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CORNWALL

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The

Imperial College Cornwall Expedition. (1960)

The following is submitted as

The Final Report

of the

Imperial College Cornwall Expedition (1960)

Imperial College. R.H.T. Garnett.

December, 1960. Expedition Leader.

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List of Illustrations

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Mr. Symons, Curator, Admiralty Chart Establishment, London, N.W.2.

The Imperial College Exploration Board, London.
The Admiralty Chart Establishment, London, N.W.2.
The British Broadcasting Corporation.
The Imperial College Union, London.

Illustration No.(1)

A diver is surfacing following the completion of the sampling and photographing operation. Cligga Head may be seen in the background.

Abstract

The area chosen for the work lies between St. Agnes Head and Cligga Head on the North coast of West Cornwall. High, plunging cliffs form the coastline, and inland the ground is undulating, rising to a maximum elevation of about 600 feet. The members of the Expedition were based in Porthtowan, to the South of St. Agnes, and each day the equipment was transported to Trevaunance Cove where the diving boat was launched. The area lies within the belt of tin-copper mineralization which is associated with the Cligga and St. Agnes Granites and has been extensively worked for these metals in the past.

During the month for which the members were at work in Cornwall, a total of two square miles of the sea-bed was geologically mapped. Depth soundings for this region were obtained from the Admiralty and compiled into a bathymetric chart to which further detail was added, as required, by the use of a small portable echo-sounder. The chart was studied and found to indicate the existence of several major underwater outcrops. When weather conditions proved to be suitable the diving boat was launched and as many spot dives as possible were made to selected parts of the sea-bed. The divers worked in pairs, obtaining a sample of each outcrop that was located. With a mean diving depth of 55 feet it required an average of 10½ minutes underwater at each location to complete all the necessary work. To facilitate the detection of outcrops, an aqua-plane was also used and a diver was towed below the surface for distances of up to half a mile by this means.

THE DIVING AREA

SHOWN IN RELATION

TO LONDON

The bed-rock was found to outcrop over approximately 40 per cent of the area of the sea-bed examined. The coastline was bordered by a belt one third of a mile wide in which all the bed-rock was covered with sand. Nevertheless, the overall frequency of outcrops was greater than that on the land, where, apart from the cliff section, very few exposures exist. All the bed-rock sampled was of 'killas' as it is commonly known in Cornwall. Variations were detected in the degree of alteration of the 'killas', and the aureole of metamorphism, as mapped on the land, was successfully traced out to sea for a distance of one mile.

From this work it was proved that aqua-lung divers provide a readily available and convenient method of mapping the sea-bed. They should in future be incorporated into any programme of off-shore geological exploration of the continental shelf.

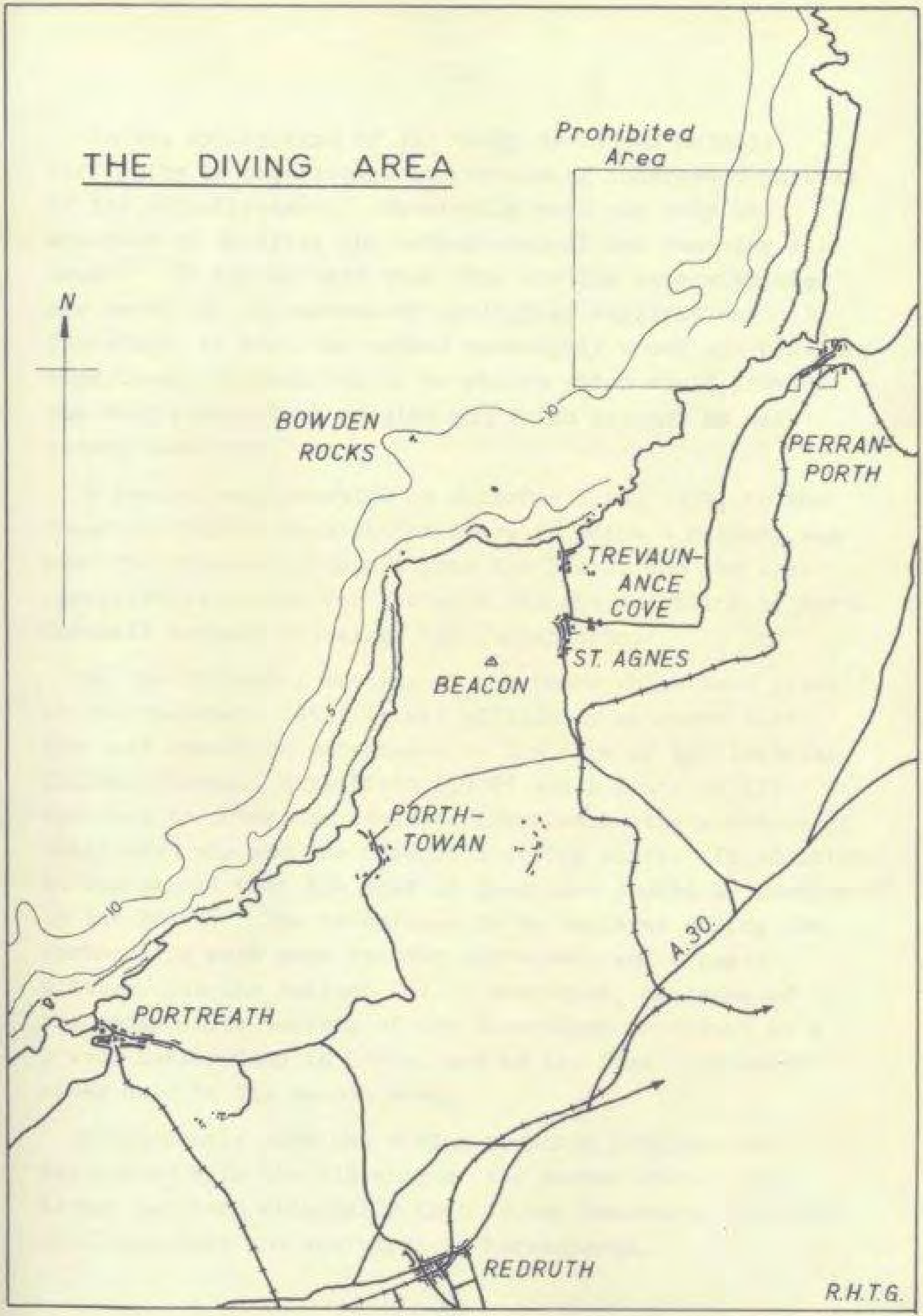
SECTION (1). INTRODUCTION

During the summer of 1959 nine members of the Imperial College, including the writer, formed an Expedition to the Azores Islands, the purpose being to make a study of the off-shore underwater fauna and flora. The new tool in this research was the aqua-lung which enabled the specialist in any particular field of study to make an investigation of a subject in situ on the sea-bed.(7)

Of volcanic origin, the Azores Islands were composed essentially of basalts and trachytes, both of which outcropped on the sea-bed at depths which were easily accessible by an aqualung diver. The shoreline outcrops were of insufficient extent to provide a solution to certain geological problems, and the geological mapping was extended to include the sea-bed outcrops. Thus, apart from some work in the U.S.A. (1) and France, (10) these were among the first attempts to be made at underwater geological mapping with self-contained underwater breathing apparatus (7).

A technique of sea-bed mapping was developed in the Azores which disclosed the vast possibilities of this new field of research and its applications. In the geological and engineering sciences these are principally as follows:-

(a) Civil and Harbour engineering, and repair work.
(b) The extension of surface geological mapping in areas bounded by the sea or inland water.
(c) Determining coastal and under-sea development areas in the field of mining geology.
(d) Underwater sampling of known existing mineral deposits.


THE DIVING AREA
Prohibited Area
N
BOWDEN ROCKS
10
PERRANPORTH
TREVAUNANCE COVE
ST. AGNES
BEACON
5
PORTHTOWAN
10
A.30.
PORTREATH
REDRUTH
R.H.T.G.

In the application of all newly developed methods difficulty is experienced in persuading interested parties of its effectiveness. Eventually this can only be acheived by applying the method oneself and removing all doubt. It may be said that this was the case with the new technique of underwater geological exploration. Therefore, to test the method thoroughly under all possible conditions, an area had to be chosen which would provide the most interesting results and which was not an easy diving locality.

A report was submitted on November 13th, 1959, to the Imperial College Exploration Board in which a request was made for financial support from the Board, and the area specified as a site for the work was the coastline of North Cornwall between St. Agnes and Perranporth.

At the following meeting of the Board which took place on 8th December, 1959, it was officially approved that the work should be undertaken in the form of the Imperial College Cornwall Expedition (1960) and a grant of £75 was made to cover the expenses incurred in the purchase of compressed air and the hire of a diving boat. In addition, it was agreed that the cost of insurance should be covered by the Board. The techniques to be employed during the forthcoming work were further perfected, and a paper written upon the subject (6). Meanwhile, training of the prospective members of the Expedition continued at a 2 week Easter Camp in Devon, and in the form of weekend dives held in the London area.

Concurrently with the diving training progress was maintained with the planning of the actual site. The latter had been originally that in the immediate vicinity of Cligga Head and westwards to Perranporth.

However, it was decided that with the time available a larger area could be covered and the diving work was extended to cover an area of sea bounded by St. Agnes Head, Bowden Rocks and Cligga Head. A report was then submitted to the Geevor Tin Mines Limited with a view to requesting further financial assistance towards the work. A reply was received from Mr. G. W. Simms, Managing Director of the Company, in which he most generously forwarded a cheque to the value of £30.

The writer spent a period of ten days in the area described above during the month of April when the preliminary fixing of the coastal survey stations was completed together with a general reconnaissance and details concerning the hire of a boat, etc.

The scheduled date for the commencement of diving work was July 1st but members of the Expedition arrived in Cornwall two days before that date in order that they could become fully acquainted with the special problems of the area before a start was made with the location diving. The work was completed on July 30th and members departed as arranged on July 31st.

The following report deals with both the diving problems encountered, the methods by which they were overcome, the geological results obtained from the location dives, and the interpretation of these results.

SECTION NO.(2). THE MEMBERS OF THE EXPEDITION.

(a) R. H. T. Garnett, D.I.C., B.Sc (Eng), A.R.S.M. F.G.S. Postgraduate in the Department of Mining Geology, Royal School of Mines, Imperial College.
Expedition Leader, Geologist and Surveyor.

(b) J. D. Woods.
Undergraduate in the Department of Physics, Royal College of Science, Imperial College.
Deputy Expedition Leader, and Photographer.

(c) J. B. Matthews, B.Sc, A.R.C.S.
Now postgraduate in the Department of Physics, Royal College of Science, Imperial College.
Diving Officer.

(d) I. D. Hounsell.
Undergraduate in the Department of Electrical Engineering, City and Guilds College, Imperial College.
Assistant Diving Officer.

(e) G. C. Wheeler.
Undergraduate in the Department of Mechanical Engineering, City and Guilds College, Imperial College.
Equipment Officer.

(f) T. Long, B.Sc (Eng), A.C.G.I.
Formerly undergraduate in the Department of Aeronautical Engineering, City and Guilds College, Imperial College..
Assistant Equipment Officer.

All the above are members of the Imperial College Underwater Club and the British Sub Aqua Club.

SECTION NO.(3). THE DIVING AREA

Following upon the development of a method of underwater geological mapping, the writer decided that the method should be further adapted and proved under conditions more unfavourable than those prevailing in the Azores Islands. For this reason an area of British coastline had to be selected which was not only of interest geologically but also provided diving conditions that were variable and on the average more difficult than the majority of English diving locations.

Through the local knowledge of the writer the area finally selected was, as already described, that in the region of Perranporth and St. Agnes on the north coast of Cornwall; an area of much old mining activity, and a highly suitable one for future economic exploration.

The petrological nature of the rock-types prevalent on the coast was such that they might be expected to outcrop on the sea-bed beyond the low-water mark, and this theory was supported by the evidence of old naval soundings dating back to 1839 (22).

For reasons described later in the report, the results that might be obtained could be expected to have a definite economic application; since the area is one of the most favourable sites for future underground mining exploration. This is a fact that has been recognized by the majority of economic geologists who have worked for any length of time in this region of South-West England, and was emphasized again during the 1958 Symposium on the "Future of Non-Ferrous Mining in Great Britain and Ireland" which was organized in London by the Institution of Mining and Metallurgy (13).

The following are, to illustrate this point, a few selected quotations from the proceedings of the Symposium.

(1) K.F.G. Hosking and J.H. Trounson. "Therefore the ground beneath the sea immediately to the north of the St. Agnes and Cligga (granite) cusps is well worth prospecting, as are also ...." Page 363.

" .... of the outcrop at Cligga Head and under-sea exploration in Perran Bay might result in important discoveries ...." Page 367.

" .... that the ground below the sea in the vicinity of St. Agnes was well worth examining, and they also thought the same applied to the submarine area near Cligga and .... " Page 385.

(2) D. Taylor-Smith. "I would like to associate myself with the remarks made by Dr. Hosking about the field of exploration in Cornwall extending to the off-shore areas. I feel that in these areas lies a vast amount of untapped mineral wealth. But how to map them? May I commend to your attention a technique that is being used in France for this purpose? I have had the good fortune to be connected indirectly with the geological mapping of the American structures in and around Mont St. Michel, off the coast of Brittany. This has been done using a simple echo-sounder which records changes in rock-type at the bottom of the sea, and frogmen trained in the collection of geological samples. The method is cheap, reliable, and an extremely detailed map of the area has resulted ....." (10).

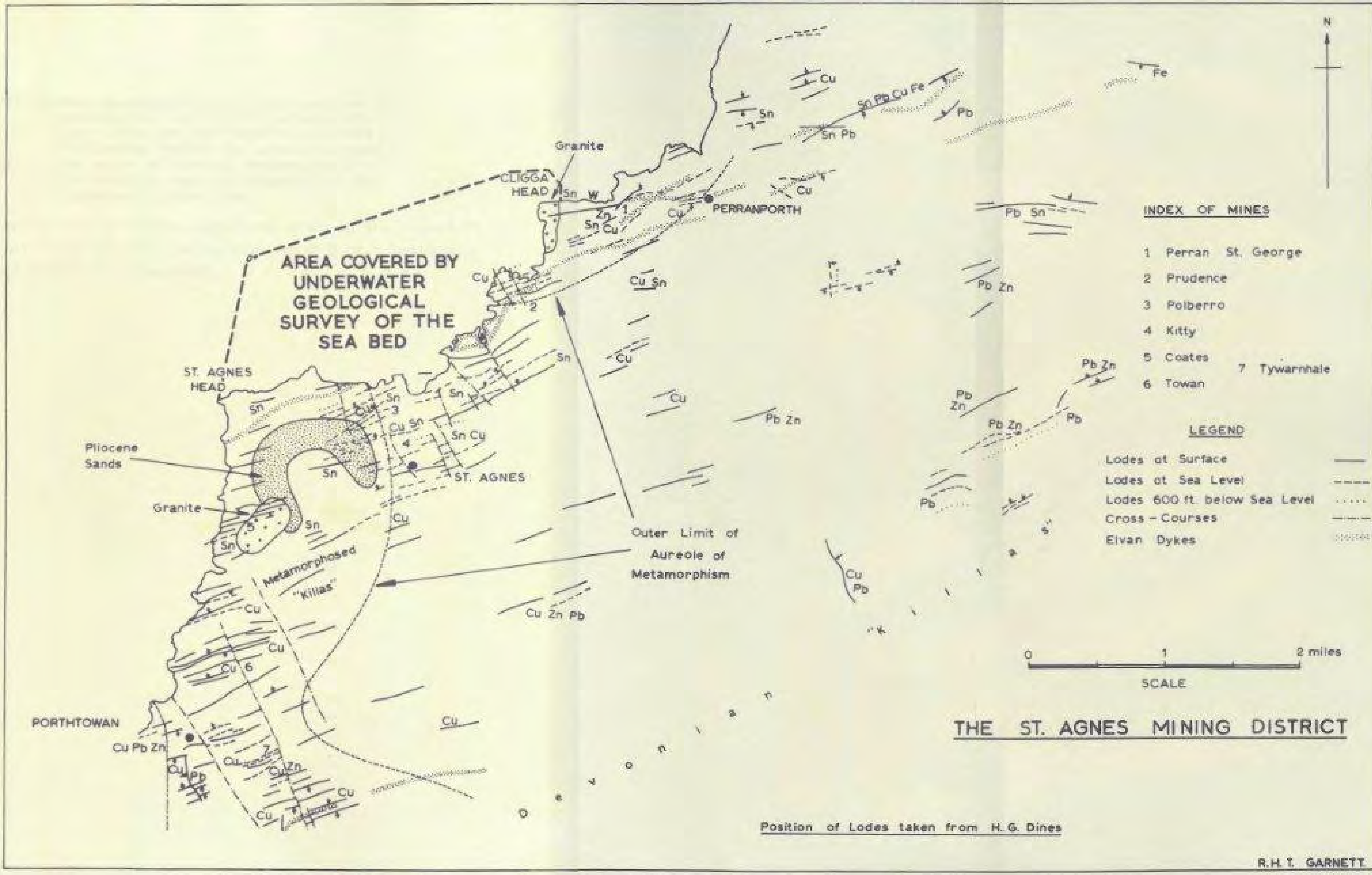
Apart from one notable exception, the St. Just area, the vast majority of the mine workings in areas of economic mineralization in the South-West of England have been confined to the land surface, both above and below sea-level. The mines of Botallack and Levant in St. Just represent the two main examples of mines, the workings of which have extended well beyond the low water mark and to a considerable depth. The Levant tin-copper lodes were worked for a distance of 5,000 feet out to sea and to a depth of over 2,000 feet below sea level.

With respect to the remainder of the mining areas in this region of the United Kingdom the majority of workings have ceased abruptly at or directly beneath the high-water mark owing to the limitations of the mining techniques in use during the times at which the mines were in production. It is obviously impossible for the existence of the high water mark to exert any influence upon the payability of the tin-copper lodes and it is therefore unreasonable to expect that lodes which have yielded large tonnages during the last Century when worked beneath the land should suddenly become uneconomic at a point directly beneath the high-water mark.

The region of St. Agnes - Perranporth is such an area where the old mine workings may be seen to halt abruptly at a line coincident with the coastline. If, as described in a later section, the zones of metamorphism of the country rock as exposed on the land are extended beyond the coast-line by interpolation, the result would appear to indicate an extension of the exposed area of possible mineralization into the St Agnes and Perran Bays. At depth there would appear to be a granite ridge under-lying the exposures of the St. Agnes and Cligga Granites, and extending in a North-Easterly direction from Cligga Head towards Perranporth.

Summarizing, it may be stated that the aim of the work was as follows :

(a) To prove that the technique of underwater geological exploration, employing aqua-lung divers was a practical economic proposition.


THE ST. AGNES MINING DISTRICT
AREA COVERED BY UNDERWATER GEOLOGICAL SURVEY OF THE SEA BED
INDEX OF MINES
1 Perran St. George
2 Prudence
3 Polberro
4 Kitty
5 Coates
6 Towan
7 Tywarnhale
LEGEND
Lodes at Surface
Lodes at Sea Level
Lodes 600 ft. below Sea Level
Cross – Courses
Elvan Dykes
SCALE
0
1
2 miles
N
Granite
CLIGGA HEAD
PERRANPORTH
ST. AGNES HEAD
ST. AGNES
Pliocene Sands
Granite
Metamorphosed "Killas"
Outer Limit of Aureole of Metamorphism
PORTHTOWAN
Devonian "Killas"
Position of Lodes taken from H. G. Dines
R.H.T. GARNETT

(b) To map geologically as large an area as possible of the sea-bed between St. Agnes Head and Perranporth, thereby continuing beyond the low-water mark the zones of thermal metamorphism of the country rocks as mapped from the exposures on the land.

For reasons which are explained later in the report it was not found possible to map the sea-bed area between Cligga Head and Perranporth.

SECTION NO.(4). GEOGRAPHICAL DESCRIPTION OF THE AREA

The St. Agnes - Perranporth district is situated in the South-West of England on the North coast of the County of Cornwall. Both towns are small holiday resorts, separated by a distance of 3 miles, (See Fig. No.2) and access to them is possible by both road and rail. Perranporth, 258 miles by road from London, forms the Eastern limit to the area in question, the Western limit being formed by St. Agnes Head. The town of St. Agnes, with a permanently resident population of 4,000 is connected by road to the A.30 and by rail to the Paddington - Penzance main line, and it provided the centre from which the diving operations were conducted.

The coastline is marked by high, North-Westerly facing cliffs which rise on occasions to a height of 300 feet. Beyond the cliffs the land is undulating and, in the form of the St. Agnes Beacon, rises to its maximum elevation of 629 feet. The land, where not desolated by disused mine dumps, is largely given over to mixed farming. The principal industries in the area are farming, tourism, and light consumer goods (Camborne and Redruth). The additional occupations of fishing and mining are no longer in evidence.

The members of the Expedition were accomodated at the village of Porthtowan, three miles South-West of St. Agnes. Here the equipment was stored in the surface buildings of the Tywharnhayle Mine which is maintained by the Surveying Department of the Royal School of Mines for underground instructional purposes. The Climate is officially stated to be mild throughout the year but details of the weather conditions during the period of diving are provided in a later Section of the Report.

SECTION NO.(5). GEOLOGICAL DESCRIPTION OF THE AREA

(a) The General Geology of the Area.

Underlying the vast majority of the South-West of England is a major granite batholith which has been revealed by erosion to provide several major granite exposures. Proceeding Eastwards, and excluding the Scilly Isles, these are the Land's End, Godolphin, Carn Menellis, St. Austell, and Bodmin Granites in Cornwall alone. Associated with them are many smaller exposures, of which the St. Agnes and Cligga Granites are but two.

Genetically related to the exposures of granite which has been intruded into the overlying sediments is a belt of tin-copper mineralization together with the associated ores of tungsten, zinc, lead, iron, antimony, arsenic, uranium, etc. In plan, the belt of mineralization is approximately ten miles wide and trends in a North-Easterly direction roughly coincident with a line joining the centre points of the major granite exposures.

Although the majority of the economic mineralization lies within the boundaries of this belt, there are selected areas, which, although outside the belt, have yielded in the past large tonnages of tin and copper ores, thereby ranking as major producing areas. The St. Agnes - Perranporth area is such a mining district and lies just outside the belt to the North of the Carn Menellis Granite. In this region the granite is intruded into sediments of the Lower Devonian Series which have been altered as a result of both dynamic and thermal metamorphism. Related to the granites are a series of quartz-porphyry dykes and a large area of tin-copper mineralization with associated lead, zinc, and iron.

(b) The St. Agnes Granite.

The St. Agnes Granite exposure takes the form of an elliptical outcrop with a major axis approximately ½ mile in length and trending North-East by South-West. It thus forms the South-Western flank of the St. Agnes Beacon which is composed essentially of the metamorphosed sediments capped by a series of Pliocene sands on the 300 feet horizon. On the whole the St. Agnes Granite is not well exposed and is no longer accessible at depth through the disused mine workings which penetrated it below the surface.

(c) The Cligga Granite.

To the North-East, and at a distance of 3 miles from the exposure mentioned above is the further outcrop of the Cligga Granite. The latter is exposed for a length of 2,000 feet in a North-South direction and for a width of 500 feet. The Northern and Western sides of the outcrop are bounded by cliffs, whilst the Southern and Eastern margins take the form of steep, irregular contacts with the metamorphosed country rocks. The granite has been extensively greisenized adjacent to numerous parallel fractures which frequently are mineralized, and doubt still exists regarding the exact mode of formation of the latter (14).

(d) The Quartz-porphyry Dykes.

Several major quartz-porphyry (elvan) dykes occur in the area and are frequently exposed along the coast between Newdowns Head and Cligga Head. The most interesting feature of the elvan dykes, which possess an average width in the order of 20 feet, is that they trend parallel to the mean lode strike within the area.

(e) The Country Rocks.

The sedimentary formations are of the Lower Devonian Series and consist of grits and slates, etc. ("killas"). They possess a strike varying between E.N.E. and E.S.E. and dip at an average of 30 degrees to the South. When unmetamorphosed the "killas" takes the form of grey and black silty shales alternating with thin bands of grit.

Apart from dynamic metamorphism the "killas" has also undergone extensive thermal metamorphism. The varying intensity of such may be detected in the field and subdivided as follows; with increasing distance from the granite contact:

(i) zone of andalusite-biotite hornfels - total width of only a few inches.

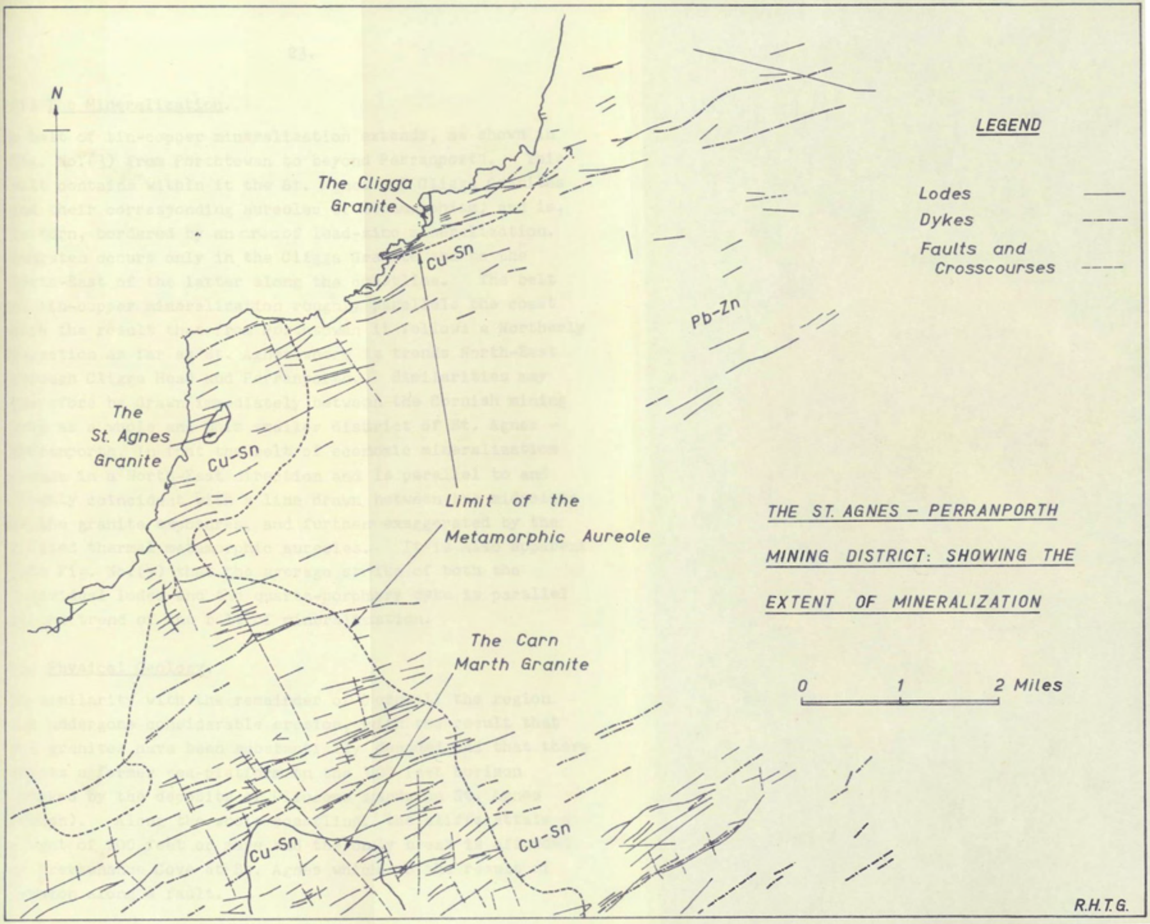
(ii) zone of tourmaline-biotite hornfels and tourmaline-schist. - width varies considerably but of the order of 200 feet.

(iii) zone of sericitization (bleaching and spotting of the "killas"). - width of the order of hundreds of feet.

(iv) zone of "spotted slates". - width of the order of hundreds of feet.

(v) unmetamorphosed "killas".

As the observer approaches the granite, therefore, and bearing in mind the tri-dimensional aspects, the first indication of the increasing proximity of the granite is the spotting of the "killas" which occurs without any other outwardly visible indication of the thermal



THE ST. AGNES – PERRANPORTH MINING DISTRICT: SHOWING THE EXTENT OF MINERALIZATION metamorphism. This feature, however, is most erratic and the division between unaltered "killas" and "spotted slates" cannot be mapped with complete accuracy at all times.

The zone of "spotted slates" is gradually superseded by the zone of sericitization of which the first sign is an apparent bleaching of the rock. The latter still maintains its spotted characteristics, but the 'spotting', which is increased, is frequently masked by the lighter colour of the specimens.

At a distance from the granite of the order of a few hundred feet, but highly dependant upon the configuration of the granite at depth, the "killas" passes, with decreasing distance from the intrusive mass, into the zone of tourmaline-schists, which is followed by the tourmaline-biotite-hornfels, and finally, at the contact, the andalusite-biotite hornfels. The tourmaline-schist is darker and harder in hand specimen than the representatives of the preceeding metamorphic zones and is easily detected in the field.

Owing to the abundance of mine dumps and the lack of exposure it is impossible to divide the metamorphic aureole of the St. Agnes Granite into its appropriate zones. In the case of the Cligga Granite, however, the coastline provides a complete section through the area in question and the various zones may be mapped comparatively easily with interpolation between the occasional exposures beyond the coast. The metamorphic aureoles of the St. Agnes and Cligga Granite, and their corresponding zones where interpretation is possible, are shown in plan in Fig. No.(12).

(f) The Mineralization.

A belt of tin-copper mineralization extends, as shown in Fig. No.(3) from Porthtowan to beyond Perranporth. This belt contains within it the St. Agnes and Cligga Granites and their corresponding aureoles of metamorphism, and is, in turn, bordered by an area of lead-zinc mineralization. Tungsten occurs only in the Cligga Granite and to the North-East of the latter along the coastline. The belt of tin-copper mineralization roughly parallels the coast with the result that from Porthtowan it follows a Northerly direction as far as St. Agnes where is trends North-East through Cligga Head and Perranporth. Similarities may therefore be drawn immediately between the Cornish mining area as a whole and this smaller district of St. Agnes - Perranporth, in that the belt of economic mineralization trends in a North-East direction and is parallel to and roughly coincident with a line drawn between the midpoints of the granite exposures, and further exaggerated by the related thermal metamorphic aureoles. It is also apparent from Fig. No.(4) that the average strike of both the individual lodes and the quartz-porphyry dyke is parallel to the trend of the belt of mineralization.

(g) Physical Geology.

In similarity with the remainder of Cornwall the region has undergone considerable erosion, with the result that the granites have been substantially denuded and that there exists a former sea-platform on the 300 feet horizon (marked by the deposits of Pliocene sands on St. Agnes Beacon). Along the whole coastline, the cliffs attain a hieght of 200 feet or more and the only break is afforded by Trevaunance Cove at St. Agnes which is the result of erosion along a fault.

SECTION NO.(6). THE HISTORY OF MINING IN THE AREA.

In common with many other regions in the South-West of England the St. Agnes-Perranporth area has been the centre of mining for many centuries. Fern (5) states that "Mining operations in the district of St. Agnes, principally for tin, but formerly for copper, have been carried on almost continuously since time immemorial. The period of greatest activity was the 18th Century, when no fewer than 25 different mines were working in the highly mineralized area included in the stretch of ground from Chapel Porth to Cligga Head, a distance of 4 miles, with a breadth of 1 mile from the coastline".

From this large number of mines have been produced the ores of tin, copper, zinc, lead, iron, tungsten, arsenic, and silver. Mining in the area ceased in the late 1920's, chiefly as a result of the following factors:-

(1) Violent fluctuations in the price of tin.
(2) Lack of financial reserves, resulting in:-
  (a) insufficient development to keep pace with the rate of production.
  (b) the inability to withstand periods of production of low-grade ore.
(3) Lack of ore reserves in some of the mines.
(4) Sporadic distribution of the tin values.
(5) Lack of the geological knowledge necessary to solve the problems encountered as a result of faulting of the lodes.
(6) Lack of labour during the 1914-18 war.
(7) Mining difficulties, arising through the proximity of abandoned mine workings, pumping, etc.

Many of the above factors are common to the whole mining district of the South-West of England in which the vast majority of the mines ceased production between the two World Wars.

The only exception in this region is afforded by the Cligga tin-tungsten deposit. Within the centre of the Cligga Granite is exposed a series of joints alongside of which the granite is greizenized. These joints are narrow lodes containing, among other minerals, cassiterite and wolfram. They possess an average strike of 70 degrees and dip to the North at an angle varying between 60 and 80 degrees. Many old workings exist in the cliffs of the Cligga Head; a result of the activities of the 'old miners' who sought only the cassiterite and discarded the wolfram. In 1938 mining was restarted on a small scale, and an old shaft on the granite-killas contact was re-opened and some development work carried out. The property was taken over by the Rhodesian Mines Trust Ltd., in 1939 when the same shaft was deepened to sea-level and development extended on three levels. As a result of the shortage of tungsten and tin during the Second World War, the deposit was sampled in 1941 on behalf of the Non-Ferrous Mineral Development Control to determine whether or not increased production could be obtained by working the deposit opencast. The grade proved to be not sufficiently high and production continued by normal underground mining methods. The mine closed at the end of the War in 1945 and since that time there has been no further mining activity in the area.

Further accounts of the History of Mining in the St. Agnes-Perranporth area are considered unnecessary in this report since excellent commentaries are provided by J. B. Fern (5), C. Reid (16) and H. G. Dines (4).

SECTION NO.(7). PRELIMINARY PLANNING

That an expedition should be held during 1960 with a view to underwater geologically mapping an area of the sea-bed in the United Kingdom was first suggested in a letter from R.H.T. Garnett to J.D. Woods on July 29th, 1959. There were, therefore, 11 months of planning before the commencement date of the Expedition on July 1st, 1960. The majority of this time was taken up with detailed drawing office and paper work and the development of further ideas upon the subject of the technique which was tested in Devon during April 1960.

The amount of planning necessary was considerable for it has been found in the past that a day spent upon planning prior to the commencement of the diving may save up to one week of diving time. In similarity with all sciences that require work in the field it is imperative that there should be no detail concerning the future field operations remaining in doubt before the commencement of the work. This general statement applies especially to diving work, which requires the recruitment and organization of a team as opposed to the direction of individuals, and when the amount of equipment and time involved is considerable.

The initial stage of the preliminary planning was the choice, as described in Section No.(3), of the diving area and the decision, based upon very little past experience, as to the area that the team of divers were capable of mapping, with a definite application of the results. Simultaneously, it was decided that the team should consist of six persons, including the leader.

This number was based upon past experience gained during the Imperial College Azores Expedition (1959) and also upon the method of organization of the diving team - a method which at that time was only in the embryo stage. It was considered that six persons would provide sufficient diving personnel to guarantee a quantity of results that would justify the amount of organization and the expenditure. In addition, it has been found that a team of six is an ideally sized unit for efficient control and direction during diving operations.

Stage 2 was, briefly, the accumulation and digestion of all possible information in connection with the area of choice. All geological maps of the area were consulted and compiled into master charts to the scales of 6" = 1 mile and 25" = 1 mile. Admiralty Charts to all scales and dating back to 1839 (22) were studied and the soundings that were available were reduced into a bathymetric chart, or what is more advisable to consider as a topographic chart of the sea-bed. It was fortunate that in this case there existed sufficient information in the form of depth soundings in the Admiralty archives. Otherwise it would have been necessary to conduct a complete echo-sounder survey of the diving area before further planning could proceed. Extremely useful information was also obtained from the current Admiralty Chart of the South-West of England (23) in the form of indications as to the physical nature of the sea-bed. Through a standard notation the Admiralty Charts denote areas in which it is known that there exist outcrops of the bed-rock on the sea-floor. An area of the sea-bed 5 miles to the North of St. Agnes was shown as having the bed-rock exposed and the writer is indebted to

Mr. A. Stride, Geologist to the National Institute of Oceanography for allowing the information regarding outcrops to be checked against the recent asdic (inclined echo-sounder) records obtained from the Survey Vessel Discovery during a cruise in the South-West of England. As a result it was found that the Admiralty Charts were most reliable in their predictions of the existence of a rock sea-bed and further evidence for this fact was obtained during the diving operations.

All the information regarding the nature of the sea-bed was combined with the bathymetric chart and incorporated into the master chart, upon which was draughted all the knowledge of the area, including the geology. The latter was obtained from a variety of sources and checked by later field work. It appeared at this stage from the information accumulated and from the local knowledge of the area that the possibility of success in the St. Agnes - Perranporth area was greater than in any other area with which the writer was equally well acquainted. A report was therefore compiled and presented to the Imperial College Exploration Board, by whom it was approved and a grant of £70 accordingly made to cover part of the expenses of the work.

The selection of the remaining five members of the Expedition was completed and work began upon Stage 3 of the planning which was the perfection of the technique of underwater mapping and the complete surveying of the area. The latter consisted of establishing a number of coastal survey stations on the cliffs which were fixed by standard triangulation methods using a 20" vernier theololite. Aerial photographs of the area were of considerable assistance in the choice of locations for the survey stations, since their positioning was dependant almost entirely upon topography. It has been found in past work that aerial photographs have provided an indication as to the nature of the sea-bed within certain depth ranges. However, as was proved later, the water visibility off the North Cornwall coast is so low as to prevent any reasonable depth penetration by the cameras.

The survey stations were plotted upon the master charts and a sextant chart, as described in Section No.(8), was designed and produced to cover the entire envisaged diving area. Through the Crown Estate Mineral Agent for Wales, Col. J. S. Sheppard, permission was obtained to conduct geological exploration in the area and to carry away geological specimens of the sea-bed from beyond the low water mark. The coastguards for the area were informed of the intended work, and although their services were never required, their assistance was warmly offered.

In conjunction with the initial surveying the writer visited all the accessible outcrops and compared his views with those of all past writers upon the area, all of which are listed in Section No.(20). At this time, April 1960, J. D. Woods was directing the sea training of the remaining members of the Expedition. This took the form of a 2 week Easter Camp in Devon and was organized with the assistance of the Imperial College Underwater Club. The members joined with the Club in what is now an annual camp and each completed one week's very vigorous training in both diving and the employment of various surveying techniques.

During April the writer was in residence in the district for a period of 3 weeks and in this time accomodation was obtained for the members in the village of Porthtowan to be available from July 1st to August 1st. A boat was examined and an agreement arrived at for the hire of such, to be taken out each day from Trevaunance Cove and to be employed as the diving boat. The local residents, from whom the boat was hired, were also interviewed and found to be most informative upon the diving conditions to be expected and their information regarding the sea-bed was later found to be extremely reliable.

At this point it is advisable to note that discussions with the local fishermen proved to be most rewarding and that a large amount of time was saved by first seeking the opinion of local inhabitants of longstanding, who were only too willing to draw upon their experience.

The above preparations were completed by June 1st and the remaining work comprised administration and the choice of equipment to be employed, together with its insurance. The final details were completed on June 24th, the last day of the Summer Term, and the members of the Expedition reassembled in Porthtowan with only one problem as yet not overcome; the weather.

SECTION NO.(8). SURVEYING AND POSITION FIXING

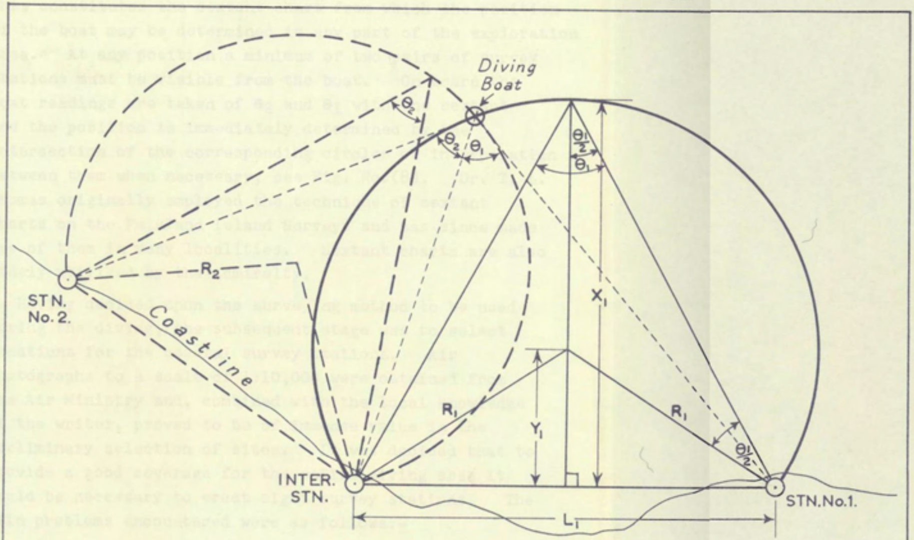
Any off-shore geological work must be accompanied by sufficient position fixing and the location of the diving boat must be known at all times. During the work in Cornwall the boat was always within sight of land and the greatest distance from the latter was never more than one mile. The requirements of any surveying technique to be used were as follows:-

(a) There were to be no observers on the shore and all observations and determinations were to be conducted on board the boat.

(b) The method was to be simple, accurate and rapid.

Dr. T. L. Thomas of the Department of Mining was consulted and he advised the use of sextant charts. These are based upon the principle that any point of a circle passing through two other points subtends a constant angle θ at those points (which may represent survey stations erected upon the coast). A series of circles of varying diameter representing different values of θ are constructed through the two survey stations. From the diving boat, as shown in Fig. No.(8) the observed angle θ_1 is measured by a sextant and the position of the boat is then known to be somewhere on a given circle passing through the two survey stations. In the same manner the angle θ_2 to two further survey stations, one of which may be common to the first pair, is measured, The position of the boat is therefore fixed by the intersection of the two circles.

In practise, mutually and easily visible coastal survey stations are erected. For pairs of selected stations sets of circles corresponding to varying values of θ are plotted on a plan.



$$X_1 = \frac{L_1}{2} \times \text{COT}\, \frac{\theta_1}{2}$$

$$Y_1 = \frac{L_1}{2} \times \text{COT}\, \theta_1$$

$$R_1 = \frac{L_1}{2} \times \text{COSEC}\, \theta_1$$

THE PRINCIPLE OF THE SEXTANT CHART

This constitutes the sextant chart from which the position of the boat may be determined in any part of the exploration area. At any position a minimum of two pairs of survey stations must be visible from the boat. On board the boat readings are taken of θ_2 and θ_1 with the sextant and the position is immediately determined by the intersection of the corresponding circles or interpolation between them when necessary, see Fig. No.(8). Dr. T. L. Thomas originally employed the technique of sextant charts on the Falkland Island Surveys and has since made use of them in many localities. Sextant charts are also widely utilized by the Admiralty.

Having decided upon the surveying method to be used during the diving, the subsequent stage was to select locations for the coastal survey stations. Air photographs to a scale of 1:10,000 were obtained from the Air Ministry and, combined with the local knowledge of the writer, proved to be of immense value in the preliminary selection of sites. It was decided that to provide a good coverage for the entire diving area it would be necessary to erect eight survey stations. The main problems encountered were as follows:-

(a) To ensure easy sighting of the stations with a compass or sextant it was essential that they should not be too far above the high water mark. However, the cliffs were from 200 to 300 feet high and almost vertical in the majority of places. As a result
 (i) the stations were located either at the base of the cliffs, or
 (ii) between the base and top of the cliffs. In either case, a large

amount of un-aided cliff-climbing (with surveying equipment) was necessary on the part of the surveyor.

(b) The correlation of the survey stations with respect to the National Grid was complicated by

(i) the lack of Ordnance Survey Stations in the area

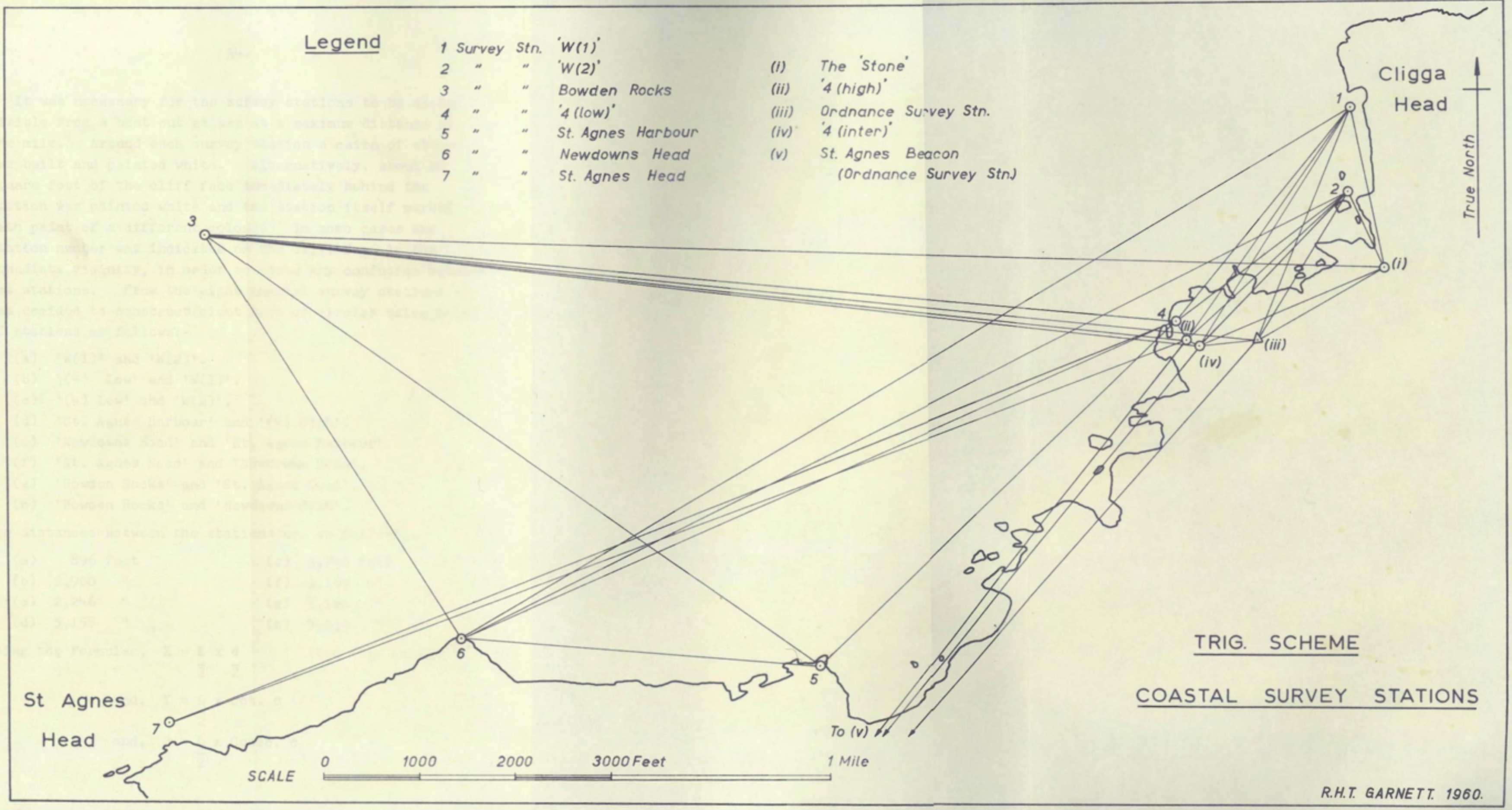
(ii) a number of small errors in the Ordnance Survey Sheets.

(iii) the amount of dead ground between the survey stations and the Ordnance Survey Stations, which was a result of

(1) the siting of the survey stations on or below the top of the cliffs,

(2) the convex slope of the ground surface for a considerable distance inland from the top of the cliffs.

The fixing of the survey stations was carried out by triangulation, using two Ordnance Survey Stations; St. Agnes Beacon, and one situated near Pen a Gader between Trevaunance Cove and Cligga Head; see Fig. No.(7). With two intermediate stations, '(4) Inter' and 'Stone', stations 'W(1)', 'W(2)', and '(4) High' were fixed. Employing the above, stations '(4) Low', 'Newdowns Head', and 'St. Agnes Harbour' were also established. A single compensated round was performed at each station with a 20" Vernier theodolite. The two remaining stations, 'St. Agnes Head' and 'Bowden Rocks' were fixed by intersection from the others.


Legend
1 Survey Stn. 'W(1)'
2 " " 'W(2)'
3 " " Bowden Rocks
4 " " '4 (low)'
5 " " St. Agnes Harbour
6 " " Newdowns Head
7 " " St. Agnes Head
(i) The 'Stone'
(ii) '4 (high)'
(iii) Ordnance Survey Stn.
(iv) '4 (inter)'
(v) St. Agnes Beacon (Ordnance Survey Stn.)
Cligga Head
True North
St Agnes Head
To (v)
SCALE
0 1000 2000 3000 Feet 1 Mile
TRIG. SCHEME
COASTAL SURVEY STATIONS
R.H.T. GARNETT. 1960.

It was necessary for the survey stations to be easily visible from a boat out at sea at a maximum distance of one mile. Around each survey station a cairn of stones was built and painted white. Alternatively, about 20 square feet of the cliff face immediately behind the station was painted white and the station itself marked with paint of a different colour. In some cases the station number was indicated on the cliff face in the immediate vicinity, in order to avoid any confusion between the stations. From the eight coastal survey stations it was decided to construct eight sets of circles using pairs of stations as follows:-

(a) 'W(1)' and 'W(2)'.
(b) '(4) Low' and 'W(1)'.
(c) '(4) Low' and 'W(2)'.
(d) 'St. Agnes Harbour' and '(4) High'.
(e) 'Newdowns Head' and 'St. Agnes Harbour'.
(f) 'St. Agnes Head' and 'Newdowns Head'.
(g) 'Bowden Rocks' and 'St. Agnes Head'.
(h) 'Bowden Rocks' and 'Newdowns Head'.

The distances between the stations are as follows:-

(a)	896 feet	(e)	3,746 feet
(b)	2,900 "	(f)	3,169 "
(c)	2,246 "	(g)	5,166 "
(d)	5,158 "	(h)	5,033 "

Using the formulae, $X = \frac{L}{2} \times \frac{\theta}{2}$ (See Fig. No.8)

and, $Y = \frac{L}{2} \times \text{Cot. } \theta$

and, $R = \frac{L}{2} \times \text{Cosec. } \theta$

Where:- L = the distance between the pair of stations.

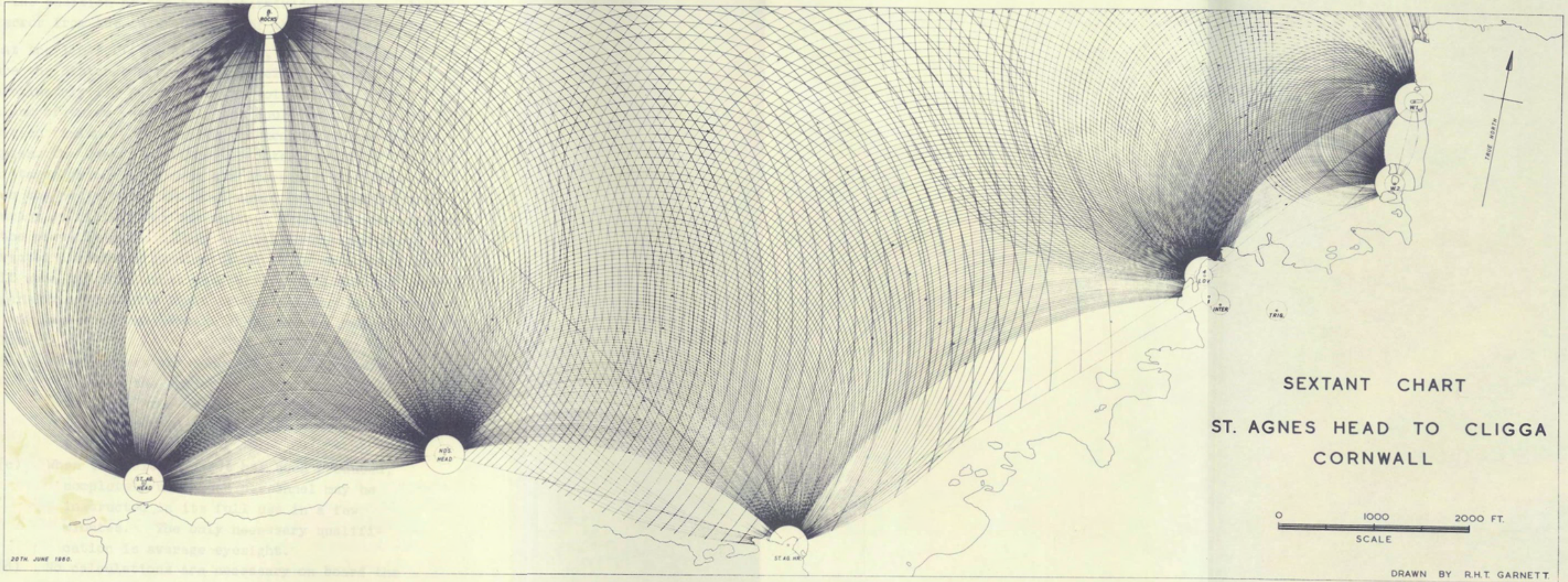
θ = the angle subtended at the two points.

R = the radius of the circle through the two points.

Y = the distance between the centre of the circle and the mid-point of the line joining the two stations.

$X = Y \times R$

for each pair of circles selected, with L constant, X,Y and R were calculated for variations in θ of 1 degree between 30 degrees and 150 degrees. Using an electrical calculating machine the constants were obtained for a total number of 968 circles for the eight pairs. The circles were then plotted on both the master chart and on tracing paper to a scale of 25" to one mile; see Fig. No.(9). The tracing was necessary in order that a large number of prints of the sextant chart could be produced for use at sea under conditions which rapidly rendered unfit for further use any maps and charts. With variations in θ of one degree, the sextant chart was designed for use with either a compass or a sextant. The sea conditions experienced made the use of a sextant impossible and consequently in lieu of reading the angle θ directly the bearings to the two survey stations in question were read with the compass and the angle θ calculated by subtraction of the two. The readings of the bearings, which were recorded, also provided a check against major errors in the plotting, since a rough estimate of the position of the diving boat could be obtained by the intersection of the two bearings. At each diving location the bearings to all the visible survey stations were read and recorded.



SEXTANT CHART
ST. AGNES HEAD TO CLIGGA
CORNWALL
0
1000
2000 FT.
SCALE
TRUE NORTH
INTER
TRIG.
20TH. JUNE 1960.
DRAWN BY R.H.T. GARNETT.

Immediately, the angles θ were calculated and recorded, and the position of the boat determined within a polygon of error from the intersections of the various circles.

At the limit of the diving area, one mile from the shore the distance between the circles represented approximately 150 feet. At any point in the area a minimum of three sets of circles could be utilized for the position fixing. Reading to the nearest degree on the compass, the boat's position was determined to $\pm$ 150 feet. A distance of one mile from the shore was the limit at which the position of the boat could be determined with accuracy sufficient for the work. This limit was imposed by the prevailing visibility and sea conditions which prevented a reliable reading of θ. The effects of the swell upon the small boat used were considerable. With a larger diving boat the limit of one mile could be extended. The advantages of the sextant chart may be summarized as follows :-

(a) No observers are required upon the shore.
(b) Following the surveying of the coastal stations, the majority of the work is carried out in the relative comfort of a drawing office.
(c) When the sextant chart has been produced, completely untrained personnel may be instructed in its full use in a few minutes. The only necessary qualification is average eyesight.
(d) No calculations are necessary on board the diving boat.
(e) No graphical constructions are necessary on board the diving boat.

(f) The position of the diving boat may be determined with accuracy on board in under 5 minutes.

(g) The only equipment necessary on board is a sextant and/or a compass.

(h) If the sextant chart is constructed on tracing paper, an infinite number of copies may be produced at a low cost.

(i) Copies of the sextant chart may be roughly torn into parts for use, provided that the values of θ and the complementary survey stations are indicated upon the circles.

At each diving location the position of the boat was determined from the sextant chart, in combination with the bearings to the survey stations as read with the compass. All members of the Expedition made use of the technique and became not only fully acquainted with the method but also reasonably accurate after only a few hours' use.

The above method supplied the position of the boat and it was then the responsibility of the person in charge of the latter to determine in addition the position of the divers relative to the boat. As is explained later, the point from which samples of the bed-rock were obtained usually coincided with the position of the boat's anchor, which could be easily determined. The importance of the positioning of the diver depends upon the accuracy with which the position of the boat is being determined at the time and upon the area of the sea-bed covered by the geologist in a single dive from the anchored boat. The boat's position was usually determined to $\pm$ 150 feet which was more often than not in excess of the distance between the boat on the surface and the location of the anchor on the sea-bed. For this reason, the position of the diver relative to the boat was very rarely determined, and the position of the boat was taken as being the location from which the relevant rock samples were obtained. Occasionally, however, a determination was required and the following method was adopted.

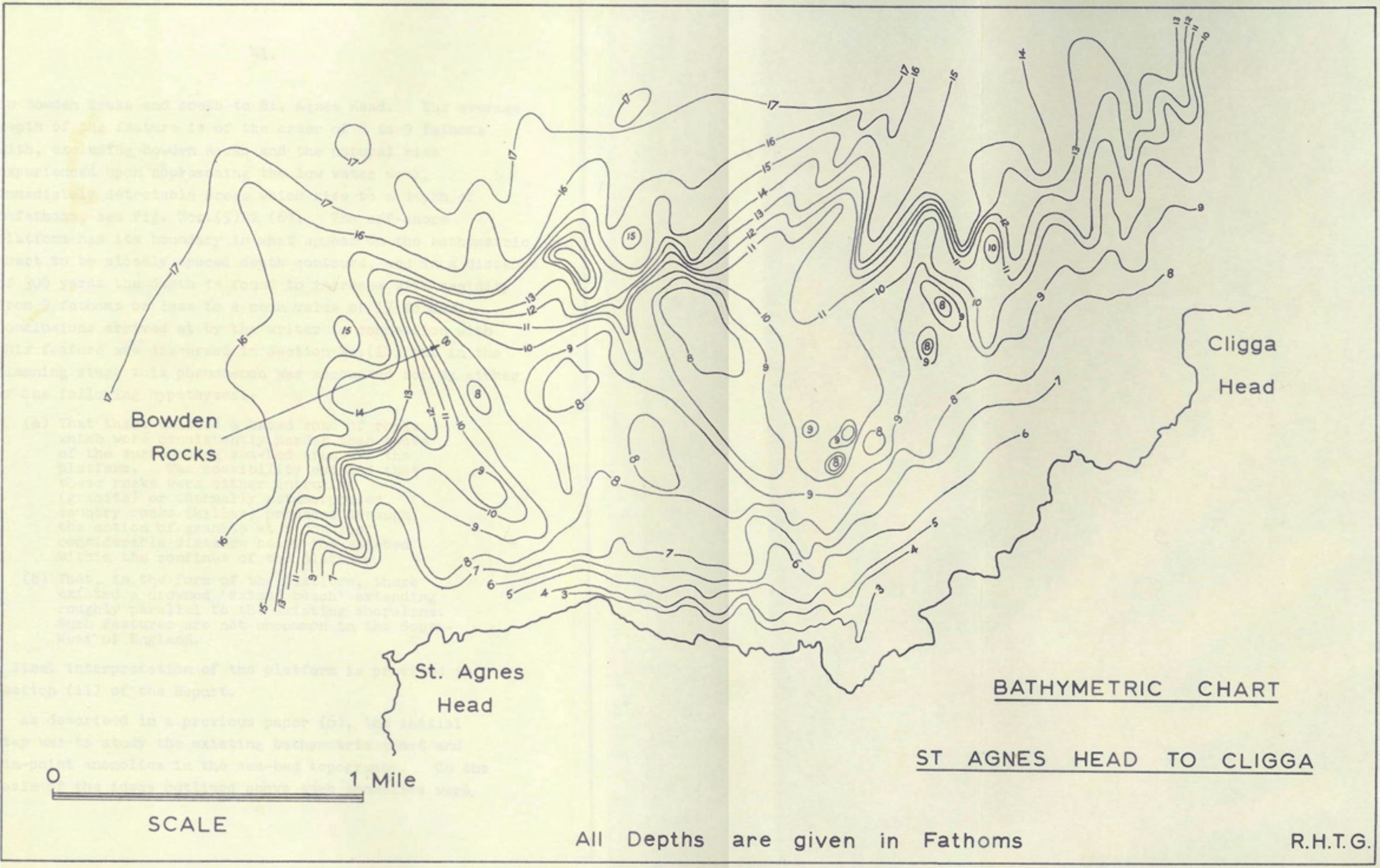
When a descent was made down the anchor line the surveyor knew the length of the anchor line in use, and the depth of the water was measured with the echo-sounder. The bearing along the anchor line was taken with a compass and an estimate of its inclination was provided by the diver as a check. The surveyor was therefore able to calculate the position of the diver relative to the boat provided the former did not leave the immediate vicinity of the anchor.

During the diving operations from Penzance and Mullion the position of the boat was determined by compass bearings on to prominent local landmarks and graphical resection on a 25" or 6" to the mile Ordnance Survey plan of the area.

SECTION NO.(9). DEPTH CONTOURING

As an introduction to this subject it is convenient to consider initially a normal topographic map of a land surface. We may expect to find in any area discrepancies to varying degrees in the level of the land surface, and it should be borne in mind that such variations, whether on the scale of mountains or hillocks, are controlled in their distribution by internal and external, but nevertheless important factors. Of these, two of the most significant, and ones with which the exploration geologist is most concerned, are geology and climate. The rate and nature of erosion of the earth's land surface in any particular district is largely controlled by the petrological and structural composition of the land and the extremes of climate that are brought to bear upon the surface.

This principle may be applied with equal validity to the sea-bed, which, in a like manner to the earth's surface, undergoes both erosion and deposition. The geological control is identical in that the harder the nature of a rock surface the less easily is it eroded by abrasive action. The latter is the most important factor in underwater erosion through the medium of matter suspended in the sea water. This varies from the suspended rocks in surf at the low water mark to fine sand held in a fast flowing current impinging upon a rock surface. The water itself possesses a denuding quality since the freely exposed rock surfaces are frequently decomposed through its action.



BATHYMETRIC CHART
ST AGNES HEAD TO CLIGGA

It is through this reasoning therefore that the observer may relate the degree of erosion of the sea-bed to the geology and structural formations and to the existing erosive elements. The most illuminating indication of the degree and type of eresion is afforded by the compilation of a bathymetric chart. This is produced by either of two methods, or by a combination of both, namely:

(a) spot depth determinations with a sounding line,
(b) spot or continuous depth determinations employing sonic methods such as the echo-sounder.

Method (a) was the first to be employed by mariners, but now, where the equipment is available, has been superseded by the sonic techniques of which there are a large variety. The latter are all dependant, however, upon the common initial principle of the reflection of articicially produced energy waves by the sea-bed and their detection after a measured time interval at the energy source on or near the water surface, where the time interval between energy radiation and detection is proportional to the distance of the sea-bed from the energy source.

By this means measurements are obtained of the depth of water at spot locations or along lines of pre-determined traverses, and a contoured map may be produced showing the variations in the depth of water (with allowance made for tidal effects) at all points in the working area. The resulting bathymetric chart should then be considered, from the point of view of a geologist, as a topographical map of the sea-bed indicating changes in elevation from any arbitrary horizon.

Admiralty charts of the St. Agnes - Perranporth area indicate a distinct platform extending from Cligga Head to Bowden Rowks and south to St. Agnes Head. The average depth of the feature is of the order of 8 to 9 fathoms with, excluding Bowden Rocks and the natural rise experienced upon approaching the low water mark, immediately detectable areas which rise to a depth of 6 fathoms, see Fig. Nos.(5) & (6). The off-shore platform has its boundary in what appear on the bathymetric chart to be closely spaced depth contours, and in a distance of 300 yards the depth is found to increase with rapidity from 9 fathoms or less to a mean value of 17 fathoms. Conclusions arrived at by the writer in connection with this feature are discussed in Section No.(11) but in the planning stage this phenomenon was accounted for by either of the following hypothyses:-

(a) That there existed a broad zone of rocks which were consistently harder than those of the surrounding sea-bed area off the platform. The possibility existed that these rocks were either intrusive (granite) or thermally metamorphosed country rocks (killas) produced through the action of granite at a not too considerable distance below the sea-bed within the confines of the platform.

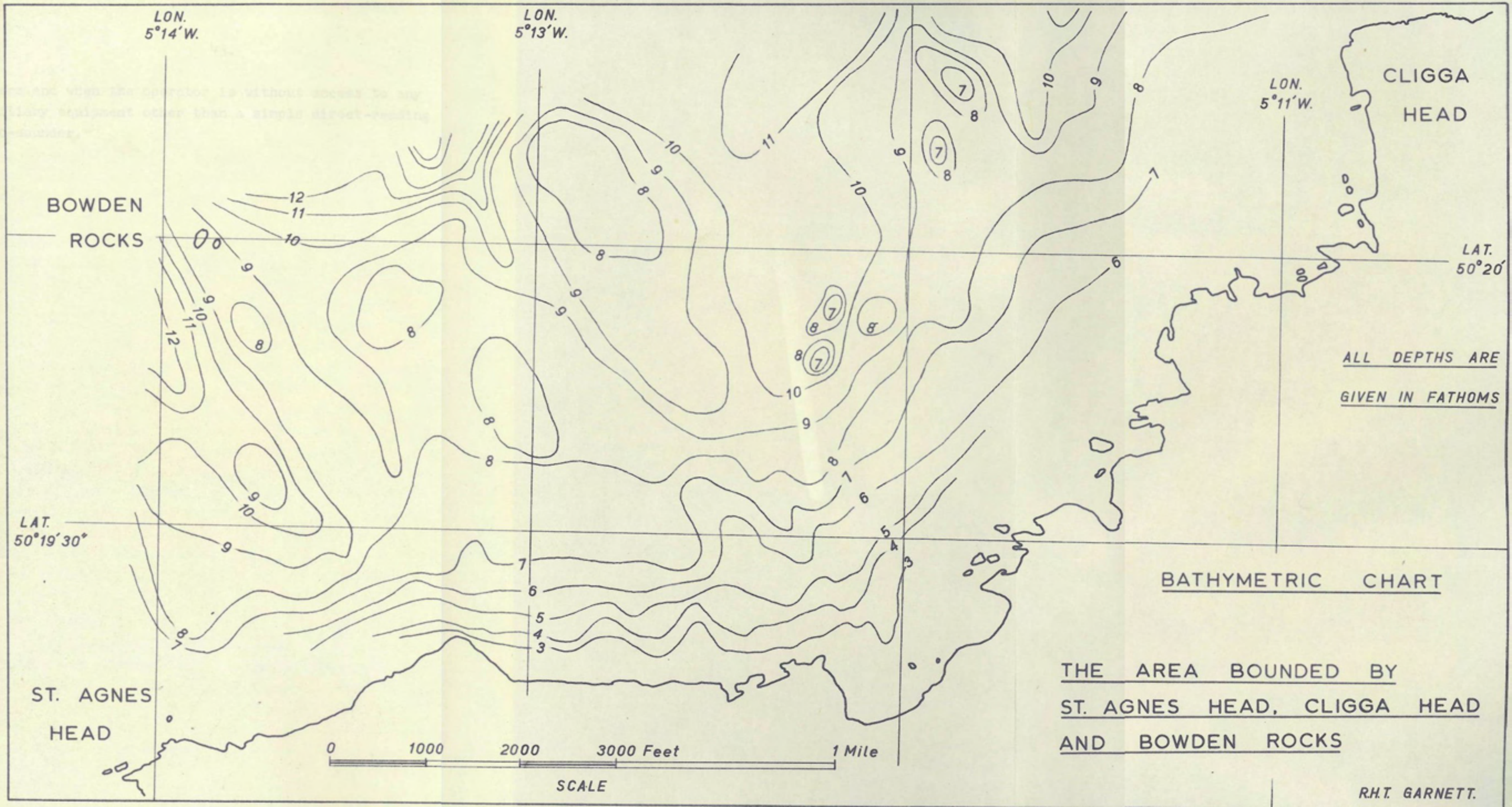
(b) That, in the form of the platform, there existed a drowned 'raised beach' extending roughly parallel to the existing shoreline. Such features are not uncommon in the South-West of England.

A final interpretation of the platform is provided in Section (11) of the Report.

As described in a previous paper (6), the initial step was to study the existing bathymetric chart and pin-point anomolies in the sea-bed topography. On the basis of the ideas outlined above such anomolies were interpreted with a view to determining whether or not there existed a sea-bed rock outcrop. In the area under study there are two areas of rapid rise in level from the sea-bed; one mile to the West of Cligga Head, and two thirds of a mile North of Trevaunance Cove. Further areas display a gradual rise in elevation; one mile North-West of Trevaunance Cove, two thirds of a mile North of Newdowns Head, and half a mile North-West of Newdowns Head. In addition, two distinct ridges are immediately noticeable; one extending across the platform in a N.N.W. direction from Trevaunance Cove and one extending with a parallel trend across the platform from Newdowns Head. Upon the latter and at a distance of one mile from the coast are situated Bowden Rocks which rise steeply out of the water from an average platform depth of 8 fathoms.

Outlined above are seven anomolies which were interpreted as indicating areas of the sea-bed, which, for many reasons, possessed rock outcrops. As a result it was necessary to confirm the interpretations and the first location to be dived upon was that situated one mile to the West of Cligga Head. The area was found to exhibit an extensive sea-bed outcrop comprising metamorphosed "killas". Following this confirmation, the remaining areas were more completely surveyed with the portable echo-sounder (for method see the Imperial College Azores Expedition (1959) Report (7) to the Imperial College Exploration Board), and locations pin-pointed at which it was intended to carry out diving operations.

This control of the choice of diving locations through the bathymetric chart is essential in all underwater geological exploration when employing self-contained


LON. 5°14′W.
LON. 5°13′W.
LON. 5°11′W.
CLIGGA HEAD
BOWDEN ROCKS
LAT. 50°20′
LAT. 50°19′30″
ALL DEPTHS ARE GIVEN IN FATHOMS
ST. AGNES HEAD
0 1000 2000 3000 Feet 1 Mile
SCALE
BATHYMETRIC CHART
THE AREA BOUNDED BY
ST. AGNES HEAD, CLIGGA HEAD
AND BOWDEN ROCKS
R.H.T. GARNETT.

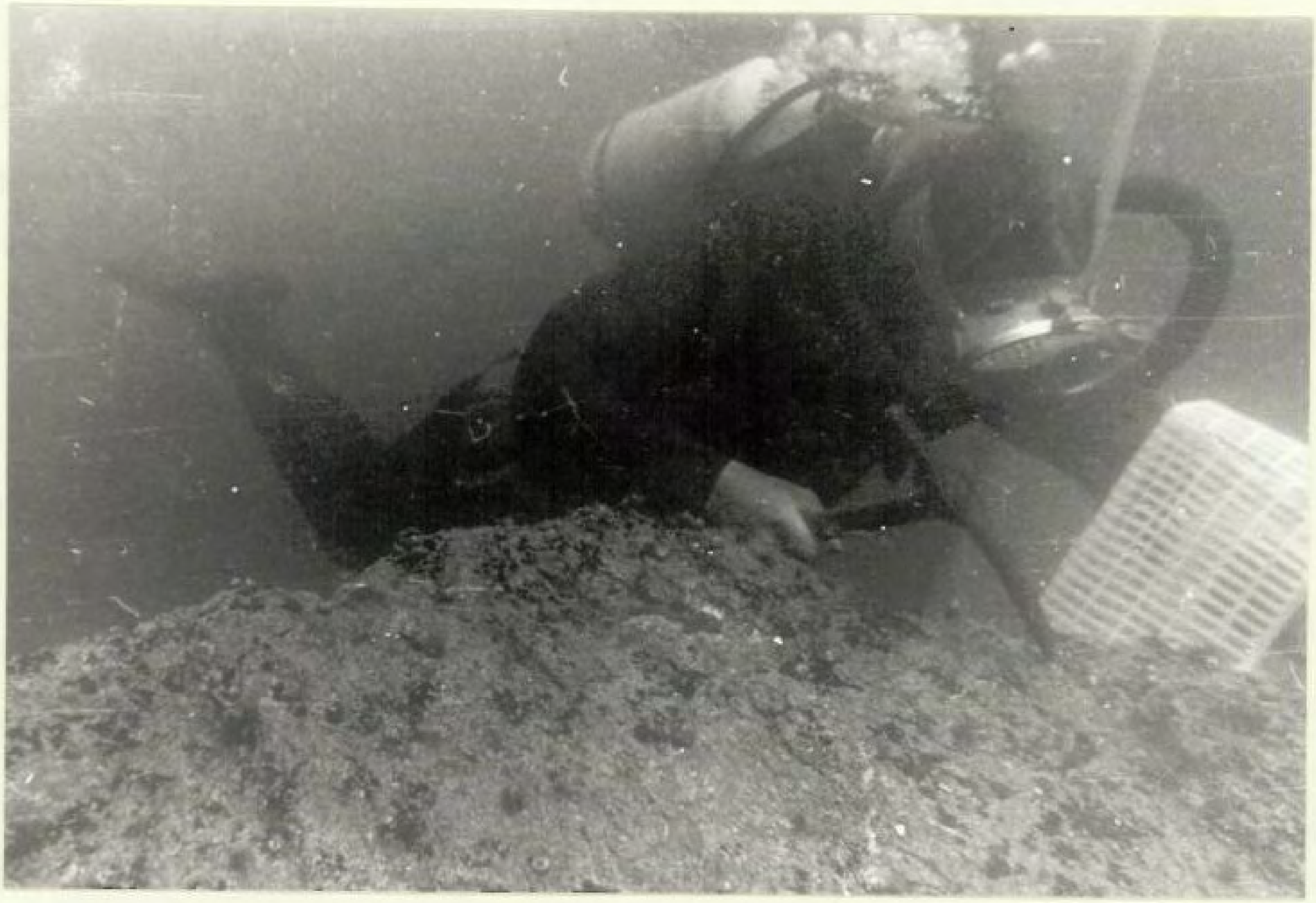
divers and when the operator is without access to any auxiliary equipment other than a simple direct-reading echo-sounder.

SECTION NO.(10). UNDERWATER MAPPING

The same principles apply to geological mapping underwater as to mapping on the land surface, but the technique varies according to the prevailing conditions. With good underwater visibility the geologist may swim along the exposed rock contacts or along the boundaries of the sea-bed outcrop with the diving boat following his movements. In the United Kingdom the visibility is the limiting factor in all the work and is only possible for the diver to make a series of spot dives. The sea-bed geological map is therefore compiled by interpolation from a large number of spot samples and observations of the structure. Underwater mapping may be compared with surface mapping when the visibility is down to a few feet owing to dense fog and it is necessary for the geologist to climb to the tops of numerous trees in order to elevate himself above the fog layer and to fix his position, access between the trees being possible only at the upper level and not on the ground. The procedure adopted was to select from the bathymetric chart areas where the bed-rock was likely to outcrop through the sand cover, and to make a number of spot dives on such areas in order to obtain specimens of the bed-rock and to record all the available geological data.

With the total personel numbering six, the organization took the following form. If the weather indicated that two launchings of the diving boat would be possible (one in the morning and one in the afternoon), two teams of three were selected. From each team two divers for that day volunteered, and the remaining person in each team was in charge of the diving boat as team leader.

Illustration No.(2)



A diver, wearing the complete standard equipment, is seen collecting a specimen from an outcrop on the sea-bed at a depth of 60 feet. He is swimming above one of the 'killas' ridges which are a typical erosion feature in the area.

All the Expedition members assisted in the dressing of the two divers and in the launching of the boat. The team then proceeded to the pre-selected diving location, whilst the second team of three remained ashore, and occupied their time upon the repair of equipment and the maintainance of a watch upon the diving boat.

The person in charge of the boat steered a course for the diving area and upon a pre-arranged signal one of the divers in the bow of the boat threw the anchor over the side as the engine was cut off by the team leader. The time and place of anchoring was decided by the leader since it was possible to take compass bearings and to consult the sextant chart even while steering the boat. Eventually, only experience was necessary to find the position required, the boat frequently being allowed to drift into position under the influence of the wind and the current.

With the boat securely anchored, the leader assisted the two divers in the assembly of their equipment. Immediately the descent had commenced, he took readings with the compass of the bearings on to all the visible coastal survey stations, and made an estimate of the position of the boat. Concurrently with the observations he also continued to watch the progress being made by the divers through noting the position of their exhaust bubbles upon the water surface.

In the event of only one launching being possible a team of four was selected, the other two members remaining ashore. In this case three members of the team equipped for diving. The team leader was again in charge of the boat, and was assisted in the position fixing and boat handling by the spare third diver. One pair of divers descended and the third was fully equipped to immediately enter the water in the event of an emergency. The same diver also interchanged with the other two on subsequent diving locations in order to spread the work and offset exhaustion.

The divers entered the water by the standard manner; simultaneous back somersaults over opposite sides of the boat, which thereby remained steady. Immediately they had entered the water and indicated to the satisfaction of the team leader that they were ready to dive, they were handed the necessary additional equipment; camera, flash bulbs, geological hammer and chisel, geological pick, clinometer (when necessary), and collecting basket for specimens. If for any reason the team leader was of the opinion that the dive should not be carried out the responsibility was vested in him to immediately discontinue the dive and order the divers to leave the water. This was necessary on only two occasions when the leader correctly suspected a mild attack of sea-sickness in one of the divers. Owing to the strong currents prevailing in the area it was essential that the divers should always maintain contact with the boat by means of a rope and down which they made the descent. The rope employed was either the anchor line or a vertical weighted shot line suspended from the side of the boat and of a sufficient length to make contact with the sea-bed. In either case the divers collected the specimens and made the necessary observations upon the sea-bed at the base of the line down which the descent had been made.

Where there was a sand cover on the sea-bed the divers attempted to dig through it in order to make contact with the bed-rock. If this was impossible they returned immediately to the surface and placed some of their equipment on board. While they rested in the water the team leader decided upon the next location for a dive. If only a short distance away, the boat was either allowed to drift to the new location or the motor was started and a rope thrown out for the divers who were then towed behind the boat. This removed the necessity for the extremely exhausting operation of climbing aboard. Frequently a small grappling iron was let out to make contact with the sea-bed and the boat allowed to drift.

As the boat passed over a rock outcrop, the grappling iron engaged with the rock and a person holding the line in the boat detected a slight shudder in the line, even though the grappling iron might be very rapidly torn free from its hold by the movement of the boat. In addition, the lead of the echo-sounder could also be suspended in the water to provide indications of the changes in the topography of the sea-bed. As soon as a suitable location was reached the anchor was again lowered and a further descent made. Even if no rock outcrop was detected the team leader in charge of the boat always found it possible to take a sufficient number of bearings on to the survey stations in order to determine the position of the boat.

When an outcrop was located by the divers they immediately obtained the necessary samples. The mode of erosion of the rock at depth on the sea-bed varies considerably from that in the vicinity of the high and low water marks.

Dive No. 59

Location: St. Agnes
Date: 25th. July. 1960.
Time: 11.15 pm.
In charge of Diving: R.H. Garnett.
Divers: (1) J. Woods (2) G. Wheeler (3)

	J.W.	G.W.		Diving equipment:
Time of start of Dive	11.30	11.35	pm.	J.W. – Dry Suit, Twin Set + 22 lb + camera.
Time of completion	12.50	11.50	am.	
Duration of Dive	20	15	mins.	
Maximum depth of Dive	60		ft.	G.W. – Wetsuit + Twin Set. + 18 lb + Hammer.

Weather: Cloudy. – with Rain.
State of Sea: Swell. – heavy.
Wind: Mod. – Freshening.
Current: No. ½ knot.
Underwater Visibility: 20-30'.
Weather Worsening.

Angle Between: ~~& ... & ... & ... &~~ Compass. Employed.

Bearing to:							
W(1).	80.	95.	→ 88.	St. Ag Hr.	190.	190.	→ 190.
W(2).	100.	108.	→ 104.	B.R.	270.	265.	→ 267.
~~4.~~	130.	120.	→ 125.	N.H.	225.	230.	→ 227.
4 (low).	125.	115.	→ 120.				

Outcrop Located: Yes/~~No~~.
True Outcrop ? Yes/~~No~~.
Sample Obtained: Yes/~~No~~.
Sample Number: 59
Photo. Obtained: Yes/~~No~~.
Photo. Number: See Later.

Method of Descent: Down anchor rope.
Position of Outcrop relative to Boat: Directly beneath the boat.

Physical Description of Outcrop: Killas ridges Str. ESE – WNW
Stony ridges of killas. up to 2' high. above the Sand level.
Have sand than seen before
Killas. Strike ESE-WNW. – dip = West.

Petrological Description of Outcrop: "Killas" occurring in Ridges on the Sea-bed.

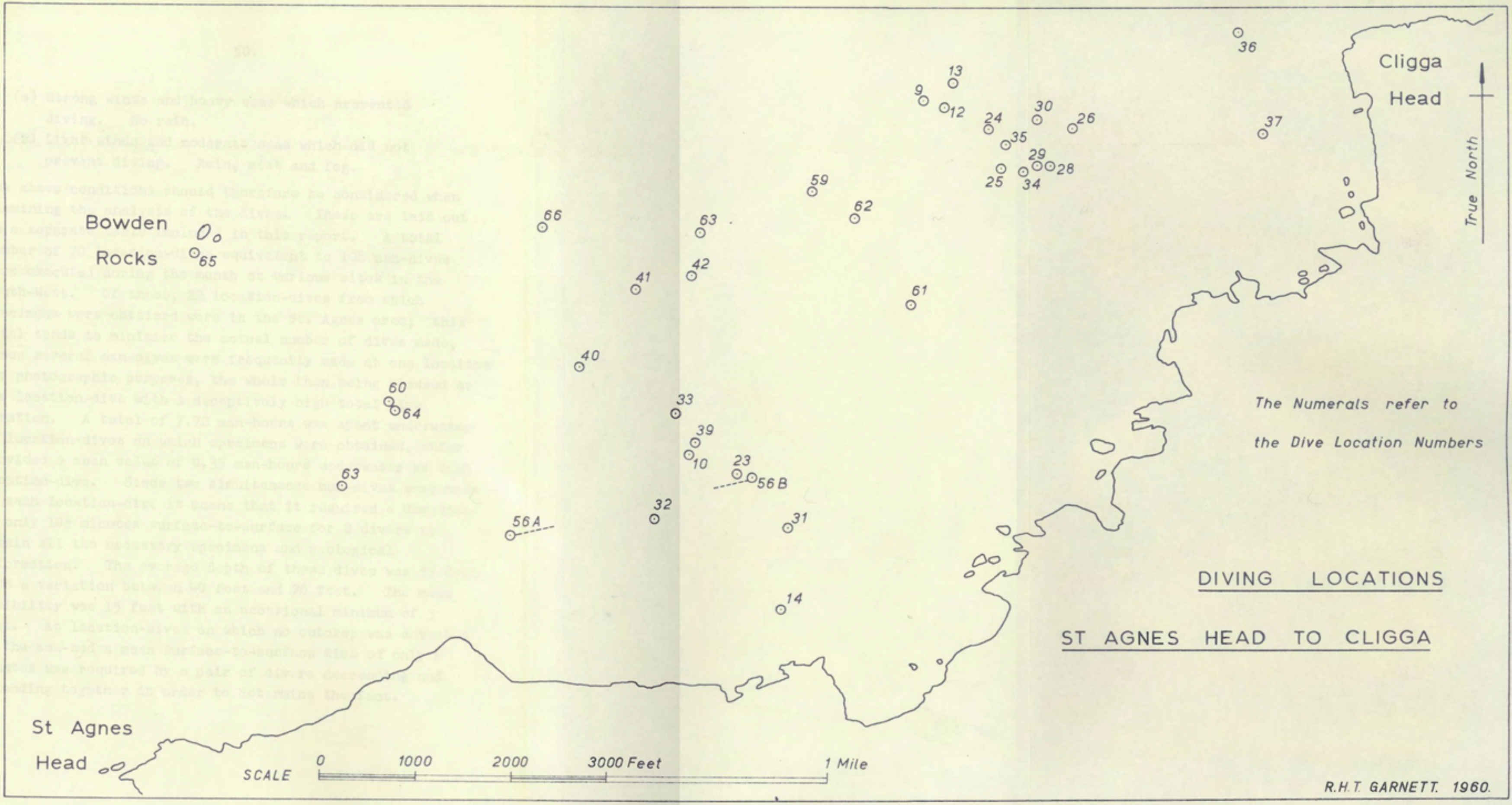
Special Features: Purposes of Dive – Photography of. outcrop.
Could all own place = photo obtain
Lots of photos obtd of outcrop etc.

12.6.60. R.H.T.G.

A typical Diving Log Sheet when completed.

In this region the major erosional factor is the abrasive action of the surf and the various materials suspended in the water. At depth the dominant factor is the effect of the percolating sea water which acts along planes of bedding and cleavage. Gradually cracks are opened up in the rock and marine organisms, both animal and vegetable, obtain a foothold on which to multiply. The pressure exerted by mussels which find a home within the fractures in the rock is sufficient to rupture the latter and to cause large pieces to flake away. In sampling a sea-bed outcrop, more importance was attached to wedging off the required specimens rather than exerting a direct blow. For this reason a 2 lb. pick, or a 2 lb. hammer and chisel, were used by the divers as opposed to a heavier hammer alone. In addition, the water impedes the travel of a hammer and a steady application of force is more efficient than a direct blow upon the surface.

While one of the divers was taking the necessary samples the other would be recording all the observed geological information on an underwater writing pad. This included an estimation of the petrology of the bed-rock, measurements of the dip and strike (where applicable), and observation of the general characteristics of the outcrop. Both divers then returned to the surface and handed their specimens aboard. The written information was given to the team leader who recorded it on the diving log sheet and then issued instructions for a further dive at the same point. The purpose of the second dive was to take photographs and make further geological observations which were partly dependant upon those recorded during the first dive.



Cligga Head
True North
Bowden Rocks
St Agnes Head
The Numerals refer to the Dive Location Numbers
DIVING LOCATIONS
ST AGNES HEAD TO CLIGGA
SCALE
0
1000
2000
3000 Feet
1 Mile
R.H.T. GARNETT. 1960.

On the second dive one of the divers took the necessary photographs, whilst the other executed a circular sweep from the sampling point. This entailed attaching a further line to the anchor. From the free end the diver swam in a circular path, the radius being equivalent to the length of free rope. By inserting knots at regular intervals in the line the diver was able to record his position relative to the anchor at any time by counting the number of knots and by reading the bearing along the line to the anchor with his underwater compass.

When the second dive was completed the divers left the water and the boat proceeded to the next diving location. As described in the Appendix, diving was conducted in not only the St. Agnes area but also at Penzance, Ilfracombe, Falmouth, Mullion, and Levant Mine. Of the number of days on which the divers were available in the St. Agnes area, diving was frequently impossible as a result of the very bad weather conditions. Details of the weather are provided in a table included in the report, and it will suffice to say that the conditions fell far short of those expected for the month of July.

Out of the 30 days spent in the South West of England a total of 23 were available for diving in the St. Agnes area. This number was reduced to 12 by the unsuitable weather. In effect the prevailing weather conditions allowed diving to be conducted during only 50 per cent. of the time. Even on the 12 days during which diving was possible in the area, heavy seas and rain were experienced and frequently only one launching was possible. It was found that the weather took two different forms:-

(a) Strong winds and heavy seas which prevented diving. No rain.

(b) Light winds and moderate seas which did not prevent diving. Rain, mist and fog.

The above conditions should therefore be considered when examining the analysis of the dives. These are laid out in a separate table included in this report. A total number of 70 location-dives equivalent to 108 man-dives were executed during the month at various sites in the South-West. Of these, 22 location-dives from which specimens were obtained were in the St. Agnes area; this total tends to minimize the actual number of dives made, since several man-dives were frequently made at one location for photographic purposes, the whole then being classed as one location-dive with a deceptively high total time duration. A total of 7.72 man-hours was spent underwater at location-dives on which specimens were obtained, which provides a mean value of 0.35 man-hours underwater at each location-dive. Since two simultaneous man-dives were made on each location-dive it means that it required a duration of only 10½ minutes surface-to-surface for 2 divers to obtain all the necessary specimens and geological information. The average depth of these dives was 55 feet with a variation between 40 feet and 70 feet. The mean visibility was 15 feet with an occasional minimum of 3 feet. At location-dives on which no outcrop was detected on the sea-bed a mean surface-to-surface time of only 6 minutes was required by a pair of divers descending and ascending together in order to determine the fact.

(a) Analysis of the Total Number of Dives (including St. Agnes and Penzance, etc.)

Number of location-dives executed 70

Number of man-dives executed 108

Total man-hours underwater 31.23

Mean man-hours underwater per location-dive ... 0.446

Mean depth of location-dive 42.3

Mean visibility per location-dive .... 17 feet

Number of location-dives from which specimens were obtained 30

Mean depth of location-dives from which specimens were obtained .... 48.5 feet

Total man-hours underwater at location-dives from which specimens were obtained 15.3

Mean man-hours underwater per location-dive from which a specimen was obtained 0.51

(b) Analysis of Location Dives in the St. Agnes area from which specimens were obtained.

Number of location-dives executed from which specimens were obtained 22

Total number of man-hours underwater at location-dives from which a specimen was obtained 7.72

Mean number of man-hours underwater per location-dive from which a specimen was obtained 0.35

Mean depth of dives in (b) .... 55 feet

Mean visibility of dives in (b) .... 15 feet

JULY 1960

WEATHER CONDITIONS IN THE ST. AGNES AREA, 100' ALTITUDE

Date July	Wind Speed (Knots)	Wind dirn. (deg.)	Pressure (Millibars) (mid-day)	Temp. Wet (oF)	Temp. Dry (oF)	Humidity (%)	Sea Height (ft)	Sea Period (secs)	Rainfall Total of 4 daily readings m.m.
1.	10	360	1032	56	59½	80	1½	4½	0
2	5	020	1030	-	-	-	-	-	0
3	5	250	1025	-	-	-	-	-	2.28
4	10	230	1026	-	-	-	5	5½	15.75
5	28	250	1015	60½	62½	88	5½	6	0.25
6	20	270	1019	58	60	88	6	5	22.60
7	5	180	1014	56	57	-	4½	6	0.76
8	17	330	1019	58	60½	85	3½	5	Trace
9	15	260	1023	-	60	-	--	--	6.09
10	15	260	1012	-	-	-	-	-	10.92
11	30	270	1015	-	-	-	6½	5½	Trace
12	18	270	1028	-	-	-	-	-	5.84
13	10	220	1021	-	-	-	-	-	0.79
14	18	270	1023	-	-	-	-	-	0.76
15	17	260	1026	56	59	85	4½	5½	Trace
16	7	210	1026	-	-	-	-	-	23.37
17	28	250	1015	-	-	-	-	-	Trace

18	25	230	1020	56½	60	80	7	6½	Trace
19	222	330	1025	58	59	94	6	6½	Trace
20	16	320	1035	56½	60	80	4	5½	Trace
21	18	250	1031	57	58	94	3	4½	1.52
22	25	250	1032	56½	60	86	6½	5	5.35
23	4	100	1026	-	-	-	-	-	4.59
24	15	250	1031	-	-	-	-	-	Trace
25	15	250	1031	56½	59½	79	4½	5½	Trace
26	16	270	1033	-	-	-	4	5½	Trace
27	17	260	1030	-	-	-	3	5	14.22
28	22	240	1022	-	-	-	-	-	1.02
29	20	250	1020	-	-	-	4½	6	0
30	8	180	1022	-	-	-	-	-	0.51
31	12	240	1025	-	-	-	-	-	1.27
								TOTAL	117.89

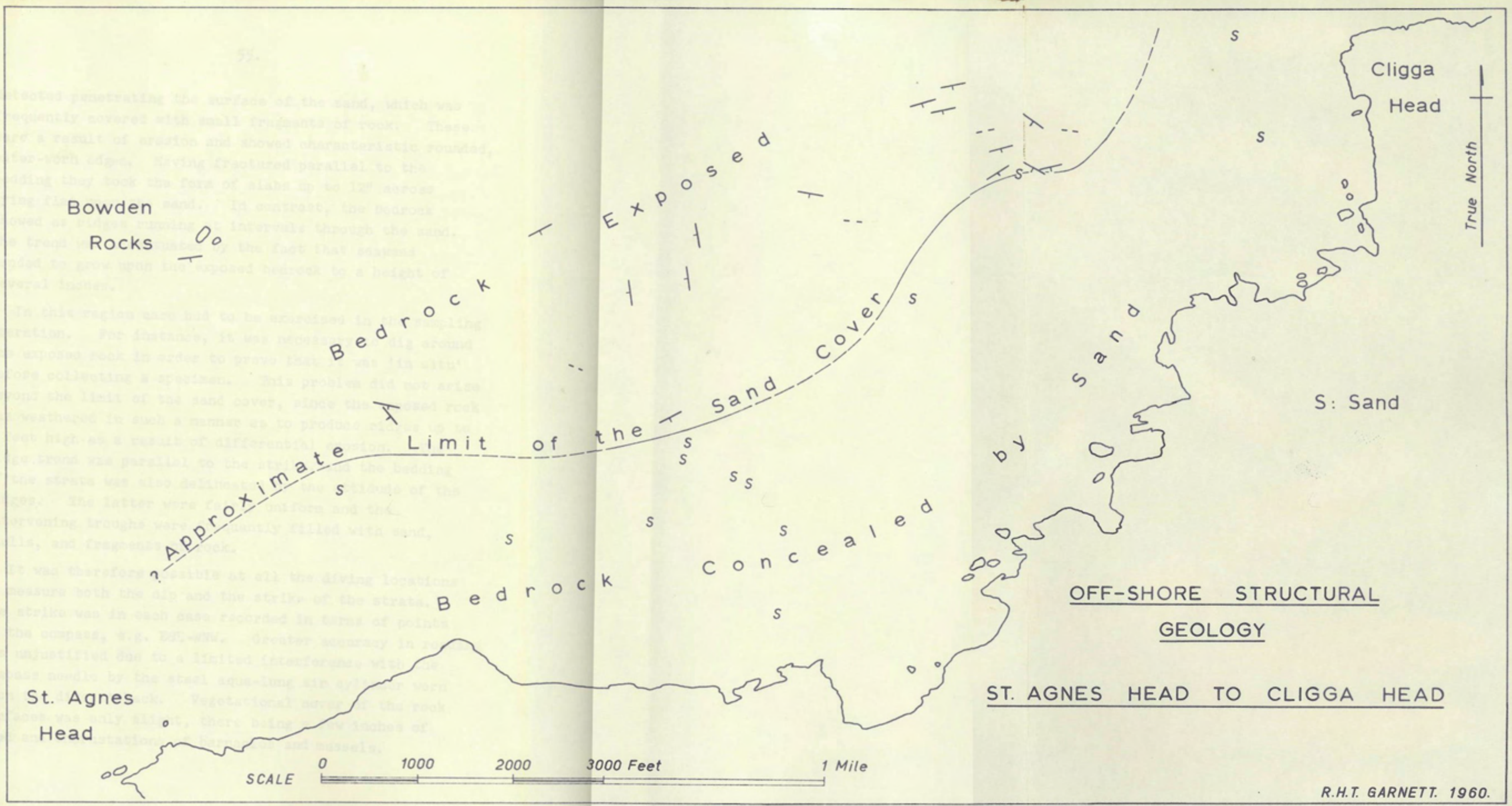
SECTION NO.(11). THE GEOLOGICAL RESULTS.

A total of 34 fixed location-dives were made in the St. Agnes area, and of these 22 yielded specimens of the bed-rock, at the positions shown in Fig. No.(10). At each location more than one specimen was obtained and in the majority of cases a small number of specimens were selected by the divers from an area determined by a circular sweep with a radius of several feet.

Considering the area bounded by Bowden Rocks, St. Agnes Head, and Cligga Head, it was found that the bed-rock was outcropping over approximately 40% of the sea-bed. In the remainder of the area the bed-rock was concealed beneath a sand cover of varying thickness. The limit of the cover may be represented, as shown in Fig. No.(11) by a line parallel to the shore and at a distance of ½ mile from the latter.

At its limit the sand cover was of the order of only 6" in thickness, increasing gradually upon approaching the coastline where it frequently attained a thickness of 6 feet. Although at any time the extent and variation of the thickness of sand cover is uniform there is evidence for large variations with the climaticseasons. For instance, during July the level of the sand surface was observed against the cliffs in Trevaunance Cove. In contrast, during the winter months of 1959-60 there were times when there was no sand present in the Cove. From these observations it was evident that a thickness of 6 feet had been removed during the Winter, only to be replaced during the Summer.

At the limit of the cover the bed-rock could be



Bowden Rocks
Cligga Head
True North
Exposed Bedrock
Approximate Limit of the Sand Cover
Bedrock Concealed by Sand
S: Sand
St. Agnes Head
SCALE
0
1000
2000
3000 Feet
1 Mile
OFF-SHORE STRUCTURAL GEOLOGY
ST. AGNES HEAD TO CLIGGA HEAD
R.H.T. GARNETT. 1960.

detected penetrating the surface of the sand, which was frequently covered with small fragments of rock. These were a result of erosion and showed characteristic rounded, water-worn edges. Having fractured parallel to the bedding they took the form of slabs up to 12" across lying flat upon the sand. In contrast, the bedrock showed as ridges running at intervals through the sand. The trend was accentuated by the fact that seaweed tended to grow upon the exposed bedrock to a height of several inches.

In this region care had to be exercised in the sampling operation. For instance, it was necessary to dig around the exposed rock in order to prove that it was 'in situ' before collecting a specimen. This problem did not arise beyond the limit of the sand cover, since the exposed rock was weathered in such a manner as to produce ridges up to 5 feet high as a result of differential erosion. The ridge trend was parallel to the strike, and the bedding of the strata was also delineated by the attidude of the ridges. The latter were fairly uniform and the intervening troughs were frequently filled with sand, shells, and fragments of rock.

It was therefore possible at all the diving locations to measure both the dip and the strike of the strata. The strike was in each case recorded in terms of points of the compass, e.g. ESE-WNW. Greater accuracy in reading was unjustified due to a limited interference with the compass needle by the steel aqua-lung air cylinder worn upon the divers' back. Vegetational cover of the rock surfaces was only slight, there being a few inches of weed and encrustations of barnacles and mussels.

Massive seaweed was not found to exist below approximately the 5 fathom line and did not prove to be any hindrance to the diver.

A distinct agreement may be found between the bathymetric chart and the area of exposed bedrock. Where the depth contours trend approximately parallel to the coastline the bedrock is concealed by sand, whereas contours unrelated to the coastline coincide with areas of outcrop. Of the areas outlined in Section No.(9) as being likely to provide sea-bed outcrops, only one, two thirds of a mile North of Trevaunance Cove, could not be verified.

Examination of the specimens showed that some were from within the metamorphic aureole of the Cligga Granite, and as a result of the large number collected from this area it is possible to continue the outer limit of the metamorphic aureole beyond the coastline and out to sea, as shown in Fig. No.(12). All the metamorphosed specimens were of the "spotted killas" type from the outer zone of the aureole. The remainder of the specimens, apart from a number between Bowden Rocks and Newdowns Head, showed no signs of metamorphism. To the North-West of Newdowns Head sporadic signs of metamorphism were observed in the bed-rock but further work will have to be carried out in this area before it can be stated whether or not the metamorphic aureole of the St. Agnes Granite extends beyond the coastline to the North of the granite exposure.

As seen from Fig. No.(11), there is a very noticeable variation in the strike throughout the off-shore area and comparison between the bathymetric chart and the strike measurements indicates a correlation between the strike variations and ridges.

The two ridges running North-West from Trevaunance Cove and Newdowns Head coincide with areas in which the predominant strike varied between North and North-West, normal to the coastline. Bowden Rocks proved to be unmetamorphosed "killas" so extensively veined with quartz that the mineral formed approximately 90 per cent. of the rocks by volume.

Although it is desirable to continue work in this off-shore area, the limited amount of results obtained indicated that the metamorphic aureole of the Cligga Granite is more extensive than is supposed by examination of the land surface alone. The platform appears to be an old erosion feature, and the changes in elevation upon the platform to be due to the attitude of the folding in the "killas", variations in the degree of metamorphism and the intensity of quartz veining. The outcropping dyke was traced for a short distance across the sea-bed from Newdowns Head to Trevaunance Cove but it was largely hidden beneath the sand cover. No outcropping lodes were detected off-shore but this is not surprising for two reasons:-

(a) Lode material is more quickly eroded than the surrounding wall-rock and an outcropping lode would appear on the sea-bed only as a sand-filled trench which would not be distinguishable from a sand-filled trough between two ridges of "killas".

(b) The visibility was such that a diver could have swum within 15 feet of an outcropping lode and have been unaware of the fact.

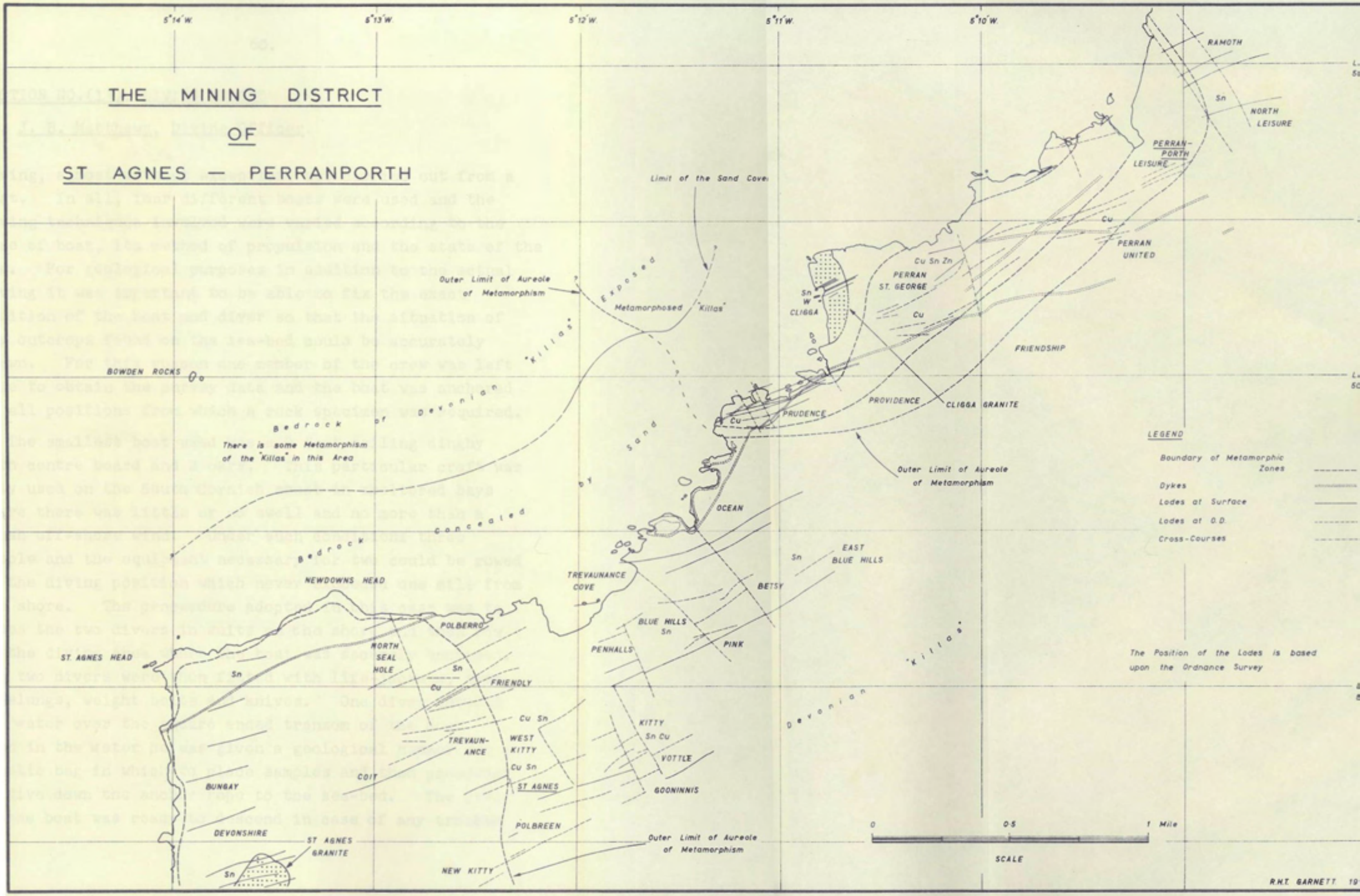
The existence of lodes is more likely to be detected in future work by geochemical examination of the specimens of "killas" and adaptations of other standard techniques of land mineral exploration (8).

N.B. All specimens and thin sections connected with this work have been deposited in the Department of Geology, Imperial College, London, S.W.7.

SECTION NO.(12). CONCLUSIONS

The completed work has enabled the writer to outline the limits of the aureole of metamorphism surrounding the Cligga Granite in the off-shore area and to indicate that the aureole of metamorphism of the St. Agnes Granite may have a greater Northerly extension than previously recognized. No granite exposures were located within the area and it is unlikely that any large outcrops are concealed by the sand cover parallel to the coast. However, the configuration at depth of the Cligga Granite is suggested by the surface form of the metamorphic aureole. Previous workers have mentioned the possibility of the existence of a crest in the granite surface extending in a North-Westerly direction from the Cligga Granite at depth and Fig. No.(13) illustrates the possible location of such a crest.

Great difficulty was caused in the work by the existence of the belt of sand cover parallel to the coastline and which could not be penetrated by the divers in the sampling operations. It is suggested that further work should be carried out in this area and a suitable method is outlined in Section No.(21).


THE MINING DISTRICT OF ST AGNES — PERRANPORTH
5°14'W.
5°13'W.
5°12'W.
5°11'W.
5°10'W.
RAMOTH
Sn
NORTH LEISURE
PERRAN-PORTH
LEISURE
Limit of the Sand Cover
Cu
PERRAN UNITED
Cu Sn Zn
PERRAN ST. GEORGE
Outer Limit of Aureole of Metamorphism
Exposed
Metamorphosed "Killas"
Sn W
CLIGGA
Cu
"Killas"
FRIENDSHIP
BOWDEN ROCKS
Bedrock of Devonian
PROVIDENCE
CLIGGA GRANITE
Cu
PRUDENCE
There is some Metamorphism of the "Killas" in this Area
Sand
by
LEGEND
Boundary of Metamorphic Zones
Dykes
Lodes at Surface
Lodes at O.D.
Cross-Courses
Outer Limit of Aureole of Metamorphism
OCEAN
Concealed
Bedrock
Sn
EAST BLUE HILLS
NEWDOWNS HEAD
TREVAUNANCE COVE
BETSY
POLBERRO
BLUE HILLS
Sn
"Killas"
ST AGNES HEAD
NORTH SEAL HOLE
PENHALLS
PINK
The Position of the Lodes is based upon the Ordnance Survey
Sn
Sn
Cu
FRIENDLY
Devonian
Cu Sn
TREVAUN-ANCE
WEST KITTY
KITTY
Sn Cu
VOTTLE
Cu Sn
COIT
ST AGNES
GOONINNIS
BUNGAY
DEVONSHIRE
POLBREEN
0
0.5
1 Mile
ST AGNES GRANITE
Outer Limit of Aureole of Metamorphism
SCALE
Sn
NEW KITTY
R.H.T. GARNETT

SECTION NO.(13). DIVING REPORT

by, J. B. Matthews, Diving Officer.

Diving, almost without exception, was carried out from a boat. In all, four different boats were used and the diving techniques involved were varied according to the size of boat, its method of propulsion and the state of the sea. For geological purposes in addition to the actual diving it was important to be able to fix the exact position of the boat and diver so that the situation of any outcrops found on the sea-bed could be accurately known. For this reason one member of the crew was left free to obtain the survey data and the boat was anchored at all positions from which a rock specimen was required.

The smallest boat used was a 9 foot sailing dinghy with centre board and 2 oars. This particular craft was only used on the South Cornish coast in sheltered bays where there was little or no swell and no more than a fresh off-shore wind. Under such conditions three people and the equipment necessary for two could be rowed to the diving position which never exceeded one mile from the shore. The procedure adopted in this case was to dress the two divers in suits on the shore and then row to the diving area where the boat was securely anchored. The two divers were then fitted with life-jackets, twin aqualungs, weight belts and knives. One diver entered the water over the square ended transom of the boat. When in the water he was given a geological hammer and a plastic bag in which to place samples and then proceeded to dive down the anchor rope to the sea-bed. The diver in the boat was ready to descend in case of any trouble and the diver himself never left the anchor rope since it was only necessary for him to obtain a rock specimen. The anchor rope was used to receive and transmit signals between diver and surface. The third member was left free to fix the boat's position from compass bearings.

Using the 9 foot dinghy under flat calm conditions when the position of the boat was not required (as for example when cine-filming or conducting 2nd class divers' tests) it was found possible to have two divers in the water at a time. In this case the two divers and oarsman kitted up in suits on the shore and rowed out to the diving position with the equipment required for 3 people. The boat was anchored and all five fitted lungs etc. The two divers entered the water over the transom as before and were roped together. The third diver raised the diving flag and acted as snorkel cover. The two divers took cine and still photographs using this method in depths of water never greater than 35 feet and under very calm conditions. Also, in such circumstances when there was not enough wind to produce white crests on the sea surface it was possible to send a solo free diver down to carry out a search and, by rowing the boat, to follow the diver's bubbles. This method could only be practised in exceptionally calm conditions with only one diver in the water, one fully kitted in the boat ready to dive and observing the bubbles, and a third member rowing the boat. Since the majority of diving was carried out on the North coast this method was only practised on two occasiona and in both cases in water shallow enough to allow the diver to be seen from the boat.

The majority of the diving took place from St. Agnes where the members had the use of one of two 14-foot boats. One of these, 'The Hawk', was a converted sailing boat with a centreboard casing boarded up and fairly low gunwhales. The 'Hawk', being old, had a tendency to leak and ship water over the gunwhales which necessitated much bailing and attention to the load and its distribution. The other boat 'Pandora III' an Orkneys-built fishing boat with higher sides and a broader beam than the 'Hawk' was much more suited to carrying divers and equipment in the seas experienced on the North Cornish coast. Both boats were fitted with a 3½ H.P. outboard motor and carried oars, rowlocks and an anchor. In planning the diving it was essential to know the wind direction and state of the tide since a Northerly wind generally made it impossible to push the boat out from the beach and even with a Southerly wind it was difficult to put out at high tide due to the swell surf on the shingle.

In the 'Hawk' and 'Pandora' four persons were always taken out at a time with two kitted up in diving suits. The boat was rolled to the water's edge on a trolley and there the lungs, weight belts, hammers, charts etc. were loaded. The boat was then pushed into the water, still on the trolley, by all six members of the party. As soon as the boat was afloat the two non-divers climbed aboard and rowed whilst the two divers weighed down on the stern so that the surf did not cascade over the bows. As soon as the surf was left behind the divers climbed aboard and the motor was mounted and started. Meanwhile the shore party pulled the launching trolley from the surf to a point above high water mark.

The boat was rowed to keep the bow head-on to swell whilst the motor was started. If the motor would not start after some considerable time the boat could be rowed to some inshore diving position and diving carried out there. If the motor started and the seas were not too rough, at the discretion of the Diving Marshall, the boat was headed for one of the further diving positions. The member acting as navigator used the compass and chart to select the required site and at his signal the anchor was dropped and the motor switched off. In all seas in which it was possible to launch the boat the lungs and weights could be fitted at sea. This proceedure was found desirable since after a boat trip in full equipment the divers were uncomfortable and not in the best of spirits, as is required for diving. Once the boat was anchored the divers were kitted up and after safety checks for equipment one diver rolled over the gunwhale into the sea. Both divers wore a life-jacket, twin aqualung set, weight belt, depth gauge, mask and snorkel. In entering the water from the boat, if one hand was kept on the gunwhale the diver did not cause a splash sufficient to swamp the boat nor lose the boat itself. Once in the water the diver was handed a hammer and a sample basket and then dived down the anchor rope. If only sand was found the diver reported the fact and re-entered the boat which moved to a new position. If rock was found the diver obtained a sample from the vicinity of the anchor noting the depth of the sea-bed. and all relevant geological features. The second diver remained ready to enter the water if the diver did not surface after five minutes in 60 feet of water.

Meanwhile, the navigator in the boat fixed the boat's position using known survey points and the other member wrote the dive details down, kept watch on the weather and, if in the 'Hawk', bailed out. On some occasions when the two divers were used a third member in the boat was kitted up ready to dive. In this case one diver obtained a sample from the bed whilst the other diver using a rope fixed to the anchor swam in a circle to obtain a general picture of the outcrop. All information about every dive was entered on the diving record sheets in the boat before the anchor was weighed. When the dive was completed the diver, using a snorkel, handed his weight belt into the boat and was pulled aboard. If two divers were in the water they used opposite sides of the boat to maintain a correct balance. Sometimes when the next diving position was only 100 or 200 yards away the boat was rowed or allowed to drift to the new location with the divers grasping a rope over the stern. The depths and durations of dives were on no occasion great enough for decompression to be required.

If the state of the tide was such as to allow landing and re-loading two diving trips were carried out in one day. Usually the two shore members from the first dive were divers on the second trip since they were still fresh. During the actual diving the diving flag was flown from a small mast and the local coastguards and officials had been warned beforehand of its significance.

On only three occasions a 28 foot boat with an inboard diesel engine was used at Ilfracombe. With this particular craft the boat handling was carried out entirely by a hired crew and the diving party was left free for diving operations.

The divers kitted up in the boat whilst the latter was still in the harbour and put lungs and weight belts on at the diving location. To enter the water the divers jumped overboard from the boat which was lying at anchor. They were roped together with a 10 foot line and to the boat with a 60 foot line. Conditions on these two occasions were such that the descent required the use of the anchor rope to prevent the divers from being swept away in the current. Both dives were abandoned since conditions proved to be too unsuitable for any useful results to be obtained. The safety precautions on this boat proved satisfactory.

An aquaplane consisting of flat board with a rudder and hand-controlled elevators was towed behind the 17 foot motor-powered boat on a 120 foot line. The aquaplane could be controlled by one hand leaving the other free for clearing the ears. To dive or ascend the best method was found to be to move bodily forwards or backwards in order to tilt the plank in the appropriate direction. The hand-controlled fins were used as very effective stabilizers. As little or no movement was required by the diver he used little air but felt the cold much more rapidly than when swimming free. The method is very desirable for quick underwater surveys but requires a confident, experienced diver and a careful watch kept from the boat since it is open to a number of dangers. It was found preferable for safety reasons to attach a weight belt to the plane to make it negatively bouyant, the diver using his normal weights.

DIVING SITES

by J. B. Matthews, Diving Officer

ST. AGNES

18 foot tides twice daily. Atlantic swell.
No harbour facilities.
14 foot boats are available for hire with outboard motors.
A Westerly current along the coast has proved fatal at beaches near by but not in the Trevaunance Cove area.
Sandy bay but with rocks on West edge of cove.
Lobsters, crabs and spider crabs within snorkel depth.
In the bay half a mile off-shore crawfish were seen frequently.
There are parking facilities above the beach with steep road down to sea level.
Lobster fishing practised.

SWANPOOL

Sheltered bay, little swell.
Mostly sandy bay. No harbour.
Rocks extending from Westerly shore for about 200 yards.
Within snorkel depth in the West there are many varieties of seaweed but in the seaward edge of the rocks there are five foot laminaria growths.
Many fish including two small dogfish or sharks were seen.
A small boat can be taken from the road straight onto the beach.
Parking facilities.

COVERACK Harbour and slipway, boats for hire.
A one in six road leads into the village and limited parking facilities are available.
The bay is very sheltered from North-West and West winds.
Mostly sandy with rocks extending from shore about 800 yards in some places. Covered in five foot laminaria.
Many fish. Lobster fishing practised.

MULLION Harbour and slipway. Boats for hire.
Limited parking facilities.
Shallow water between island and mainland, rocky bottom covered in five foot laminaria, many fish.
Lobster fishing practised.

MOUNTS BAY PENZANCE Harbour at Penzance with boats for hire.
Access to beach is direct from road only at the harbour and at Marazion.
Bay of sand with rocky outcrops covered in laminaria.
Large fish seen out in the Bay particularly near the Gear and Long Rock beacons.
Parking facilities at Marazion, Long Rock and Penzance.

SECTION NO.(14). EQUIPMENT - by G. Wheeler, Equipment Officer.

The main requirements of the Expedition from an Equipment viewpoint were as follows:-

1. Transport sufficient to carry six people together with the Diving Equipment.
2. An adequate Store and Diving Base, from which to operate.
3. A motor boat capable of carrying four persons, three of whom were fully equiped for diving.
4. Diving Equipment together with spares to fully equip three Divers.

SECTION (A) - DETAILED LIST OF EQUIPMENT

Transport Equipment

1. 10 h.p. car
2. Motor Scooters
1. 14 ft. dinghy with 3½ h.p. Seagull Motor.
1. 9 ft. dinghy with trailer

Diving Equipment

2 Wet suits
2 1-piece dry suits (Dunlop)
4 2-piece dry suits
6 Siebe Gorman and Hienke Bottles of 40 cu.ft. capacity made up into three twin-sets.
1 ex-W.D. bottle with capacity 60 cu.ft.
1 Hienke Venturi action valve
4 Siebe Gorman Mistral valves
2 Sea-Lion valves
6 Siebe Gorman and Hienke pressure gauges

4 Dunlop mk.2 weight belts: 76 lbs of lead cast into 2 lb. and 4 lb. weights.

3 Beaufort mk.4 like-jackets plus two spare inflators.

2 depth gauges with built-in compasses.

2 champion spear guns

1 G.E.C. underwater torch

1 adapted Ever-Ready waterproof torch

2 Hienke knives

1 three-bottle manifold

1 bottle tester

1 lb. French Chalk

50 ft. ½" grass rope

100 ft. ½" grass rope

100 ft. 1" grass rope together with anchor

60 ft. ½" nylon rope

1 Diving flag (Royal Navy numeral 4)

1 underwater camera case with flash equipment to fit an Agfa Silette 35 m.m. camera

1 Aquaplane

Repair Equipment

1 Dunlop suit repair kit

2 Beaufort mk.4 life jacket repair kits

2 adjustable spanners and several open ended spanners.

Camping Equipment

1 Ridge Tent with fly sheet - 15' x 10' x 10'

3 ground sheets

6 sleeping bags

1 first-aid kit

Geological and Surveying Equipment

1 20" Vernier Theodolite
1 Theodolite tripod
1 Box Sextant
2 oil-filled compasses
1 three-lb. geological hammer
1 geological pick
1 steel chisel
2 specimen collection bags
1 echo-sounder
1 set of drawing instruments
Admiralty charts
Ordnance Survey maps
Sextant Charts
Aerial Photographs
Diving Record Sheets
Diving Log Book

SECTION (B) - DETAILED DESCRIPTION OF EQUIPMENT

(a) Land Transport

It was necessary to transport six divers together with the day's diving equipment across ten miles of some of Cornwall's steepest hills. Using the vehicles available it was found that this was possible by using two motor scooters and one ten-horse power Austin with Trailer. The only disadvantage with this system was the complete dependence of the expedition upon the road-worthiness of three semi-reliable machines.

(b) Sea Transport.

The boats used during the work at St. Agnes were one

14 foot length dinghy with $3\frac{1}{2}$ h.p. outboard motor; secondly, a 10 foot dinghy with outboard motor. Difficulty was experienced in both launching and landing since the boats had to be propelled through the surf to the open sea or beach. The anchor consisted of a $\frac{1}{2}$ cwt. cast iron weight attached to a 100 foot rope. This enabled the boat to be anchored comfortably in 60 feet of water or with difficulty to a maximum depth of 80 feet. At localities beyond St. Agnes the small dinghy was used under calm conditions only, when it was anchored with a grappling iron on a 50 foot grass rope. This system worked satisfactorily provided a diver released the anchor on surfacing. During the dive at Ilfracombe and Levant Mine respectively, the following boats were used:-

(1) 27 ft. x 7 ft. open motor boat with a 15 h.p. motor.

(2) 27 ft. x 9 ft. open fishing boat with a 33 h.p. motor.

(c) Aqualungs.

Six 40 cu. ft. bottles and one 65 cu. ft. bottle were assembled in the form of three twin-sets and one single set. It was found that the twin sets were necessary to provide a certain number of dives without the necessity of changing aqualungs. In addition, the twin-sets were more convenient for refilling and for handling in the boat. Two bottles were found to leak at the taps, but it was thoughtthat this was the result of the constant use and may be rectified by an overhaul.

(d) Demand Valves

In continual use were 3 Siebe Gorman Mistral demand valves and one Hienke Venturi demand valve, together with two Sea Lion valves as spares. The Hienke Valve gave no trouble and the occasional leaks experienced with the Mistral valves were due to the unnoticed loosening of joints and were easily rectified. Pressure gauges were fitted to all the aqualungs and whilst the Hienke gauges proved to be more often in correct adjustment compared with the Siebe Gorman gauges they were found to leak more frequently being of a less robust construction. The polythene sealing washers on the bottles and twin manifolds were the only parts requiring constant replacement.

(e) Bottle Tester.

Since the bottles were used almost every day, the pressures within them were known at all times. The bottle tester was therefore useful only for its pressure gauge, which was employed as a spare for the demand valves.

(f) Diving Suits

Included in the equipment were four Dunlop two-piece dry suits; two Dunlop one-piece dry suits; one Tarzan wet suit, and one home-assembled wet suit. Of the two makes of dry suit the two-piece was preferred, being easier to put on and remove. The Tarzan wet suit was more comfortable in use, and was therefore worn a larger number of times by various divers. The home-assembled wet suit was worn to the same extent, but being designed personally for one expedition member, and not constructed of such an elastic material as the Tarzan suit, was worn by only one member. The Tarzan suit required hardly any repairs, since, with careful handling it was not easily torn.

The home-assembled suit, however, required repairing on several occasions because the seams had a tendency to separate. This was due mainly to the adhesive and could perhaps be avoided by the use of an adhesive other than Evo-Stik. The majority of the members preferred the wet to the dry suits. The advantages of the former are:-

1. Quicker and easier to put on and remove than the dry suit.
2. More comfortable in use than the dry suit. There is no possibility of pinching at depth in a wet suit.
3. No venting is necessary.
4. No special clothing is required.
5. Leaks are not so annoying.

The disadvantage of the wet suit was that it gave no protection to the wearer as the boat returned to the shore following a dive. The dry suit, however, could be inflated by mouth and the wearer insulated from the cold.

(g) <u>Bottle Filling Manifold</u>

The aqualungs were refilled from a bank of large 165 cu.ft. and 120 cu.ft. compressed air cylinders. A 3-branch copper pipe manifold with a fitted pressure gauge was employed. This proved to be adequate but a more efficient and convenient manifold would be a 4-branch type with flexible piping. The constant bending of the copper pipes on the one employed tends to weaken the joint, and strain hardens the pipes to such an extent, that they eventually become extremely difficult to bend to the required shape.

(h) Aquaplane

The aquaplane was towed behind the 14 ft. dinghy when powered by the $3\frac{1}{2}$ h.p. Seagull outboard motor. It was found that the maximum depth obtainable was 50 feet when the engine was running at half throttle. When towed at full throttle, the diver riding on the aquaplane found it impossible to reach depths below 30 feet.

(i) Additional Diving Equipment.

Additional items were the personal preference of individual divers. All used straight snorkels with no valves. A liking for Tarzan Compensator Masks was apparent since the task of clearing the ears requires the use of only one hand. This fact can be important if the diver is carrying a specimen bag, or trying to descend along an anchor rope in a strong current. Full-foot flippers were popular but almost impossible to fit over a dry suit, whereas they could be fitted easily over the bootees of a wet suit.

(j) Camping Equipment.

Members slept in a Ridge tent kindly loaned by the Zoology Department of the Royal College of Science, whilst sleeping bags were supplied by the Imperial College Exploration Board. Meals were provided by Mrs. P. Cokes of the Glen, Porthtowan, on whose ground the tent was pitched.

(k) Life Jackets

Three Beaufort Mk.4 Life Jackets were in use together with two repair outfits. The life jackets were worn over the neck and tied around the body with tapes.

Inflation is either by mouth through a tube or, in an emergency, by breaking a bottle of carbon dioxide within the jacket. The Repair Kits contained a new carbon dioxide cylinder complete with a lever for breaking the latter. Both kits were used owing to the jackets being accidentally inflated during diving. The main fault to be found with the life jackets was that they leaked through the mouth-inflation tube and valve, and also that the water collecting inside was difficult to remove except by disconnecting the access panel to the carbon dioxide cylinder. The jackets also leaked while inflated through the valve, and, while not being dangerous to a conscious person floating, they would eventually fail to support an unconscious diver on the surface. These faults apart, the jackets proved to be satisfactory, being comfortable in use and capable of easily supporting an exhausted diver on the surface until he could be picked up by a boat.

(l) Weights and Weight Belts

The weight of lead available totalled 80 lbs. and was cast in 2 lb. and 4 lb. units. When carried on the four Dunlop aquafort Mk.2 belts difficulty was experienced in sliding the weights along the belt, since the very small deformations of the weights resulted in jamming with the eyelets.

(m) Depth Gauges

Two combined depth gauges and compasses were in use on each dive. Neither was found to be entirely satisfactory owing to incorrect calibration. One read 10 ft. low and the other approximately 5 ft. high.

Eventually both gauges ceased working, probably due to the presence of sea water inside the gauge mechanism itself. The compasses, as might be expected, were affected by the steel aqualung bottles, but could be used satisfactorily to determine the rough direction of ridges of rock outcrop. Before use underwater, it was necessary for the divers to ensure by means of a bubble, that the gauges were held horizontally before a reading was taken. This was sometimes not easy due to the current or swell.

(n) Underwater Torches

One G.E.C. Underwater Torch was loaned and found to be completely useless. Water entered the compartment containing the reflector and bulb as soon as the torch was immersed in the water. The reflector quickly became covered in a thick layer of corrosion.

(o) Knives

Owing to the abundance of a thick growth of seaweed frequently attaining a length of six feet or more, the divers each found it necessary to carry a knife during all the dives. Out of four knives taken on the Expedition, two Hienke knives and one floating knife were lost while diving.

(p) Spear Guns

Two Spear Guns were loaned by Messrs. Lilywhites and were found to be of a very satisfactory design. They were elastic-propelled, approximately three feet in length, and capable of considerable accuracy at short range, depending upon the skill of the person using them.

Although the design of the guns was satisfactory, it was found that the materials used in their manufacture were not so. The safety catch on one of the guns became completely corroded (in the off position) into the handle. The catch was made of brass and the handle of some light aluminium alloy. The other gun was similarly affected but to a lesser degree, and although the safety catch became very stiff, it was kept free by the use of light oil and grease. The wire catch on the end of the elastic which engaged in the notches of the harpoon also broke on one of the guns while loading in the water. It was found advisable to thoroughly wash the guns in fresh water and quickly dry immediately after use.

SECTION NO.(15). PHOTOGRAPHIC REPORT - by J. D. Woods, Deputy Leader and Photographer

A large number of photographs, both surface and submarine, were taken during the expedition. 50 of the best monochrome prints have been mounted in an album and are now lodged in the Haldane Library*. The colour photos have been used for illustrating lectures on the expedition.

General details

A variety of 35 mm. cameras were used - all proving satisfactory. The surface shots presented no difficulty, but the combined effect of salt, sand, and sea spray caused mechanical failure of three of the cameras. For under-water shots an Agfa Sillette was used in a new commercial housing. Despite trouble with this housing at depths greater than 30', several successful photographs were taken both in colour and black and white.

Comments and recommendations for future expeditions

1. All the cameras to be taken on the expedition should be thoroughly overhauled before leaving.
2. Cameras should be protected when not in use in a strong waterpooof box - this is particularly important when out in an open boat. Suggested size:- 12" cube with hinged lid.
3. During the Cornish Expedition the success ratio was 1:3 for surface shots, and 1:20 for underwater shots. Although these values could undoubtably be improved, especially the latter, the number of photos.taken must allow for unavoidable wastage of this order.

*Imperial College.

4. Each film should be developed (with the exception of colour) immediately after being exposed, to allow time for repeat shots, if necessary.
5. At least one photographer should gain as much experience as possible in underwater photography before leaving on an expedition.
6. One camera should be reserved exclusively for use underwater. On no account should surface and underwater shots be mixed on the same film.
7. The use of flash for underwater photographic photos is recommended, but with care a lot of available light work can be accomplished in relatively shallow water. Films recommended are Agfa colour, and FP3 or HP3.

Technical details of underwater camera housing

details	method	comments	suggested method
camera housing construction	Cast Aluminium	Corrodes	should be Anodised
Front plate fastening	Brass bolts	Aluminium: Brass joint corrodes	separate brass and aluminium with plastic sleeve.
Front plate sealing	O ring	Satisfactory	no change
Film wind-on	rotating brass coupling	"	"
Focusing	rotating brass rod with O ring drive on to front lens element	"	"
Aperture	Plunger with mechanical coupling	hydrostatic pressure operates this	similar to focus control
Shutter release	Plunger, direct action	"	rotating trigger.

SECTION NO.(16) ACKNOWLEDGEMENTS

The Members of the Expedition are indebted to the following organizations and persons for the loan of equipment and instruments.

Lilywhites Ltd., London -

- 2 depth gauges with built-in compasses.
- 2 Champion spear-guns.
- 1 G.E.C. Underwater Torch.

The Imperial College Union Underwater Club -

- All Club diving equipment

The Imperial College Exploration Board -

- 6 sleeping bags (Black Icelandics)
- 1 primus stove

The Department of Zoology, Imperial College -

- 1 ridge tent and groundsheets

Mr. J. S. Sheppard, Department of Mining, Royal School of Mines -

- One 20" vernier theodolite with tripod.
- 1 box sextant.
- Admiralty charts

Mr. D. Lambeth, Imperial College -

- One 60 cu.ft. compressed air diving bottle.
- 1 Heinke Venturi action valve
- Assorted lead weights.

Mr. D. H. McSorley, Marine Electronics Ltd.

- 1 echo-sounder.

Mr. J. S. Sheppard, Royal School of Mines, very kindly placed at the disposal of the Expedition the use of the surface

buildings of the Tywharnhayle Mine, Porthtowan, where all the Expedition equipment was stored.

Hospitality and meals were provided by Mr. and Mrs. C. Cokes, "The Glen", Porthtowan, in whose grounds the tent was pitched.

The 14 ft. dinghy and $3\frac{1}{2}$ h.p. Seagull outboard motor were hired from Mr. B. Reynolds of St. Agnes.

Secretarial services were provided through Mr. D. H. Batchelor, Manager, Geevor Tin Mines, Limited., Pendeen, Cornwall.

SECTION NO.(17). FOOD SUPPLIES - T. Long, Assistant Equipment Officer

Food for the Expedition was very kindly provided by the following firms:-

Tea bags: 8 x 30 tea bags - W.H. & F.J. Horniman & Co. Ltd.

Complan: 4 x 2 lb. tins - Glaxo Labs. Ltd.

Ovaltine: 3 x 1 lb. tins - A. Wander Ltd. London, W.1.

Ostermilk: 6 x 1 lb. tins - Glaxo Labs. Ltd.

Horlicks: 1 x 1 lb. tin - Horlicks Ltd.

Coffee: 1 doz. 2 oz. tins - The Nestle Co. Ltd.

Golden Syrup: 9 x 1 lb. tins - Tate and Lyle, Ltd.

Cheese: 8 x 1 lb. tins - Kavli Ltd.

Tomato Sauce: 2 x 3¾ oz. tubes - Keddie Ltd.

Primula Crispbread: 4 x 8 oz. packets - Kavli Ltd.

Ovaltine Biscuits: 1 x ½ lb. packet - A. Wander Ltd.

Marmite: 2 x 4 oz. tins - Marmite Ltd.

Soups: 33 x 2 oz. packets - Anglo-Swiss Food Products Ltd.
12 x 2½ oz. packets - W. Symington & Co. Ltd.
12 x 2 oz. packets.

Horlicks tablets: 6 doz. rollpacks - Horlicks Ltd.

Boiled Sweets: 2 x 7½ lb. tins - Pascall sweets.

Chocolate: 6 doz x 2 oz. bars - The Nestle Co. Ltd.

Kendall Mint Cake: 24 doz. bars - Geo. Romney Ltd.Kendall.

John Player and Sons: 400 Medium Navy Cut Cigarettes in 50's airtight tins.
4 oz. Medium Navy Cut Tobacco in 1 oz. airtight tins.

SECTION NO.(18). FINANCIAL STATEMENT

Income:

	£.	s.	d.
Granted by the Imperial College Exploration Board	70.	0.	0.
Granted by the Geevor Tin Mines Ltd.	30.	0.	0.
Personal contribution by the Members of the Expedition - 6 x £25	150.	0.	0.
	£250.	0.	0.

Expenditure:

Accomodation, meals etc.	96.	0.	0.
Land Transport, including members and equipment	72.	6.	4.
Hire of diving boat	20.	5.	0.
Compressed Air	17.	14.	6.
Photography	15.	3.	5.
Additional Food	5.	2.	11.
All other Expenses, including surveying equipment, administration etc.	23.	7.	10.
	£250.	0.	0.

Considering the expenditure listed above it would appear that the total work was completed at a net cost of £250. However, this figure is deceptive owing to the following factors:-

(a) It includes the cost of accomodation and meals for the entire team.

(b) It excludes any wages that would have to be paid to a professional team for such work.
(c) It excludes the initial capital cost of the diving equipment.
(d) It excludes insurance of both the personel and the equipment. (This cost was met by the Imperial College Exploration Board and appears on a separate account).

Nevertheless, the total expenditure is abnormally low when considering the duration of the work and the amount of results obtained from an area which was so unsuited to such work. The cost in negligible compared with that entailed by use of the conventional techniques of off-shore geological exploration.

SECTION NO.(19). APPENDIX

(a) Diving in the Penzance Area.

Before the commencement of the work in Cornwall it was agreed that an alternative diving site should be chosen in the event of diving being impossible in the St. Agnes area through the weather or other reasons; if possible, a site should be selected on the South coast when the prevailing winds, which might prevent diving on the North coast, would not hinder operations. As a result it was decided to focus attention upon Mount's Bay which is the area of sea bounded by Mousehole, Penzance, and Marizion, and overlooked by the granite intrusion of St. Michael's Mount.

The Mylor series of the Lower Devonian "killas" is intruded into by the Land's End Granite and the junction between the two rock types outcrops on the shore at Mousehole. To the North it runs inland where it can be traced with difficulty. To the South the contact has been traced by the writer on the sea-bed by skin-diving during September, 1959. A strong current runs between the shore and St. Clement's Isle thereby preventing the deposition of any sand upon the bed-rock. Laminaria is common and provides the chief danger to a skin diver in this area since strands of weed grow to a length of 10 feet.

Interbedded and folded with the "killas" are intrusions of "greenstone" which have also been metamorphosed by the granite. Cross-cutting through the rocks exposed on the coastline are a series of felsite, or "elvan" dykes. The only outcrops occur along the shore, especially between

Mousehole and Penzance and the region of St. Michael's Mount. Between the Mount and Penzance the bed-rock is concealed beneath an extensive covering of sand through which only "greenstone" and "elvan" penetrate. The latter can be mapped down to the low-water mark and the result is shown in the Geological Survey Map of the Land's End District. The whole Bay up to a distance of 1½ miles off-shore rarely exceeds a depth of 10 fathoms and the diving conditions, owing to the sheltered nature of the coast were extremely good.

The majority of the sea-bed was found to consist of a thin covering of sand, by which the "greenstone" masses and "elvan" dykes were selectively not concealed, as a result of their greater resistance to erosion compared with the "killas". A number of specimens of the bed-rock were obtained from selected points and as a result the dykes were traced across the Bay.

SECTION NO.(19). APPENDIX

(b) Diving in the Ilfracombe area.

On May 17th, 1960 a request for assistance was received from the Department of Geology of Bristol University. During a recent geological study of the Bristol Channel in the R.R.S. "Discovery II", Dr's D. T. Donovan, R. Savage, (Bristol University) and Mr. A. H. Stride (National Instiution of Oceanography) obtained specimens of sedimentary and igneous rocks by dredging from a point offshore. The exact location was "Horseshoe Rocks", about 4 miles North-West of Ilfracombe in Devon.

Specimens of "greenstone" were obtained and it was thought that they had originated from the "Horseshoe Rocks" which rise from a sea-bed of 22 fathoms average depth to a peak of approximately 8 fathoms depth; at their minimum depth range they cover an area of several hundred square yards. It was decided that the only reliable method of determining the true origin of the "greenstone" was by sending divers down to examine the "Rocks" underwater and to obtain specimens 'in situ'.

Arrangements were therefore made for three members of the party; R.H.T. Garnett, J.D. Woods, and G. Wheeler, to reside at Combe Martin near Ilfracombe for a few days during which an attempt would be made to dive upon the "Rocks". The three members arrived in Combe Martin on the evening of July 18th and stayed in the town until July 21st.

A 28 ft. motor boat was available for the work and the first attempt was made on July 19th but diving proved to be impossible for the following reasons:-

(a) the existence of a strong wind and heavy seas,

(b) the lack of sufficient equipment with which to locate the "Horseshoe Rocks", either by position fixing or depth sounding.

The weather proved to be unsuitable on July 20th and a second attempt was made on July 21st. This again failed for the same reasons as given above, and the three members returned to Cornwall on the same day.

In conclusion it may be stated that it does appear possible to dive on the "Horseshoe Rocks" under the following conditions:-

(a) Calm weather.

(b) If an echo-sounder is employed to detect the "Rocks".

(c) If the attempt is made during the slack period at low tide.

SECTION NO.(19). APPENDIX.

(c) Divers investigate Levant Mine (9)

N.B. Figures in parenthesis denote references applicable only to Section No.(19c)

Introduction

The Levant Mine is situated on the North-Western flank of the Land's End Granite in the Mining district of St. Just, Cornwall. One of the most famous mines in this region, it has been worked for tin, copper and arsenic since the beginning of the 18th Century. The abandoned mine workings extend for a total distance of 7,000 feet in both country rock and granite. The lodes have been followed for a distance of 5,000 feet out to sea and to a depth of approximately 2,000 feet below sea-level.

The bottom levels of the Levant Mine, from which the majority of the production was being won, became inaccessible in 1919 after the failure of the man-engine and the consequent disaster. Mining of the upper levels continued until 1930 when the mine finally closed. The mine development prior to 1919 was directed in depth and in a seawards direction. If production from this region had not been brought to a stand-still by the disaster and the flooding of the lower levels, there is the possibility that continued development in depth and exploration along the granite contact would have proved further areas of mineralization.

Some recent underground development in the adjoining Geevor Mine has been in the direction of the abandoned workings of the Levant sett.

For this reason, it was essential to know the exact source of the water with which the Levant Mine is flooded. The possibility existed that the water was the result of either rainfall or the entry of the sea into the workings. Even when the mine was in production it was considered by some engineers that part of the levels close to the sea-bed, known as the '40 Backs', were dangerous, and doubt had existed as to whether or not the sea had broken through to the workings at this point since the mine's abandonment. The first mention of the '40 Backs' is made in 1818 by Hawkins (1) who states that -

"the first level of the mine is 17 fathoms below the high water mark and is extended 40 fathoms. As the shore declines very rapidly there can scarcely be more that 10 fathoms between the end of the level and the sea. In one part of it, workmen, tempted by a bunch of copper, followed it to the height of 5 fathoms above the level, but feared to proceed further. Not only the roaring of the sea in stormy weather but the ordinary breaking of the waves on the beach is distinctly heard by the miners. The water is salt, but there is so little of it that, although the depth is 42'fathoms, the whole is drawn to the adit in a bucket by the labour of two men".

By June, 1869 (2) some concern was felt about the safety of this level and an independant referee was engaged to report upon the ground in question. The referee, Captain J. Vivian, reported as follows (3) -

"in conformity to your request I have carefully examined the 40 level under the sea and the backs worked over the same. I consider the workings perfectly secure and, had I the supervision of the property as Manager of the Mine, or Lords Agent, I think it quite unneccessary to take any further precautions to render the mine safe from the sea. I should not, however, stope any more ground in the back of the 40 nor drive the level further.

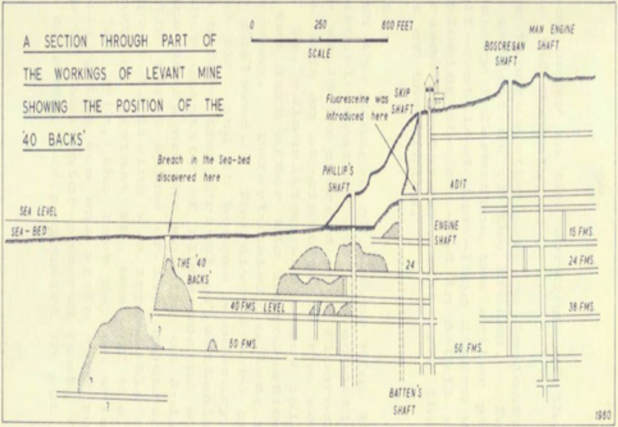
Memoirs and first-hand verbal witnesses, (4) and (5), report that the '40 Backs' caused condiderable concern to the management during the years immediately prior to the final closure of the mine, and the various statements are summarized in correspondence between Major B. Llewellyn and Mr. J. H. Trounson (6). The latter writes,

> "it is at this place, (the '40 Backs') that the greater part of the water making in the mine enters through the lode at a place where it was unwisely stoped too near to the ocean floor many years ago. The lode here is apparently of a somewhat friable and soft nature, and it has always been regarded as somewhat of a danger area. To make matters worse the worked out stopes or 'gunnies' at this point are unusually wide for Levant. A few years before, this area collapsed and an effort was then made to fill the gunnies by stoping adjacent country rock. This, however, failed by reason of the large volume of the old stopes that it was necessary to fill, and subsequently heavy timbers were put in to support the danger area.
>
> According to my information however, this precautionary work was never satisfactorily completed and it would seem to be a matter of considerable urgency that if ever the mine were re-opened this relatively small yet dangerous area in the back of the 40 fathom level stopes should be reinforced by cementation and, possibly, by means of a masonry arch or some other form of support more permanent than timber".

By examination of the underground plans of the Levant Mine it was discovered that the '40 Backs' area is directly connected with the entire remaining levels of the mine. Therefore if access was to be gained by de-watering to any part of the mine workings below sea-level it was necessary to determine whether or not the sea had gained entry to the mine through the sea-bed in the region of the '40 Backs' or in any other part.

Preliminary Investigation.

During the early part of 1960, the use of fluorescein was suggested for the detection of any breach between the


A SECTION THROUGH PART OF THE WORKINGS OF LEVANT MINE SHOWING THE POSITION OF THE '40 BACKS'
0
250
500 FEET
SCALE
MAN ENGINE SHAFT
BOSCREGAN SHAFT
SKIP SHAFT
Fluoresceine was introduced here
PHILLIP'S SHAFT
ADIT
Breach in the Sea-bed discovered here
SEA LEVEL
SEA-BED
ENGINE SHAFT
15 FMS.
THE '40 BACKS'
24
24 FMS.
40 FMS. LEVEL
38 FMS.
50 FMS.
50 FMS.
BATTEN'S SHAFT
1960

Levant workings and the sea. Already widely used in air-sea rescue and spelaeology, this chemical is said to be capable of being detected when as little as one part of fluoresceine is present in 40 million parts of water; a quality attributable to the brilliant green fluoresceine of its alkaline solution.

The adit above high water mark which connected to the Levant Skip Shaft had previously been cleared during 1959. Observations on the water level in the latter showed that there existed a variation in the water level which could be correlated with the rise and fall of the tides. A plan was devised whereby a quantity of fluoursceine was introduced into the workings through this adit during March 1960, imparting to the water in the mine an intense green colouration. Two days later during an ebb tide there could be observed a patch of water well beyond the low water mark possessing a distinct green appearance in contrast to the remainder of the sea. This was due to the fluoresceine which was again visible at the same spot on the following day. Taking advantage of the excellent sea conditions a boat put out from Sennen Cove and the fisherman, after sailing directly over the area reported that he had seen "a funnel-shaped mass of green water bubbling up from the sea-bed at a depth of about 5 fathoms below the boat".

In addition, the position of the green colouration was calculated from theodolite intersections and plotted in relation to the known Levant Mine workings. The fixed position agreed to within 10 feet with the expected position of the '40 Backs'. This, together with the fisherman's evidence, appeared to prove beyond reasonable doubt that the sea had gained entry to the workings of the mine in the region of the '40 Backs'.

The use of the fluoresceine gave no indication as to the exact nature and extent of the breach. In order to supply this necessary information the writer proposed the employment of self-contained aqua-lung divers who would be capable of exploring the sea-bed in detail and observing the flow of fluoresceine-charged water from the flooded mine at the point of the breach.

The Use of Divers.

It was agreed with the Manager of Geevor Mine that upon the arrival of suitable weather and sea conditions, the Levant mine water would be charged with fluoresceine. The divers would then make an examination of the sea-bed upon the appearance of the colouration which was calculated to be approximately two days after the introduction of the chemical into the mine. Unfortunately a long period of inclement weather followed. The divers were available for only a limited time and it became necessary to start the investigation before the arrival of suitably calm weather. A further quantity of fluoresceine was introduced into the Shaft on the morning of July 26th. On the 28th when the first signs of its appearance in the sea were to be expected, diving was impossible owing to the heavy swell running against the base of the cliffs. On the morning of the 29th, the last day on which the divers were available, the sea was again very rough, but the captain of the 28 foot motor-powered boat, from which the dives were to be made, was persuaded to put out from Sennen Cove.

Owing to the high seas the fluoresceine was not visible from the shore and the boat had to be manoeuvered into position by the captain, taking his instructions from two observers, who, equipped with theodolites on the overlooking cliffs, signalled with the use of flags. The heavy swell allowed the boat to anchor only at a known position relative to the '40 Backs' and not directly over the breach. Despite the adverse conditions two divers entered the water at 2.5 p.m. With the boat anchored securely in 45 feet of water, the descent was made down a shot line from the boat.

The divers were roped together by a life-line, the other end of which was tended by a person in the boat. With the extra precaution of a safety-line connected to the base of the shot-line, they proceeded to swim in a South-Easterly direction, guided by underwater compasses. The sea-bed was composed of greenstone outcrops, and the breach, with the green-coloured water issuing from it, was located immediately at a distance of about 75 feet from the boat and in visibility of 5 feet. Upon their return to the surface at 2.35 p.m., all information was recorded, and a further solo dive was commenced at 2.40 p.m. in an attempt to gain a sample of the fluoresceine-charged water for laboratory, as well as visual, confirmation. This proved to be impossible since the heavy swell experienced underwater prevented the diver from employing both his hands for the sampling operation and he surfaced at 2.55p.m. The boat weighed anchor and returned to Sennen Cove.

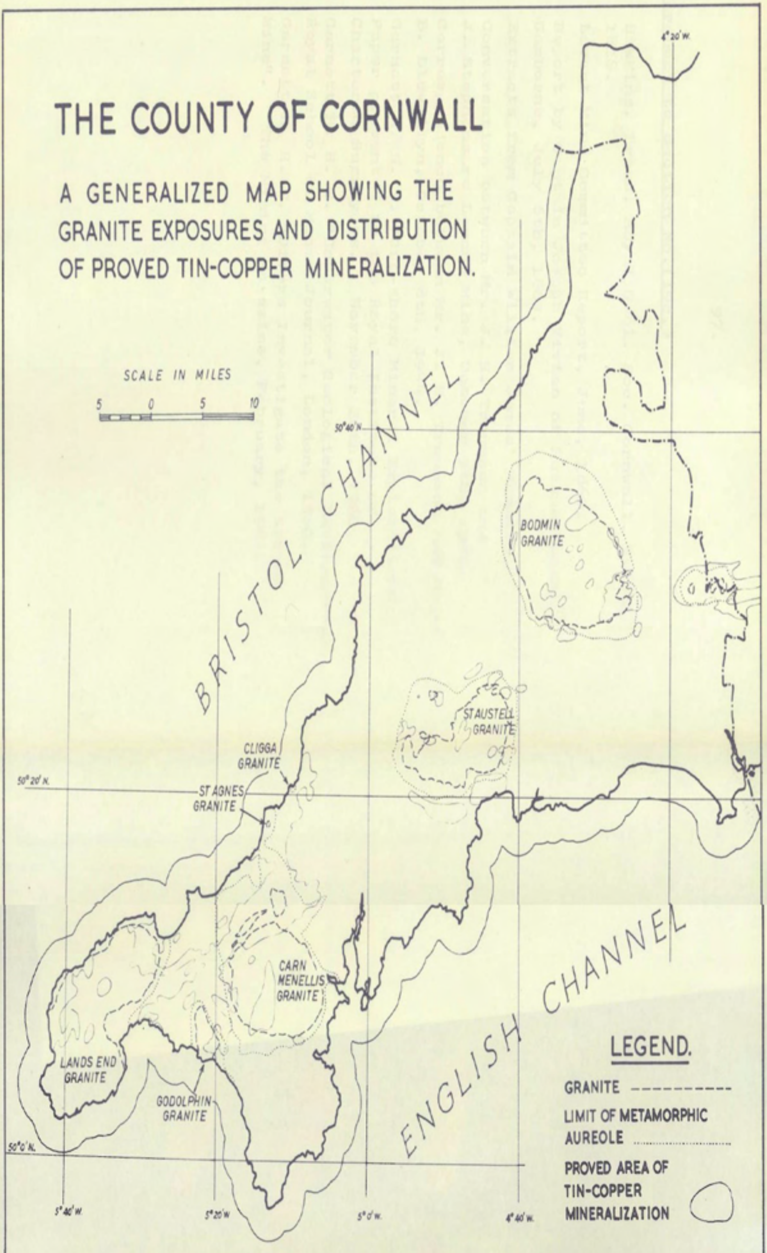
The diving equipment consisted of standard twin aqualungs with dry and wet-suits, as described in a previous paper (8).

Conclusions.

The fluoresceine was found to be issuing from an area of the sea-bed measuring 2 ft. x 2 ft. in one corner of a large trench filled with coarse sand. With a length of 20 feet and a width of 10 feet, the trench appeared to be a continuation of the Levant Zawn. This is a feature of the cliff erosion along a mineralized fracture and the Levant Skip Shaft is situated at one end of the Zawn. The trench was surrounded on three sides by rocks reaching a height of 5 feet above the sand level, the fourth side being bounded by low rocks of a maximum height of 1 foot. The fluoresceine flowed strongly from the trench, but was quickly dispersed by the swell which also caused the flow to be intermittent. The rise and fall of the tides was later found to control the appearance of the fluoresceine since the water flowed from the mine workings only when the tide was falling.

From the dimensions of the trench on the sea-bed and the rate of flow of the water it would appear that the stope in the '40 Backs' has been broken into by the sea. This has been caused by the continual fritting away of the lode material, aided by its lubrication by percolating sea water, and by the constant pressure difference existing between the mine workings and the sea-bed prior to flooding.

The investigation of the Levant Mine provides yet another example of the usefullness of the aqua-lung diver in the field of engineering and exploration.


THE COUNTY OF CORNWALL
A GENERALIZED MAP SHOWING THE GRANITE EXPOSURES AND DISTRIBUTION OF PROVED TIN-COPPER MINERALIZATION.
SCALE IN MILES
5 0 5 10
BRISTOL CHANNEL
ENGLISH CHANNEL
BODMIN GRANITE
ST AUSTELL GRANITE
CLIGGA GRANITE
ST AGNES GRANITE
CARN MENELLIS GRANITE
LANDS END GRANITE
GODOLPHIN GRANITE
4° 20' W.
50° 40' N.
50° 20' N.
50° 0' N.
5° 40' W.
5° 20' W.
5° 0' W.
4° 40' W.
LEGEND.
GRANITE
LIMIT OF METAMORPHIC AUREOLE
PROVED AREA OF TIN-COPPER MINERALIZATION

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(2) Levant Mine Committee Report, June, 1869.

(3) Report by Captain Joseph Vivian of Roskadinnick, Camborne, July 6th, 1869.

(4) Extracts from Captain William James' Memoirs.

(5) Conversation between Mr. J. H. Trounson and J. Stephens re Levant Mine, October 5th, 1949.

(6) Correspondence between Mr. J. H. Trounson and Major B. Llewellyn, October 8th, 1944.

(7) Garnett R. H. T. "Off-shore Mineral Exploration". Paper presented to the Royal Institute of Chartered Surveyors. November 26th, 1960.

(8) Garnett R. H. T. "Underwater Geological Exploration". Royal School of Mines Journal, London, 1960.

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SECTION NO.(19). APPENDIX

(d) The Diving Log.

July 1st	Equipment unpacked and stored. Weather excellent.
2nd	Practice Diving at Penzance. Weather excellent.
3rd	Practice Diving at Trevaunance Cove. Weather excellent.
4th	Diving in the St. Agnes area. Rain, high wind, heavy sea, swell.
5th	Diving impossible. Rain, high wind, heavy seas.
6th	Diving impossible at St. Agnes. Diving at Penzance. Showers, high wind.
7th	Diving in the St. Agnes area. Rain, strong wind, strong swell.
8th	Diving in the St. Agnes area abandoned. Rain, high wind, heavy seas.
9th	Diving in the St. Agnes area. Heavy rain, slight breeze, slight swell.
10th	Diving impossible. Rain, strong wind, heavy seas.
11th	Diving impossible in the St. Agnes area. Diving at Penzance. Strong wind.
12th	Diving in the St. Agnes area. Rain, strong wind.
13th	Diving in the St. Agnes area. Rain, strong wind.
14th	Diving in the St. Agnes area. Cloudy, fairly strong wind.
15th	Diving in the St. Agnes area. Sunny periods, fresh winds.
16th	Diving in the St. Agnes area. Rain, fresh winds.
17th	Diving impossible. Continuous rain, high winds.

18th	Three members of the party travelled to Ilfracombe. Sunny periods.
19th	Diving impossible at Ilfracombe. Rain, bright.
20th	Some diving near Combe Martin. Excellent weather.
21st	Diving impossible at Ilfracombe. Very heavy seas. The three members of the party returned to Cornwall.
22nd	Underwater photography at Falmouth. Cloudy, strong wind.
23rd	Diving in the St. Agnes area. Continuous rain, fog.
24th	Diving impossible in the St. Agnes area. Fog.
25th	Diving in the St. Agnes area. Bright periods, fresh wind, swell.
26th	Diving in the St. Agnes area. Sunny periods, fresh winds, swell.
27th	Diving impossible in the St. Agnes area. Diving at Mullion Cove. Continuous rain, strong winds.
28th	Diving impossible. Rain, strong winds, heavy seas.
29th	Diving impossible in the St. Agnes area. Diving at Levant Mine. Bright periods, very heavy swell.
30th	Equipment packed.
31st	Members departed from Cornwall.

The Diving Log Book, which was also used for the Imperial College Azores Expedition (1959) has been lodged with the Imperial College Underwater Club.

SECTION NO.(20). REFERENCES

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(2) Dill R. F. and Shumway G. "Geologic Use of Self-Contained Diving Apparatus". Bull. Amer. Ass. Petrol. Geol., Vol. 38, No.1, Jan. 1954.

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(18) Scrivenor J. B. "The Granite and Greisen of Cligga Head". Q.J.G.S. Vol. LIX. 1903. pp. 142-159.

(19) Thomas T. L. Personal discussion on 'Sextant Charts'.

(20) Taylor-Smith D. Symposium of the "Future of Non-Ferrous Mining in Great Britain and Ireland." Page 592.

(21) Reid C. and Others. "Geology of the Land's End District". Memoir Geol. Surv. England and Wales, 1907.

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SECTION NO.(21). FINAL CONCLUSIONS.

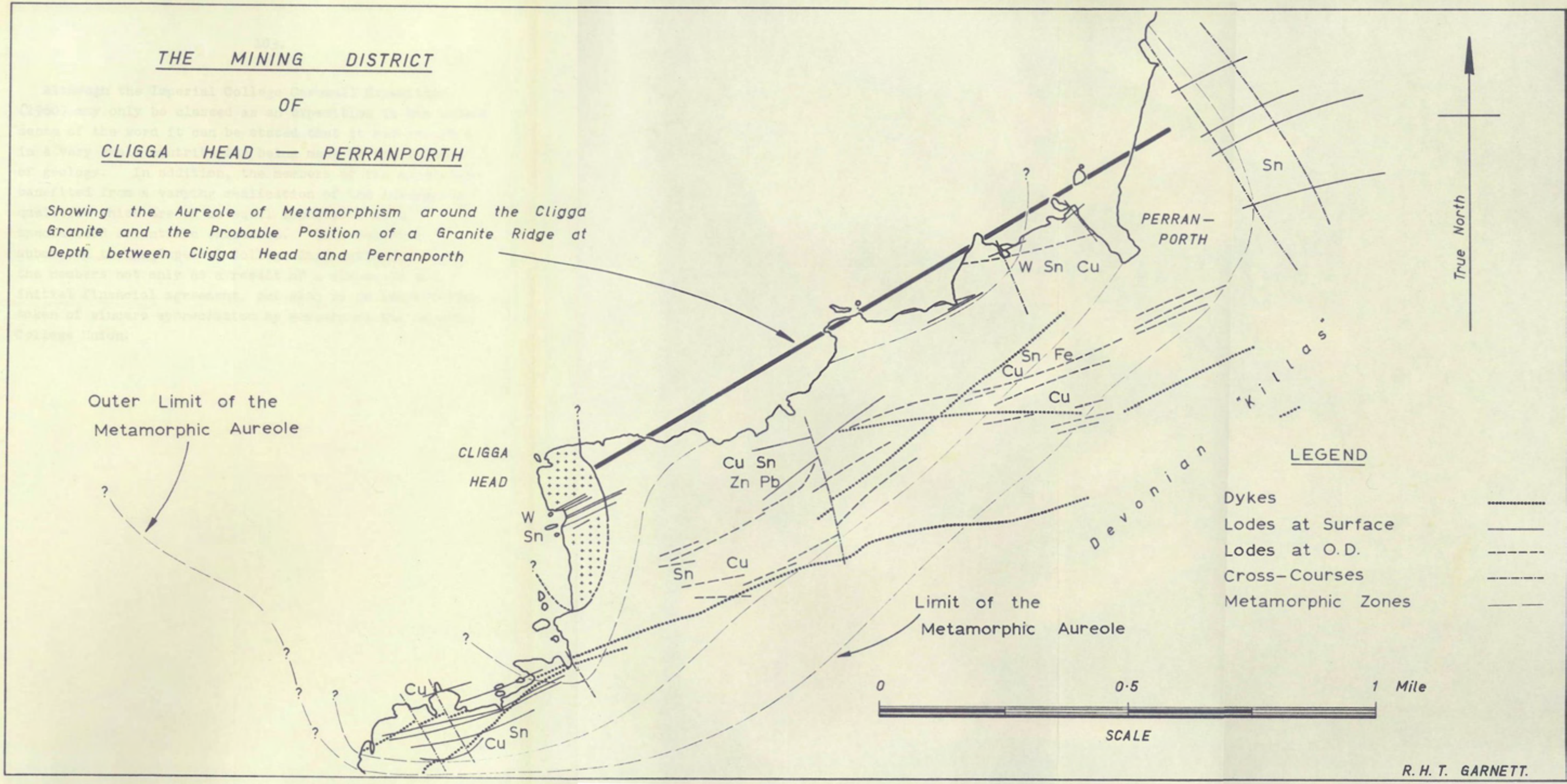
The work outlined in this report has constituted the first major attempt to utilize technically-trained aqua-lung divers in a programme of underwater geological exploration in the United Kingdom. In comparison with other off-shore geological projects, the work was conducted under very limited financial and climatic conditions. At the start the intention of the writer was as follows:-

(a) To perfect a technique of underwater geological exploration using aqua-lung divers; a technique which had been partly developed during the Imperial College Azores Expedition (1959).

(b) To discover whether or not there existed in the off-shore area extensions of the metamorphic aureoles of the Cligga and St. Agnes Granites; aureoles which had already been mapped upon the adjacent land surface.

Both ambitions were fulfilled and it is now the aim of the writer to complete more intensive surveys of this off-shore area in the future, employing a diving team working from a geophysical survey vessel.

Since the foundation of the Imperial College Exploration Board in 1955 many small and large scale expeditions have been initiated in many parts of the world. Although differing in every aspect they have had one common aim which is stated simply in the Report for 1955-57 as being "to encourage initiative on the part of all members of the Union in organizing scientific expeditions at home and abroad and ....."


THE MINING DISTRICT
OF
CLIGGA HEAD — PERRANPORTH
Showing the Aureole of Metamorphism around the Cligga Granite and the Probable Position of a Granite Ridge at Depth between Cligga Head and Perranporth
Outer Limit of the Metamorphic Aureole
CLIGGA HEAD
PERRAN-PORTH
W Sn Cu
Sn
Sn Fe
Cu
Cu
Cu Sn
Zn Pb
W
Sn
Sn
Cu
Cu
Cu
Sn
Devonian "Killas"
Limit of the Metamorphic Aureole
True North
LEGEND
Dykes
Lodes at Surface
Lodes at O.D.
Cross-Courses
Metamorphic Zones
0
0·5
1 Mile
SCALE
R. H. T. GARNETT.

Although the Imperial College Cornwall Expedition (1960) may only be classed as an expedition in the widest sense of the word it can be stated that it has resulted in a very small contribution being made to the science of geology. In addition, the members of the expedition benefited from a varying realization of the intangible qualities which are of an equal importance as a specialized scientific education. This report is submitted to the Imperial College Exploration Board by the members not only as a result of a clause in the initial financial agreement, but also as an insufficient token of sincere appreciation by members of the Imperial College Union.