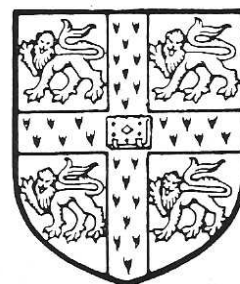


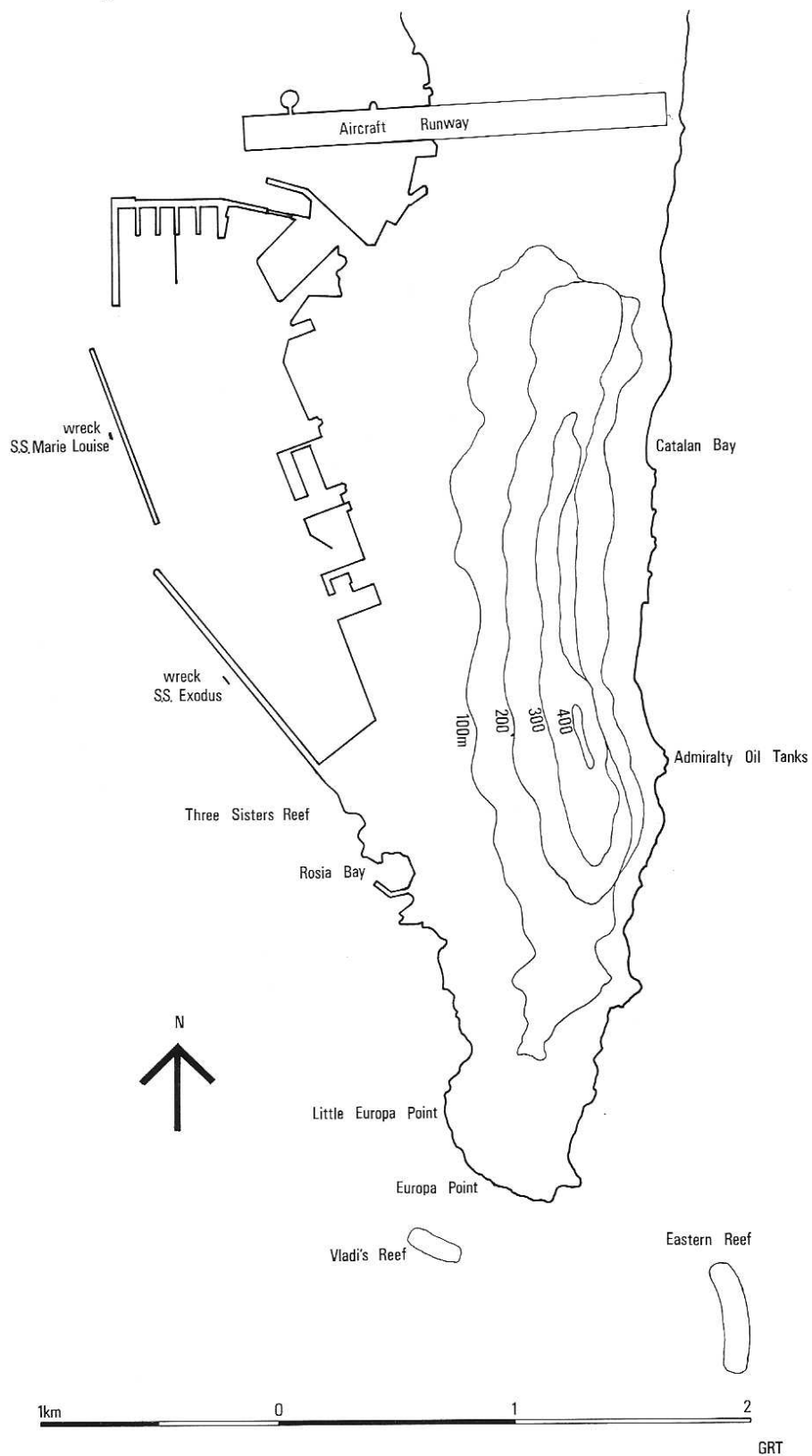
Cambridge
University
Underwater
Exploration
Group



Cambridge Expedition to Gibraltar 1969

Patrons: Admiral of the Fleet Sir Varyl Begg GCB, DSO, DSC, His Excellency
The Governor and Commander-in-Chief of Gibraltar.
Sir Edward Bullard, Professor of Geodesy and Geophysics, the
University of Cambridge.

Figure 1



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I MEMBERS OF THE EXPEDITION

P. J. Riley	(Henbury School, Bristol and Selwyn), Expedition Leader, Diving Officer, worked with P. Throckmorton in 1968. Now in his fourth year at Cambridge, reading Chemical Engineering.
N. Warren	(Enfield and Sidney Sussex). Engineer, photographer. Now with Thorn Electrical Industries.
G. R. Tubby	(Elizabeth College, Guernsey and Fitzwilliam). Engineer, draughtsman; worked with P. Throckmorton in 1968. Now with W.H.Allens.
C. W. Sparkes	(Royal Grammar School, Worcester and Churchill). Photographer. Now in his fourth year at Cambridge, reading Chemical Engineering.
D. Warwick	(Imperial College, London). Geologist. Now working with the Timor Oil Company.
R. C. Cole	(Enfield and Christs). Engineer. Now with the British Petroleum Company.
J. D. P. Kendall	(Dulwich and St. Johns). Diver. Now in his second year at Cambridge, reading Natural Science.
M. S. McCloy	(North London Collegiate and Newnham). Zoologist. Now in his third year at Cambridge, reading Zoology.
J. Miller	(Fitzwilliam). Zoologist. Now with Imperial Chemical Industries.
J. Coppock	(University College of Wales, Bangor). Zoologist. Now in his third year at Bangor, reading Marine Zoology.
A. Brooks	(University College of Wales, Bangor). Zoologist. Now in his third year at Bangor, reading Marine Zoology.
N. A. Mace	(Christs Hospital and Sidney Sussex). Diver; member of the Cambridge Expedition to Elaphonisos 1968. Now with the British Petroleum Company.

All members of the Expedition were experienced divers.

CAMBRIDGE EXPEDITION TO GIBRALTAR 1969

REPORT

II Aims of the Expedition

The Cambridge Expedition to Gibraltar was formed by members of the Cambridge University Underwater Exploration Group in the autumn of 1968 to carry out geological and zoological projects.

Geology Project

The Expedition had two geological objectives:

- (1) By taking rock samples from the sea floor around Gibraltar to build up a map of the surrounding sea floor geology and from this to suggest the most likely geological origin of the peninsular.
- (2) To estimate when the sea level changes of the Pleistocene Glaciations occurred by dating bone from breccia deposits in underwater caves. It was intended to use Carbon-14 Dating.

Zoology Project

There were three zoological objectives.

- (1) To make a collection of the marine fauna of Gibraltar for the Gibraltar Museum.
- (2) To collect specimens of *Alcyonium* for Dr. M. Robbins of Birckbeck College, London.
- (3) To carry out an ecological survey of Gorgonians (colonial coelenterates called Sea Fans).

III Introduction

After preparations which began early in 1969 the Expedition received sufficient financial support to proceed. The special requirements of a diving boat and Radio Carbon Dating were kindly met by offers of assistance from the Royal Navy and the Cambridge University Radio Carbon Dating Laboratory respectively. A licence to excavate the underwater caves was granted by the Gibraltar Museum.

There is an acute housing shortage in Gibraltar, and camping is not permitted. It was only the offer of free accommodation from His Excellency The Governor of Gibraltar which finally allowed the Expedition to proceed.

The equipment was taken to London Docks on 20th June and arrived in Gibraltar on July 4th. Expedition members were left to make and finance their own travelling arrangements as the Expedition was short of funds. It was hoped to make some contribution to these expenses, if possible, at a later date. Seven members flew directly to Gibraltar and the rest made their way overland. Of these, a few were fortunate enough to arrive at Algeiras before the direct ferry link with Gibraltar was cut, the others had to go via Tangiers.

An advance party arrived in Gibraltar on June 25th to make final arrangements for accommodation and for equipment which could not be shipped from England. The Expedition ceased working on August 1st.

The Expedition is very grateful to Dr. and Mrs. Toomey, Cpl. and Mrs. D. Whittyer and the Army for accommodating the early arrivals until the Expedition's living quarters were ready.

IV Accommodation

The living quarters were situated just above South Barracks, within convenient walking distance of the Town and Dockyard, and consisted of a rectangular concrete yard surrounded by huts on three sides. Though the site had been derelict for some time, it was quickly cleaned up and made hospitable. The Army installed an electric cooker, a water heater, a shower, a basin, a W.C. and provided the Expedition with beds, bedding, tables, chairs, cutlery, crockery and cooking utensils.

A number of the huts were used for drying and pickling an ever increasing collection of marine specimens.

V Medical

Dr. Hawtrey May had kindly ensured that we were well stocked with medical supplies. Happily these remained almost untouched. As usual small cuts and abrasions refused to heal when repeatedly immersed in sea water, and there were a few cases of mild intestinal infection.

The only real casualty occurred in the first few days, when one member was taken to hospital suffering from heat exhaustion and mild sun-stroke after having spent several days in the unfamiliar strong sun. His ailment was not serious however, and he returned, recovery complete, after a few hours.

VI Equipment

Thanks to Dr. N.C. Flemming, the R.A.F. Sub-Aqua Club in Gibraltar and G. Palao the Expedition had advance knowledge of the local conditions, in particular the existence of strong currents and the need for at least a 30 foot boat.

The Expedition was fortunate in being able to hire a 36 foot Harbour Launch Diesel (H.L.D.) from the Royal Navy, who kindly loaned other essential items such as ropes, buoys, anchors, batteries, electric cable and generally afforded the Group all the help it required. The boat was moored in the Dockyard at the quay adjacent to the Port Auxiliary Store Workshop, in which Expedition diving and scientific equipment was stored.

The Navy and Army Recreation Clubs loaned the Expedition a dinghy and an outboard motor respectively. Without these the zoology team would have been severely restricted and diving in currents, especially on Vladi's and Eastern Reefs, would have been hazardous.

Dr. Flemming lent the Expedition a Ferrograph 'Offshore' echo-sounder which proved invaluable for locating reefs and studying seabed profiles.

A 'Hymatic 180' diesel-driven compressor was hired from the Ministry of Public Buildings and Works, and was securely lashed to the H.L.D. The compressor provided a more than adequate air supply to operate an airlift and a pneumatic drill.

Air for breathing sets was provided by the Torpedo Section in the Dockyard. The R.A.F. Sub-Aqua Club lent the Expedition two 600 cu.ft. storage bottles, an anchor and a decanting manifold. In addition two 300 cu.ft. and two 150 cu.ft. storage bottles were loaned by Torpedo Section. Unfortunately the Expedition was short of storage capacity and so lost some time.

Several companies and institutions offered to loan the Expedition current meters for the Gorgonian Project (To see if the direction and strength of water movements affected the orientation and distribution of Gorgonians). However, the meters were bulky, sophisticated and required a measurement-head underwater and a recording device on the surface. The Expedition required a hand-held meter giving readings directly to the diver, because in the absence of an instrument which could be left in situ to monitor current strengths continuously, it was desirable to take readings at different habitats at the same state of the tide. A meter, simple to operate and to maintain, was designed and built; the force of water pushed a cup against a hair spring and moved a pointer over a graduated scale. However there was insufficient time to test the instrument before leaving England, and in Gibraltar it proved to be insufficiently damped and operated only over the lower range of current strengths.

An inclinometer was made from perspex with a lead-weighted pointer for rock orientation measurements. It proved simple and reliable. In addition a combined compass and inclinometer was bought and fastened to a perspex sheet. The edge of the perspex sheet was used as a straight edge for dip measurements and the compass gave strike measurements directly. All readings were written on the perspex sheet with a wax pencil. This system was found to be most convenient.

The Expedition was loaned a CP-9 Pneumatic Drill by the Consolidated Pneumatic Tool Company together with sealed beams spotlight units by Thorn Electrical Industries. A more detailed report on these items is given below as they were not designed for use underwater and their simple conversion and operation is worthy of further discussion.

The Consolidated Pneumatic CP-9 Drill

The cave investigation was expected to involve the removal of large quantities of breccia from underwater caves. The Consolidated Pneumatic Tool Company Ltd. was consulted and agreed to loan the Expedition a CP-9 hand drill which was considered suitable for the proposed work.

Modifications and Maintenance

Some corrosion of ferrous parts exposed to sea water was inevitable. The following modifications and maintenance procedures were intended to minimise this problem:

- a) The inlet 'Trigger' was fixed in the 'On' position, the airflow through the drill was controlled by a tap installed in the outlet port. This ensured that, during use, the drill always contained air under pressure, thereby preventing the entry of sea water.
- b) After use the drill was washed thoroughly in fresh water, filled with oil, and run for a few seconds to distribute oil to all working parts. The Ministry of Public Buildings and Works at Gibraltar has considerable experience of operating pneumatic tools under water, and suggested, as an additional precaution, storing the drill in diesel fuel.

Operation

The drill was never used for the main purpose envisaged, i.e. obtaining large pieces of breccia from the floors of underwater caves, as the type of breccia in which the expedition was interested was not found in any of the caves investigated. However the drill was tested in open sea conditions in order to gain experience of its operation prior to the excavation of the submerged caves and was also used to obtain small samples from the caves, when searching for the breccia.

The rotating drill bits provided a speedy means of drilling holes in soft breccia, rather slower in harder rocks such as shalestone. The non-rotating chisels proved effective in splitting all types of rock along existing cracks and speedily cut through breccia.

Several difficulties were encountered in using the drill underwater. The most important was simply that of exerting sufficient force on the drill handle, since a free diver is normally neutrally buoyant. Weighted boots and a chest mounted weight would be necessary for work on a horizontal surface. Working on a vertical surface a diver would require to be anchored to the wall by means of ropes. However it was found that, while taking samples in the confined conditions of the caves, a diver could exert sufficient force by bracing himself against the roof or walls of the cave.

Operation of the drill caused considerable, sometimes complete, reduction of visibility. This was due to air bubbles from the drill and the disturbance of sand and mud in the vicinity. A flexible tube, a few feet in length, fitted to the air outlet would remove the main exhaust bubbles, though air also escaped from other parts of the drill. (It is appreciated by the authors that Consolidated Pneumatic tools designed specifically for use underwater have such a fitting). Clouds of sand and mud particles could possibly be cleared using an airlift. Visibility was a serious problem in the caves where the still water enabled particles to remain suspended for several hours. Drilling under these conditions would have been very slow, though not impracticable.

The tap fitted to the outlet to control the airflow through the drill proved awkward to operate. Vibration tended to loosen the adjustment nut on the tap unless it was tightened to an extent which made the tap very stiff to operate. Some form of trigger allowing one handed operation of the drill would effect a considerable improvement.

Discussion

The modifications and precautions necessary to enable the drill to be used underwater are simple and inexpensive. The problems of operating the drill underwater, though considerable, may be overcome fairly simply by the methods outlined above.

A larger drill would cut through rock more quickly but the rate of working in caves is limited by the low visibility that is encountered, and larger drills are more unpleasant to use especially in the confined space of a cave.

Thorn Electrical Industries Sealed Beam Spotlamps

It was expected that some form of underwater lighting would be necessary for the cave explorations. Thorn Electrical Industries were approached and agreed to loan the Expedition twenty 12 volt 55 watt Sealed Beam Spotlamp Units.

Mounting

The lamps were mounted in marine ply boards, pressed into position by the handle, which was a single brass strip bent to shape and fixed to the board with brass bolts. Galvanised iron mesh was spot welded to form a front guard, and the rear of the lamp was protected by the handle. The assembly was buoyant in fresh water, and the mounting enabled the lamps to be used individually, handheld. Robust multi-directional clamps attached to steel spikes also allowed the lights to be wedged on rocky surfaces, in groups or individually.

Operation

Initial testing at Cambridge in fresh water for two hours using 25 metres of cable, a 12 volt supply and insulating tape on the lamp terminals was successful. However, in sea water the Nilo alloy (42% Ni, 52% Fe) used to seal the conductor terminals into the glass envelope of the lamp was rapidly corroded, and dissolved sufficiently to allow water to enter the lamp within ten minutes. This corrosion was caused by electrolysis and partly by galvanic action with the brass terminals. Insulating tape failed to prevent this, but a coat of Araldite was successful.

The lamps produced narrow beams, 0.3 metres across at 3 metres, and were useful for surveying caves in clear water. However as the beam could not penetrate clouds of sand and mud particles suspended in the water, the lamps could not be used while working in the caves.

The lamps proved to be suitable as portable units, but at large horizontal distances from the boat the cable drag made swimming difficult.

Altogether the lamps were tested for nine hours at 16 metres with the terminals covered with Araldite. 55 metres of cable was used with an 18 volt supply to compensate for the voltage drop down the cable. The lamps worked reliably and corrosion was negligible.

Discussion

The modification necessary to allow the units to be used underwater are very simple. The units have apparently been tested in a pressure vessel down to 300 metres so operation in deep water will be no problem.

The lamps are compact and provide an efficient portable source of illumination, except when there is suspended silt in the water. For general illumination, for example around an underwater house, a broader beam would be desirable. A diffuser could be fitted to the unit or Sealed Beam Foglamp Units used.

VII PHOTOGRAPHY

Land: Zorki 4 50 mm f2 Jupiter lens.

Underwater: Nikonos with 35 mm lens.
Lightmeter with pressurised jam jar case.
Super Paxette with wide angle lens, encased in a football bladder.
Flash attachment for Super Paxette with perspex case.

Iford FP3 black and white film was taken in 100ft. tins and loaded into cassettes in Gibraltar using a Watson Cassette Loader. 20 exposure cassettes of Agfa CT18 were taken out from Britain. 36 exposure cassettes of Ektachrome were purchased in Gibraltar.

Facilities for developing films were not taken out from Britain. The Ektachrome colour films were processed in Gibraltar. The first few cassettes of black and white film were also developed in Gibraltar. This provided an invaluable check on exposure for underwater photography.

The visibility was usually in the range 7-10 metres, but depended on the state of the tide and on the weather. Iford FP3, rated at 250 ASA and developed in Acutol with a 50% increase in development time, was used for all black and white photography underwater, using natural light only. Both Ektachrome and Agfa colour films were used underwater. The Ektachrome, 80 ASA, was exposed under both natural light conditions and with flash. Both methods yielded good results. Agfa CT18 rated at 50 ASA exposed under natural light conditions, but not at depths below 7 metres, did not yield results comparable with those obtained using Ektachrome. Kodak Wratten CCR 40 and 50 filters gave good colour balance for light paths up to about 3-5 metres. Colour balance deteriorated rapidly with longer light paths.

VIII. GEOLOGY REPORT

(A) Outline of the Geology of Gibraltar

Gibraltar, although relatively complex structurally when examined on a small scale, can be considered in terms of two Pre-Quaternary rock units. The topography is dominated by limestones which are well-bedded in places and generally dip westwards, although in southern Gibraltar they are truncated by an ESE/WNW fault. The limestones form the bold relief of the summit ridge and cliffs overlooking the town. To the east and west, the limestones apparently overlie a shale group; in the west this lies beneath the town and Dockyard, and in the east outcrops from Sandy Bay to Catalan Bay. There is also a small outcrop of the Shale Group at the base of the North face of Gibraltar.

Structurally the Limestone Group always overlies the Shale Group. However, in a paper by Bailey (Q.J.G.S. 1952), it is clearly demonstrated on palaeontological evidence that the limestone is older than the shale. Both are Jurassic, but the Limestone Group is apparently Lower Lias and the Shale Group Middle or Lower Jurassic.

In addition to the limestones and the shales there are younger rocks derived from the limestones. At many points on the coast there are limestone breccias which overlie the limestone and Shale Groups. The breccias are by no means uniform or isochronous and their relationships are complex.

In a broader context, Gibraltar is structurally associated with the Alpine orogenic movement, as it lies between the Betic Cordillera of Spain and the Rif of Morocco, both of which are structurally Alpine.

Interpretation of the structure of Gibraltar has until now been strictly a matter of opinion, as the surface geology of Gibraltar can be interpreted in many ways. It was hoped that offshore sampling might elucidate the problem.

(B) The Mapping Project

This project was limited by the poor sea conditions, making diving on the south and east impossible for much of the expedition. It was hoped that by making diving traverses offshore at various points around Gibraltar a geological map could be produced.

Two offshore traverses were made on the western side, one from north of Rosia Bay and the other from the south of Little Bay. Both dives were terminated at a depth of about 36 metres.

From north of Rosia Bay, the initial steep slope, on which caves are located, gives way to a very shallow slope which is entirely covered with coarse rippled sands and some loose boulders. No rock outcrops were observed. This dive was later followed by an echo-sounding run, also revealing the smooth and shallow nature of the slope.

The traverse from south of Little Bay was started just offshore, diving directly to 23 metres and then going due west down a gentle slope to 36 metres. As before the sea floor consisted of coarse loose sediment, which was mainly sand and silt. No rock outcrops were seen.

From these traverses and from examining the Admiralty charts it seems unlikely that there will be any rock outcrops within diveable depths on the west side. On the east side echo-sounder runs, taken due east from the Ammunition Pier and from Europa Advance Battery, indicated benches, where rock outcrops could occur. Unfortunately there was insufficient time to investigate these features.

More favourable conditions towards the end of the Expedition permitted diving off Europa Point on the two 'reefs' marked in Figure 1.

Vladi's Reef (nomenclature from Flemming), which lies about 400 metres south west of the Radio Station at Little Europa Point, was located on the echo-sounder. One dive was made from the shore on a bearing to the reef, but currents took the divers off course, and the reef was not reached. This traverse commenced on the 'Older Breccia', but quickly passed onto a sand rippled surface with no rock outcrops. Later dives on Vladi's Reef revealed the first good offshore rock outcrops seen. The reef runs WNW/ESE and is composed of limestone and breccia, the former being well bedded and dipping at 24 degrees towards N.038 degrees E. In other words, the strike of the bedding planes roughly accords with the trend of the reef edge. Samples of the bedrock brought to the surface varied from a rather typical Gibraltar limestone to a white recrystallised limestone. Unfortunately there was insufficient time to elucidate the distribution of the different rock types seen.

The reef has a plateau at about 21 metres near the cliff edge, but the plateau slopes off gently to greater depths offshore. The cliff face is about 6 metres high and has many caves (which are described later). At its extremities, to the NW and SE, the cliff loses height and the plateau and floor merge, although slight ridges of rock continue outwards for some distance.

To the south east of Great Europa Point there is another reef, about 1000 metres offshore. This is Eastern Reef and it covers a large area of which only a small part was seen during dives. The first dive on Eastern Reef was severely hampered by currents. The plateau top of the reef was reached at 23 metres and was swept clear of organisms and rock debris by the consistently strong currents. Steeply dipping beds can be seen outcropping, forming a series of parallel ridges. Over the area searched, the dips and strikes of bedding planes appeared to be concordant. In this area the cliff face on the edge of the plateau faces west and descends vertically to over 55 metres. The cliff does not appear to be controlled by the dip or strike of the beds, which dip at 45 degrees to the SE. A later dive over the cliff edge of Eastern Reef to a depth of 50 metres, revealed very well preserved bedding planes, again dipping to the SE.

Samples brought to the surface from Eastern Reef indicate that it, like Vladi's Reef, is part of the limestone block composing most of Gibraltar. The other interesting feature of this reef is the total lack of marine erosion on the cliff face, indicating perhaps that Eastern Reef has never been exposed.

Conclusions from the Mapping Project

Underwater geological mapping is an attractive idea in theory, but can be extremely difficult to carry out in practice.

The underwater geology of Gibraltar seems to have one basic drawback, that of poor rock exposure in important localities.

The only exposures investigated offshore proved to be continuations of the main limestone of Gibraltar. The few dip measurements and samples taken unfortunately do not allow a definitive interpretation of structure; they are nevertheless the first samples from these outcrops.

A further investigation of Eastern Reef and of the area to the north of the Reef and to the south of a line due east from the Admiralty Oil Tanks would be interesting, and might reveal a continuation of the main fault of Gibraltar.

(C) The Caves

Gibraltar has many caves both above and below sea level. The origin of these caves can be attributed to two processes, either that of marine erosion or that of sub-surface solution by ground waters.

Owing to changes in sea level during the Pleistocene glaciations, caves which were formed at sea level now lie either above or below present sea level.

It is likely that caves which were once above sea level were inhabited by animals or men, who may have left behind bones which could have become consolidated in bone breccias, such as those found in some of the present surface caves. If the caves were then flooded by a rise in sea level, the bones would provide an indication of the age of the sea level change. Whether a cave was inhabited or not would depend entirely on the shape and size of the cave and therefore the process by which the cave was formed is irrelevant.

Hence, the purpose of the cave project was to locate any underwater caves at any depth and to take samples from the cave floors to see if they contained bone.

At the onset, exploration was confined to the West side of Gibraltar because of the poor weather conditions.

Several exploratory dives were made to locate various caves on the West side G. Palao, a local diver, who had previously mapped the positions of many of the underwater caves acted as guide and was of great assistance to the Expedition. It was found that all sizeable caves were filled with sediment to a considerable depth and that some of the reported smaller ones appeared to have disappeared entirely.

North Rosia Bay Cave (see Figure 2)

The first cave to be chosen for investigation was the largest of a series on the point just north of Rosia Bay. In all, four caves were located at 9-11 metres and all were undoubtedly formed by marine erosion. The large cave is developed along a vertical cleft which is probably a joint rather than a fault. The cave has two branches which taper away at the back. It lies at the base of the cliff, which gives way to a shallow slope that gradually increases in depth offshore.

In order to study the cave floor, it was first necessary to remove a two metre thickness of sediment using an airlift. The sediment varied in grade and grain type from top to bottom. At the top was a black mud of silt and very fine sand with shell debris, giving way to brown sand and silt with abundant barnacle and oyster remains. At the base the sediment was noticeably coarser and, in places, was semi-consolidated to well-cemented, consisting of a mass of barnacles and oysters as above, with a silty matrix and calcareous cement.

Examination of the freshly exposed cave floor revealed that it is composed of a limestone breccia which is identical to the walls and roof of the cave and indeed, to the whole cliff at North Rosia. Thus no bone breccia was found in this cave.

While the airlift was at this site another smaller cave nearby at a depth of 6 metres was tackled, but large boulders on the floor of the cave defeated the attempt to clear it.

The other caves in the series at 9-11 metres appeared too small to be promising and so investigations were switched to the caves at the 'Three Sisters'.

Three Sisters Cave (Figure 3)

To the north of Rosia Bay, off the southern extremity of the South Mole are several pinnacles of rock commonly known as the 'Three Sisters'. It was known from the work of Flemming that there were caves located at the bases of the 'Sisters', particularly on the most northerly 'Sister', which is a very extensive outcrop underwater although it is an insignificant pinnacle above water.

Of the several caves located, the most promising appeared to be on the south side of the rock at a depth of 15 metres. As in the previous case, there was a considerable thickness of sediment to remove before the floor was exposed.

Examination of the floor of the freshly airlifted cave revealed a limestone breccia much bored by marine organisms, overlying an unbored breccia. The breccia was identical to that comprising the roof and walls of the cave, which in the case of the 'Sisters', is the so-called 'South Barracks' Breccia.

The sediment overlying the breccia had a basal boulder horizon, which was incipiently cemented. There were boulders not only of 'South Barracks Breccia' but also of a black siltstone and brown sandstone, which would appear to have been derived from the Shale Series. Above the boulder horizon was a very dark coloured mixture of silt and clay with barnacle remains.

The cave was surveyed after being cleared and was found to be similar in some respects to the North Rosia Cave in that it tapered towards the back and in all respects indicated a product of marine erosion.

The southernmost 'Sisters' although the most prominent above water do not have any large caves, but rather a system of gullies and undercuts at their bases.

Little Europa Point Cave

At Little Europa Point there is a submerged cliff composed of so-called 'Older Breccia'. The cliff, running roughly parallel to the shore, drops from a plateau at 5 metres below sea level to a sandy bottom at 15 metres. To the north and south the sandy bottom gently rises and the plateau and sea bed merge, although isolated breccia outcrops occur for some distance. The base of the cliff is undercut and in places erosion has opened up vertical joints into more extensive caves. The cave chosen was in the middle of the cliff face in 15 metres of water.

Again it was necessary to remove a considerable layer of sediment. However there were considerable practical difficulties in working on this cave. The current was strong and prevented diving for 1½ hours each side of high tide. On one occasion the air hoses were torn off the airlift by the current. In addition operations were hampered by large quantities of rubbish such as tyres and an old car chassis, which had collected in the cave. Thus it proved impossible to clear the cave in the time available.

The top layer of sediment was fairly coarse sand and the underlying layer although containing shell debris was sandier than the sediment in the other caves. This is probably explained by the sand drifts, shown on the Ministry of Public Buildings and Works drawing C.E.1643 'Geological Sketch Map of Gibraltar Bay', that approach the shore at this point.

The cliff was surveyed and the undercuts and caves appear to have been formed by marine erosion. The cave excavated has been opened up along two joints and tapers to the rear in both branches.

Caves at Vladi's Reef

These caves were only studied on reconnaissance dives. The northward facing cliff on the edge of Vladi's Reef has caves chiefly located at its base. There are some caves which appear to be little more than wide undercuts at the cliff base.

Others are controlled by rock structure and are developed along prominent joints to form deep, narrow clefts which extend right back into the cliff. One or two caves have blow hole connections to the reef plateau.

It is again apparent that these caves were formed through the agency of marine erosion, at a time when the reef was above sea level.

Caves on the East Side

As already indicated, conditions were too rough on the eastern side of Gibraltar during most of the expedition. However good weather towards the end of the expedition permitted a few trips around the East Side.

Reconnaissance snorkel dives were made under the hotel on the southern end of Catalan Bay. Very small caves were located at 3 metres, but visibility was very low because of suspended sand due to the earlier bad weather.

A more detailed search was carried out under the Admiralty Oil Tanks, where there are numerous small caves in no more than 4½ metres. Again suspended sand and a heavy swell made exploration difficult.

The submarine caves, developed exclusively in limestone breccia, seemed to be mostly horizontal slit type caves, with very low entrances and floors of large boulders and sand.

Caves on Eastern Reef

In view of the lack of marine erosion on the cliff face of Eastern Reef, it would have been interesting to see if there are any caves at the base of the cliff or whether the cliff is undercut. However the base is between 55-61 metres below sea level and we did not have enough time to undertake such a dive.

Diving

A total of 97½ man hours of diving were recorded on the Geology Projects.

Conclusions from the Cave Project

No bone breccia was found in the two caves which were completely excavated. This was disappointing, but this does appear to be the first occasion on which an airlift has been used to clear underwater caves in this manner.

We think that the caves on the Eastern side are a better prospect, since the surface caves in which bone breccias are found are on this side and there seems to be a greater concentration of larger caves on this side. The latter is to be expected from a comparison of the reach on the East and West sides: about 1000 miles for the former and 5 miles for the latter. In addition the proportionate decrease of reach with fall of sea-level would be much greater for the West side. As waves take up to 200-300 miles to reach full height and energy (controlled by the wind speed) the seas on the East side would be far more erosive. These same considerations of course make working from a boat on the East side a more difficult proposition.

However the idea of collecting bone from caves in order to date sea level changes is a good one and worth pursuing. It is also possible that bones and flints in the breccia could have intrinsic archaeological value.

FIGURE 2

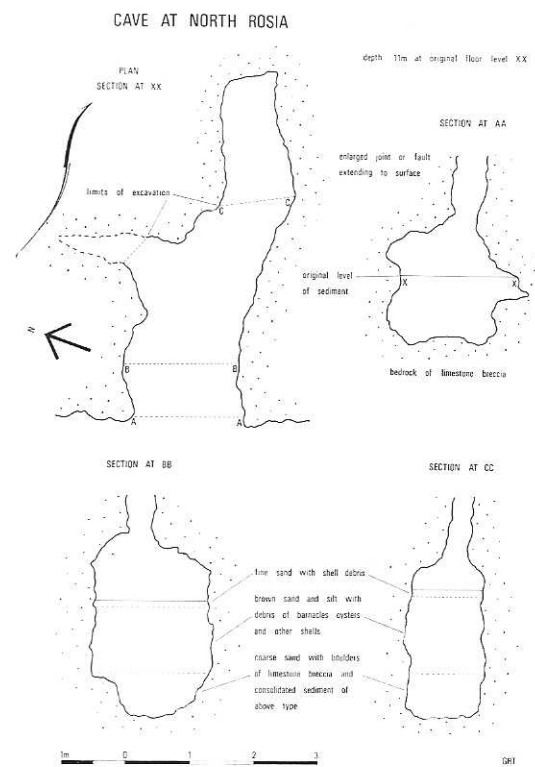
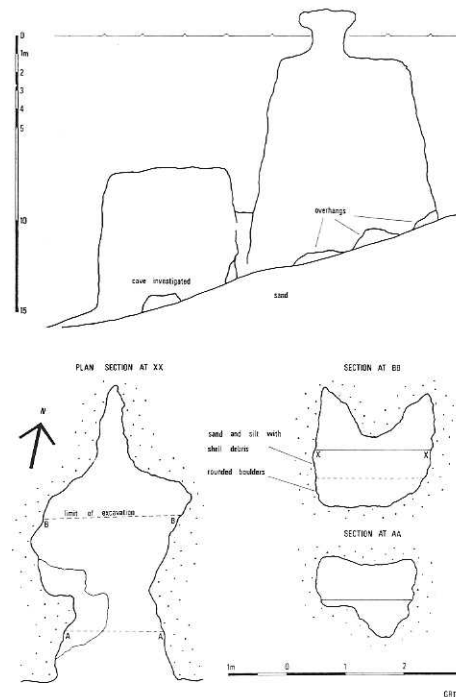


FIGURE 3

CAVE AT THREE SISTERS REEF



IX ZOOLOGY REPORT

(A) Organisation

Our team of four usually dived from the dinghies, except in rough weather when we joined the geologists on the H.L.D. We dived mostly on the two 40 year old wrecks off the harbour moles, because their fauna was especially rich and varied, and they offered a variety of different conditions of depth and current within a small area.

We dived for ten days on the wreck of the 'Exodus', sunk in 22 metres of water off the South Mole, and for four days we dived on the wreck of the 'Marie-Louise' in 28 metres of water off the Detached Mole.

Exploratory dives were made at Rosia Bay, the Three Sisters, Camp Bay, and Little Europa. Bad weather prevented similar dives on the Eastern side of the Rock, so a comparison of the fauna of the two sides was unfortunately not possible. A total of 36 man-hours diving was spent on the zoology project.

(B) The Collection of Specimens for the Museum

Specimens were marked with coloured bands as they were found, and recorded with pencil on Formica boards. They were collected in polythene bags and nylon shopping bags and were then taken to the Lourdes School, where we were very fortunate to be able to use the laboratory. The specimens were there identified and preserved either in 4% neutral formalin or 70% alcohol, sometimes after relaxation in 7½% magnesium chloride. Larger specimens, especially Gorgonians, could only be preserved by drying.

Species Collected

PHYLUM CNIDARIA Class Actinozoa

Sub-class Zoantharia

Order Zoanthidea *Gerada* sp.

Order Madreporaria *Dendrophyllia ramea*

Sub-class Alcyonaria

Order Alcyonacea *Alcyonium acaule*
Parerythropodium coralloides

Order Gorgonacea *Eunicella stricta*
Eunicella cavolinii
Paramuricea chamaeleon
Leptogorgia sarmentosa

Order Pennatulacea *Veritillum cynomorium*

PHYLUM ECHIUROIDA *Bonellia viridis*

PHYLUM ARTHROPODA Sub-phylum Crustacea Class Malacostraca

Order Decapoda *Homarus vulgaris*
Pisa gibbsi
Maia squinado
Pinnotheres pisum

PHYLUM MOLLUSCA

Class Gastropoda

Sub-class Prosobranchia *Astraea rugosa*
Tritonalia nodifer

Sub-class Opisthobranchia *Oscanius testudinarius*
Glossodoris gracilis

Class Lamellibranchia *Pinna squamosa*

Class Cephalopoda *Octopus vulgaris*

PHYLUM ECTOPROCTA *Myrionozoum truncatum*
Frondipora verrucosa

PHYLUM ECHINODERMATA

Class Asteroidea	<i>Echinaster sepositus</i> <i>Marthasterias glacialis</i>
Class Ophiuroidea	<i>Ophiothrix fragilis</i> <i>Ophioderma longicauda</i> <i>Gorgonocephalus costosus</i>
Class Echinoidea	<i>Centrostephanus longispinus</i> <i>Paracentrotus lividus</i>

(C) Collection of Alcyonium

All the specimens of *Alcyonium* collected for Dr. Robins proved to be *A. acaule*, the Mediterranean species. As expected, no specimens of *A. digitatum*, the northern species, were found.

(D) Ecological Survey of Gorgonians

Gorgonians are Coelenterates which form upright branching colonies attached to a firm substratum. Unlike true Madreporarian corals, they have a flexible horny skeleton rather than a calcareous one. Being Alcyonarians they have eight pinnate tentacles to each polyp. This distinguished them from a Zoantherian, *Gerardia*, although the latter had a similar gross morphology. (Two colonies of *Gerardia* were found, one in 15 and one in 23 metres of water. Both were about 40 cms. high.)

Very little work has been done on Gorgonians and the literature is confused, which made identification of the four species we found in Gibraltar difficult. According to G. von Koch (1889 Fauna und Flora des Golfes von Neapel, Monog. XV) the species were *Gorgonia verrucosa*, *Gorgonia cavolinii*, *Muricea chamaeleon*, and *Leptogorgia sarmentosa*. By more modern nomenclature the species are identified as:

a) *Eunicella stricta*

The colonies are very variable in size and shape, but have straight branches bifurcating close together. The polyps are fully retractile into shallow cups. The colour is off-white.

b) *Eunicella cavolinii*

The colonies are uniplanar and fan shaped, often up to 40 cms. high. As with *E. stricta* the branches are 2-3 mm. in diameter, but are more bent and the cups into which the polyps retract are very pronounced. The colonies are usually white, but sometimes pink

c) *Paramuricea chamaeleon*

The size and shape of these colonies are similar to those of *E. cavolinii* but the branches are thicker and more contorted. The polyps are large and not fully retractile. The colour is purple or less commonly orange.

d) *Leptogorgia sarmentosa*

This is the most delicately formed species, with thin branches 1 mm. in diameter, extensively ramified in one plane. The small polyps retract into barely protruding cups. The colour varies from mustard to orange. The identification of this species was confirmed by a positive result of von Koch's test: it was the only species whose skeleton effervesced in hydrochloric acid, indicating the presence of calcareous matter in the horny matrix.

Distribution of Gorgonians

The four species differed in their distributions and we hoped to correlate these differences with physical factors in the environment which might affect the growth of the Gorgonians.

Our first approach was to consider the geographical distribution around the coast. This did not provide much information since *E. stricta* was common everywhere except off Little Europa, and the other species were much less common and appeared to be randomly scattered.

Considering the vertical distribution, no Gorgonians grew in water shallower than six metres, possibly because of the swell from surface waves. This upper limit was particularly clear for *E. stricta*, whereas the other species were rare above 15 metres. No lower limit was found to the distribution of Gorgonians, specimens being found at 50 metres, which was the limit of our diving.

We next examined in more detail the distribution on the two wrecks, where the species grew in abundance on the firm substratum of the hulls. Their distribution was not mutually exclusive, as illustrated by an area near the stern of the 'Exodus' where colonies of all four species grew within three metres of each other.

We investigated the current strength in the different habitats, but comparison of the readings proved difficult because the currents altered markedly with the state of the tide, and above 12 metres the swell made measurement difficult. Ideally a current meter left in situ to record over a whole day would have been used.

E. stricta may have a preferred range of currents, since it was rarely found in very sheltered places (such as in the holds of the 'Exodus'), nor was it found on the exposed side of the hull where maximum meter readings were obtained and the Admiralty charts give the current as 1-1½ knots. Similarly it was found in gullies on Eastern Reef, and not on exposed points where the current is estimated to be 2½-3½ knots.

Current strength could not be seen to affect *E. cavolinii*, which was most abundant in the holds of the 'Exodus' but was also found in exposed places. Similarly *P. chamaeleon* was most abundant in cavities of the 'Marie-Louise' which were very sheltered and along the bottom of the outer side of the 'Exodus' where the current was strong. As well as depth, low light intensity might be a factor common to both situations but we were unable to measure this. *L. sarmentosa* was not common anywhere, only one or two specimens being found on any dive. These often grew in gullies or crevices, and so this species might prefer a channeled water current.

Variations in Population Density of *E. stricta*

This was investigated by placing a metre quadrat on the hull of the 'Exodus' on the side facing the mole, and collecting all the colonies growing within the area. Five quadrats were taken at each station, their positions being chosen by swimming an arbitrarily chosen number of strokes between each one. *E. stricta* was the only Gorgonian species in these samples.

Station	Depth	Inclination	No. of colonies in each quadrat					Mean for station
1	11 m	Horizontal	43	64	78	66	53	61
2	11 m	Vertical	62	125	29	18	38	54
3	13 m	Vertical	30	32	27	31	43	32
4	15 m	Vertical	47	43	48	35	44	43

Although the means indicate a difference between the density on a horizontal and a vertical substratum, analysis of variance shows that there is so much variation between the five quadrats at each station that the difference in density between any of the stations is not statistically significant. However in five quadrats taken at Station 5 (at 18 m where the hull formed an overhang) there was a total of only six colonies. This sparse population is probably due to the difficulty of larval settlement of an overhang. Overhanging areas around the propeller were similarly free of Gorgonians.

Measurements showed that the current was the same for stations 1 and 2, and decreased with increasing depth at stations 3, 4 and 5.

Thus neither depth nor current strength seems to have any effect on population density. Inclination of the substratum appears to be the most important factor.

Effects of Water Movement on Growth of Gorgonians

This line of investigation was suggested by a paper by Jacques Theodor (1963, Vie et Milieu 14 815) who reports observing three shapes of colonies of *E. stricta* which were determined by water movement. A flagelliform shape he thought occurred in turbulent water, and a fan shape in water where the movement was limited to oscillation in one direction. He records a concave shape in waters with a dominant current flowing in one direction.

The colonies of *E. stricta* found in Gibraltar were also of various shapes, and our preliminary observations seemed to confirm those of Theodor. Flagelliform colonies, with only a few very long branches, were found on exposed rock slopes where water movement would be turbulent. Fan shaped colonies were found on the sides of the wrecks where the current flow is parallel to the wreck and changes direction with the tide. We did not find any concave colonies, but these might occur in deeper water. We did however find a fourth shape: bushy colonies with many closely packed vertical branches which were not in one plane. These were most common on the deck of the 'Exodus', where they would be subject to swell

More systematic observations did not confirm the correlation of shape with type of water movement, because all three forms could often be found together under identical conditions, e.g. within the same quadrat.

We did however, find a clear relationship between direction of water movement and orientation of fan shaped Gorgonians. These grew with the plane of the fan orientated perpendicularly to the current direction with less than ten degrees variation. (Where water flow was less constant, the variation was up to thirty degrees.)

E.stricta also showed an orientation towards vertical. This was particularly evident on the 'Exodus' where colonies growing out from the side bent their branches up towards the surface. The other species did not show this to the same extent, but tended to be perpendicular to the surface on which they were growing.

Variation in Size of *E.stricta* Colonies

A pilot investigation had indicated that the height of *E.stricta* colonies increased with depth. We therefore decided to investigate whether there was any systematic variation in the size of colonies from the quadrat samples taken on the 'Exodus'. We first considered how to measure size, since there was no accurate method of weighing available. There were two variables, the number and the length of the branches. So we counted the number of branches and measured the maximum height of 213 colonies collected from three quadrats at Station 2. The product of these two numbers gave an estimate of the relative biomass of the colonies (in arbitrary units). Since this increased with height, as shown in the graph in Figure 4, we decided to use height as a measurement of the size of the colonies. We therefore measured the heights of all the colonies of *E. stricta* in the quadrat samples:

Station	Depth	Inclination	Mean Height in each Quadrat (cms.)	Mean Height for Station (cms.)
1	11 m	Horizontal	30.3,29.6,32.6,32.2,25.8	30.1
2	11 m	Vertical	20.8,18.9,25.2,22.6,22.6	22.0
3	13 m	Vertical	26.3,22.0,24.5,24.7,26.7	24.9
4	15 m	Vertical	26.7,21.5,23.5,26.6,19.8	23.6

The distribution of heights of colonies for each station is shown in Figure 4.

Although the distributions of heights at Stations 2,3 and 4 were significantly different, the mean heights from the quadrats showed no significant variation with depth. However there was a statistically significant difference in both the mean heights and the distribution of heights between colonies from Stations 1 and 2. This was significant at the 1% level.

Thus it would seem that depth and the factors varying with it, such as current, swell and light intensity, have little effect on the size of *E.stricta*. However the size does seem to be influenced by the inclination of the substratum, which is the only measurable difference between Stations 1 and 2. This would also explain the lower mean height of 18.3 cms. found for the six colonies at Station 5.

Additional Observations

- 1) No pattern was found in the expansion of the polyps of Gorgonian colonies. There was no synchronisation between neighbouring colonies, and sometimes not even between branches of the same colony.
- 2) Microscopic examination of the Gorgonian nematocysts after staining with Magenta was attempted, but the resolution of the microscopes available proved insufficient.
- 3) Many colonies of Gorgonians had parasites. An unidentified barnacle formed galls on *E.stricta*, *E.cavolinii*, and *P.chamaeleon*. *E.stricta* was also commonly found bearing colonies of *Parerythropodium coralloides* and *Fron dipora verrucosa*.

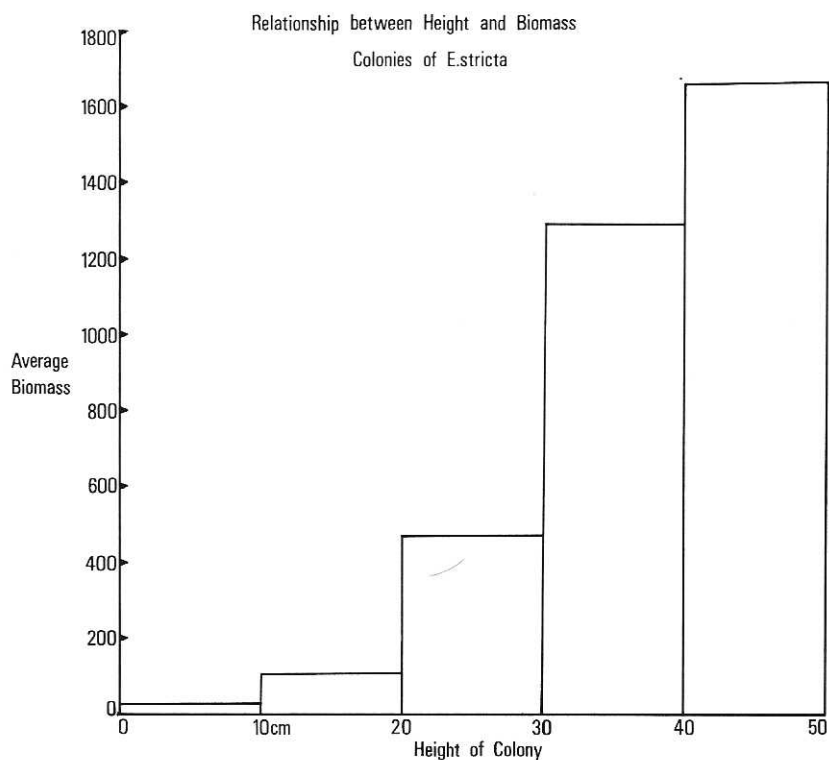
Conclusions

Gorgonians are a class of Coelenterates that have been very little studied. The observations made on this project were necessarily pilot investigations, finding out which factors affecting Gorgonian distribution need to be examined. This will require more quantitative measurement, which were not possible in the limited time available.

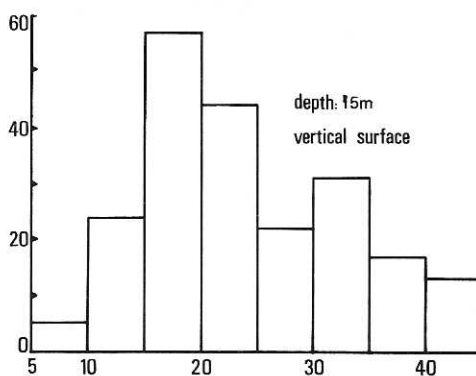
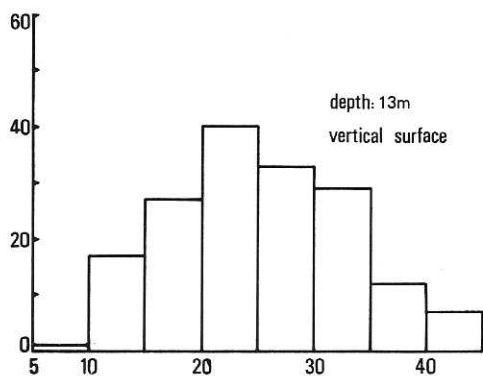
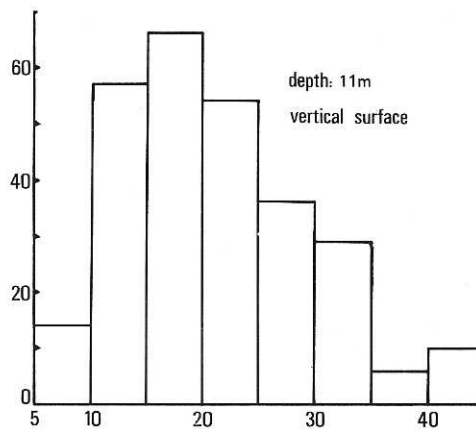
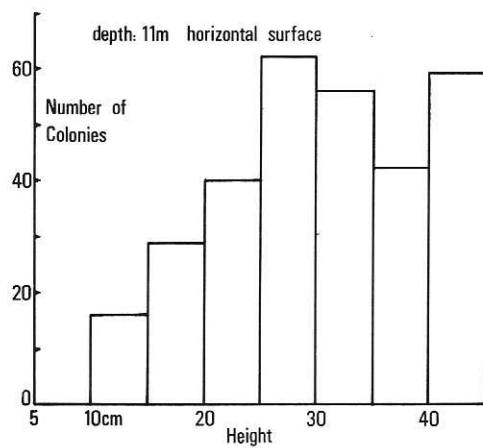
More accurate current and swell measurements might show that it is water movement that limits the distribution of *E.stricta*. This seems the most likely factor from our observations. No factor was found that might limit the other species, except possibly light intensity for *P.chamaeleon*.

Our results indicated that both the numbers of *E.stricta* growing in an area and their size, were influenced by whether they were growing on a horizontal, vertical, or overhanging surface. This species seems to grow best on a horizontal surface. Within its limiting values the current did not seem to be influential, neither did depth over the range investigated.

FIGURE 4



Height of *E. stricta* Colonies in Quadrat Samples



GRT

X FINANCIAL STATEMENT

CREDIT	£	s	d	DEBIT	£	s	d
The British Petroleum Co. Ltd.,	50	0	0	Medical Insurance	18	0	0
The British Association	50	0	0	Marine Liability & equipment insurance	34	6	10
The Challenger Society	20	0	0	Administration	55	1	10
The Drapers Company	40	0	0	Printing (prospectus)	15	0	0
The Gilchrist Educational Trust	50	0	0	Transport of equipment; Shipping,			
The John Sepdan Lewis Trust				storage, handling	80	0	3
for the Advancement of the				Van hire & crates	24	13	6
Natural Sciences	50	0	0	Boat Hire;			
The American Museum of				H.L.D.	240	6	7
Natural History, New York	100	0	0	Dinghies & outboard	16	7	3
Blyth Fund, Selwyn College	40	0	0	Photography;			
Fitzwilliam College	40	0	0	Cassette loader	7	0	0
Newnham College	30	0	0	Films & processing	18	12	2
Sir Edward Bullard	5	0	0	Exposure meter & case	4	10	2
Personal Contributions	497	0	0	Food	148	1	9
				Equipment;			
				Compressor hire	25	1	0
				Hire of diving gear	20	0	0
				Inclinometer, compass, charts	5	18	9
				Spares, medical kit, etc.	9	5	3
				Diving equipment	18	14	8
				Report (estimated)	50	0	0
				Allowances to fares	181	0	0
Total	972	0	0	Total	972	0	0

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Mr. Styche
H. Licudi, esq.
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Rank Precision Instruments Ltd.

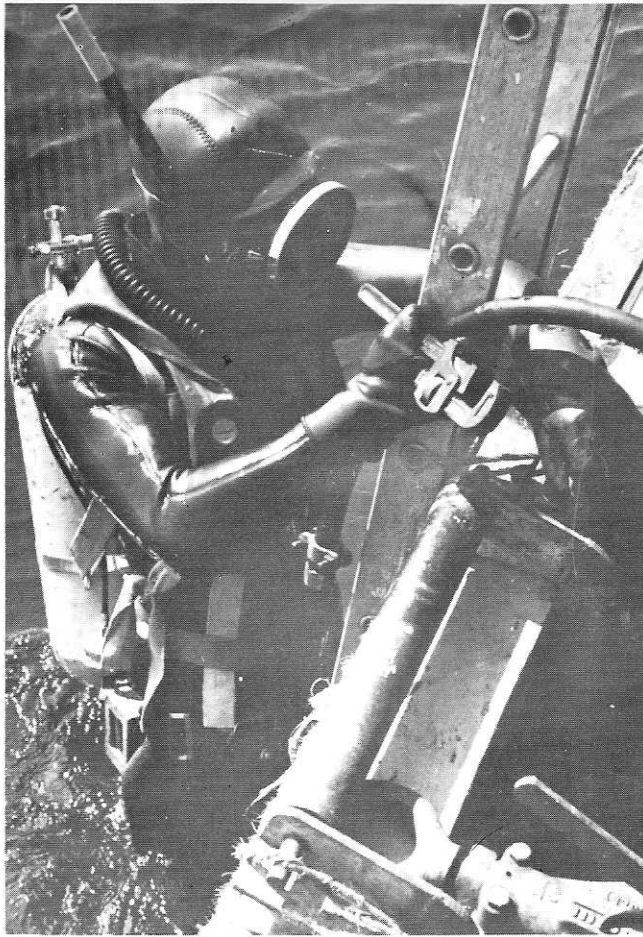
For loan of equipment and facilities

The Royal Navy
The Dockyard, Gibraltar
The Army
The Royal Navy Recreation Club (HMS Rooke Welfare Fund)
The Army Recreation Club
R.A.F. Sub-Aqua Club
Consolidated Pneumatic Tool Company Ltd.
Thorn Electrical Industries Ltd.
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Mr. Bassadoni, Gibraltar Divers
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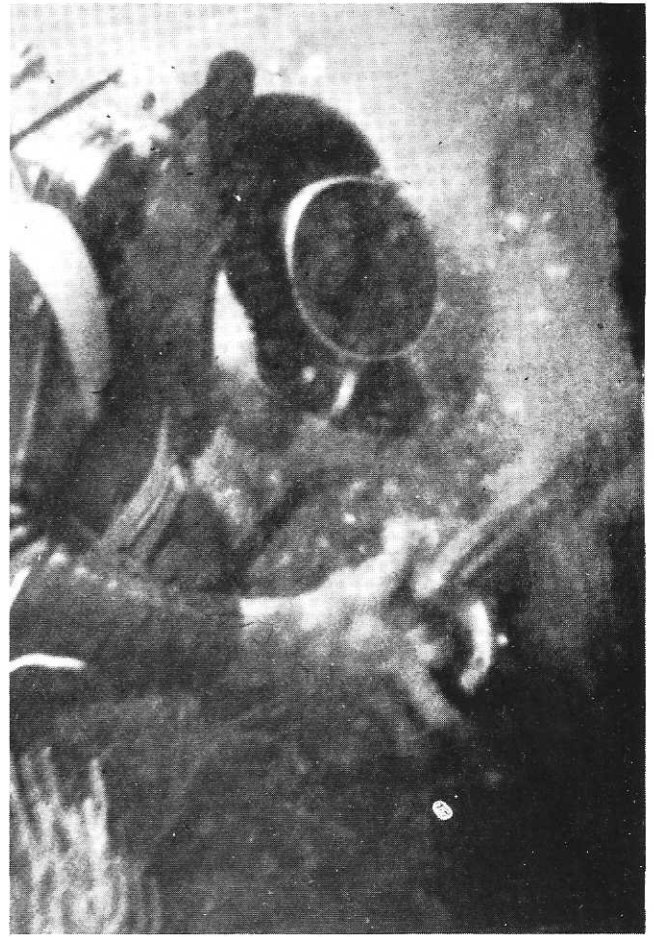
For generous discount on goods or hire of equipment:

Cambridge University Underwater Exploration Group
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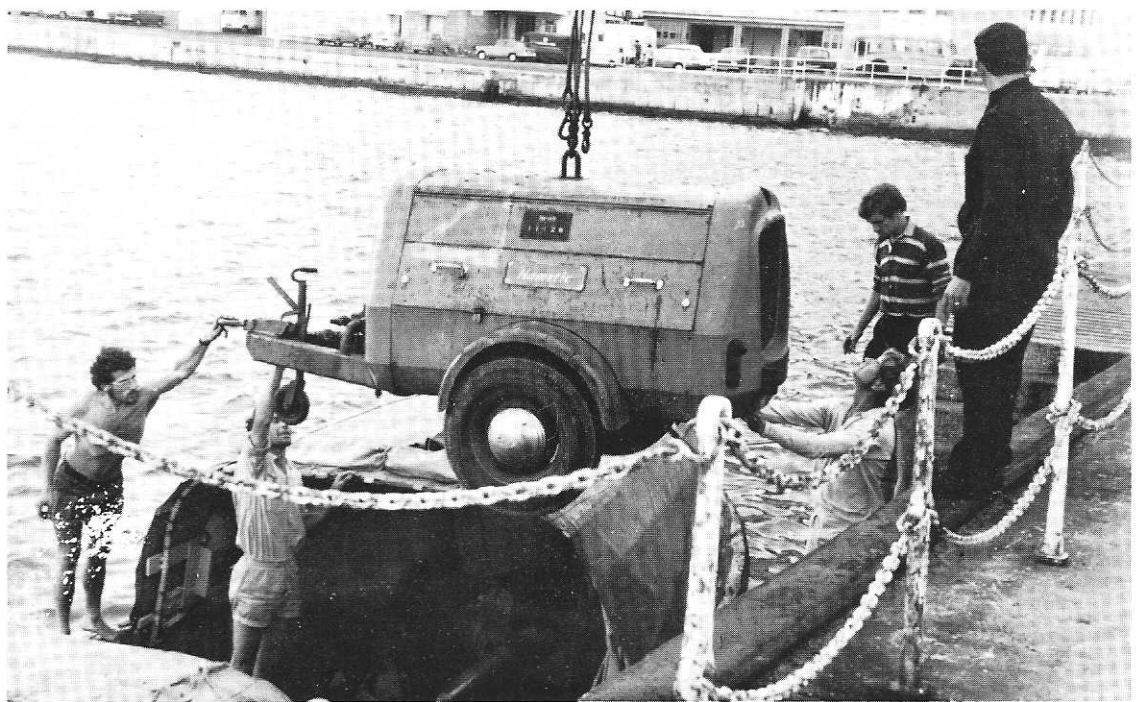
Also, those firms and organisations who made financial contributions, and whose names appear in the statement of accounts.



1 Diver returns from setting up the airlift



2 Taking a rock sample with the CP-9 Drill



3 Loading the compressor onto the boat