IMPERIAL COLLEGE

OF SCIENCE & TECHNOLOGY

CORNWALL

1964

THE EXPLORATION BOARD

"SCIENTIFIC DIVING" - CORNWALL 1964

IMPERIAL COLLEGE UNDERWATER CLUB

WITH

THE DEPARTMENTS OF GEOPHYSICS AND GEOCHEMISTRY.

GEOPHYSICAL AND GEOCHEMICAL SURVEY

CORNWALL 1964

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Abstract

This report gives a detailed description of the work carried out by the divers of I.C. in the summer season of 1964. The purpose of the work was to act as seabed samplers and as underwater operators of various pieces of equipment for the Geophysics and Geochemistry Departments of I.C. The report describes the techniques and proceedures adopted, and touches on the scientific reasons for the work.

The author and diving leader would like to thank his supervisor, Mr. D. Taylor Smith, for the opportunity of leading the diving team in this interesting and informative work.

Members

Research Workers:	Wei Ning Li	P.G. Geophysics
	J. Wheildon	P.G. Geophysics
	P. Ong	P.G. Geochemistry
Diving Team:	N.C. Kelland	P.G. Geophysics (Diving Leader)
	D. Durney	2nd Yr. Geology (Secretary)
	Miss.L.J. Dunn	1st Yr. Zoology (Quarter Master)
	E. Sigurdson	P.G. Elec. Eng.
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	F. Davey	P.G. Geophysics
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	R. Warton	3rd Yr. Mech. Eng.
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	J. McKie	P.G. Aeronautics
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	R. Powell	1st Yr. Mech. Eng.
	J. Love	1st Yr. Mech. Eng.
Boat Crew:	E. Stevens	Skipper "Shamrock".
	E. Bennet	Skipper "Cape Cornwall".
Diving Tender:	F. Dewes	Tech. Assist. Geophysics.
	V. Tomkin	Mining Crew "Shamrock".

Background

Mining has been an industry in Cornwall since the Bronze Age, and throughout the centuries Cornish Copper Tin and Silver has travelled in trading boats to many different parts of the world. However, fortunes in the mining industry are very liable to change and, today, the visitor to Cornwall is presented with a rural, rugged landscape, and a mass of old, derelict mine shafts and engine houses: these are the sole reminders of the great industry of the past - an industry which is now represented by only a few working mines, (for example the mines at Cambourne and Geevor), and only rates third to farming and tourism in modern Cornwall.

However, within the last decade new interest has arisen in the possibility of restarting this great industry and, today, Cornwall is an area of fairly large scale prospecting by many mining companies.

It has been appreciated that in the past extensive mining has taken place in many areas in Cornwall that lie both above and below sea-level, but hardly at all out to sea, and economic geologists are now slowly beginning to realise the tremendous potential reserve of this untapped, and little known, region. However, the techniques of geological, geophysical and geochemical prospecting which are applied to sub-aerial geology are unsuited to the underwater world and new techniques must be devised.

The exact techniques to be used in any one area will depend, to a certain extent, on the depth of water, but whatever this depth, a variety of geophysical methods must be used in collaboration with a form of geological sampling: geophysical measurements in themselves are not sufficient due to ambiguity inherent in their interpretation and geological correlation plays a very important part. Geochemical exploration depends on the laboratory analysis of samples taken in the field and so this exploration method also relies on some form of seabed sampling, whether applied to rocks or sand. It is in this very important problem of sampling techniques that, in waters up to 200 ft., the Aqua-lung diver comes into his own. In fact it has been estimated that in Cornwall, aqualung-fitted geologists would increase the prospecting area by 50%, and this all within 2 miles of the shore. Also, further techniques of both sciences rely, for their effecient usage, upon some form of monitoring, and it is again in this connection that valuable work can be done by the aqualung diver.

Work Programme

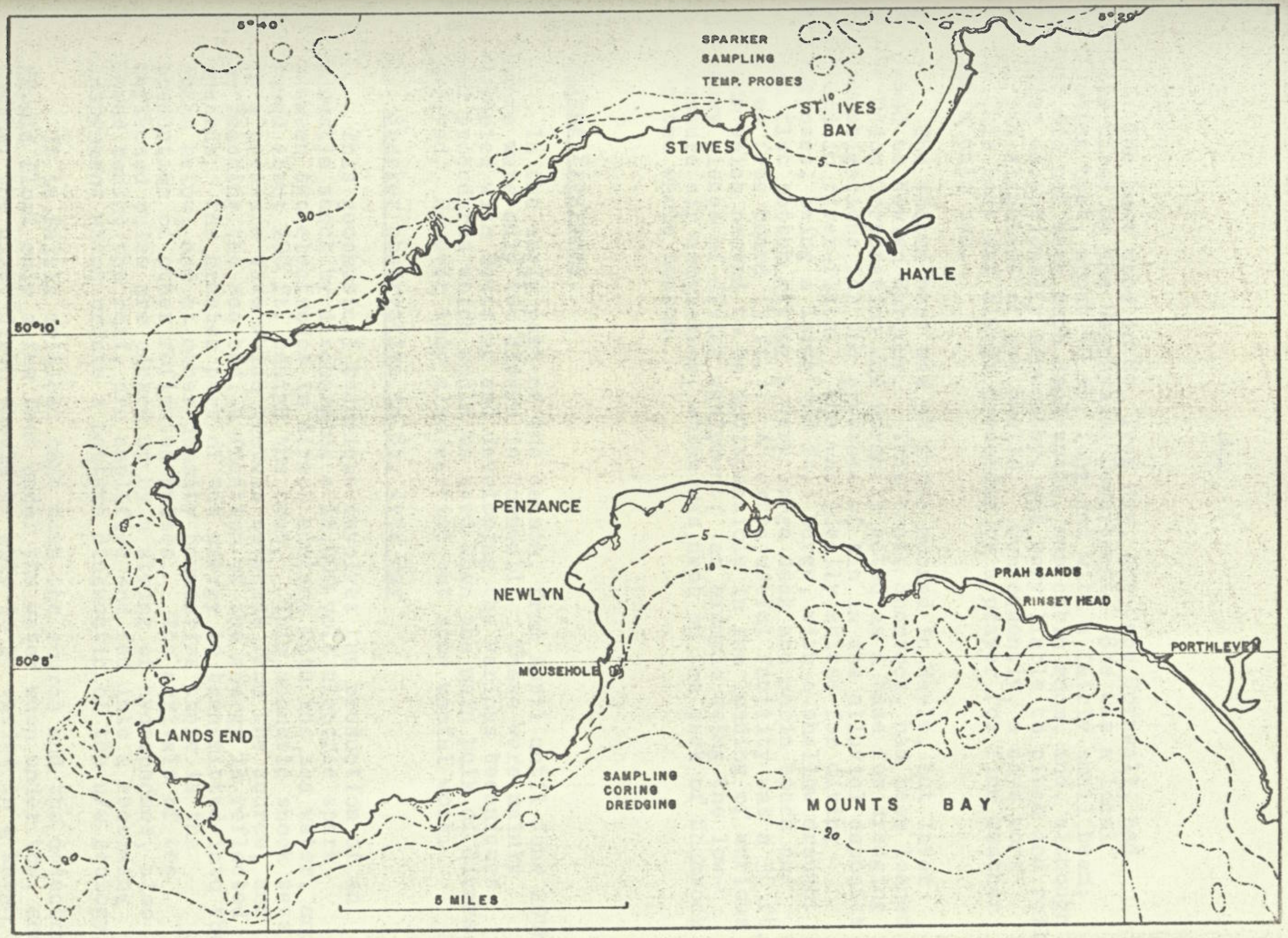
Since 1960 the Geophysics Department of I.C. has engaged in a detailed instrumental investigation of the seabed around St. Ives and Mounts Bay, using various resistivity and sparker techniques. This year further work was performed using the sparker equipment, and an attempt was made to initiate a programme of sea bed temperature measurements using specially modified thermistors. Geochemical exploration, as applied to underwater geology, has not been attempted before by this College, and this year saw the initiation of a large geochemical research programme in Mounts Bay with the aim of investigating the feasibility of locating mineralised zones underwater by an analysis technique.

Both departments anticipated the need for a fairly large team of divers and so asked I.C. divers to act as underwater samplers and monitors for the season. In fact, divers from this College have been working in these areas since 1960, and have already aided the Geophysics Department in delineating the u/w geology of the Cligga Head area and parts of St. Ives Bay, as well as helping in an investigation to locate the u/w. breach in the Levant Mine.

This year saw the largest and most varied programme yet undertaken, and the 14 divers, in various combinations from April to the end of July logged the amazing total of nearly 70 hours. The major part of this time was used in obtaining sand, rock and seaweed samples for the Geochemistry Department in Mounts Bay, and in the knocking of various u/w. thermistor probes into the sandy areas of St. Ives Bay. The remainder was used in monitoring the performance of various Geophysical and Geochemical instruments.

Preparation

The months before departure were fully occupied with the general organising and training of divers, and the designing, assembly, and collection of the various pieces of equipment thought to be necessary for a successful season's diving. This included the hiring and collecting from Bristol University u/w Club of a low-pressure Air Compressor; the designing and building of diving ladders; the designing and development of an u/w telephone unit, and the general maintenance of all equipment already in the possession of the Geophysics Department and I.C. Diving Club. This was then all transported, by Land Rover, to Cornwall and loaded onto the two boats which were to be used.



MAP OF WORKING AREAS — DEPTHS IN FATHOMS

The boat used in St. Ives Bay, the Cape Cornwall, had been hired by the Geophysics Department. She was a local fishing boat, about 40 ft. long and with a fairly small beam; she did not have much deck space, nor cabin room, and, although being exceptionally seaworthy, was very liable to pitch and roll in the slightest of sea swells. Consequently, a days work in this boat was always preceeded by a prayer for fine weather and a calm sea.

The second boat was at first moored in Hayle, but later moved to Newlyn Harbour. This boat, Shamrock, had been loaned by Union Corporation and normally acted as a base for dredging investigations for the presence of tin in the alluvial deposits found in river-flats. She was ideally suited for diving purposes, being a large (60 ft.) barge, with a shallow draught and flat bottom giving a very large deck and cabin space and a low free board (3 ft.). An extra useful facility was a 30 ft. boom which proved to be indispensible in the loading of various heavy pieces of diving equipment; an example being the low-pressure air compressor, which was dept on the deck of Shamrock for the whole season.

Diving Programme

In the early part of the season, from April until June 20th there were only two divers in Cornwall. These were mainly occupied with devising and developing the various techniques and procedures which would be used when the main bulk of divers arrived. However they also carried out some useful work.

a. Sparker observation in St. Ives Bay

This geophysical technique involves the production of an acoustic shock by discharging a 12,000 volt electric spark between two electrodes in direct contact with the sea water, and towed about 200 ft. behind the boat. This acoustic shock sets up a pressure wave which travels outwards from the source, and on reaching the sea bed, a fraction of the energy is reflected upwards. The greater part of the energy is transmitted into the rocks below, and at other density boundaries there is the production of other reflected pulses. The arrivals of the reflected pulse are picked up by a string of hydrophones, also towed behind the boat, are amplified and fed into a recording instrument which prints a pattern diagnostic of the u/w geology.

It is fairly critical that both the source and the detector should float only a few feet under the water when under tow, and further the exact depth should be able to be varied in a known manner by simply moving the boat end of the device. The task of the diver was to observe and note the exact flotation depth of the electrodes and hydrophone under varying conditions. To achieve this the diver, wearing air-cylinders, remained in the water whilst the towing boat sailed past; he then observed the varying depth of the towing line, and, finally, the device under test relative to a vertically hanging, buoyed marker line. To avoid errors of parallax this marker line could be moved by the diver such that the towing line actually ran in the same vertical plane as the line. This proceedure was repeated a number of times for different towing speeds and for varying positions of the towed device. The divers found that the depth of floatation could be fixed to within one foot, and hardly varied for different runs at the same towing speed.

b. Temperature Probe Investigation - Mount's Bay

A possible manner in which ore bodies can be located is by the measurement of the heat flow of the earth. Theory indicates that an ore body gives rise to exothermic reactions in its neighbourhood, and thus its presence might be indicated by an increase in heat flow, and thus temperature, as measured at the surface over the body. Further, different rock, possessing different conductivity coefficients, will also give rise to varying temperature conditions. This type of measurement has been successfully carried out on land, and this summer it was hoped to extend the work to underwater geology.

Initially, as this was a new technique the divers helped in developing the exact manner of taking temperature readings. A diver, in telephone communication with the surface, swam down the temperature probe cable and, on reaching the bottom gently twisted the sensitive thermistor probe a known distance (6") into the sandy bottom, the exact depth being decided by the project research student. This was repeated for different test probes, and then the diver ascended. After a sufficient time to allow the probe to have come to equilibrium, and the temperature to have been taken, the diver re-entered and pulled out the probes. The whole procedure was repeated at different stations, the exact position of the stations being determined by sextant readings.

As a result of this investigation a heavy plate, carrying two temperature probes was assembled. It was lowered by winch over the side of the boat and a diver observing the plate reported that its weight was sufficient to allow the probe to penetrate six inches into the sand. Consequently for the following weeks these measurements were made without the active employment of the divers, and it was not until much later that they were again actively used - this will be described later.

c. Geochemical Sampling

In the vicinity of an ore body measurements show that, under the influence of different natural phenomena, such as water and wind weathering, the elements will slowly migrate and diffuse through the surrounding country rock. The quantity diffusing decreases with the distance from the ore body, and the distance travelled will depend on the media of migration, e.g. stream sediment migration will be far larger than ordinary surface migration. Consequently, a detailed analysis of samples taken around the area of an ore body will give a pattern diagnostic of the presence of that ore body, even though no samples were taken directly over it.

This technique has been very well developed for land geology, and an attempt was made this summer to discover its potentiality as a sea bed exploration tool.

Three types of sampling can be effected underwater: sand or mud, seaweed and rock sampling, each with its own peculiar problems.

1. Sand Sampling: In this case problems arise due to the continual sea water movement, whether tidal or current, and a consequent unknown factor is the degree of sand migration. Thus would a sand sample taken in any one area actually be accurately representative of that area? To investigate this problem it was determined to collect samples from the surface using a shovel and polythene bag, (both of which were tied to the diver's wrist) and to compare the analysis i.e. composition and grain size, with the samples using a grab sampler and a geochemical auger. The first device was controlled from the surface, whereas the second required the use of a diver who would collect a sample about 1½ feet below the sea bed.

Using a shovel proved very easy, and the initial work was performed from a small, 20' gig "The Bonnie Lassie", using air cylinders, with the diver controlled either by rope signals, or a telephone. The grab sampler was operated from the surface, although in the beginning its performance was observed by a diver to check that it worked efficiently and to note how much "fine" sediment fell out whilst it was being pulled back to the boat. The augering proved a far more difficult task, and required about 10 - 15 mins. of hard physical effort to twist it to the required depth. However, the analysis of these preliminary samples showed that it was not all that important to use the auger and thereafter either the grab or a diver was employed to take a surface sample.

Diver's Limitations: At this juncture some of the limitations of a two man diving team, using air cylinders and working from a small boat became obvious. Firstly, the tossing of the boat made it very difficult to dress, and practically impossible to re-enter the boat: secondly, there were no facilities for dressing or sheltering, if the weather was bad, and thirdly, the use of air cylinders greatly limited the available diving time.

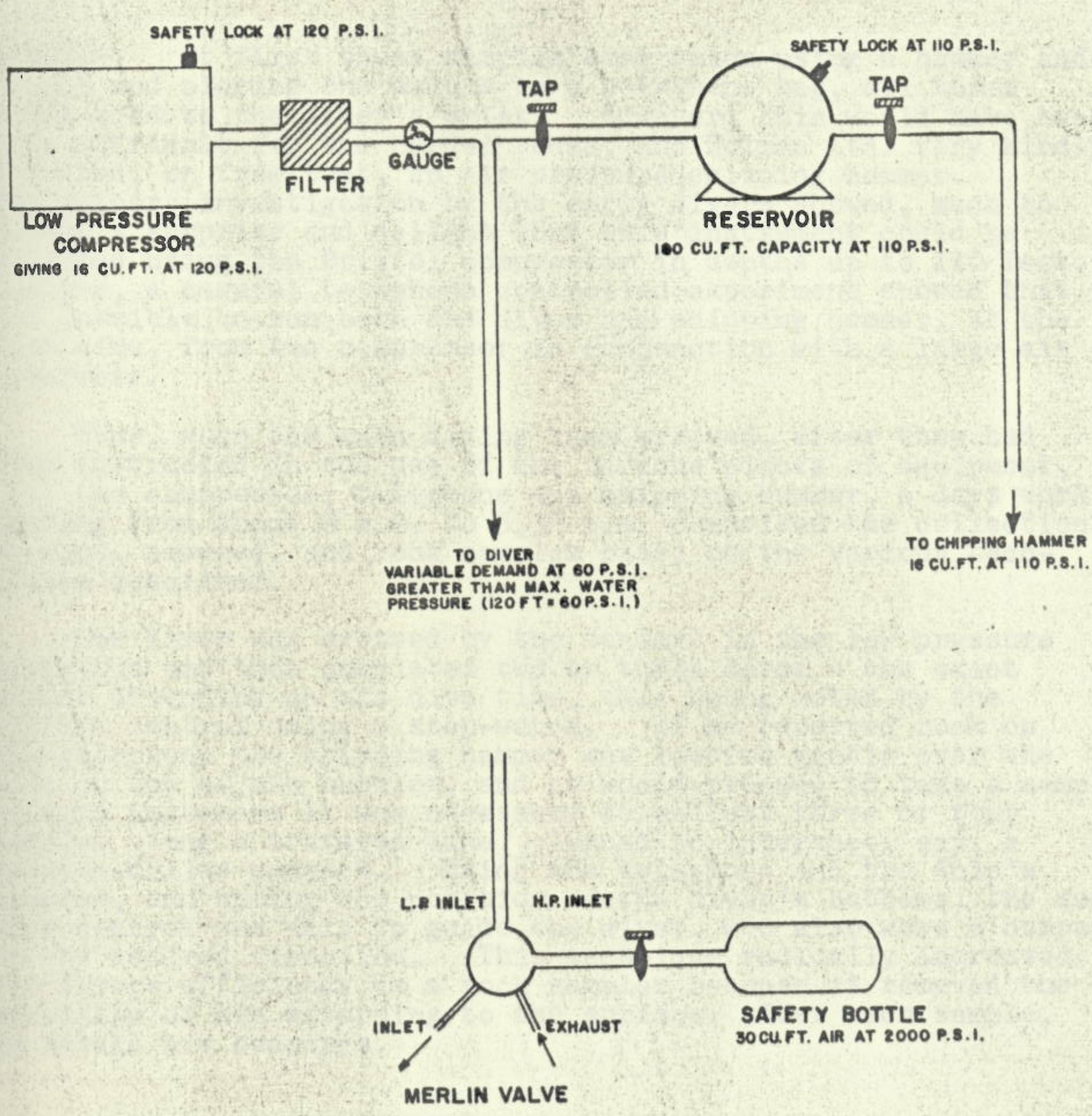
Eventually all the sampling work was done from the "Shamrock" using a low pressure compressor and air line. This allowed air to be pumped down to the diver and enabled him to stay for considerable lengths of time in deeper water. However, a further problem now arose, that of decompression. When a diver is working in deep water his system accumulates nitrogen, and should he remain under water for any excessive length of time, he must stop, whilst ascending, at various depths and decompress. The decompression time increases with the time of dive and the working depth. Also, excessive physical exersion under water increases the respiration rate, and compensation has to be allowed for this. Thus, although using the air line allowed the diver as much time as he desired under water, his physical limits now dictated how long he could dive for, let alone the other limiting factor of the cold, thus the two divers began to eagerly anticipate the arrival of the main team.

2. Seaweed Sampling.

This was very easy to collect and was simply pulled or cut off the rocks, and carried to the surface in the divers hand.

3. Rock Sampling

The analysis of in situ rock samples is more diagnostic of the presence of any ore body, and a large part of the programme involved a half mile scale grid collection of rock samples. (It is to be noted that for this work an underwater topographical map, prepared in previous years by the Geophysics Department from the results of a Sparker survey, was used to denote areas of rock or sand; the position plotting, in this case, being achieved using sextant readings and a sextant chart of Mount's Bay. The accuracy of this map was strikingly confirmed by the divers description of each sample point). Three types of rock were collected, Killas or slates, a harder metamorphic rock called Blue Elvin or diabase, and finally very hard, coarse grained



LOW PRESSURE AIR SYSTEM ON 'SHAMROCK'.

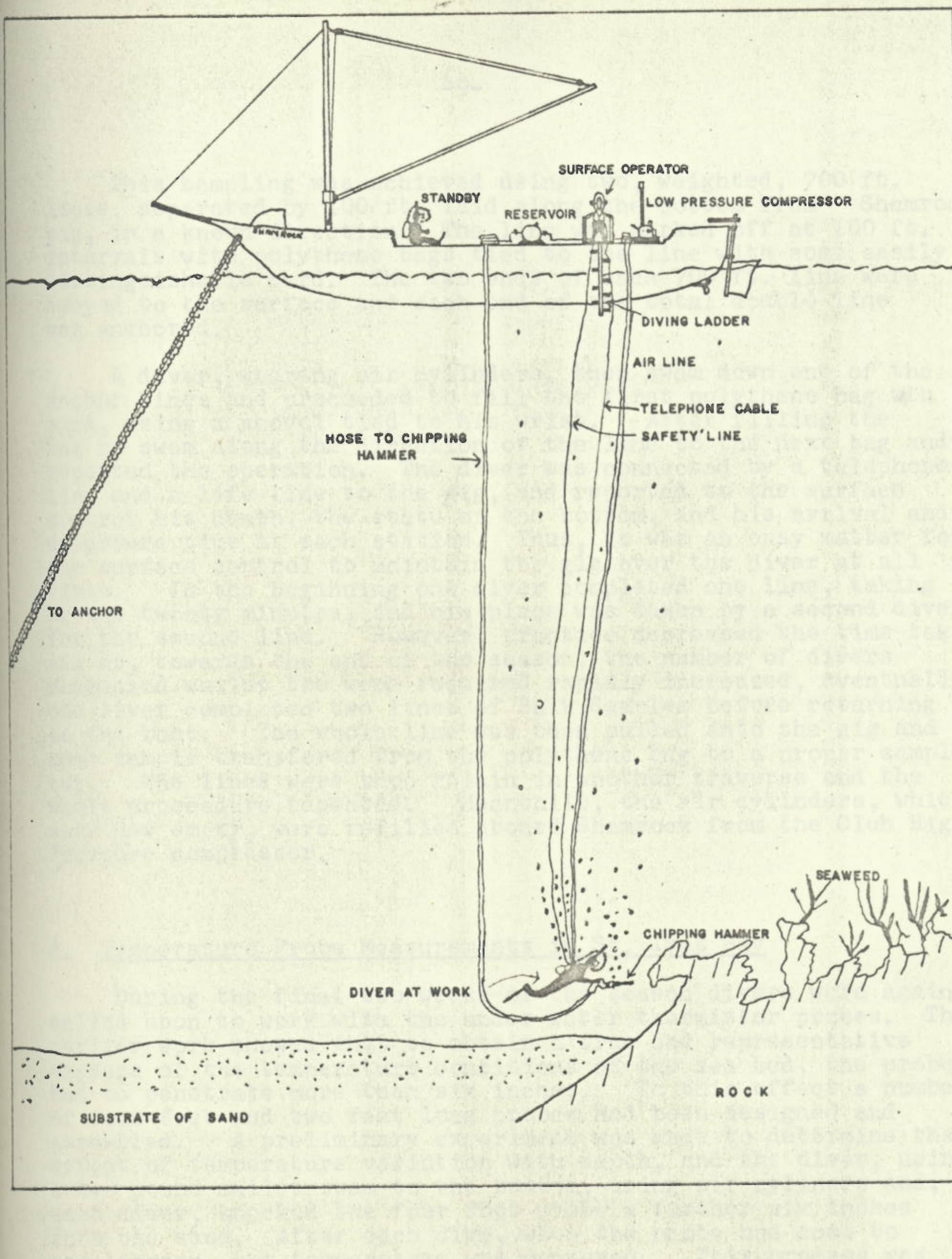
granite. At first these samples were taken using a hammer and chisel and placing the sample in a polythene bag, all three being tied to the diver's wrist. However, this would have been very difficult for the harder rocks, and Holman Ltd. very kindly supplied, on free test, an air pressure chipping hammer. Preliminary investigation by the early divers showed, much to Holman's surprise and delight that this instrument could be operated using the Bristol compressor in depths up to 110 feet. Further, a careful telephone controlled experiment showed that it was possible to run both the diver and chipping hammer, at the same time, from the compressor in conjunction with a large air reservoir.

Thus, when the main diving team arrived, after they had been instructed in the use of the various pieces of equipment, i.e. the compressor, telephone and chipping hammer, a days work, lasting from about 8 a.m. to 5.30 p.m. comprised the collection of sand, seaweed, and rock samples based on the various techniques described.

One diver was dressed by the tenders in the low pressure apparatus and then completed two or three dives - the exact number depending on his dive time, this being noted by the surface control using a stop-watch. If he reported rock on the telephone the chipping hammer was lowered gently over the side on top of his bubbles, and he would proceed to take a sample. In some instances it was necessary to collect three or four samples along a traverse line, planned to intersect, say, a granite-Killas contact. Using the telephone and the Ship's compass, and noting the position of the diver's bubbles, the surface control was able to guide the diver, who also wore a compass, in the desired direction. This technique radically increased the divers efficiency as a rock sampler because it removed the necessity of his returning to the surface, after each sample, to retake his bearings.

4. <u>Bulk Sand Sampling</u>

All the sampling described, except for some detailed rock sampling near Rinsea Head and St. Michael's Mount (in order to delineate the edge of the Godolfyn Granite Mass), was carried out at stations on the ½ mile grid plan, giving a regional geochemical map of the area. Preliminary examination of the sand samples revealed two areas of special interest as locations of tin mineralization; one at Prahh Sands, and the other off Porthleven, and it was decided to implement more detailed sampling in both areas.



AIR LINE DIVER AT WORK FROM 'SHAMROCK.'

This sampling was achieved using two, weighted, 700 ft. lines, separated by 100 ft. laid along the bottom from Shamrock's gig, in a known direction. The line was marked off at 100 ft. intervals with polythene bags tied to the line with some easily distinguishable cord. The two ends of each 700 ft. line were byoyed to the surface and each end of the total double line was anchored.

A diver, wearing air cylinders, then swam down one of the anchor lines and proceeded to fill the first polythene bag with sand, using a shovel tied to his wrist. After filling the bag he swam along the direction of the line to the next bag and repeated the operation. The diver was connected by a telephone line and a life line to the gig, and reported to the surface control his depth, the state of the bottom, and his arrival and departure time at each station. Thus, it was an easy matter for the surface control to maintain the gig over the diver at all times. In the beginning one diver completed one line, taking around twenty minutes, and his place was taken by a second diver for the second line. However, practice decreased the time taken, and as, towards the end of the season, the number of divers decreased whilst the work required rapidly increased, eventually one diver completed two lines of Bulk Samples before returning to the boat. The whole line was then pulled into the gig and each sample transfered from the polythene bag to a proper sample bag. The lines were then relain in another traverse and the whole proceedure repeated. Meanwhile, the air cylinders, which were now empty, were refilled aboard Shamrock from the Club High Pressure compressor.

d. <u>Temperature Probe Measurements in St. Ives Bay</u>

During the final two weeks of the season divers were again called upon to work with the under water thermistor probes. The earlier work showed that to obtain a true and representative picture of the temperature conditions of the sea bed, the probes had to penetrate more than six inches. To this effect a number of four feet and two feet long probes had been designed and assembled. A preliminary experiment was made to determine the effect of temperature variation with depth, and the diver, using a two pound mallet swam to the bottom, using air cyliners and, on each diver, knocked the four foot probe a further six inches into the sand. After each dive, when the probe had come to equilibrium, the temperature was measured. This process was repeated until just over three feet penetration was achieved;

at this depth divers found that the effort required was so great that it took up to twenty minutes to knock in the last six inches. It would have been to no avail to have used a heavier mallet, as this would have introduced buoyancy difficulties caused by the reaction of hitting the probes.

Thereafter measurements were taken at different Decca points using one probe knocked in one and a half feet and the second one three feet. Great difficulty was experienced in this work due to the severe ground swell of St. Ives Bay which swept the diver away from the probe such that only one in three hammer strokes connected.

e. Monitoring Work

This type of work was spread out over the whole season using different instruments. In each case the diver reported by telephone, to the surface the manner of operation of each instrument under test. These included piston corers, gravity corers, the temperature plate, a dredging device, and a special Ship-X sampler. The observation of the corers proved to be by far the most exciting. These instruments were lowered from the boom of Shamrock, over the side, and brought to rest about twenty feet from the bottom. The diver then entered the water and swam to the instrument. When he was ready he told the surface control, via the telephone, who gave the signal to drop the corer. The diver was then able to observe it manner of entry into the sand, and its depth of penetration. In some cases this type of sampling did not prove too successful due to the compactness of the sand.

The dredge was a box-like device which, when towed behind the gig would collect a large sand sample. A number of different types were tried and each time a diver reported its performance under tow, for example, did it tip over. As an outcome of this work, some of which was filmed, a reasonably efficient dredge was developed.

The special grab sampler had been provided on test, and was the modification of an American device. At the first attempt the grab refused to collect a sample, and when a diver observed its operation he was able to state the reason and to suggest a critical modification which would improve it.

<u>Achievements</u>

These are best indicated by the following tables:

1. Diving Logs:

Total time under water	4145 mins.	(69hrs.05 min)
Geochemistry diving	3192 mins.	(53hrs.12 min)
Geophysical diving	833 mins	(13hrs.53 min)
Other diving (filming etc.)	120 min	(2hrs. 00 min)

2. Geochemical work:

Number of stations occupied

a. Sampling

Total number of samples	875	
Number of rock samples	126	
Number of sand samples	395	
Others (Seaweed, etc.)	30	

b. Bulk sampling:

Total number of traverses	46	(760 mins.)
Total number of samples	324	

c. Monitoring:

Corer observations	15	(112 mins.)
Dredge observation	6	(72 mins.)
Ship-X Sampler	2	(8 mins.)

3. Geophysical Work

Total number of dives	91	(833 mins.)

a. Sparker Observations

Number of dives	5	(190 mins.)

b. Rock sampling

Number of stations occupied	7	(35 mins.)
Number of samples taken	4	

c. Temperature Probes

Number of dives	79	(568 mins.)

The working depth in both Mount's Bay and St. Ives Bay averaged around sixty feet, although the exact depth varied from the seashore to the deepest recorded diver of 155 feet. However, only six of the fourteen divers recorded dives of over 100 feet, and only two of these exceeded 120 feet. This, in view of the rather inexperienced nature of the diving team, was perhaps all to the good.

Diving Safeguards

At all times during the season the greatest possible number of safety precautions were taken whilst working. Only one diver was in the water at any one time, except during filming and other similar operations. When the air line was being used the diver was connected to the surface by the air line, a safety line, and the telephone. This latter proved indispensable and with its use the surface operator at all times knew the exact condition of the diver, and could hear him breathing. Further, using the air compressor it was possible to "hear" the diver breathing by simply noting the change in the revolutions as he demanded air. Finally, should both system fail, he always had the safety rope along which signals could be sent. At all times, there was always a stand by diver ready to enter the water at the slightest provocation. When not using the air line and working with air cylinders the diver was connected to the surface by a safety line, and the telphone. That all these precautions were both necessary and sufficient was adequately proved on the only emergency occasion when the air to a diver was cut, due to his tubes being "pinched". The telephone operator immediately realised his difficulties and warned the diving leader to be ready. The stand-by leapt into the water, and the diver surfaced and was in the boat within a very short time. He soon recovered and, after a warm drink, was in the water diving again.

Other dangers can beset the aqualung diver and one only becomes aware of their large number the more one partakes in such activities. Perhaps the most important lesson learnt this summer was the danger of fatigue. When working hard under pressure the slightest ailment, or complaint of tiredness is vastly accentuated, and it is important, in a full programme of work, to have a large enough team so as to permit, by regular rotation, frequent rest days for all divers. This was easy to achieve in the beginning, due to the large number present, and a diver averaged between 20 to 30 minutes per day and had on average every third day off. However, towards the end of the season the divers decreased and the work increased; consequently the stamina of the divers was more heavily taxed. It is felt that this is a large part of the reason for the temporary disability of, fortunately, one of the more experienced divers, and it is hoped that this type of accident will result in a more careful realisation of a diver's limitations in the future.

Special Equipment

a. Diving Ladders: These were designed by Nigel C. Kelland with helpful comments by Fred Davey and were built in the Geophysics workshop by Mr. Denman and company. They were based on a central piece of tubular steel with alternative projecting pieces on either side. This was felt to be the easiest type of ladder to ascend in flippers. The ladder was suspended about one foot away from the side of the boat on a tubular frame. This design, although not perfect, proved to be very effective.

b. Air Equipment:

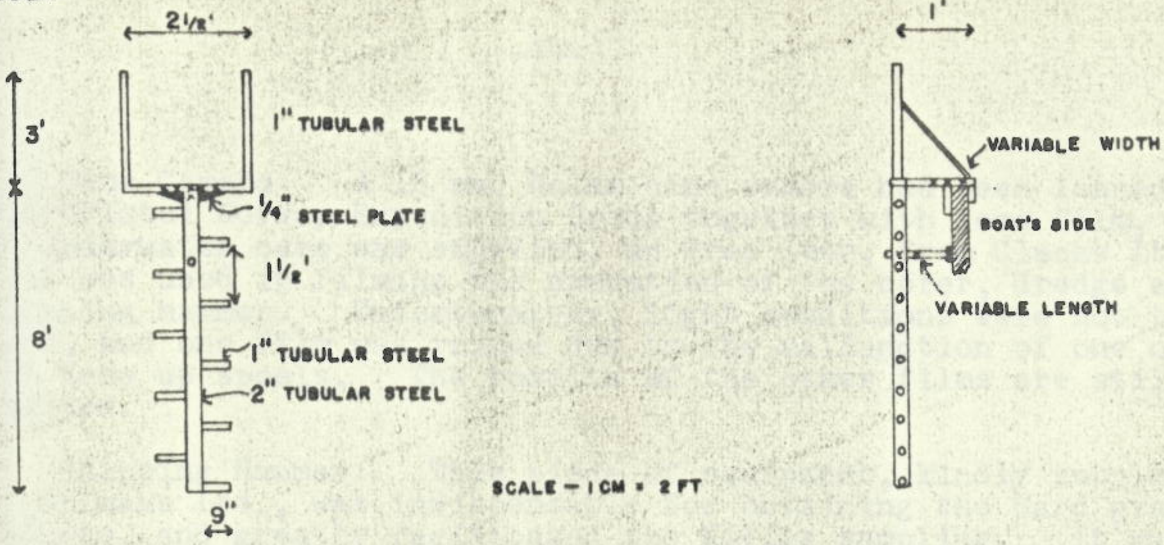
i. Low Pressure Compressor: This had been presented by the Bristol Pneumatic Tool Co. Ltd. to the Bristol Norway Underwater Expedition of 1962, and had been hired by the Geophysics Department for this season. It was a diesel driven compressor giving 16 cu. ft. per minute at pressures up to 120 p.s.i., which via an air line hose, was fed to the low pressure inlet of a Merlin demand valve. This valve was strapped to the diver's back, and in the case of the compressor cutting out was connected to a high pressure air supply, also carried on the diver's back, via the high pressure inlet. This instrument proved of great value both from a point of view of finance and of convenience, and certainly justified its considerable use.

ii. High Pressure Compressor: The compressor belonging to I.C. Diving Club, giving 10 cu. ft. of air per minute at 2000 p.s.i. replaced the bank of B.O.C. cylinders which had been used to fill the air bottles. This compressor was eventually located on Shamrock, and thus proved easy and convenient to fill the air bottles whenever they were empty, without having to transport them a long way, and also at a considerable financial saving.

c. Telephone: This was designed and built by Mr. J. Partridge, (who lead the Bristol Norway Expedition), and, perhaps was the most useful piece of equipment employed. It incorporated a 100 m. watt, 4 stage push pull, two way amplifier which was strapped to the surface operator's belt. Communication was effected at the surface through ear phones and microphone, whilst the diver wore a bone conduction transceiver, bought from Fortephone Ltd. With practice it proved perfectly easy to communicate in both directiohs, although the diver had to modify his normal method of speech. The members of the diving team are greatly indebted to Mr. V. Tomkin, who spent many hours in the very important capacity of surface operator with this instrument.

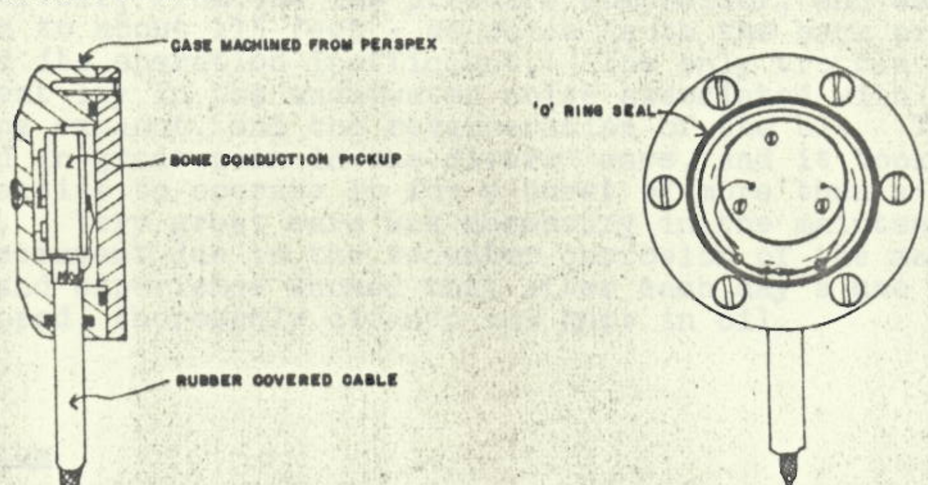
SPECIAL EQUIPMENT

DIVING LADDER



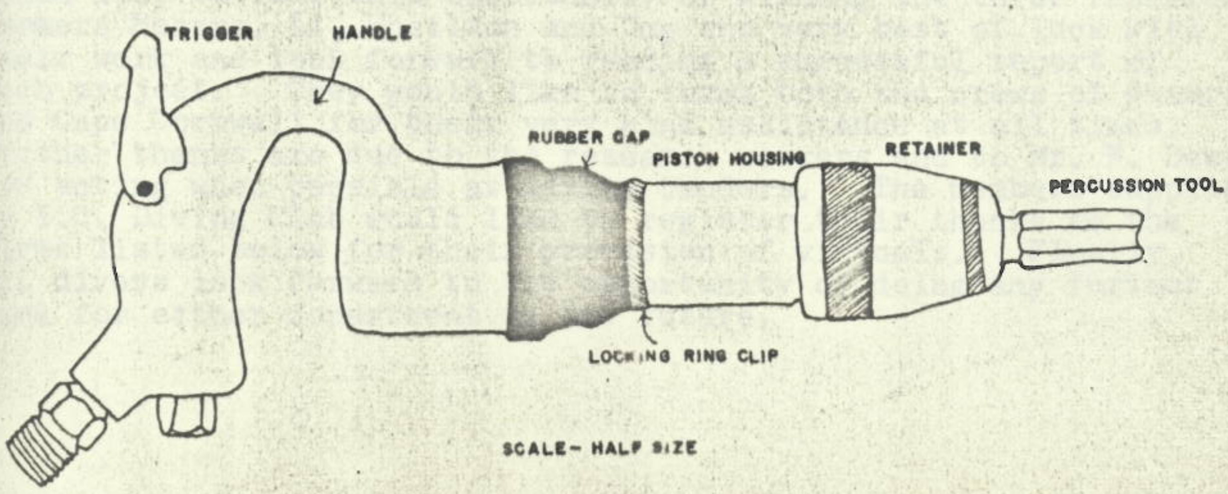
SCALE — 1 CM = 2 FT

TELEPHONE BONE CONDUCTION EARPIECE



SCALE — FULL SIZE

CHIPPING HAMMER



SCALE — HALF SIZE

d. Cine Camera: A 16 mm. Bolex cine camera had been loaned by the Bristol Norway Expedition Group together with some film, and an underwater case was supplied, on free loan, from Clacks Ltd. This was used in filming the operation of the corer, dredge and chipping hammer. Unfortunately, light conditions were not too good, and one film was ruined due to the malfunction of one of the take up spools. The results of the other films are still awaited.

e. Chipping Hammer: This piece of equipment, kindly supplied by Holmans Ltd., was indispensable for obtaining the hard granite samples, and greatly facilitated the Killas sampling. It was a small hand held percussion instrument, taking 16 cu. ft. per minute at about 80 p.s.i. It was operated via a large 100 cu. ft. reservoir, from the low pressure compressor, and was effective down to about 115 feet - at which depth the back pressure rendered its operation inefficient. The only trouble with this instrument lay in the underwater noise associated with the expanding exhaust, and the reverberation of the bit. This resulted in great pain in the divers' ears, and it took considerable practise to operate it for a burst of more than a few seconds. Very great care was necessary in the maintenance of this instrument due to the seawater corrosion of the many moving parts, and experience showed that after each day's use it had to be stripped, thoroughly cleaned and kept in oil.

Conclusion

The divers logged a very large time and it is felt that the work they achieved in this time was 100 per cent successful. All the divers greatly enjoyed the work due to the large variation in diving conditions and the type of work to be carried out. They would like to take this opportunity of wishing the three research workers Messrs. Li, Wheildon and Ong the very best of luck with their work and look forward to reading a successful report of each project. They would like to thank both the crews of Shamrock and Cape Cornwall for their very kind assistance at all times. Further thanks are due to the research workers and to Mr. F. Dewes for acting when possible as diving tenders. The members supplied by I.C. Diving Club would like to register their thanks to the firms listed below for their provision of victuals. Finally, all divers look forward to the opportunity of doing any further work for either department in the future.

Acknowledgements

1. Diving Equipment:

Low Pressure Compressor	Bristol University Under-Water Club
Chipping Hammer	Holman Bros. Ltd. Camborne.
Cine camera and under water telephone	Mr. John Partridge Medical Dept. St. Thomas's Hospital, London.
Camera case	Verena Sports Ltd.

2. Food:

Alfred Bird and Sons Ltd.
James Robertson & Sons P.M. Ltd.,
Tate and Lyle Refinery Ltd.
D.J. Hynes Co. Ltd.

3. Financial Aid

Imperial College Exploration Board - Diver's insurance.
Geophysics Department.

SUPPLEMENTARY REPORT ON SOME ASPECTS OF MARINE PHYSIOGRAPHY, GEOLOGY AND BIOLOGY

Cornwall, 1964

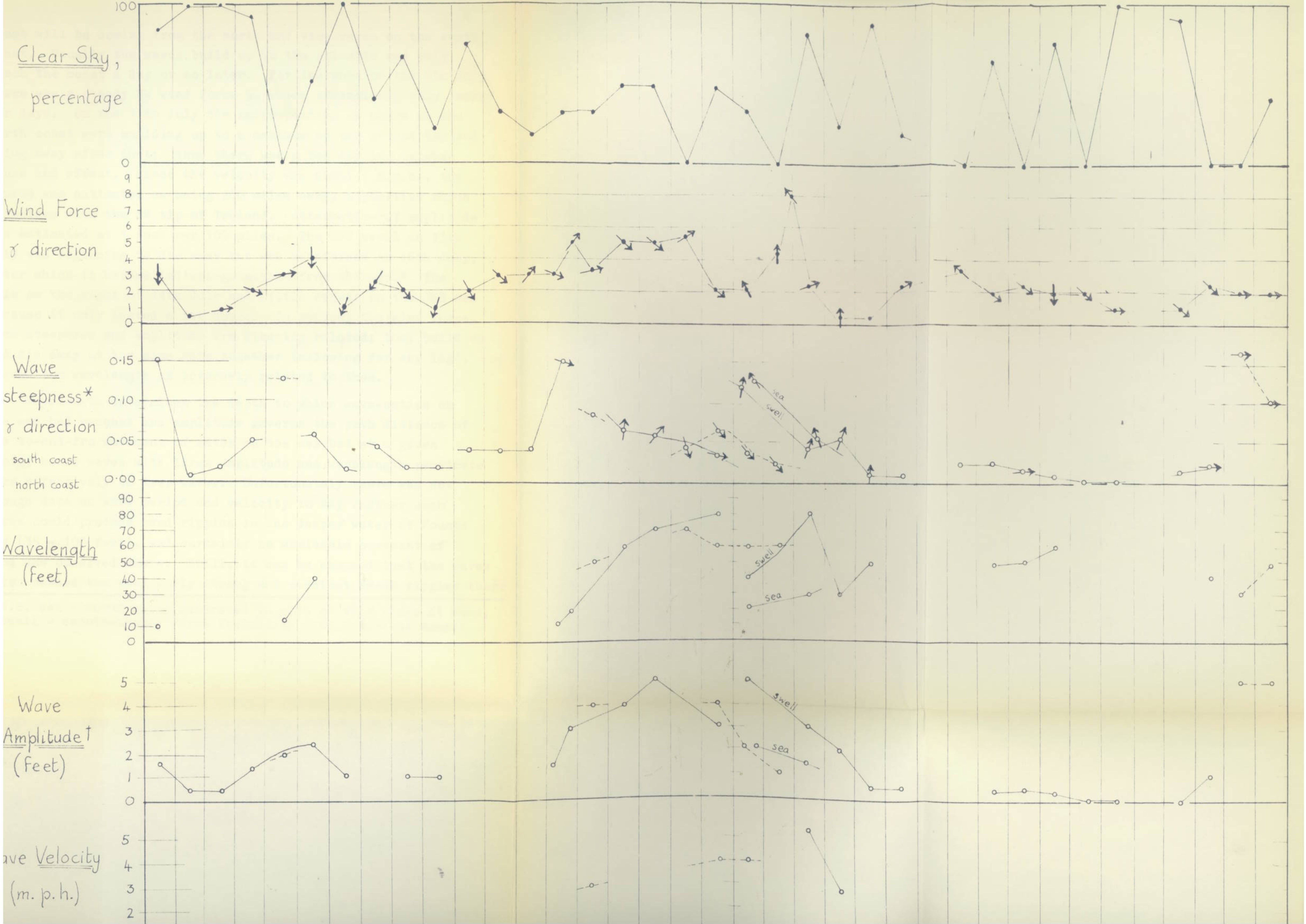
D.W. Durney
Geology Department,
Imperial College.

WEATHER, SEA AND SAND RIPPLES

A record of these three conditions was kept during the six week period, because of their relevance to each other, and in the case of weather and state of sea, their influence on diving conditions and on the behaviour of sand ripples and the mass movement of sand across the sea-floor. The latter would be of interest to the Geochemists because of the effect on the distribution of tin sand. Most work was done on sand ripples since measurements could be easily made by divers on the sea-bed.

Data on the first two have been drawn up graphically from the logbook to show a number of relationships (fig. 1). The temperature, rainfall and percentage of clear sky did not affect diving nor did the wind itself, although its effect on the wave amplitude and direction the waves were travelling could control a decision to dive in Mounts Bay or St. Ives Bay (or not at all if the sea was too rough). Fortunately the weather was reasonably good for most of the time, therefore little diving time was lost on this account. This achievement was also due to the great stability of our boat in rough water as compared with the rowing boat used on the 1960 Cornwall Expedition. Even so, a rough sea could prevent the boat from venturing close in shore. We had very little mist.

A comparison of wind force and clear sky show, as expected, that they are, in general, inversely related. When considering the relation between wind and sea it should be remembered that they must be travelling in the same direction if they are related and that wave amplitude and steepness result from the wind force, its duration and the expanse of open water in that direction, combined. Clearly, waves reaching the north



Clear Sky, percentage
100
0
Wind Force & direction
9
8
7
6
5
4
3
2
1
0
Wave steepness* & direction
south coast
north coast
0·15
0·10
0·05
0·00
sea
swell
Wavelength (feet)
90
80
70
60
50
40
30
20
10
0
swell
sea
Wave Amplitude† (feet)
5
4
3
2
1
0
swell
sea
ave Velocity (m. p.h.)
5
4
3
2

coast will be coming from the north and vice versa on the south coast. Usually the waves build up in the Atlantic and only reach the coast a day or so later. For instance on the 9th July there was a steady NW wind force 5, which effectively only lasted two days. On the 11th July the corresponding NW waves on the north coast were building up to a maximum on the second day and dying away after that; thus there was a two day lag between cause and effect. Since the velocity was about 4 m.p.h., the source was estimated as being 200 miles away, a position which coincides with the SW tip of Ireland. Attenuation of amplitude was estimated at 1 foot per 100 miles. The SSW swell on 13th July was beginning to die away but was reinforced on 16th July, after which it became indistinguishable from SSE sea.* The gale on the night of 14th July had little effect on the SSE sea because it only lasted a few hours. In general the wind force, wave steepness and amplitude are directly related; they build up and die away at the same rate together (allowing for any lag), though the wavelength is inversely related to them.

Wavelength determines the depth to which wave-action on the sea bed reaches and amplitude governs the path distance of the to-and-fro movement of water on the sea bed at a given depth; hence waves with large amplitude and wavelength penetrate more effectively to deep water. Unfortunately there was not enough data on wave period and velocity to say whether such waves could produce sand ripples in the deeper water of Mounts Bay (35 - 100 feet), and certainly no wholesale movement of sand was observed there. Still, it can be assumed that the waves which caused the remarkably strong and constant NW-SE ripples there

* N.B. sea = waves being generated in situ or very close at hand, swell = smooth-topped waves travelling from a distant source.

were caused by unusually big, fast waves travelling from the SW only. This does not tally with the prevailing wind direction of WNW during our summer period, so possibly they were produced during the more severe winter conditions, and were merely being sustained by smaller waves during the summer.

Number of Wind Directions recorded

E	SE	S	SW	W	NW	N	NE
0	13	6	12	22	28	11	2

Prevailing Wind approximately WNW.

One such wave would be that recorded on July 10th. The greatest expanse of open water lies from west and south in Mounts Bay, so this would allow large south-westerly waves to enter.

Formation and Types of Ripples

Symmetrical or oscillation ripples are produced by wave action, which is simply the oscillation of water on the sea bed. They can be regarded as two opposing current or assymmetrical ripples produced by a two-way flow of water, and this effect was often observed in shallower water. Material is removed from the ripple troughs and laid near the crests. See fig. 6.

A graph showing grain size of sand plotted against wavelength of ripples shows how the smaller ripples are made of fine sand whereas the larger ripples are of coarse sand, sometimes gravel. This agrees with findings of experimental work (Forrel, 1884), which also shows that ripple wavelength is a function of water depth. An obvious factor to consider is that

Fig (2)

DISTRIBUTION OF WAVE-CREST AZIMUTHS,
From 22 random localities in Mounts Bay

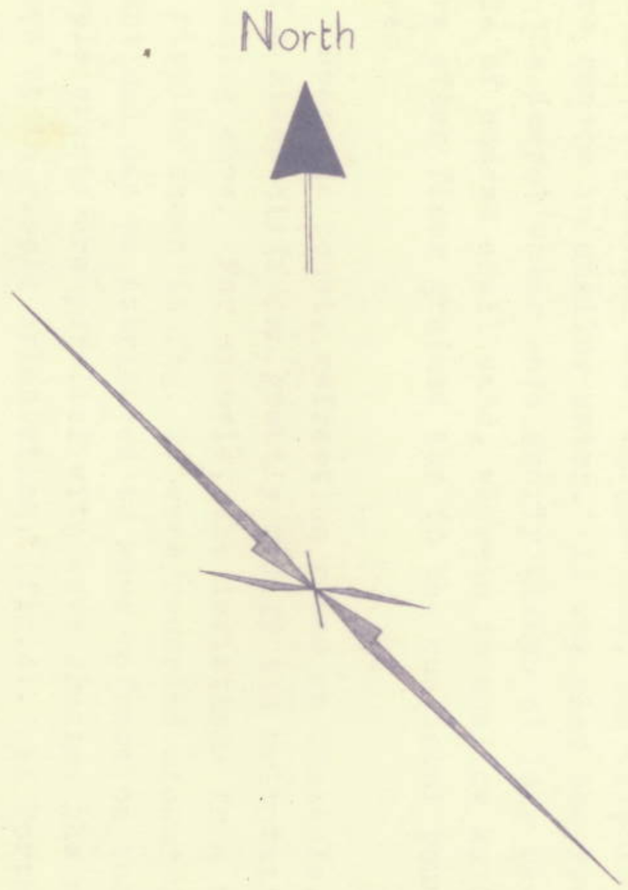
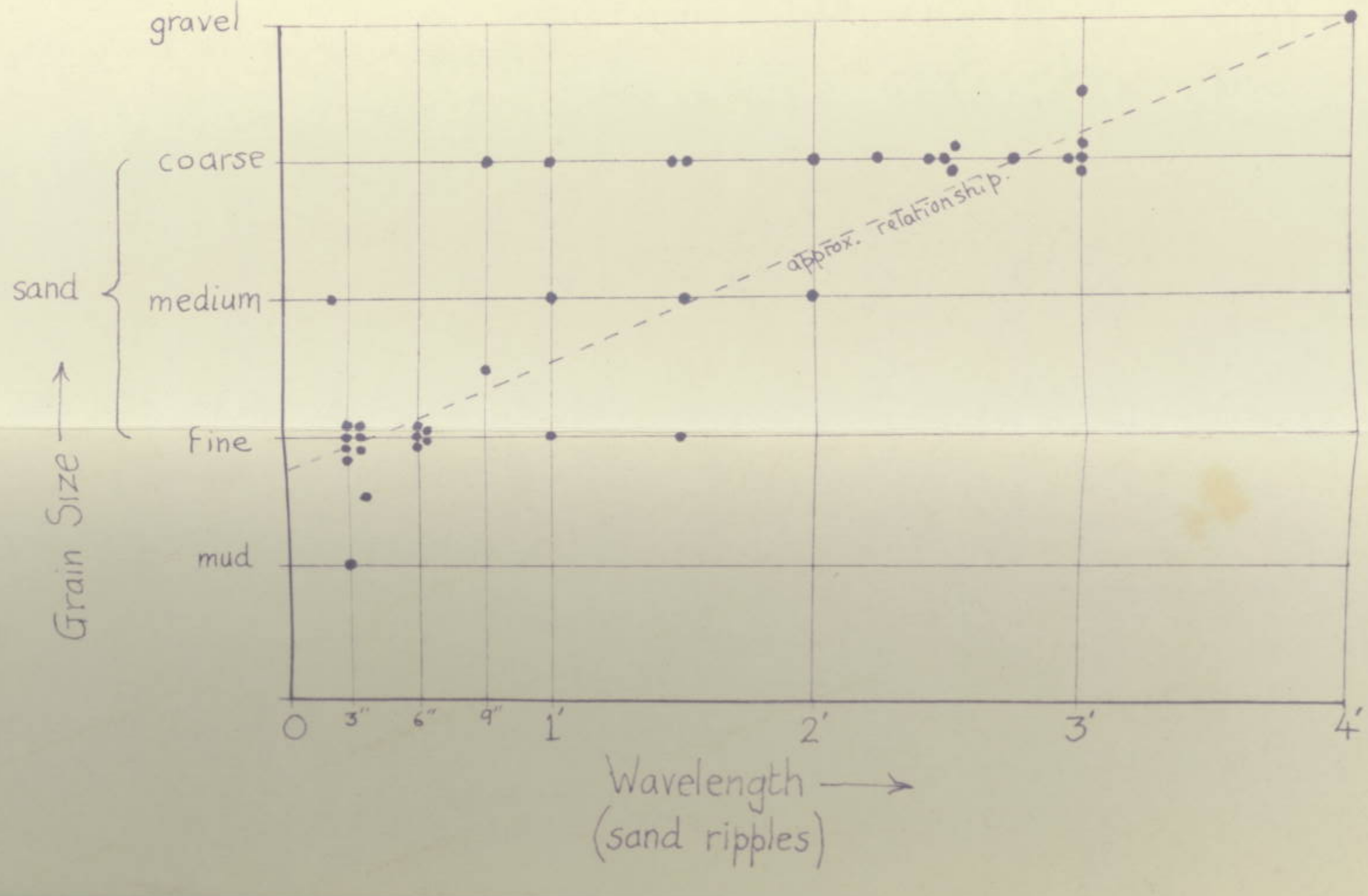


Fig. (3)



finer material (except clay) will require slower currents to move it, and will thus build up a ripple faster than with coarser material. Therefore at any one place the larger ripples will record the last most intense oscillation, whereas smaller ones would be more liable to change under gentler conditions. The latter would thus be more of a reflection of recent weather conditions. That is why the smaller ripples are rather more randomly orientated than larger ones, and orientation becomes more random in shallow water. It was also observed that ripples in the deeper water were nearly always of long wavelength and made of coarse shell sand, whereas in shallow water the sediments were often finer grained due to the continual pounding of the waves.

Near the coast, refraction round an obstacle, or reflection off a steep cliff can greatly modify the orientation of an incoming wave. For example, the deviations from the NW-SE trend of ripples shown in fig. 2, were recorded around St. Michael's Mount and can be attributed to wave refraction there. Since ripple crests are parallel with wave crests, the refraction shows up in ripple orientation, (fig.4). At Porthcurno, a steady rotation of ripple azimuth was noted on the sandy sea-floor as one swam northwards, which corresponds to the refraction of the prevailing wave direction around the headland (fig. 5), swinging from SE to E. At Mullion Cove, sand ripples just outside the harbour had an apparently chaotic pattern with ripple crests criss-crossing in different directions (fig. 9c). This could be attributed to several sets of ripples forming simultaneously at the same place, i.e. an interfering wave pattern produced by the reflection of the incoming waves from the harbour wall and

Wave Refraction

Fig 4.

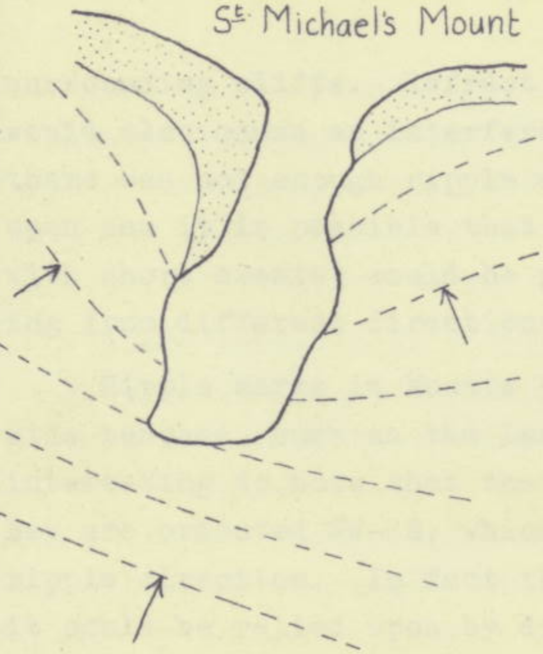
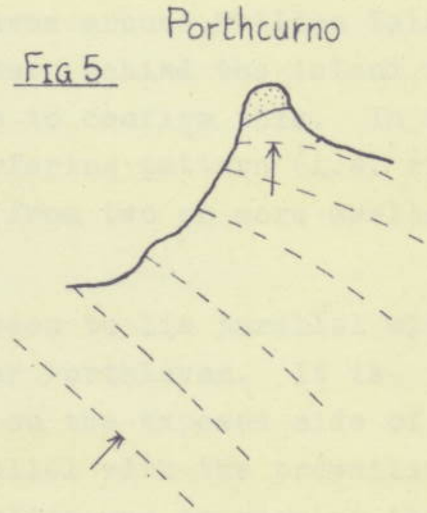
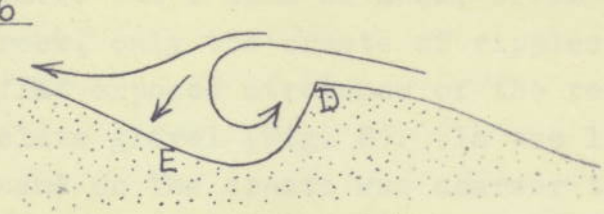


Fig 5



Sand Ripples

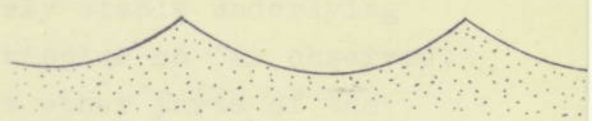
Fig 6



E = erosion D = deposition

Asymmetrical

Fig 7



Symmetrical

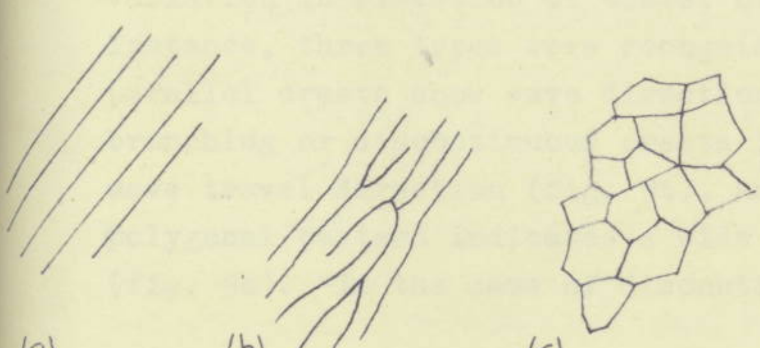


Fig 8

Symmetrical with
Flat trough

Fig 9 Ripple Patterns

surrounding cliffs. Refraction of waves around Mullion Island would also cause an interference pattern behind the island though there was not enough ripple data here to confirm this. In the open sea it is possible that an interfering pattern (i.e. ripples with short crests) could be produced from two or more swells arriving from different directions.

Ripple marks in Mounts Bay are seen to lie parallel with wide beaches, such as the Loe Bar near Porthleven. It is interesting to note that the beaches on the exposed side of Mounts Bay are oriented NW-SE, which is parallel with the prevailing ripple direction. In fact this direction was so regular that it could be relied upon by divers as a navigational aid when underwater.

The profile of ripples seen (cross section) was always symmetrical with sharp crests, (figs. 7 & 8). In cases where there was a lack of sand, or in a small sandy patch amongst rock, only the crests of ripples could form, the troughs being flat exposed stretches of the relatively stable underlying slate gravel (fig. 8). In the large ripples so far observed, sand on the crests was coarser than at other parts of the profile.

The pattern of ripple crests indicated the angular variation in direction of travel of their parent waves. For instance, three types were recognised. Those with very long parallel crests show wave direction to be constant (fig. 9a), branching or discontinuous crests indicate some variation in wave travel direction (fig. 9b), and criss-cross crests, or polygonal pattern indicates a wide variation of wave directions (fig. 9c). In the case of discontinuous crests, the pattern may also be the result of an early set being replaced by a later, slightly different, set. In deep water on open sand, the ripple crests were always long, though generally if close to rock or boulders crests became shorter (more discontinuous) owing to the influence of the former on the prevailing wave direction.

There seems to be no evidence that the behaviour of ripples has a direct influence on mass movement of sand below a depth of say 30 feet, whereas tidal and wind generated currents on the sea-floor would be a primary agent. A clue to a possible strong wind suitable for causing sediment to move, is given by the strong NW-SE ripples which in turn depend on a strong SW wind. Using this argument sand would be carried towards the SW by such a wind generated current, since these currents always move in the opposite direction on the bottom to those on the surface. However, this would only be a minor effect compared with tidal currents. The study of tidal currents on the sea bed was considered beyond the scope of the present expedition, though it would be an interesting study for any future expeditions. Thus there could be no definite conclusions about mass transport of sand, apart from the way in which it works. There will be mass movement of sand (according to Stride, Q.J.G.S. 1963), when

a) the difference in maximum velocity between ebb and flood is at least 0.1 knots or 0.17 feet per second.

Another case is self-evident, when

b) ebb and flood tide directions are not exactly opposite there will be a net movement in one direction.

No tidal current ripples were observed in our area despite the fact that we often dived at or near the maximum tidal velocity, so it may be said that the effects of tides, per se, were not a significant factor. In fact since tidal activity is fairly constant throughout the year, wave action would be the dominant agent for stirring up sand on the sea bed, especially during the winter, as already pointed out. The more wave action is able to keep sand in suspension the more liable it would be to mass transport by a super-imposed tidal current. Hence evidence suggests that tidal transport of sand would probably be most effective during the winter, and a similar behaviour would be expected for wind currents.

Stride has concluded that the sand would move WSW away from the south Cornish coast. The largest patches of sand at Penzance and Loe Bar appear to open into the English Channel judging from the extent of the sand and the continuation of smooth depth contours (see depth chart fig. 1 by N.C. Kelland, and geological map of Mounts Bay), as opposed to the irregular contours on the rocky sea-floor around Prah Sands area. This means that some sand would move offshore towards the south, with (a) as a possible mechanism. However, a good deal of sand is confined to isolated areas near the coast and appears to be relatively permanent there. Further evidence for this is that all the sand in deeper water contains a high proportion of shell material whcih indicates that influx of sediment from rivers and beaches is small, and that loss of sediment from these patches to the English Channel is also small. Much of this shell sand is generated in the regions with rocky sea bed.

Beaches

Beaches always tend to align themselves perpendicular to the prevailing wave direction, otherwise the sand will move alongshore in an attempt to adjust the situation. The geological map shows that beach sands are locked in isolated bays around

Mounts Bay with little longshore drift, especially on the east coast, and are therefore in equilibrium with the prevailing waves. This notion is supported by the fact that the large sand ripples are parallel with the closest beaches. Longshore drift would be most significant from headlands into the adjacent bays, (e.g. St. Michael's Mount, fig. 4), and the coast in the Mousehole region which is not perpendicular to the prevailing waves. Waves are caused to strike the sides of St. Michael's Mount obliquely by wave refraction, hence sand moves towards the N and NE in the shore zone and shallow water.

Beaches are subjected to the greatest possible amount of wave energy and so sand grains are quickly sorted out according to grain size and density, and distributed zonally from the shore to the shallow sea. It is a well known fact that the biggest particles are concentrated at the top of the beach, but not so obvious is the fact that the densest of any particles with the same size (e.g. cassiterite or tin oxide is a very dense constituent) behave in just the same way.

The Loe Bar, a storm beach blocking the mouth of the River Caber, is a remarkable stretch of shingle which is very well sorted and well rounded, therefore must have been subjected to wave action for a very long period. Certainly for a longer time than all the other beaches in Mounts Bay.

Concerning beach profile, incoming waves with a wave steepness less than 0.03 tend to move material onshore, and if greater than 0.03, to move sand offshore a short distance, i.e. the steeper the wave, the gentler the beach slope. Of the waves reaching the south coast, 16 were less that 0.03 and 16 were greater than 0.03 wave steepness, indicating that average sea conditions were intermediate. However, since waves with low steepness are often not easy to detect, it is quite possible that there were many more of these present, thus indicating a net onshore movement of sand at that time.

GEOLOGY

The method of rock sampling by divers has already been described by N.C. Kelland, and in addition a few still photographs of the sea bed and geological observations, were made. As a result of plotting the collected rock samples, three geological maps of Mounts Bay have been drawn up with the kind permission of the Geochemistry Department and Mr. P. Ong (who is preparing a thesis on the Geochemistry of these specimens). The small scale map is necessarily generalised regarding the distribution of rock types and structure on account of the sample points being separated by more than quarter mile intervals, and no detail of the slate/dolerite boundaries can be given. St. Michael's Mount and Rinsey Head areas are more detailed because sample points were more concentrated and short traverses were often made across the sea bed by divers to prove geological or sedimentary boundaries.

Slates

The oldest rocks found were slates (Killas is the local name) which were dark blue and very fine-grained except for a number of specimens that were of silty or sandy texture, or buff coloured. Cleavage was usually more dominant than bedding and in places there was evidence for intense shearing and faulting. These beds cover practically the whole of the exposed area and are almost certainly a continuation of the Mylor and Gramscatho Beds which compose most of the surrounding land. Within the thermal metamorphic aureole of the granites, specimens of spotted slate and Andalusite Schist were collected. Slatey cleavage around the Godolphin Granite dipped away on all sides from the intrusion owing to the upward movement of the granite while it was still molten.

Dolerite

The slates were followed by a period of intrusions of basic igneous rock which is known as dolerite, diabase or 'blue elvan'. These are gently dipping sheet-like bodies which are characteristically black to dark grey-green in colour, moderately crystalline and harder than slate. They were easily identified by their lack of cleavage except in places where they had been slightly sheared. The three specimens found off Porthleven may be considered part of the swarm of intrusions which passes through this town.

Echo-sounding off Perranuthnoe revealed a ridge on the sea bed that extends from the dolerite dyke peninsular, but unfortunately no specimens were taken to confirm that it was in fact dolerite.

Granite

The youngest rocks were of granite and its associated group of acid intrusions and period of mineralization. The granite itself was a very characteristic light coloured coarsely crystalline igneous rock composed of Quartz, Felspar and Mica and was harder than the slate or dolerite. Specimens were rather difficult to collect, even with the pneumatic hammer, because there were so few planes of weakness (cleavage absent)

The Godolphin Granite

Granite, Head on the upper slopes. Trewavas Head

Contact, Granite on left, Slate on right. Between Trewavas Head and Porthleven

Underwater Granite/Slate contact west of Rinsey Head

Facing west, Slate on the left (with cleavage), Granite on the right, sand in between.

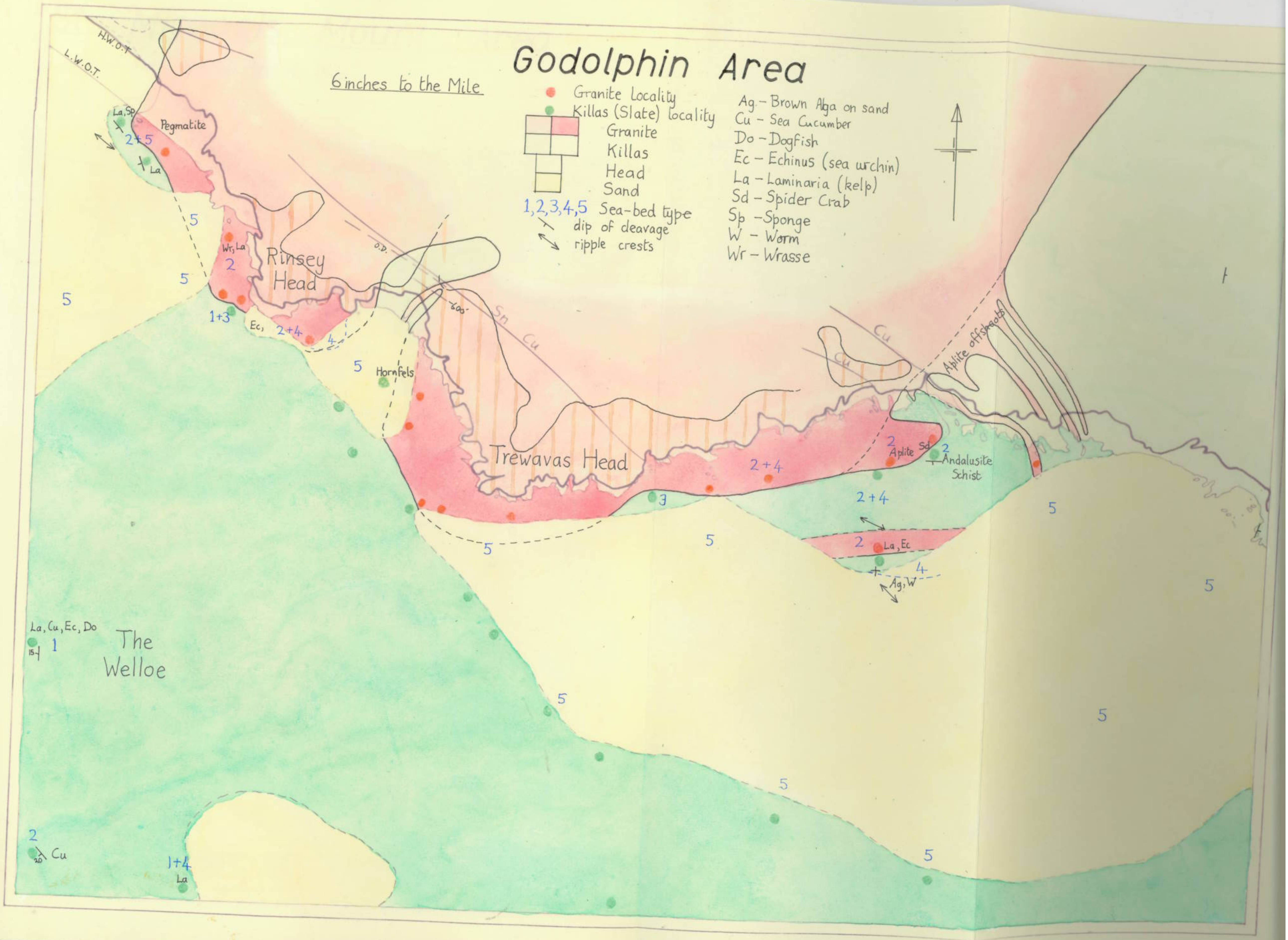
Showing Anchor Chain. Calypsophot, f4·0, 1/60 sec, focus 2·5 metres

Calypsophot, f5·6, 1/60 sec, focus 2·metres and the surfaces were always smooth and round. Pegmatite and Aplite are practically similar in all respects to their parent, the granite proper, except that they both occur in sheet-like bodies; the former is composed of much larger crystals and the latter of much smaller crystals than the granite. Good examples of both were seen on the sea bed around the Godolphin granite mass (Rinsey Head, Trewavas Head). To the east of this area outcrops of al least three Aplite Sills (containing black Tourmaline) were seen to overlay slate with a horizontal contact, and although very close to the main granite, they do not strictly indicate the boundary of the main mass. A vertical granite/ slate contact was seen west of Rinsey Head (photos 1 & 2) so the boundary for the main mass is justifiable here.

The most surprising fact revealed by this study was that the granite, aplite and pegmatite never extended further than 200 yards from the cliff at Godolphin and not more than 100 yards at St. Michael's Mount. Almost as surprising was the fact that no Aplite (also known as Felsite, Quartz Porphyry and Elvan) was found in the rest of Mounts Bay, but this could conceivably be due to collection failure. At both St. Michael's Mount and Godolphin the aplite sills are concentrated on the east side of the intrusion.

Mineralization

Hot vapours and solutions emanating from the granite during its emplacement were the cause of deposition of tin (cassiterite), copper (chalcopyrite), lead (galena), zinc (sphalerite), iron (pyrite) and many other useful minerals, and much, though not


Godolphin Area
6 inches to the Mile
Granite locality
Killas (Slate) locality
Granite
Killas
Head
Sand
1,2,3,4,5 Sea-bed type
dip of cleavage
ripple crests
Ag - Brown Alga on sand
Cu - Sea Cucumber
Do - Dogfish
Ec - Echinus (sea urchin)
La - Laminaria (kelp)
Sd - Spider Crab
Sp - Sponge
W - Worm
Wr - Wrasse
H.W.O.T.
L.W.O.T.
Pegmatite
Rinsey Head
Hornfels
Trewavas Head
Aplite offshoots
Aplite
Andalusite Schist
The Welloe
Sn Cu
O.D.
600'

St. Michaels Mount Area

Scale :- 6 inches to the Mile

Geology of Mounts Bay

all of the vein quartz which occurs in the slate. No mineral lodes were discovered beneath the sea, though small pockets of pyrite were often in the slate and dolerite. One specimen of dolerite contained small pockets of chalcopyrite and fibrous actinolite. Hollow rusty pockets seen in the slate may represent decomposed pyrite or chalcopyrite.

Observations at Mullion Cove

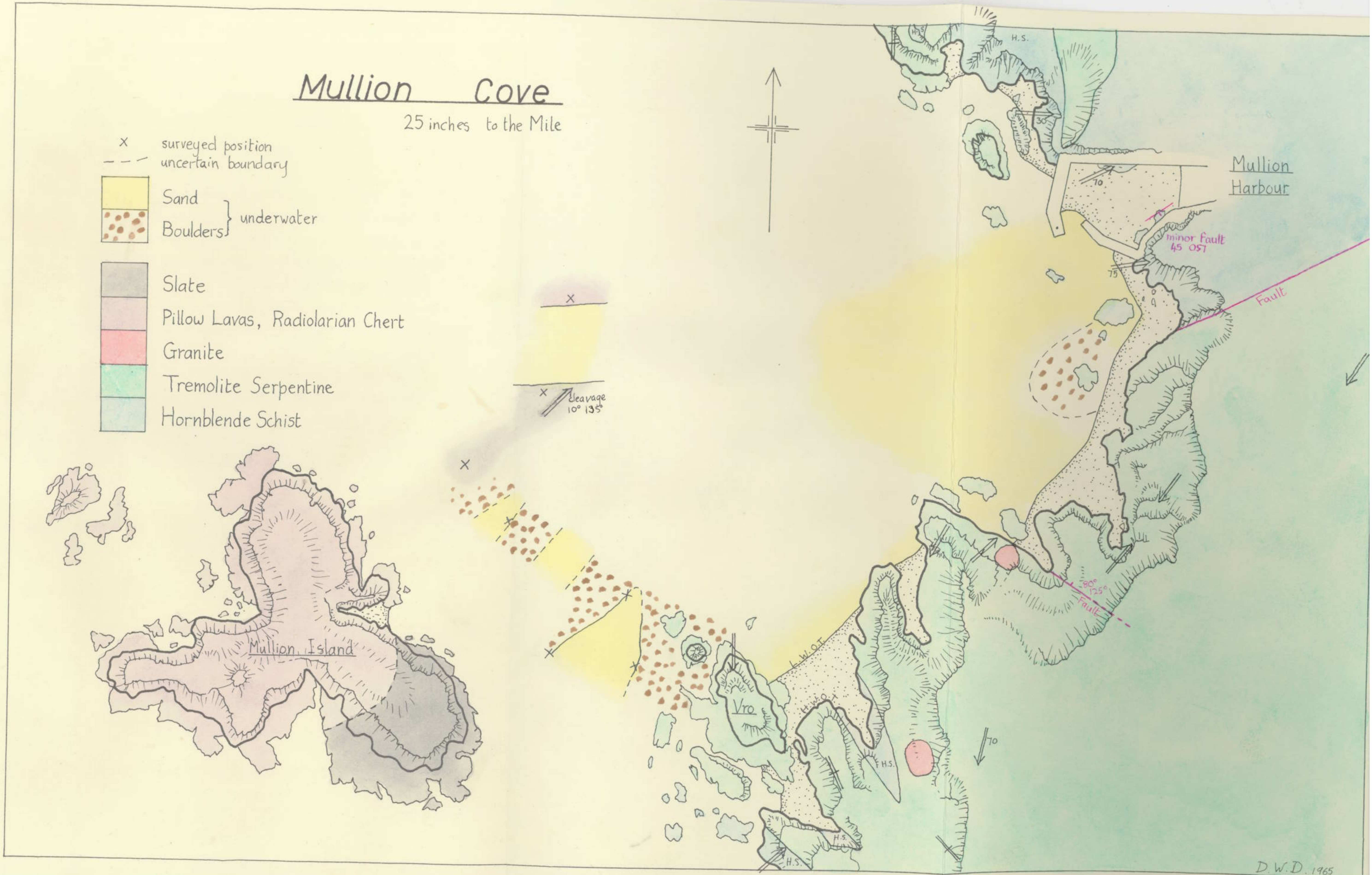
This region lies on the western extremity of the Lizard Boundary Fault or Line which separates the ancient Lizard Complex of rocks from younger slates etc. further north. The nature of this contact has puzzled Geologists for many years owing to the fact that on land it remains hidden beneath thick soil or sand. So a preliminary investigation of the sea bed was made here to see if underwater exposures were any better, and if so what the characteristics of this contact were.

Excursions were made on July 7th, 15th, 16th, 17th and 25th by P. Jenkins, L-J. Dunn, D. Durney and J. McKie using aqualungs. On two occasions a rowing boat was used, partly for surface safety cover and partly to avoid the long swim to and from the harbour. Two divers worked simultaneously on the bottom, keeping a record of depth, time, type of bottom with appropriate measurements and position fixing. Both Sphericompass and prismatic compass (prism protected by perspex) were used, and for distances measured on the bottom a cord of known length was held taut between two poles. By recording azimuth of the cord and repeating the procedure on a sedimentary or geological boundary on the sea-floor, short distances could be (and were) accurately plotted, no matter how curved. One of the disadvantages here was the effect of swell in the shallower regions which carried the diver to-and-fro about 6 feet across the bottom. Also, strong tides only allowed work at slack water.

Positions were accurate to plus or minus 50 feet or less except for the most westerly point which is about plus or minus 100 feet. The presence of Serpentine which contains Magnetite may have had some effect on the compasses.

The results were plotted on the accompanying map, and showed that the area of interest, a N-S line between Mullion Island and the mainland was largely covered with sand, gravel and boulders, thus obscuring the geology. There appears to be good exposure in the seaward direction whereas most of the sediments accumulate in the lee of Mullion Island. The slate found NE of Mullion Island and on the island itself was an unexpected find though it does fit in with the pattern found along the L.B.L. on the mainland. The underwater outcrop of Pillow Lava indicates that a promising region for future divers would be approximately the position of the Northern Point. Most detail of the land geology was taken from the six-inch map by Sir J. Flett, 1906, who did not record the slate on Mullion Island.

Lack of exposure along the L.B.L. suggests that it is a zone of weakness such as a large fault.



Mullion Cove
25 inches to the Mile
surveyed position
uncertain boundary
Sand
Boulders
underwater
Slate
Pillow Lavas, Radiolarian Chert
Granite
Tremolite Serpentine
Hornblende Schist
Mullion Island
Cleavage 10° 135°
Vro
L.W.O.T.
H.W.O.T.
H.S.
Mullion Harbour
minor Fault 45 057
Fault
80° 125°
D.W.D. 1965

RECENT AND SUB-RECENT FEATURES

Submerged Land-features

Before the Ice Age, the level Pliocene platform at +430 feet in SW England, was cut by the approximate sea level at that time. During the Ice Age sea levels were lowered to about -300 feet and this in turn caused rapid river erosion along the coastline and the steep-sided valleys that are seen today. A bouldery deposit known as 'head' was also formed at this time on valley sides. Since then the bulk of the glaciers have melted and produced a rise to the present sea level; corresponding with an infilling of the valley bottoms along the coast and as indicated by the geophysical survey, in submerged valleys in Mounts Bay. At Loe Bar the old valley has actually been thwarted by a recent beach. Most, if not all, of the vertical sea cliffs around Mounts Bay have been formed by the present sea level. At Trewavas Head erosion has been slow since the cliff is not far from the granite contact, and the old deposits of head can still be seen.

Characteristic Rock forms underwater

The smoothness of a rock surface was seen to increase from slate to dolerite to granite, paralleled with a decrease in the propostions of attached seaweed and encrusting organisms. A surprisingly large number of quartz veins were collected from slate areas because, being very hard, they jutted out from the outcrop and were therefore the easiest part to hammer or chisel away. Dolerite and granite or aplite tended to project above low lying regions of gravel or boulders, more than the slate.

Spectacular channels and ridges often appeared in the slate, controlled in some places by joint and fault directions. The slate was evidently disintegrating more than the other rocks, for the cleavage surfaces were usually smeared with clay and rock waste, which was even inhabited by worms. Even in the deepest places visited slate outcrops were always encrusted with algae and Bryozoans. Rock outcrops were rarely completely exposed over wide areas, usually there would be frequent small pockets of coarse shell sand and rock gravel with a few boulders. The Admiralty Chart marks the position 1 mile south of Trewavas Head as gravel whereas it is mostly rock and some gravel associated.

Sea Bed Types

An attempt was made to classify types of sea bed according to roughness of topography and extent of the proportions of its components, which range from sand to boulders to massive outcrops.

(1) Flat Bedrock - up to 2 feet variation in relief, with or without thin sand or boulders.

(2) Rough Bedrock - strong relief, gullies and ridges, shell sand and pebbles in gullies.

(3) Boulders - with or without cobbles and gravel.

(4) Local Sand - usually shell or local rock material.

(5) Extensive Sand - composed of quartz, shell, mica, felspar, chert, granite, etc. Grain size: c = coarse, m = medium, f = fine.

(6) Mud - often kaolin with large amounts of silt.

This system aided a quick assessment of the type of bottom when underwater and a brief record with one or two appropriate numbers in the logbook. Boundaries between types of bottom were either sharp or gradational, and information given by the diver also depended on whether he was 'landed' well within an area or on a boundary. Out of the 123 localities recorded from June 24th to July 30th, were found the following associations:

Nine localities with extensive sand and rough bedrock mostly covered by the sand, or the gradation or boundary between the two areas.

Boulders were associated with extensive sand in seven places; with bedrock in six places; with flat bedrock in six places, and with local sand in three places but not with mud.

By definition, local sand was rarely found by itself, thus in three places with rough bedrock (also contained in definition (2)); in four places with flat bedrock, and in three places with boulders.

In three places flat bedrock with extensive sand, and one place with rough bedrock.

Associations which were not found were (4) and (5) (separated by definition) except where two quite different types of sand were seen to have a sharp boundary (e.g. coarse granite sand and muddy silt off Trewavas Head, see map). Mud was not found with any other type except sand. Only two with pure mud were recorded and even these are doubtful. During a calm period a thin film of mud would always settle on the sand, rock and seaweed. In a number of places the rapid change in type of sand was noticed because of the dramatic contrast between the types of sand ripple.

MARINE LIFE

The more ostentatious forms of marine life were frequently observed by divers and noted in the logbook by means of abbreviated names. Thus we arrived at a list of animals and seaweeds seen in Mounts Bay and made some correlation with the type of sea bed they were found on, and in some cases correlation with the depth at which they occurred. The results are not meant to be a complete assessment, but do serve to show the main tendencies.

Faunal List

(Those without abbreciations were only seen once or twice)

Fish

Cornuba Ray
Do = Dogfish
Ee = Sand Eel
Fl = Flat fish (unknown identity)
Gb = Goby
Mullet
Plaice
Pollack
Ro = Rockfish
Skate
Wr = Wrasse

Tunicates

Sq = Sea Squirt

Echinoderms

As = Asterias (Common Starfish)
Br = Brittle Star
Cu = Sea Cucumber
Ec = Echinus (sea urchin)
    Heart Urchin
He = Henricia (Purple Starfish)
Ss = Marthasterias (Spiny Starfish)

Crustaceans

Ed = Cancer (Edible crab)
    Pilumnus (Hairy crab)
Hc = Hermit crab
Hy = Hyas arenas
Sd = Maia (Spider crab)

Worms

    Arenicola
Fa = Fanworm
Pe = Peacock Worm
W = Worm (unidentified)

Molluscs

Ch = Chiton
Ha = Sea Hare
Sc = Scallop

Coelenterates

Al = Alcyonium (Dead Man's Fingers)
An = Anemonia (Snakelocks Anemone)

Ca = Caryophyllia (Devonshire Cup Coral)

Go = Gorgonia (Sea Fan)

Hl = Haliclystus

Hy = Hydroid

Te = Telia (Dahlia Anemone)

Sponges

Sp = Sponge (unidentified)

Floral List

Zo = Zostera (Eel Grass)

Red Algae

Co = Corallina Officinalis (calcareous alga)

De = Delessaria

Po = Porphyra

Re = Red sea-weed

Green Algae

Ul = Ulva lactuca (Sea Lettuce)

Brown Algae

Ag = Filamentous alga found on fine sand

Fs = Fucus serratus

La.d = Laminaria digitata

La.p = Laminaria polyschides

'La'.s = 'Laminaria' saccharina

Habitats

(Explanation of abbreviations given above)

	FAUNA	FLORA
(1) Flat Bedrock	An, As, Br, Cod, Cu, Do, Ec, Gb, Go, Ha, He, Sd, Sp, Sq, Ss, Wr.	La.d, La.p, La.s, Ul, Po.
(2) Rough Bedrock	An, Al, As, Br, Ca, Cod, Cu, Ec, Ed, Gb, He, Pilumnus, Sd, Sp, Ss, Wr.	La.p, La.d, De.
(3) Boulders	An, As, Br, Ch, Ec, Ed, Ee, Gb, He, Hl, Hydroid, Mu, Pe, Sd, Sp, Sq, Ss.	La.d, La.p.
(4) Local Sand	Br, Cu, Ed, Gb, Ee, He, Mu.	
(5) Extensive Sand	Arenicola, As, Br, Cornuba Ray, Ed, Ee, Fa, Fl, Gb, Heart urchin, He, Hc, Hy, Mn, Mu, Plaice, Rockfish, Sc, Sd, Skate, Sc.	La.d, La.s, Co, Zo, Re.
(6) Mud with silt	As, Ed, Hc, He, W.	Ag.

General Ecological Observations

Laminaria was often extremely dense just below the low tide level, but thinned out steadily to about 60 feet where it disappeared. Because of this the collection of rock samples and measuring of geological structures was easier in deeper water. Spider Crabs (about one foot or more leg span) and large sea urchins (Echinus) were commonly associated with Laminaria in the shallower water.

On the other hand Gorgonia, Devonshire Cup Coral, Sea Cucumber, and cartilaginous fishes and most of the Brittle Stars were confined to deeper water below about 50 feet.

The distribution of organisms in their habitats appeared to be quite uneven. For instance, Sea Cucumbers, Sea Hares, Brittle Stars and Echinus were found in great numbers at certain places and not at all at certain other, similar places. In such cases the distribution would be dominantly affected by factors such as clarity of the water, availability of food and oxygen and temperature.

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Marine Life

Wrasse amongst kelp.   Calypsophot, f4·0, 1/60 sec, focus 2 metres

Spider Crab (Maia squinado).   Calypsophot, f8·0, 1/60th sec., focus 1 metre

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Also:

Admiralty Charts,
Ordnance Survey Maps,
Geological Survey Maps.