4

PLEISTOCENE SUBMERGED CLIFF OFF THE OTWAY COAST OF VICTORIA, AUSTRALIA

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Abstract: A submerged cliff with its base at ~45 m has been traced for about 20 km on the Otway continental shelf. Sonar traces show that the declivity of the shelf increases appreciably seaward of the cliff. Rock outcrops are extensive (~20%) on the shelf landward of the cliff, while seaward of it the shelf is covered with sediments. The cliff coincides with a change in basement depth determined in a geophysical survey, and appears to be a fault trimmed during a eustatic 'stillstand'. Beach calcarenite from a clifftop site at ~42 m dated 14 830 yr BP by ^{14}C assay.

INTRODUCTION

There is a sharp contrast between the strongly dissected eastern flank of the Otway Ranges and the flat continental shelf of Bass Strait. Nevertheless there are significant features offshore between Cape Otway and Point Roadknight (Fig. 1), which are the concern of this paper.

CONTINENTAL SHELF

Ten traverses with a Furano 250 echo-sounder were made (by I.H.) normal to the coast (Fig. 2). The gross vertical exaggeration conceals the flat nature of the shelf here; the actual declivities shown by traverses A1-10 are respectively 1 in 95, 110, 156, 155, 131, 97, 142, of the Otway Range of 1 in 16, 21, 2, 5 (in Tertiary terrain), 3, 3, 3, 6, 9 and 6 (in Cretaceous terrain). Thus the land slopes are about 15 times greater, reflecting the different geomorphic processes and history of the two.

Echo-sounding, fishing and scuba diving have revealed the following general characteristics of the sea floor under study. The only major break is a submerged cliff about 20 km long from off the Sugarloaf to off Point Roadknight (Fig. 2). The shelf is steeper seaward of the cliff than landward in its vicinity. In the shallower waters are rocky outcrops and boulder beds which are worked for crayfish. Thin silt and sand beds with eel grass, where fish are netted, occur between the George and Wye Rivers, and off Big Hill, at depths of 13-23 m. Fish frequent the water upwelling along the submerged cliff and this is why it is well known to professional fishermen. Describing a similar submerged Pleistocene cliff near Plymouth in England, Cooper (1948) writes, 'the fish are reminiscent of birds soaring above a cliff in an ascending current of air'.

One of us (I.H.) has noted that about 20% of the seafloor between the submerged cliff and the shore consists of rock outcrops, and the sediments (where present) are thin and predominantly siliceous. Off the Cumberland River there is a bed of extra large boulders. Submerged islands occur off Cape Otway. By contrast, the shelf seaward of the cliff is covered with sediments, and rock outcrops are rare.

SUBMERGED CLIFF

This feature can be traced (although not always clearly) for some 20 km (Fig. 1). It is not a straight line, but is approximately parallel to the coast. The height of the cliff varies, but 7 m is an average. Ramparts in two places on the top of the cliff have been described by fishermen. The submerged cliff can be seen particularly clearly in profiles A3, 5, 6 and 9. The varying direction, height, base and geomorphic definition are comparable with those on the existing coast. The marine transgression that submerged the cliff has depressed its morphology. The most irregular sections are those nearest the present coast, viz. near Point Roadknight, Point Grey and Point Hawdon. On the present coast the cliff base varies from low water level to 7 m above it (e.g. Mount Defiance), but the cliff base is usually within 4 m. The spring tidal range is 1.75 m in this area. Platforms graded to low water

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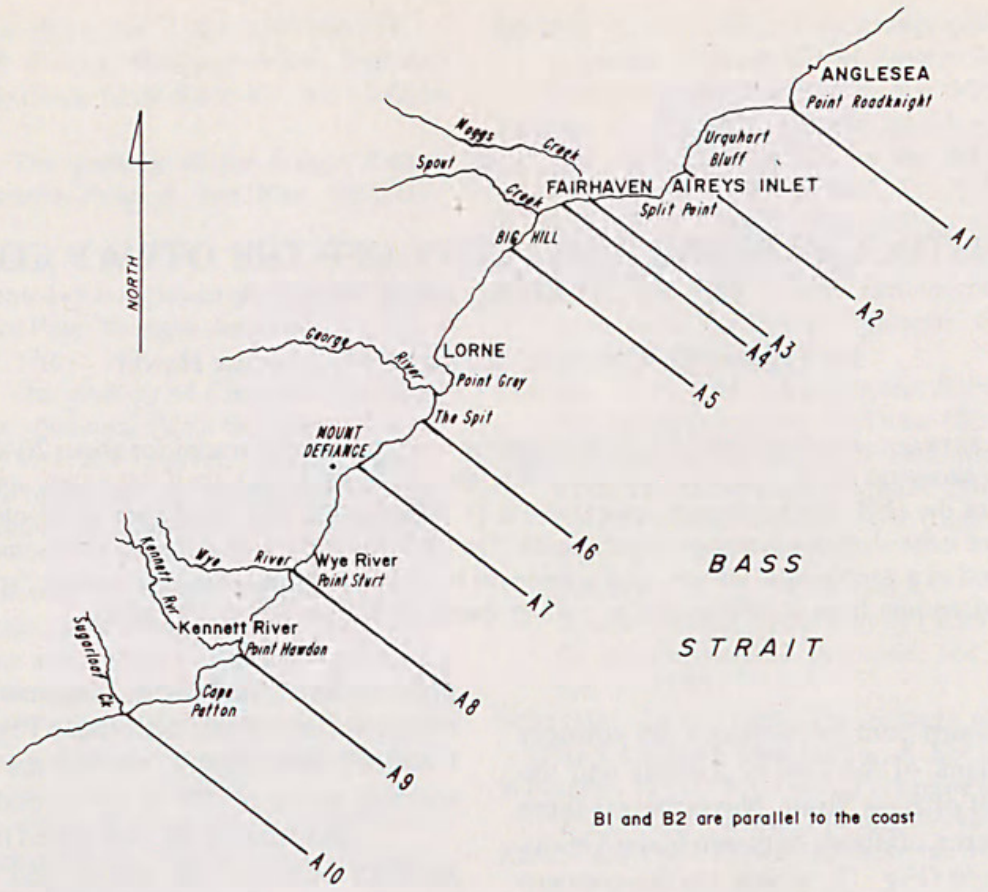

Fig. 1.—Map of sonar traces over the Otway continental shelf, Victoria.

level have been cut in Otway siltstone, but the greywacke is more resistant (Gill 1973), resulting in the range of level of the cliff base given above. As sea level is at the lower limit of this range, the same relationship may be inferred for the submerged cliff. That is, it was cut when sea level was of the order of 45 m lower than now. This level was determined where the ^{14}C sample was collected, more accurate information being available there.

SUBMERGED BEACHES

Both on top of the submerged cliff and at its base are layers of calcarenite, which are interpreted as relict beaches. One of us (I.H.) obtained some 20 pieces from the top of the cliff at a depth of about 23 fathoms (−42 m) about 5.6 km southeast of the mouth of Godfrey Creek, which is southwest of Lorne. The pieces were up to 23 cm in diameter (a size that could be brought up in fishing nets), irregular in outline, and platey (up to 8 cm thick). The surface was irregular and numerous voids were present as a function of incomplete cementation. Top and bottom could be readily distinguished by the colour (lighter on top) and the encrusting organisms. The tops were off-white (Munsell about 10YR 6/6) to pale brown (10YR 7/2). The bottoms were brownish yellow (10YR 6/6) to strong brown (7.5YR 5/4 to 5/6) dry. These are oxidation colours.

The encrusting growths on top included seaweeds, sponges, bryozoa, calcareous worm tubes of two kinds, and a solitary coral. One species of bryozoan with an erect, rigid, rather fan-shaped colony was determined by Mr. Michael Cooper of the Department of Geology, University of Melbourne, as *Adeona grisea* (MacGillivray). The fauna of the undersurface was less rich, but included encrusting bryozoa and calcareous algae, calcareous worm tubes of two kinds, and a secondarily cemented spinose mollusc. The rock consisted mainly of sand-sized particles, including Foraminifera, but also of fragments of molluscs, cidaroid spines and bryozoan colonies.

One of us (E.R.S.) made a mineragraphic study of a sample, and found it to be a porous limestone composed mainly of detrital particles which include quartz, felspar, minor biotite and occasional small particles of shale. The rock is estimated to be about 50% calcite, occurring as individual grains, finely crystalline, in many cases clearly organic in origin. The whole is loosely cemented by later carbonate, which is present as more transparent rims around calcite grains, or as cement between other mineral grains.

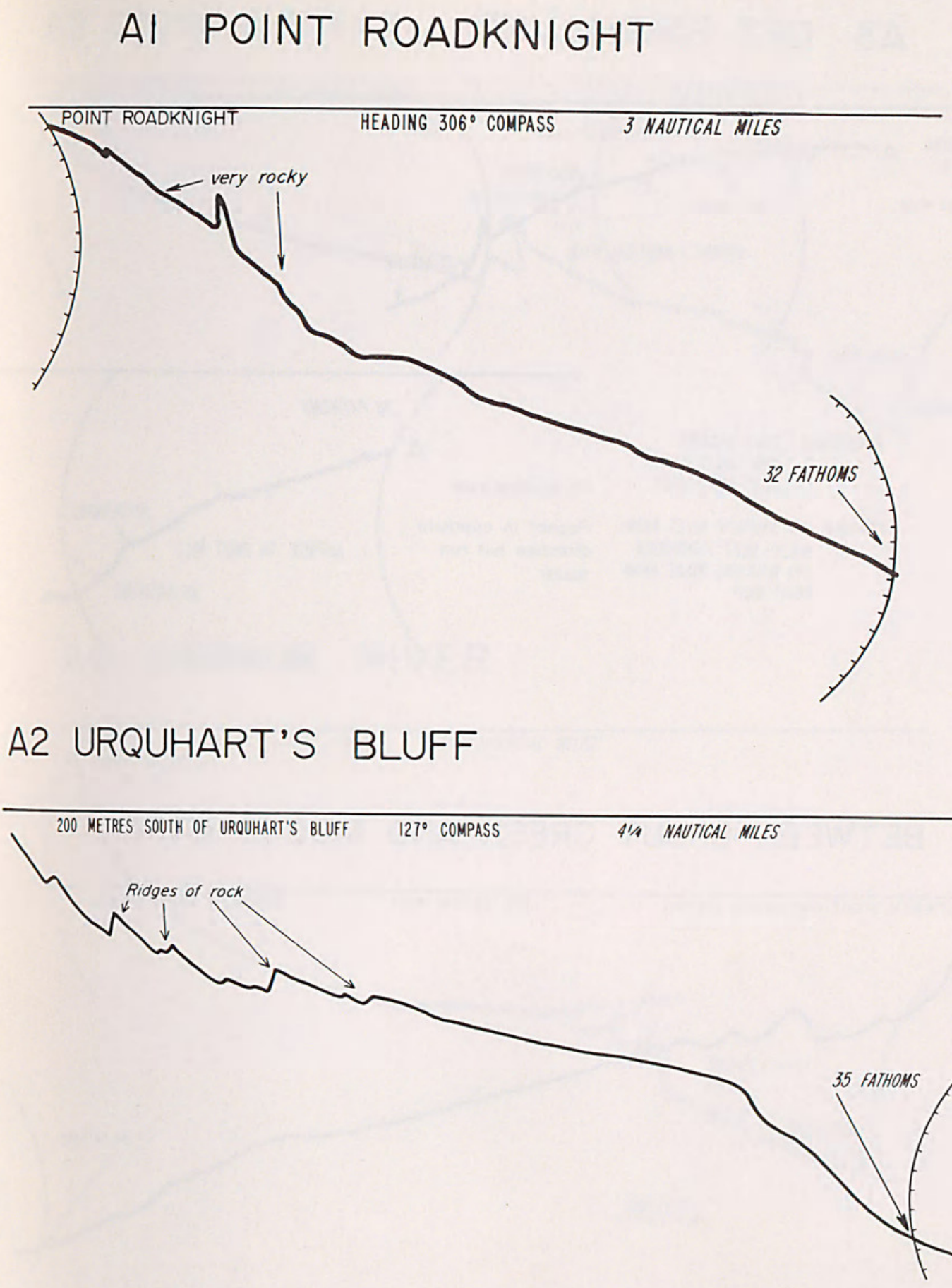

Fig. 2.—Sonar traces A1-10 (as shown in Fig. 1) run normal to the coast on compass courses, but not corrected for drift. A3 has two traverses run close to one another to show the variation in seafloor morphology.

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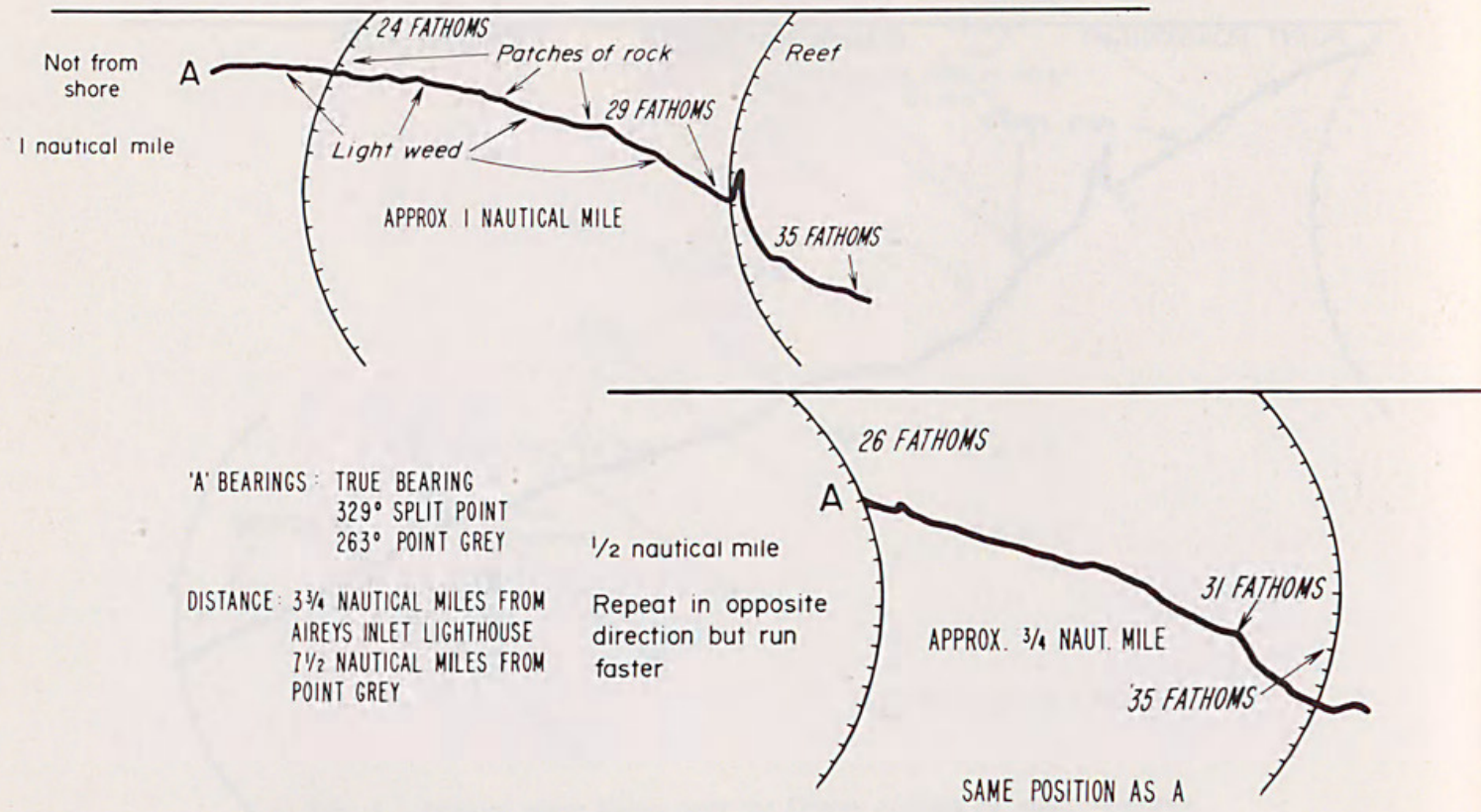


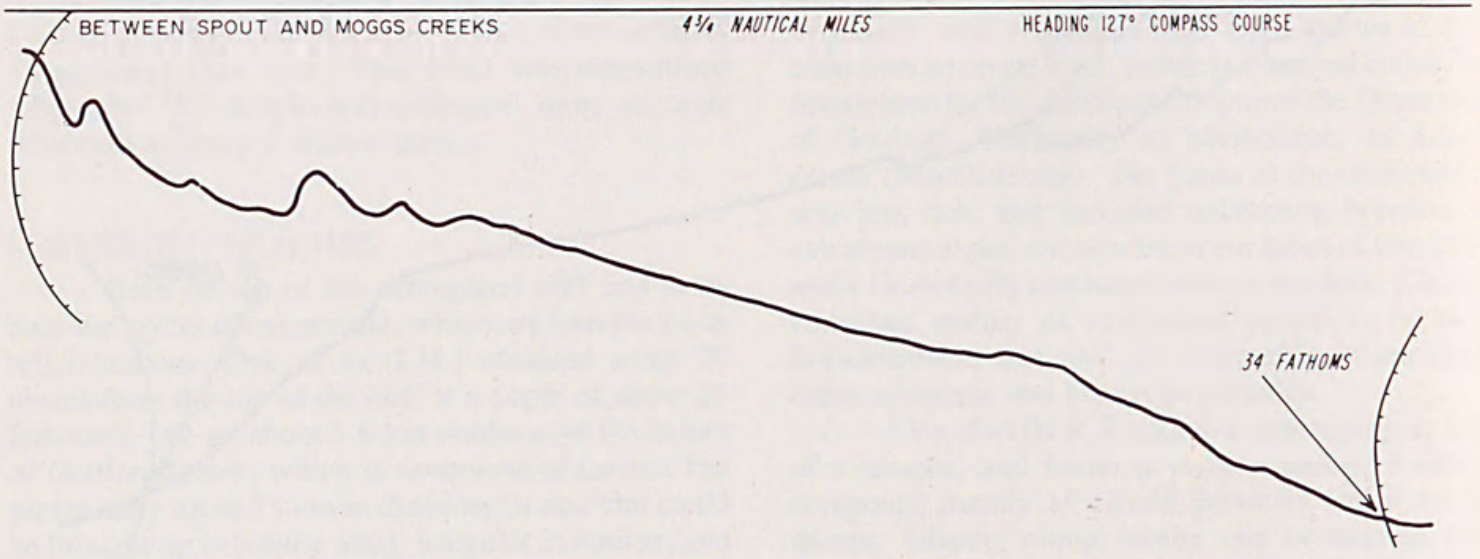
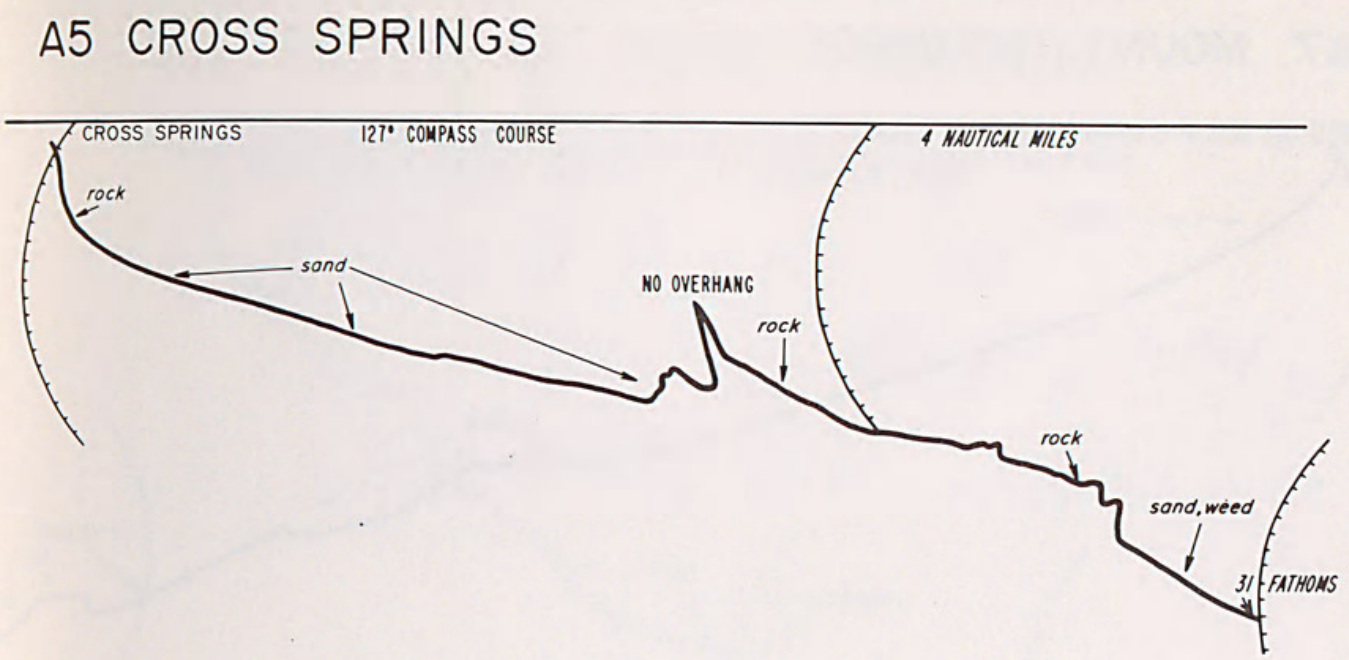


Fig. 2 (*continued*) Sonar traces A3-4



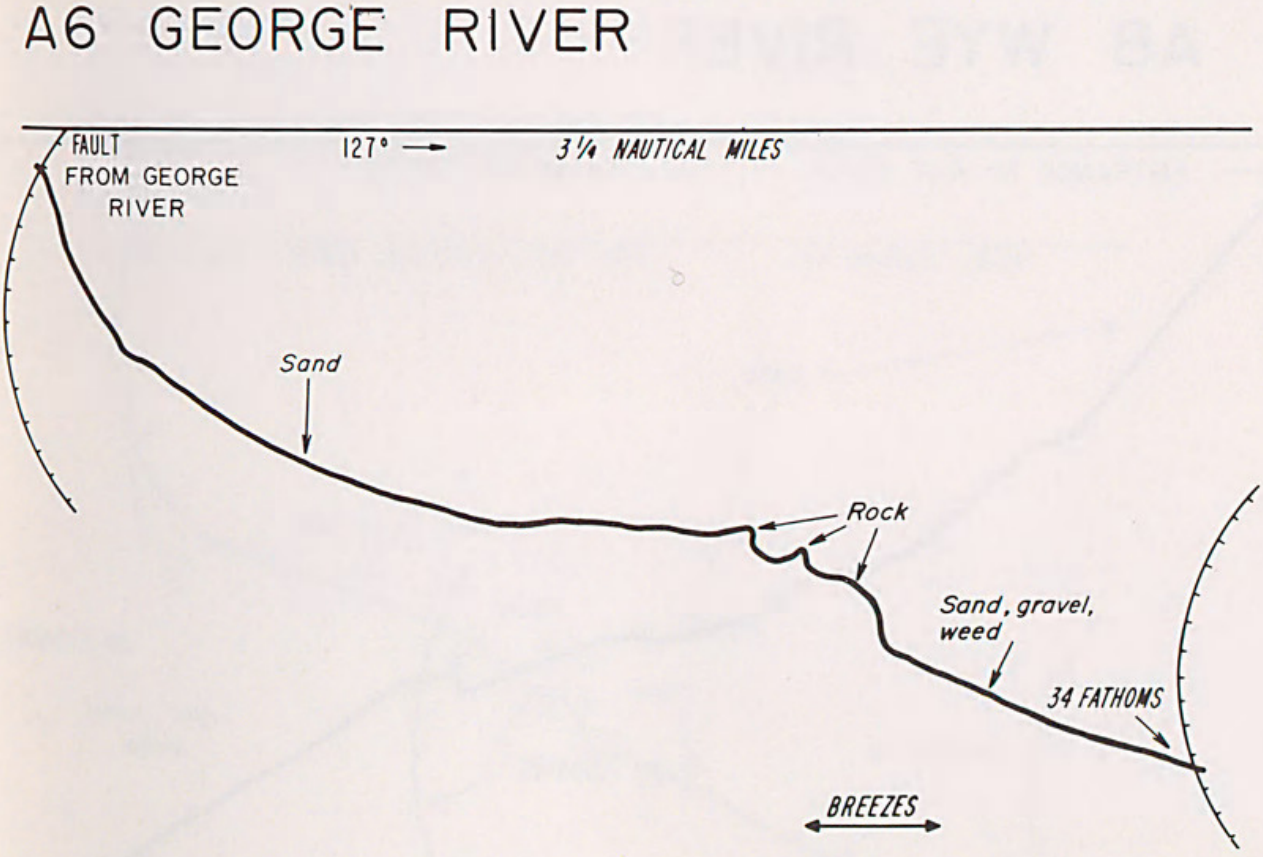
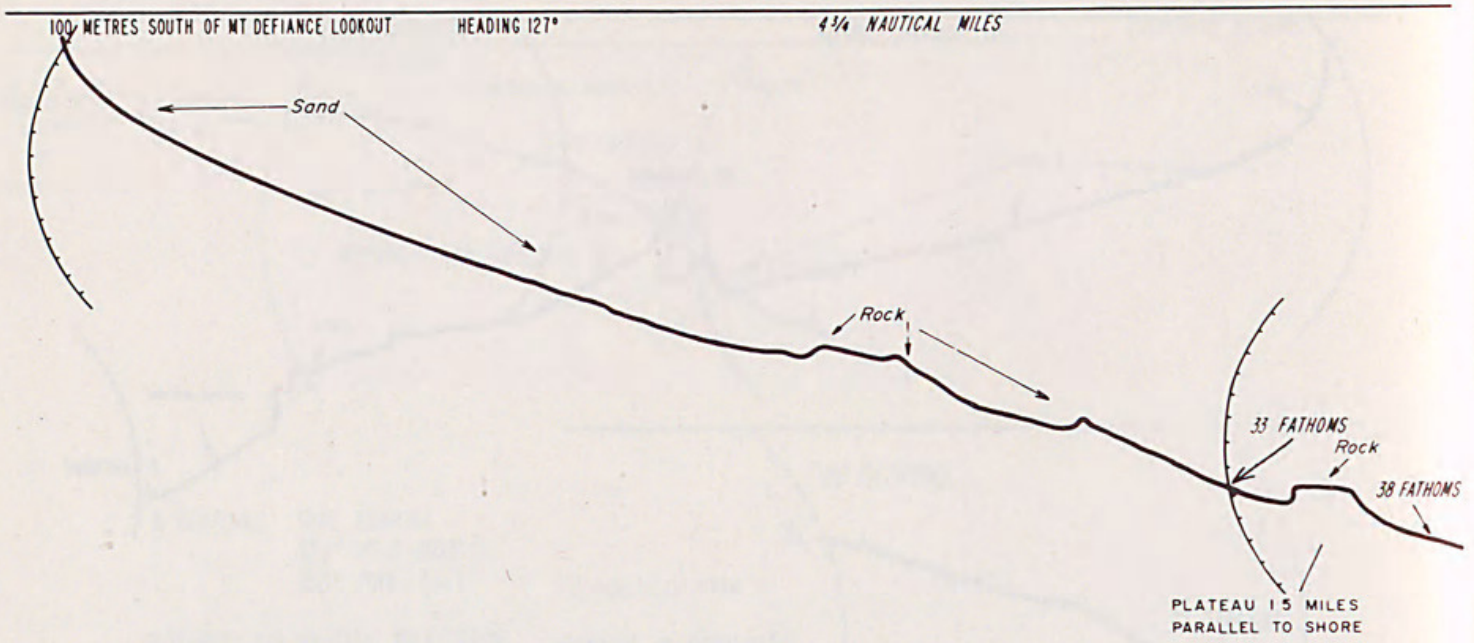


Fig. 2 (*continued*) Sonar traces A5-6



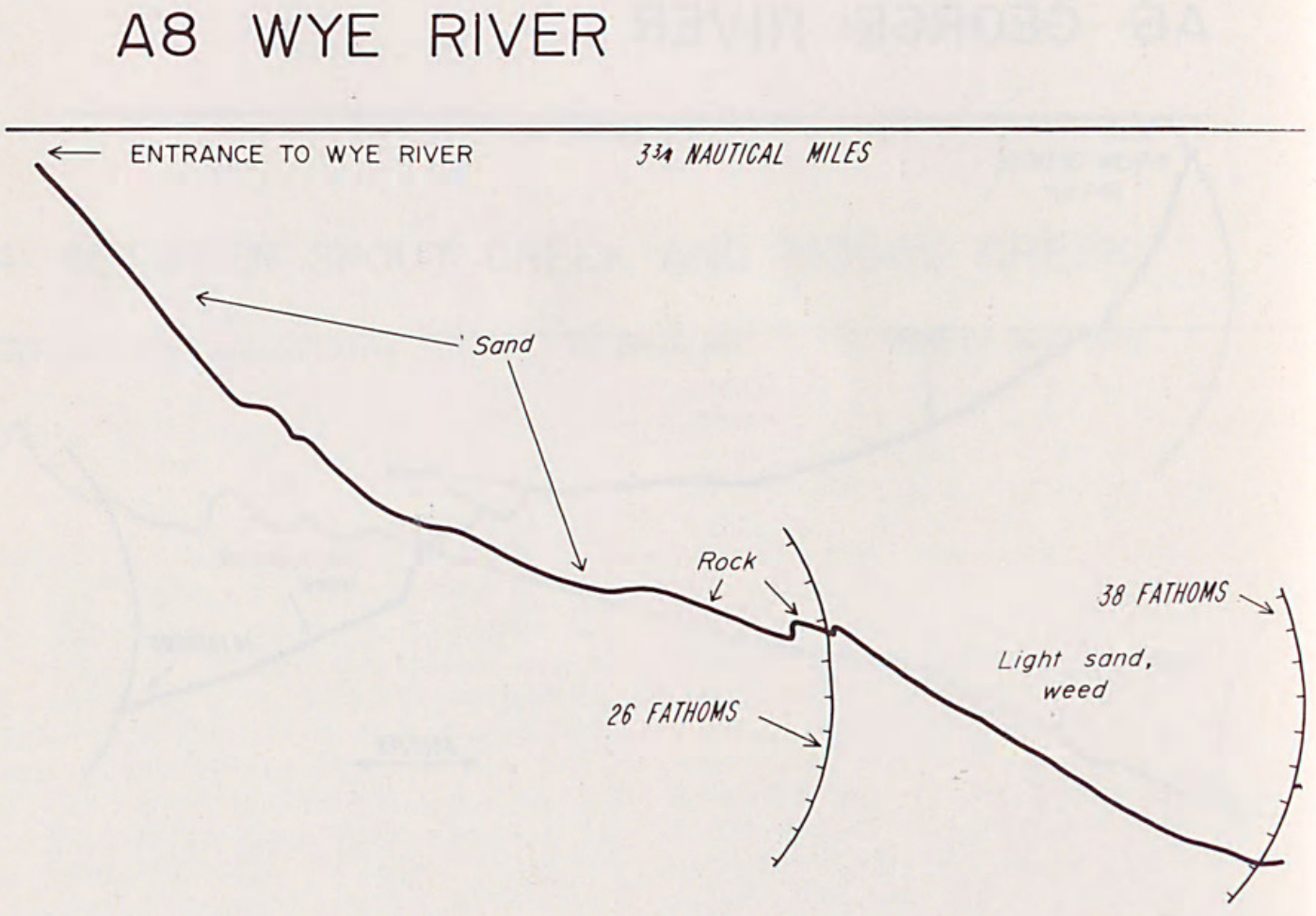
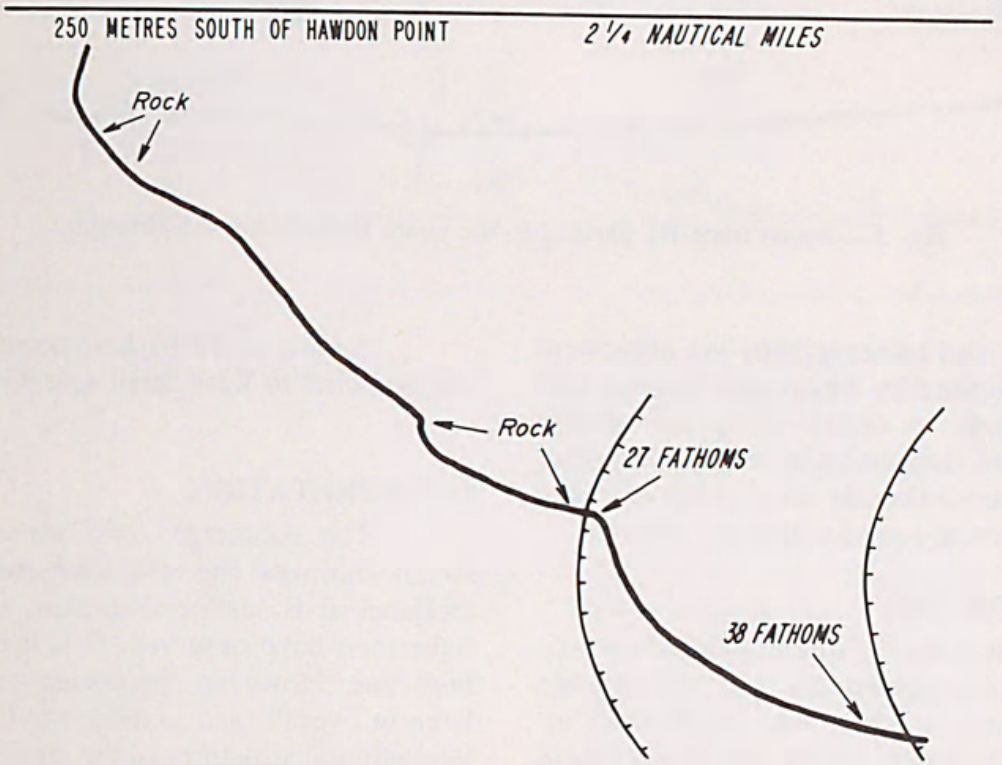


Fig. 2 (*continued*) Sonar traces A7-8



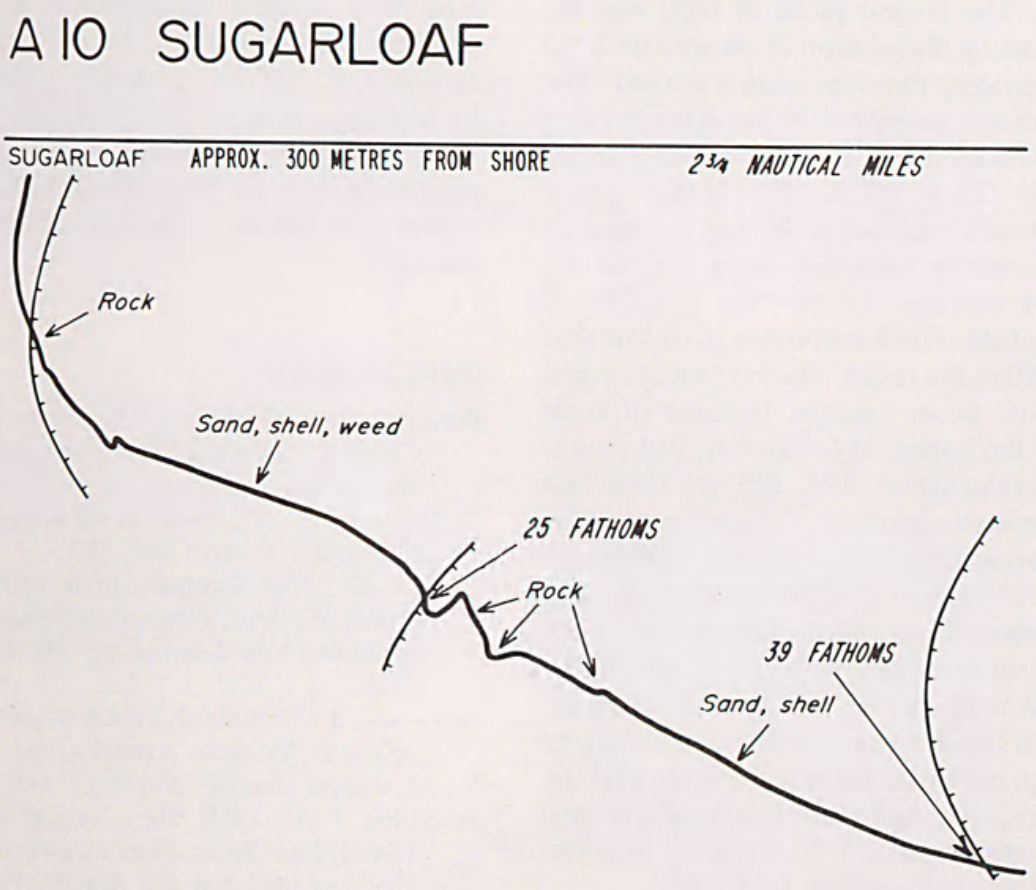


Fig. 2 (*continued*) Sonar traces A9-10

Fig. 3.—Sonar trace B1 parallel to the shore from Lorne to Fairhaven.

The geology and mineragraphy are consistent with a beach rock formed by freshwater seeping into carbonate beach sands, as occurs along the present coast. This is not to be confused with the beach rock of tropical shores. Other sediments seen so far from the seafloor in this region are predominantly siliceous.

RADIOCARBON DATING

A second reason for the mineragraphic investigation was to determine whether the rock was suitable for radiocarbon dating, as there was insufficient included shell for this purpose. As the calcite rims were of the order of 0.002 mm only, it was estimated that the secondary calcite was less than 2% of the total carbonate present. The largest piece of rock was reduced to half its size by dissolution in an acid bath, to ensure that all penetrating crevices were removed. The sample so obtained was submitted to the Radiocarbon Laboratory of the University of Sydney, which assayed a date of 14 830 ± 185 yr (SUA-553). If the sample was formed as a beach rock when the sea was at that level, then the secondary carbonate is of similar antiquity to the beach, and does not alter the age. Even if it is not, the percentage of this carbonate is so low that it cannot grossly affect the result. On the Otways coast carbonate sediments do not persist because of their small volume and the appreciable rainfall. For example, the Last Interglacial (c. 125 000 yr) shoreline deposits are completely leached of carbonates. The sample assayed no doubt had some recycled carbonate, but if so it must be Flandrian (in the wide sense) in age. Any veneer of carbonate sediments left on the continental shelf as the sea retreated during the Last Glacial would be leached away before sea level rose again. This contrasts with the Warrnambool area of Western Victoria, where quantitative work has shown that the majority of the shoreline carbonate has been recycled from the Pleistocene because of the high erosion rate (4 cm/yr) of the calcarenite cliffs (Gill 1973).

Jennings (1959) has recorded a similar submerged cliff in Bass Strait near King Island.

INTERPRETATION

The submerged cliff varies in direction between southwest and west-southwest, while off Mount Defiance it is scalloped in plan, as the professional fishermen have observed. It is not simply a straight fault line. However, the present coast is remarkably straight overall, and is related to the direction of the fundamental structures of the area (Benedek & Douglas 1976, Fig. 7.2). Dr. J. G. Douglas has informed me that the structure shown on the continental shelf in their map was inserted because the geophysical survey showed a change there in the bedrock depth. The submerged cliff was certainly a shoreline in the late Pleistocene, as is shown by the beach deposits. As the sea was rising so rapidly (1-1.5 m per century, according to how low sea level was 18 000 yr BP) an oscillation was necessary to provide the time in which to cut the cliff.

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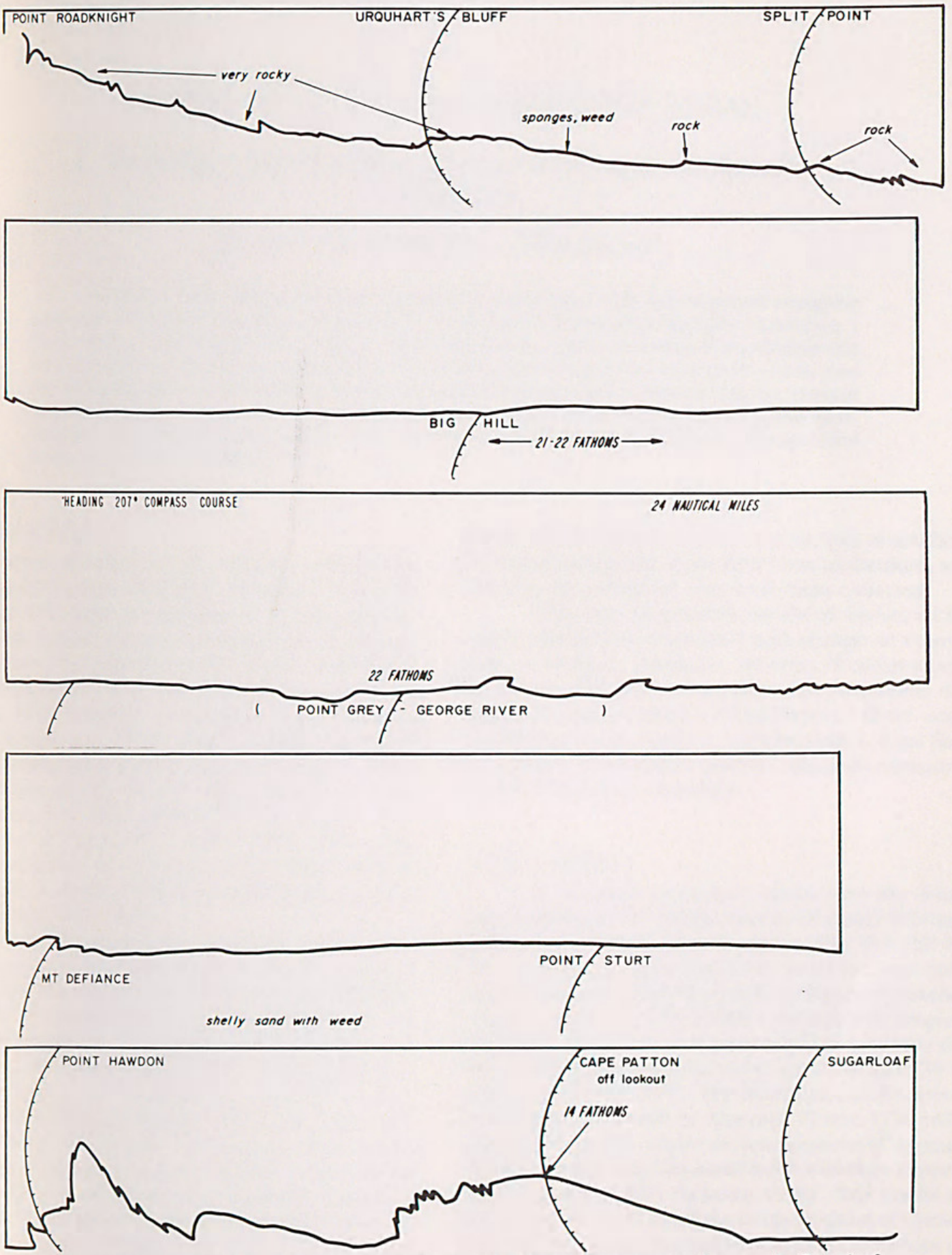

Fig. 4.—Sonar trace B2 parallel to the coast from Point Roadknight near Anglesea to the Sugarloaf southwest of Cape Patton. As the trace covers 24 nautical miles, it has been necessary to cut it into sections for reproduction.