COMPARATIVE SIDE-SCAN SONAR AND PHOTOGRAPHIC SURVEY OF A CORAL BANK

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INTRODUCTION

The South China Sea contains a number of banks, the largest of which is Macclesfield Bank, which measures 70 by 35 miles. This bank lies some 400 miles southward of Hong Kong, almost midway between the Philippines and South Vietnam (figure 1). It is a typical submerged atoll, with its lagoonlike structure revealed by the relatively deeper central area and a much more elevated reef rim. The submergence may have been caused by a relatively rapid isostatic subsidence, with significant subsequent shoaling by aggradation, leaving an average depth of 300 feet at the present time. The bank now has many shallow patches, and of these Oliver Shoal is one of the most prominent at its northern edge.

Macclesfield Bank has been known for a long time to be a productive fishing ground, but it was not sampled during the extensive surveys of the surrounding sea floor (Klenova, 1958; Niino and Emery, 1961; and Ching, 1963). Fish productivity here is high, possibly because nutrients are concentrated in this region by local upwelling due to obstruction of the water flow and by solution of minerals from the coral rocks. The abundant occurrence of coral offers a variety of footholds to the faunas, and numerous places for the fishes to shelter from their predators.

To start a systematic ecological study of this fishing area, it was essential, among other things, to acquire data on the bottom sedimentological environment of the area. A cruise was therefore conducted in April 1966, by the University of Hong Kong, with a view to obtaining some information on superficial sediments as a help to orient future fisheries research programs. The area of Oliver Shoal chosen for investigation was approximately two miles square, centering at the point 16°05'.5 N and 114°19'.5 E. The depth enclosed by this area varied over a fair range (70-290 feet), and so a variety of bottom types was expected.

METHODS OF INVESTIGATION

The first use of a side-scan sonar device for sea floor survey was described by CHESTERMAN *et al.* in 1958. In the subsequent decade, advances in instrumentation have been made (TUCKER and STUBBS, 1961) and a number of acoustic surveys carried out. These include the detection of linear sand patches off Plymouth (STRIDE, 1959) which led to the recognition of the pattern of sediment transport in the tidal current environment around southern Britain (STRIDE, 1963), the mapping of the marine geology off the coast of Dorset (STRIDE, 1960; DONOVAN *et al.*, 1961*a*) and in the Bristol Channel (DONOVAN *et al.*, 1961*b*), a detailed study of the herring spawning ground at Ballantrae Bank, Scotland (STUBBS and LAWRIE, 1962), and a survey of sets of parallel ridgelike features on the continental rise off the eastern seaboard of North America (CLAY *et al.*, 1964). More recently, the microtopography of the continental shelf in five areas between Nova Scotia and New York (SANDERS *et al.*, 1969) and sand waves on the European shelf (KENYON and STRIDE, 1968) were investigated, and the occurrence of off-shore tidal current deposits were demonstrated (BELDERSON and STRIDE, 1966). Studies on bottom sediment distribution were also made in the southern Gulf of St. Lawrence (LORING *et al.*, in press) and around the coastal waters of Hong Kong (CHESTERMAN *et al.*, 1967).

The sonar equipment used in the present work operated at a frequency of 48 kHz, and had a normal range athwartships of 2 400 feet. The magnetostrictive transducer, used both as sound projector and listening hydrophone, was pulsed at a rate of 1 p.p.s. with the peak electrical output power rated at 8 kW. The receiver signal was processed by a time-varied-gain amplifier as described by TUCKER and STUBBS (1961) and CHESTERMAN *et al.* (1967), and recorded on a modified Muirhead facsimile recorder.

Since much of Macclesfield Bank was not charted, an echo-sounding survey was first conducted. The main investigation consisted however of a side-scan survey, a photographic survey along several lines within the area, and scuba dives at a few predetermined locations (figure 1). In addition, bottom samples were collected by means of a Phipps underway bottom sampler.

While the photographic runs provided detailed information on the bottom environment and its microtopography, the side-scan results yielded data on large-scale features not easily revealed by photo-mosaics. The scuba dives and bottom samples provided confirmatory spot checks on the general findings, as well as helping to decipher the minute details of photography.

Two complete acoustic surveys of the area were made looking from opposite directions along 8 north-south lines of which any two adjacent ones had a 25 % overlap. The coverage from both sides ensured identification of genuine bottom features and also made their height estimation possible. Lines for photographic runs were determined from results of the acoustic survey. The camera employed was an EG&G underwater system

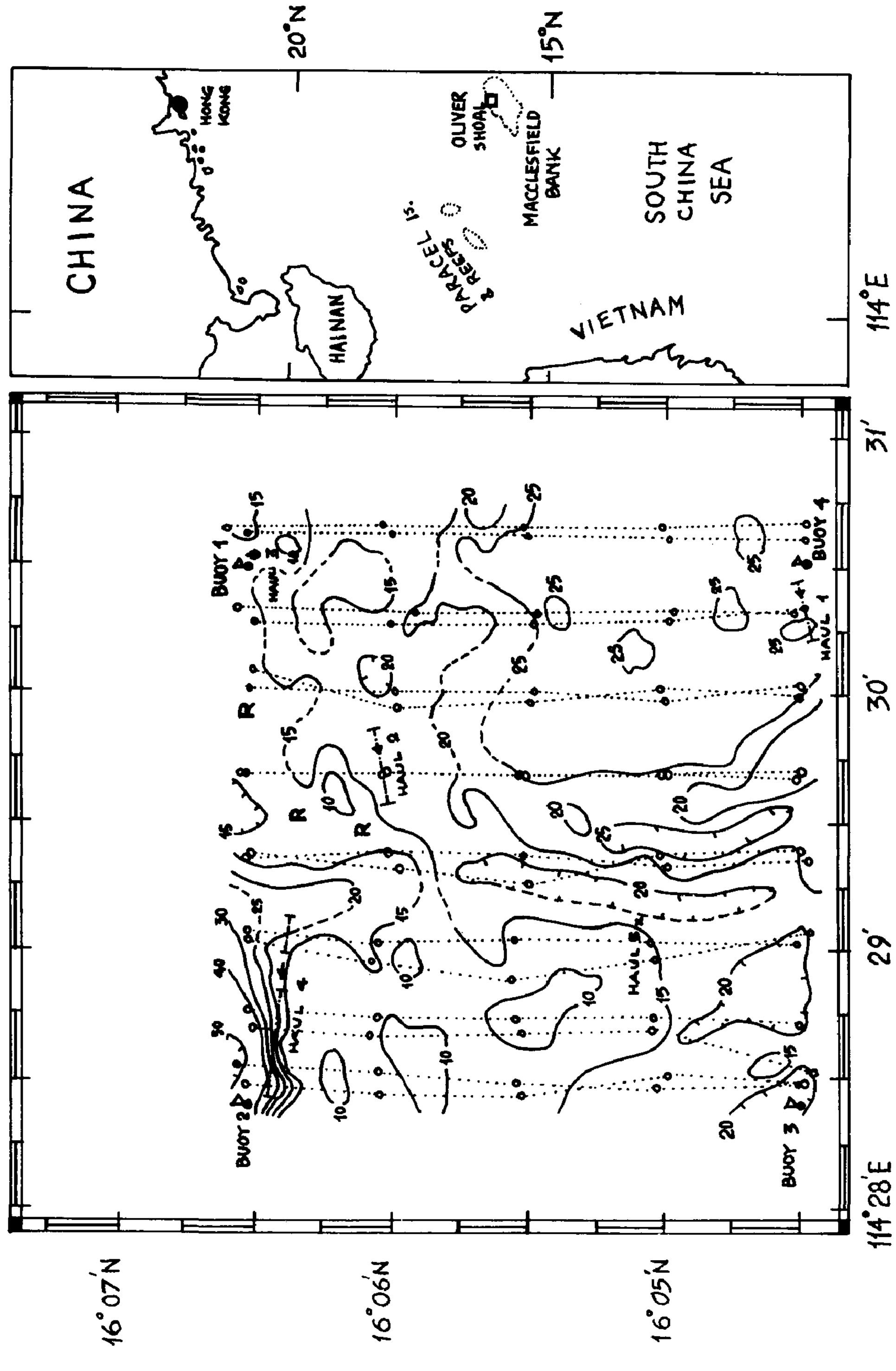


FIG. 1. — Bathymetry of the study area in Oliver Shoal, Macclesfield Bank. Fixes are shown by open circles, the contours are in fathoms, and R indicates area where bottom is particularly rugged. Acoustic survey track is shown dotted, and photographic hauls dot-and-dashed. Insert gives location of Macclesfield Bank.

mounted on a modified National Institute of Oceanography frame with a bottom pinger. The scuba dives were made to examine *in situ* the topography and textural properties of the seabed and to study the flora and fauna in their natural habitat.

Navigation throughout the survey was made by range and bearing with respect to four radar buoys whose positions were determined by repeated astronomical fixes with a probable accuracy of about 3 miles. The relative positions of the traverses were better than 100 feet.

RESULTS AND DISCUSSION

Bathymetric Results

From the bathymetry of the study area (figure 1), it is seen that the seafloor slopes down relatively rapidly at the north-western corner, while the rest of the area is somewhat undulating, with several ridges running roughly in a north-south direction.

Acoustic Results

In figure 2 the bottom sediment distribution as deduced from the acoustic survey is depicted. The seafloor consists mostly of undulating coralline ridges separated by coral sand (figure 4). Coral boulders and smaller coral fragments are more dominant in the hatched areas. Towards deeper waters, the sea bottom tends to be more uniform, with fine-grained sand as the major constituent.

The difference between the acoustic nature of the sandy and coral types of bottom is brought out in figure 3. The problem of delineating bottom sediments by the quantitative characteristics of the backscattered acoustic energy has been discussed elsewhere (McKinney and Anderson, 1964; Wong and Chesterman, 1968), and it suffices here to point out that the reverberation curve for a coral bottom is highly peaked and irregular, while that of sand is less fluctuating and lower in the backscattered level by about 8 dB.

A comparison of figures 1 and 2 reveals that the seafloor relief is largely controlled by the coral ridges, which trend approximately north-south and are arcuate in shape, with the concave side to the east (figure 2). They become oriented NW-SE north of 16°05'.8 N, running at right angles to the submerged rim of the Macclesfield atoll. It should also be noted that the abundance of coral rapidly decreases to the northwest where the water is deep, confirming that coral requires warm, relatively shallow, clear saline waters to flourish (Vaughan, 1916).

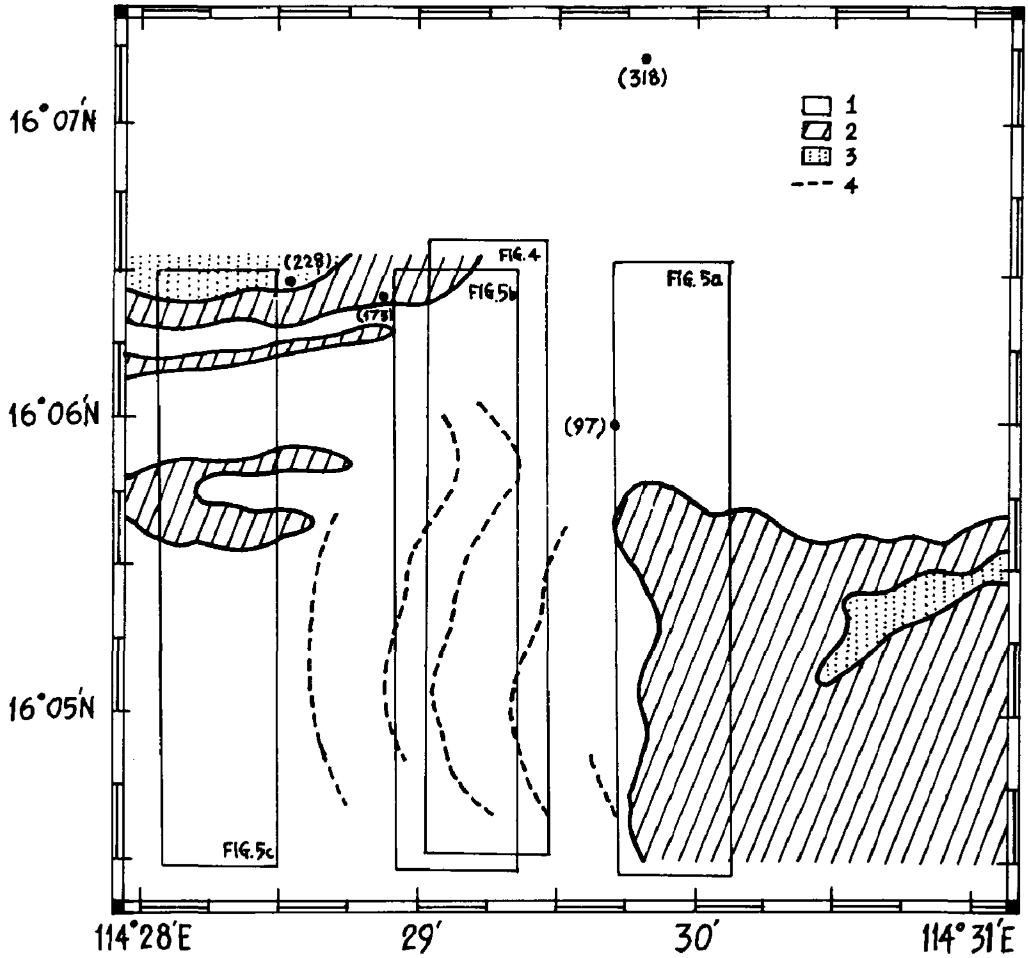


FIG. 2. — Bottom character of the study area based on all available data. 1 : coral, 2 : coral bottom mixed with broken up material, 3 : sandy bottom sparsely covered with broken up material, 4 : crests of coral ridges. Black dots give positions of photographs numbered in parentheses. Rectangles indicate the limits of subsequent figures.

Three isometric records are reproduced in figure 5, in which the bottom types of coral, coral boulders and small fragments of coral, and sand can be clearly discerned. Figure 6 shows two mosaics of isometric records covering the study area, looking from the east and from the west respectively. It may be noted that details on opposite sides of the coral ridges are revealed separately by the two mosaics, thus illustrating the advantage of sonar-scanning from two opposite directions.

Photographic Results

Results of the photographic survey are in excellent agreement with the acoustic runs, and they illustrate in a strikingly consistent manner the bottom classes of figure 2. In the coral-covered area many ecological

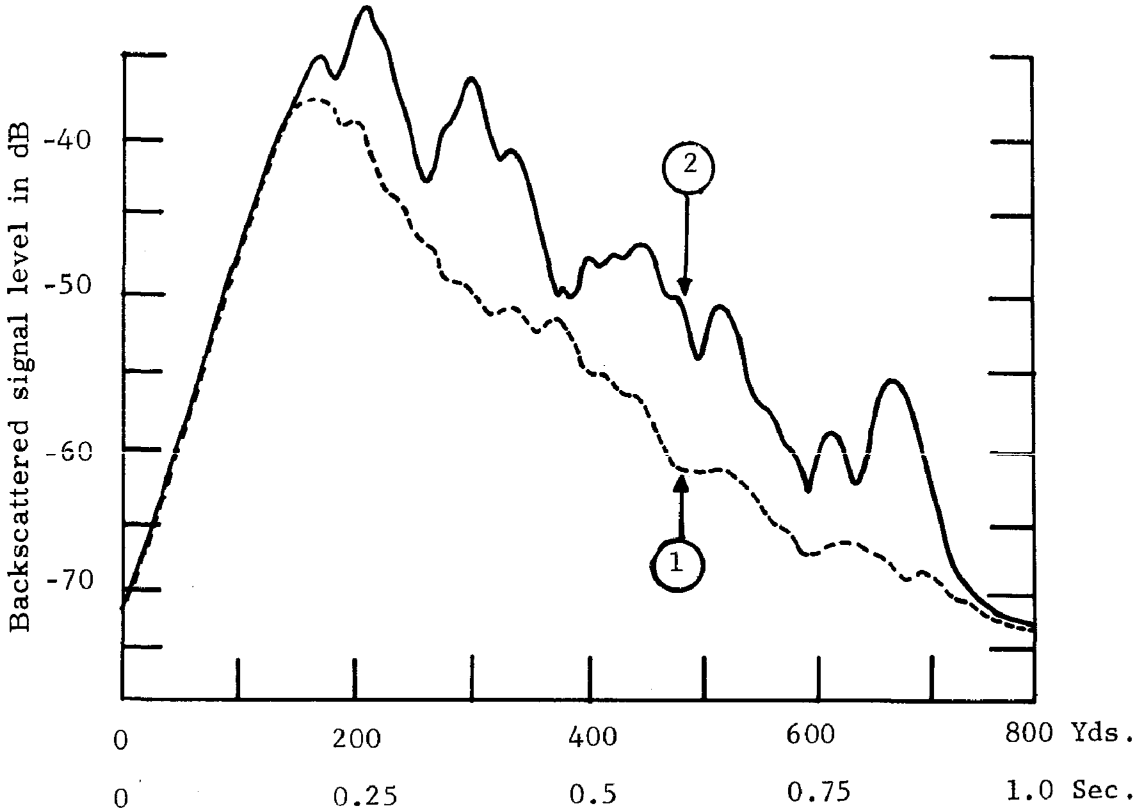


FIG. 3. — Reverberation curves for sandy and coral bottoms.

Curve	Station	Bottom
1	71	sandy
2	58	coral

variants of dense coral colonies were photographed (figure 7, photo no. 97). These include the Acroporidae, notably the genera *Acropora* (staghorn coral) and *Montipora,* which are mostly branching and very porous. Astraeid corals, typically rounded and massive, are also numerous, and so are the smooth Poritidae and the solitary, mushroom-shaped *Fungia.* Occasionally, a Meandrine (brain coral) which forms a large rounded mass is found. Life is very abundant in this environment. Brightly-hued fish, horny gorgonians, feathery hydroids, contracted sea anemones, sea urchins, starfish and crinoids are often noticeable.

Figure 8 (photo no. 173) shows a bottom densely covered with coral debris, including dead coral, loose fragments in which the polyps are still living, and young coral colonies which are beginning to grow. Coralline algae and encrusting or branching algae impregnated with lime grow upon the coral debris. Large living corals are absent as the water depth here is in excess of 27 fathoms.

Figure 9 (photo no. 228) is composed largely of poorly-compacted fine coral sand, dotted here and there with coral debris, notably of dimensions less than 6 inches. Holes and tracks are common features, indicating the presence of life.

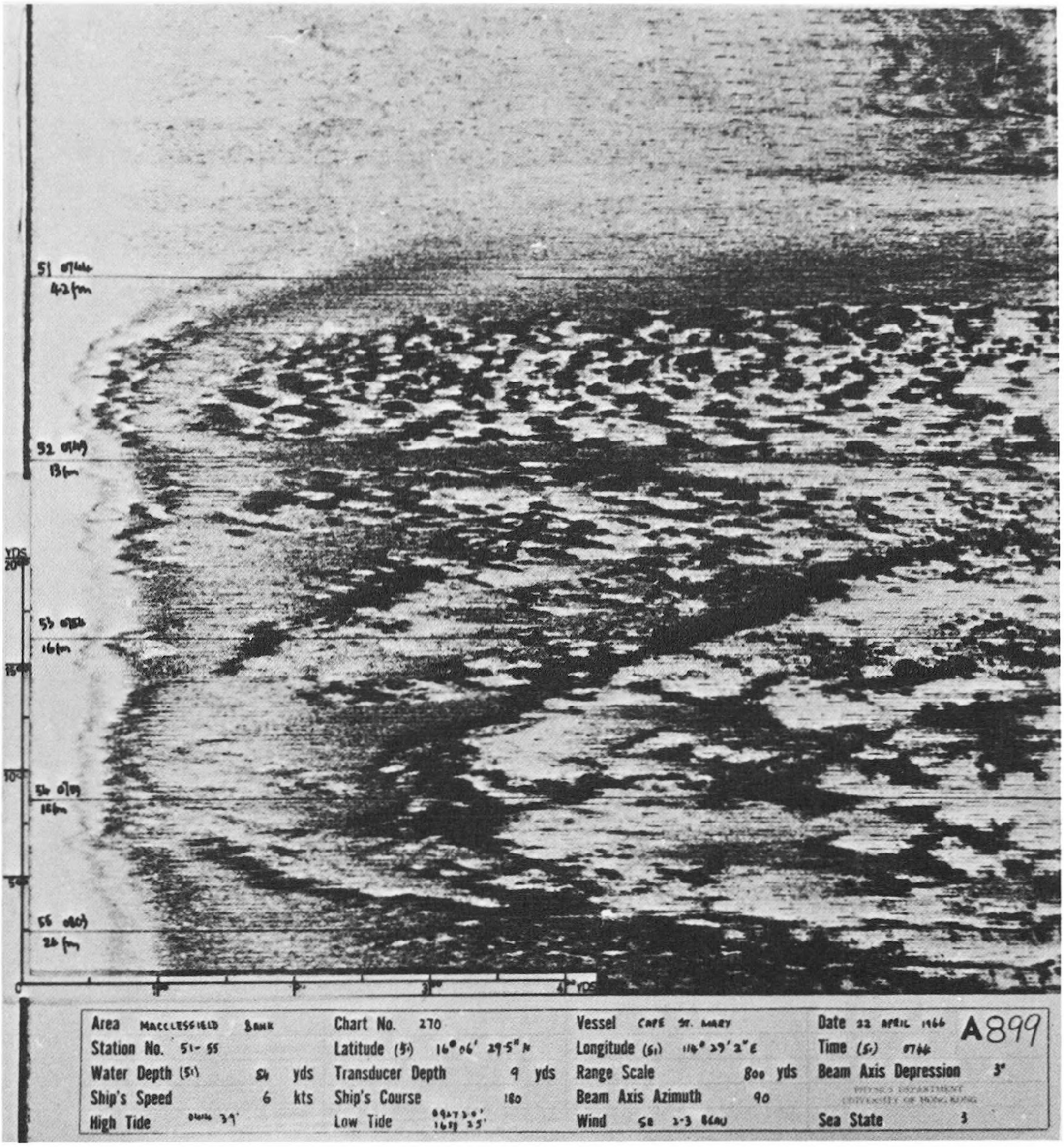


Fig. 4. — An acoustic record of a prominent coral ridge with a sandy seafloor in the upper part.
Horizontal exaggeration approximately 6 times. Location shown in fig. 2.

Figure 10 (photo no. 318) is selected out of a run approximately half a mile north of the survey area. The water becomes progressively deeper, and the seafloor passes from one of encrusted coral boulders and coral ledges buried in sand to one of pure sand. Throughout this transition, numerous burrows, tracks and mounds are found, indicating that much of the animal life responsible for them is buried.

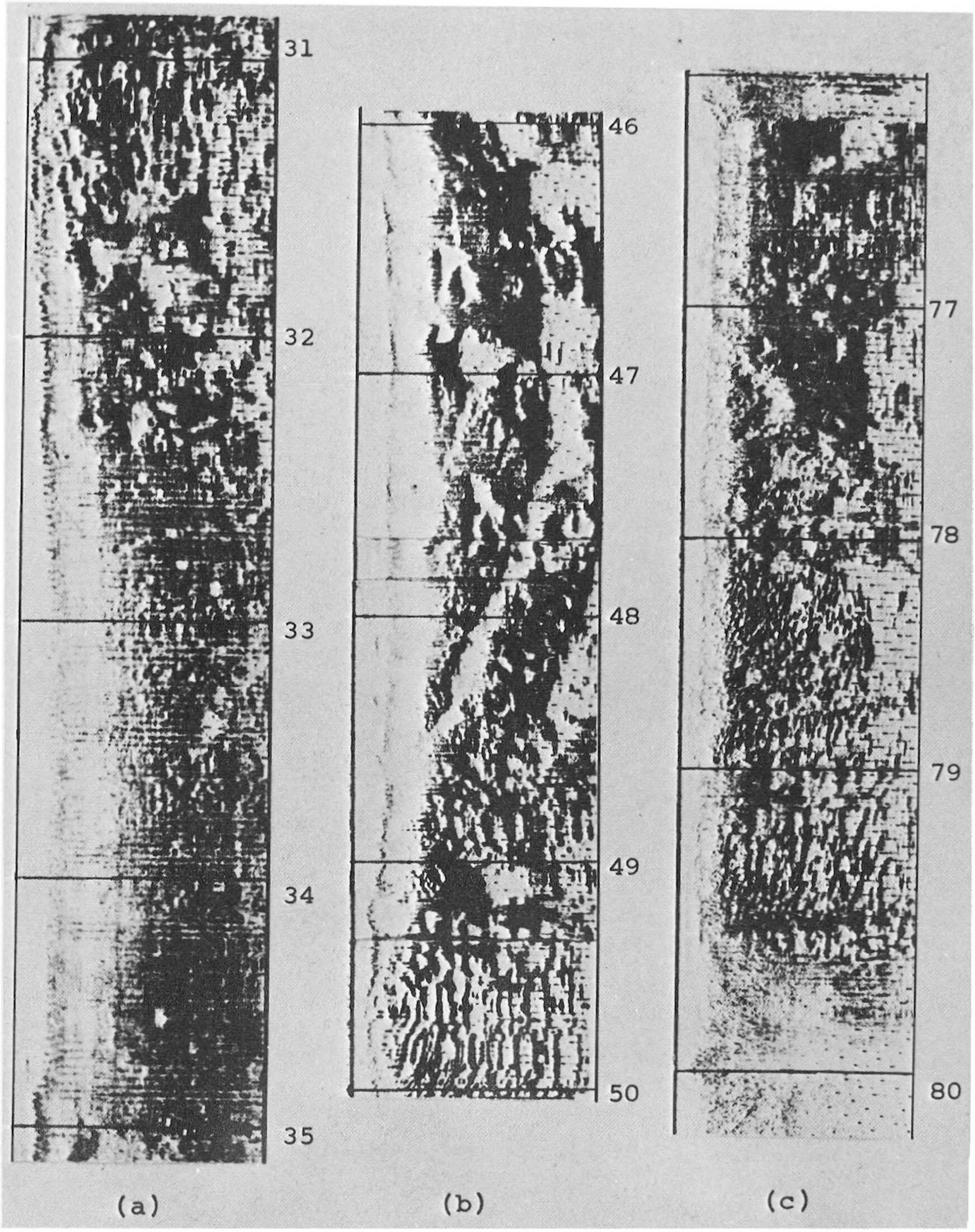
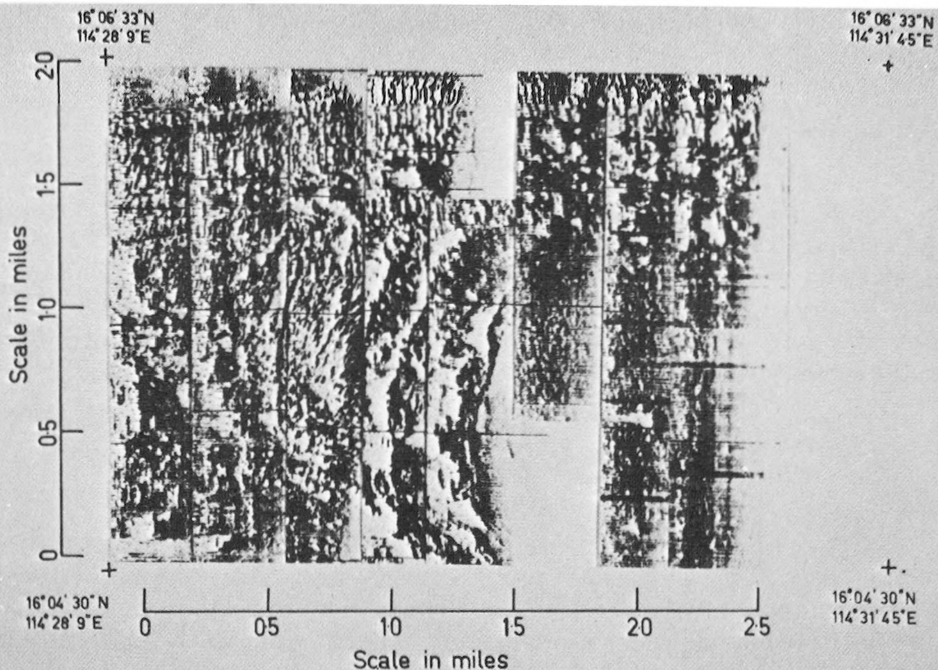


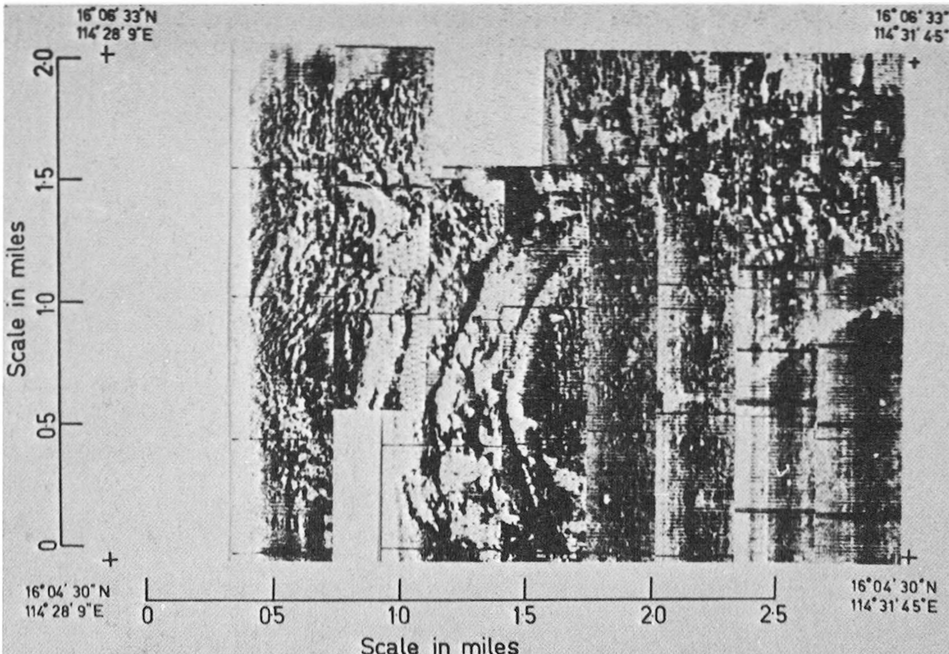
FIG. 5. — Three isometric acoustic records showing (a) coral-covered seafloor (b) coral ridges and (c) coral and sandy bottoms. Locations shown in fig. 2.

FIG. 6. — Two isometric mosaics of the whole study area, viewed from E and W to illustrate the bottom environment.



TRUE-TO-SCALE MOSAIC OF MACCLESFIELD BANK
LOOKING WEST

Area	OLIVER SHOAL, MACCLESFIELD B^K	Chart No.	270	Vessel	CAPE ST MARY	Date	21 & 22 APRIL, 1966 A933
Station No.	—	Latitude	—	Longitude	—	Time	—
Water Depth	— yds	Transducer Depth	9 yds	Range Scale	800 yds	Beam Axis Depression	3°
Ship's Speed	6 kts	Ship's Course	0°	Beam Axis Azimuth	270°		
High Tide	0905 4·5' 2320 4·7'	Low Tide	0407 3·1' 1626 2·8'	Wind	ESE 2 BEAU	Sea State	3



TRUE-TO-SCALE MOSAIC OF MACCLESFIELD BANK
LOOKING EAST

Area	OLIVER SHOAL MACCLESFIELD BANK	Chart No.	270	Vessel	CAPE ST MARY	Date	21 & 22 APRIL 1966 A934
Station No.	—	Latitude	—	Longitude	—	Time	—
Water Depth	— yds	Transducer Depth	9 yds	Range Scale	800 yds	Beam Axis Depression	3°
Ship's Speed	6 kts	Ship's Course	180°	Beam Axis Azimuth	90°		
High Tide	0905 4·5' 2346 4·7'	Low Tide	0407 3·1' 1628 2·8'	Wind	ESE 2 BEAU	Sea State	3

Other Results

The scuba dives and bottom samples show that in addition, polyzoa are important reef builders and that they occur very commonly as leaf-like growths and great massive encrustations built by successive formations of sheets of their thin calcareous shells. Lime-forming worms and various kinds of sponge are often found holding loose sand together and binding coralline rocks firmly to the subjacent reef.

CONCLUSIONS

This study of Oliver Shoal on Macclesfield Bank has demonstrated the value of the side-scan sonar and underwater camera system used together as reconnaissance tools for an environmental study of potential fishing grounds. Mosaics of side-scan sonar records provide a rapid and accurate means for the recognition and demarcation of bottom types, which is essential to determining whether a given area is hazardous to the use of a certain fishing gear and to the location and breeding of stock. Similarly the combined use of acoustic and photographic survey techniques is very effective for studying seafloor morphology, bottom sediments and ocean circulation, all of which control the distribution of nutrients that support the fish population.

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Fig. 7. — Sea bottom densely covered with coral colonies (Photograph no. 97). Area approximately 11′ × 7′, camera slanting 35° and 12 feet off bottom.

Fig. 8. — Sea floor densely covered with dead coral and coral debris (Photograph no. 173).

Fig. 9. — Fine coral sand, with coral debris and burrows (Photograph no. 228).

Fig. 10. — Encrusted coral boulders buried in coral sand (Photograph no. 318).

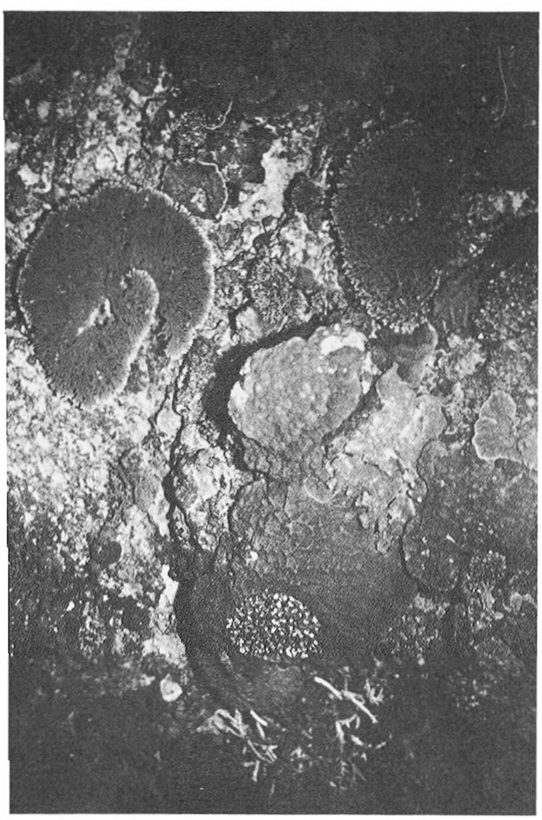
Fig. 7

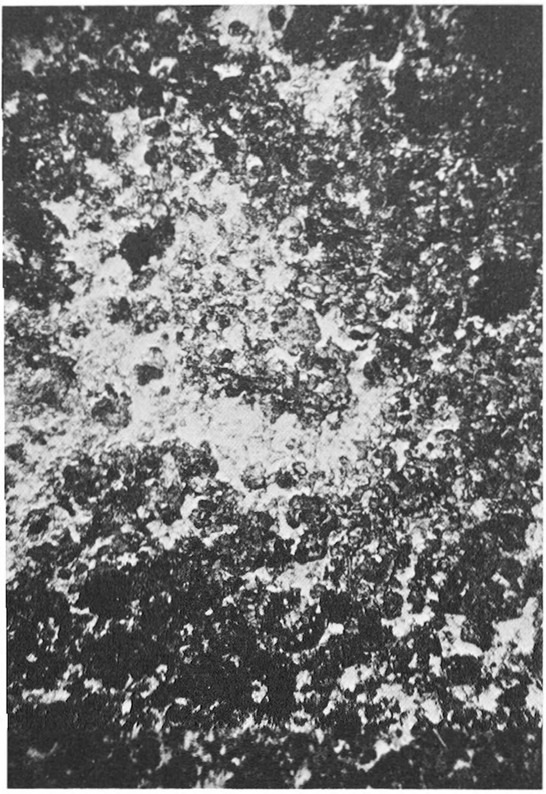
Fig. 8

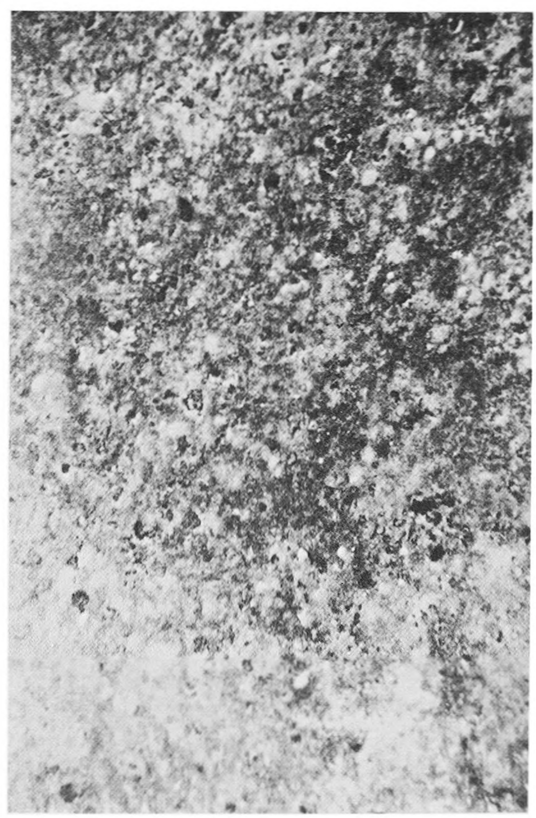
Fig. 9

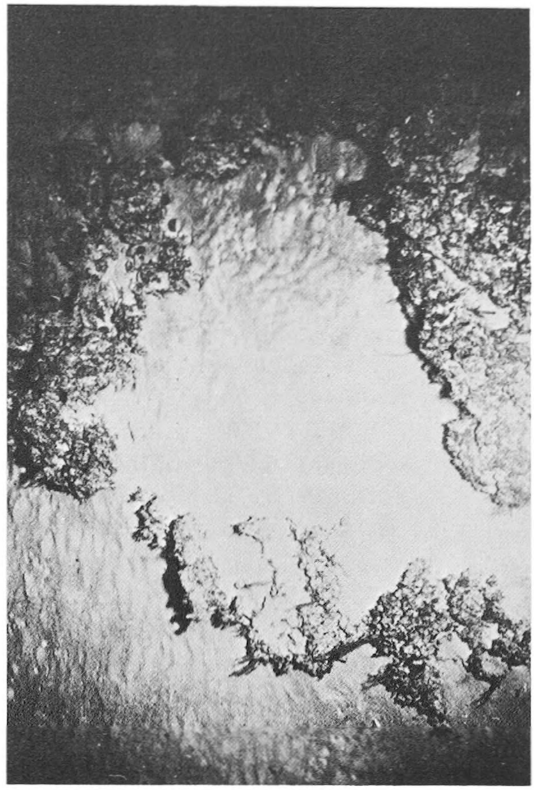
Fig. 10

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