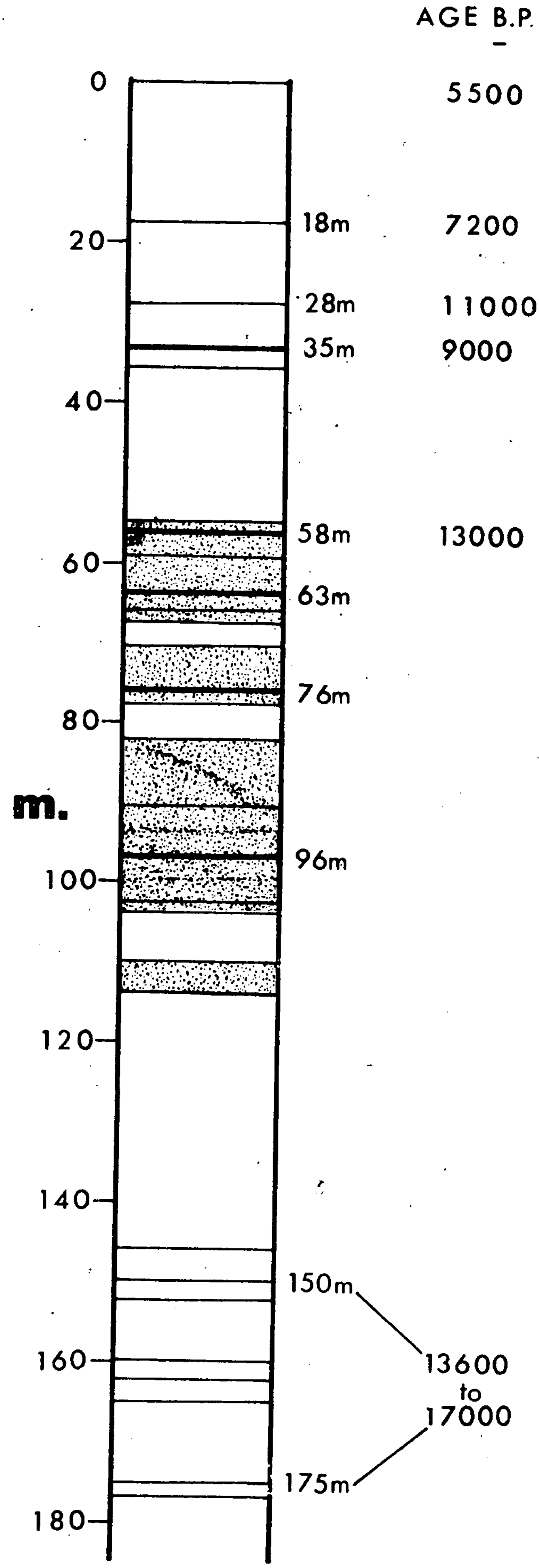

Fig. 6. The depth of terraces in the Capricorn Area, stippled areas represent depths at which terraces are commonly encountered. Thick barred lines represent depths at which terraces were repeatedly encountered during BMR survey 1971.
(Data after Maxwell 1968, 1969, 1971; Veeh & Veevers, 1970; Marshall, 1972; Cook & Polach, 1973).

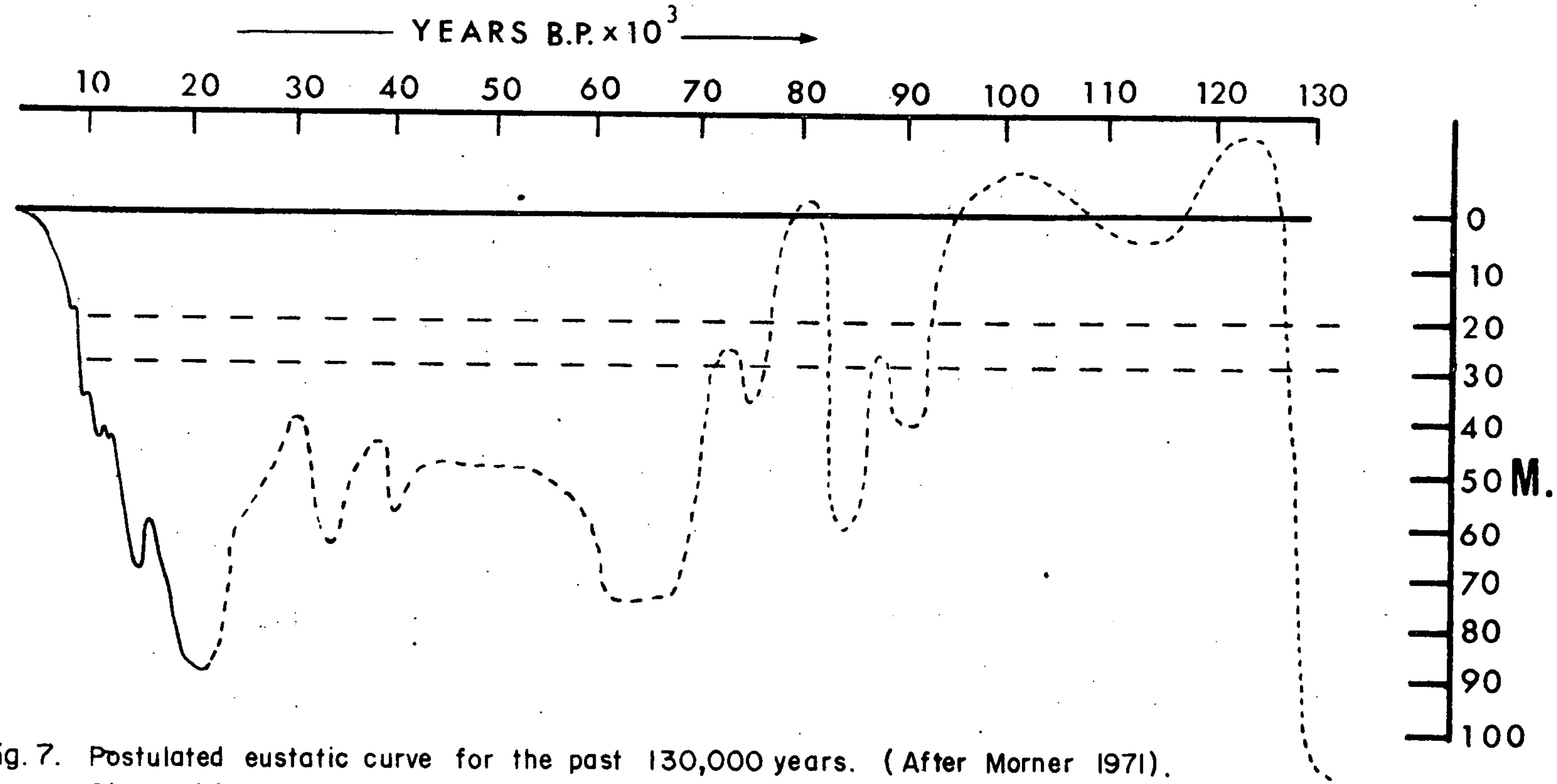

Fig. 7. Postulated eustatic curve for the past 130,000 years. (After Morner 1971).
The position of the 20 m and 35 m subsurface borehole horizontal barred lines.