IMPERIAL COLLEGE

1972

MALTA EXPEDITION

IMPERIAL COLLEGE SUB-AQUA CLUB

1972 MALTA EXPEDITION

CONTENTS

Section 1

INTRODUCTION

The Imperial College Sub-Aqua Club organised a team of twelve divers to perform a group of experiments off the coast of Malta for six weeks in the summer of 1972.

The team consisted of divers all belonging to the Sub-Aqua Club who had in most cases been totally trained within the club. The expedition members are listed at the end of this section.

The planning of the expedition commenced in 1971 and the exact structure of the work to be performed took many months to finalise.

Our selection of experiments was based on the experience existing within our diving club and on the known requirement of such organisations as the Gatty Marine Laboratories. Once our work had been established the choice of a suitable diving site was narrowed considerably and although there was some reluctance to organise yet another expedition to Malta, the facilities and sea conditions around Malta could not be bettered without imposing greatly increased expenditure.

The experiments performed during our visit to Malta are described in detail in the following sections.

However, I have described below an abbreviated program of our work.

All the basic diving and experimental equipment required for the expedition was driven to Malta only a short time ahead of the contingency of divers who flew from Gatwick Airport.

We were based in two flats in St. Julians. This area was chosen because of its convenience in relation to the University and because our work would be carried out in as many different parts of the island as possible and St. Julians is reasonably centrally placed.

The first few days were spent acclimatising the team to the new conditions and in sorting our equipment. The main delay being the air compressor. Once we had established its whereabouts and obtained permission from the local custodians to use it, we then had to spend some time making it serviceable. Continuous difficulties were experienced with this machine throughout our stay.

Once the preparatory work was complete the first 2 to 3 weeks of diving were mainly associated with the Posidonia experiment. However, during the evening and non diving part of the day much time was spent preparing our experimental equipment for the surveying experiment.

The Posidonia experiment split into two areas. The first being the collection of samples for analysis, this work was carried out throughout our visit as new diving sites were visited. The second part required some preliminary experiments to establish the optimum method to be used to locate and tag plants to enable their growth to be measured over periods of years. Again, once a suitable technique had been established the work was performed on individual days during our stay. Much discomfort and not a little unrest was aroused by this work as it involved laying face down in a mass of Posidona for long periods of time while either tags were fixed or samples extracted. The majority of divers said they experienced a stinging sensation much like a nettle and some of our team had quite severe rashes. Also the ever present threat of sea urchins forced us to treat our work with extreme care.

Apart from the problem with sea life we also experienced problems with the sea. Towards the end of our visit we had several days where the swell was so severe that our work was made extremely difficult and one days work had to be completely cancelled. However, despite all these inconveniences, 500 plants were tagged and it is hoped that this will greatly assist in the understanding of the sea grass Posidonia and possibly in our understanding of the balance of nature in the Mediterranean.

The last 2 or 3 weeks of our visit were mainly spent working on the surveying experiment. This work requiring both divers and snorklers and a well organised shore party made it necessary for our diving to be centred on one particular site. As with previous expeditions we could not improve on the Marfa Quay area and so we erected a permanent site there for the last 2 weeks. This consisted of a Geodetic dome that had been designed as a third year project by students in the Civil Engineering Department. It acted as a shelter for all our equipment and two members of our party remained with the equipment overnight. This task was much detested because of both the quantity and violence of the local insect population!

The expedition members returned to England in the same fashion as they arrived, except that some difficulties were experienced in Rome because of fog delays to the flight departure from Malta. The transit van returned safely to Imperial College.

LIST OF MEMBERS OF EXPEDITION

H.G. Evans	
Miss J. Farradane	
P.G. Fearnhead	
A.R. Gardner	Leader
N. Houghton	
J. Johnston	
A. Moore	
J.R. Nicholls	Asst. Leader, Treasurer
M. Owen	
M.C. Seeley	
J.A. Trimble	
D.B. Watt	

ACKNOWLEDGEMENTS

I would like to give my sincere thanks to all those people and organisations who so kindly gave us assistance. The help we received whether equipment, advice or financial was of much greater than face value. For without their moral backing the expedition would never have taken place. I find it extremely difficult to make a complete list of all our helpers, they were so numerous and so generous.

However, I must first start with our financial benefactors:

The Imperial College Exploration Board.

The Royal Geographical Society.

Comex Diving Ltd.

The World Expeditionary Association.

British Petroleum.

For help and guidance we are ever indebted to members of the Imperial College Exploration Board.

The staff of the Royal University of Malta very kindly layed the facilities of the University at our disposal.

A particularly warm thanks is extended to The British High Commissioner who very graciously entertained the expedition leader to lunch and offered his best wishes and encouragement for the continuation of our work.

We are very grateful for the assistance given by very many members of the Imperial College staff who were constantly badgered for advice.

I would also like to thank the many industrial organisations who gave us such valuable assistance on the design, construction and safety aspects of our equipment and who so very kindly assisted our expedition with equipment and supplies. A list of these companies will be found at the end of this section.

Adcola Products Ltd.

Aquamatic Ltd.

George Angus and Co. Ltd.

Arrow Hart (Europe) Ltd.

British Petroleum.

C.P. Clare Electronics Ltd.

Ciba-Geigy Ltd.

Comex Diving Ltd.

Critchleys

Daly (Condensers) Ltd.

Electro Match Ltd.

Evershed and Vignobles Ltd.

Evode Ltd.

Ferranti Ltd.

F.R. Electronics

Glaxo Laboratories Ltd.

John Gosheron

Ilford

Imperial Chemical Industries Ltd (Pharmaceuticals Div.)

Imperial Chemical Industries Ltd (Organics Div.)

Integrated Photomatrix Co. Ltd.

Klippon Electricals Ltd.

Light Soldering Development Ltd.

Joseph Lucas Ltd.

3 M Ltd.

Marconi Instruments Ltd.

McMurdo Inst. Co. Ltd.

Mullard

Optical Works Ltd.

Pirelli General Cables Works Ltd.

Plessey Co. Ltd. (Semiconductor Div.)

Rotunda Ltd.

Royal Geographical Society

Scientifica and Cooke Electronics Ltd.

Sellotape Products Ltd.

Silkolene Lubricants Ltd.

Smith Kline and French Labs. Ltd.

T.J. Smith and Nephew Ltd.

Souriau Lectropon Ltd.

Special Products Distribution Ltd.

Standard Telephone and Cables Ltd.

Survey and General Inst. Co. Ltd.

Tessa Tapes Ltd.

Visijar Laboratories Ltd.

The Wellcome Foundation Ltd.

World Expeditionary Association

Section 2

POSIDONIA PROJECT

Miss J. Farradane
Mr. A. Gardner

The plant Posidonia has been found to grow in large underwater meadows, that are extremely abundant throughout the Mediterranean, forming a focal point for sea life and a vital link in the Mediterranean marine cycle. As a result of their ecological importance the density and distribution of such meadows have been extensively researched around Malta and to a lesser degree at other sites in the Mediterranean, by Dr. E. Drew of the Gatty L aboratories and his associates.

A sketch of the plant is shown in Fig.1. The leaves are up to 1 metre long and 1 cm wide and grow out from the rhizome. New leaves form at the base and in the middle of the existing leaves and the old leaves die and break off. The leaf bases, that remain, decay to leave a fibrous coat to the rhizome. Roots grow out of the rhizome and interweave to form a solid base to the meadow. The plants will grow on almost any substrate and it was their growth rate that we were primarily investigating.

The work split into two main sections, the first and smaller being an extension of a study instigated by the Gatty Marine Laboratories using a random sample technique to study the composition of the meadows. The second was to investigate the methods for tagging the plant so that it could be located and its growth measured. Once a method had evolved a sample run was to be performed that would then be monitored in future years.

Part 1

This work was carried out as part of a continous program to establish the nature and growth rates of the submarine plant Posidonia by a random sampling technique. The aim was to take samples of the Posidonia meadows so as to gain information on the type and number of leaves and shoots and the amount of other sea life.

We used a rigid weighed wooden quadrat (50cm sides and an area of $\frac{1}{4}$ square metres) to delimit the area of meadow to be cropped. We used $\frac{1}{2}$cm mesh carrot sacks to put the crop in and gloves to protect our hands whilst collecting.

Having selected our meadow, we deposited the quadrat on a typical part and arranged the Posidonia leaves so that it sank to the bottom all round. As it was easy to loose the quadrat we attached a float on a short length of cord to it. Our diver would then pull up all the Posidonia shoots, taking care to take hold of the rhizome top rather than pulling the shoots off. The second diver had to place all the rhizomes and leaves in the bag for subsequent sorting. Any other items that were found were also included, this usually meant sea urchins.

The sacks were then left to dry in the sun and then sorted and tabulated. The instructions below are an exact copy of those given to us by the Gatty Marine Laboratories. The only difference being that we used a 5% not 10% sample.

<u>Analysing the Samples</u>: The following procedure is as stated by the Gatty Marine Laboratories.

Keep the samples in the shade until you are ready to deal with them; they will start to smell badly after about 24 hours! Take care not to get samples from different depths mixed up at any time; if you think you might have, tell us.

1. Count the number of shoots, that is discrete groups of leaves at the top of a rhizome, by breaking each one off the rhizome and arranging them in groups of ten shoots. Then take one shoot from each group; this gives you a random 10% sample for further analysis and also an easy way to count them all!!

2. Put all the shoots except the selected 10% in the sack, spread thinly, and place in the sun to dry, weighted with a stone if it is windy. Make sure they are still labelled.

3. Keep the selected shoots in a damp cloth or bucket of water and take them one at a time to separate the individual leaves. Record the number of leaves, and then measure each one for:- width at base of green part, entire length, length of basal white part and length of healthy green part omitting the brown moribund extremity. When measured, these leaves can be added to the sack.

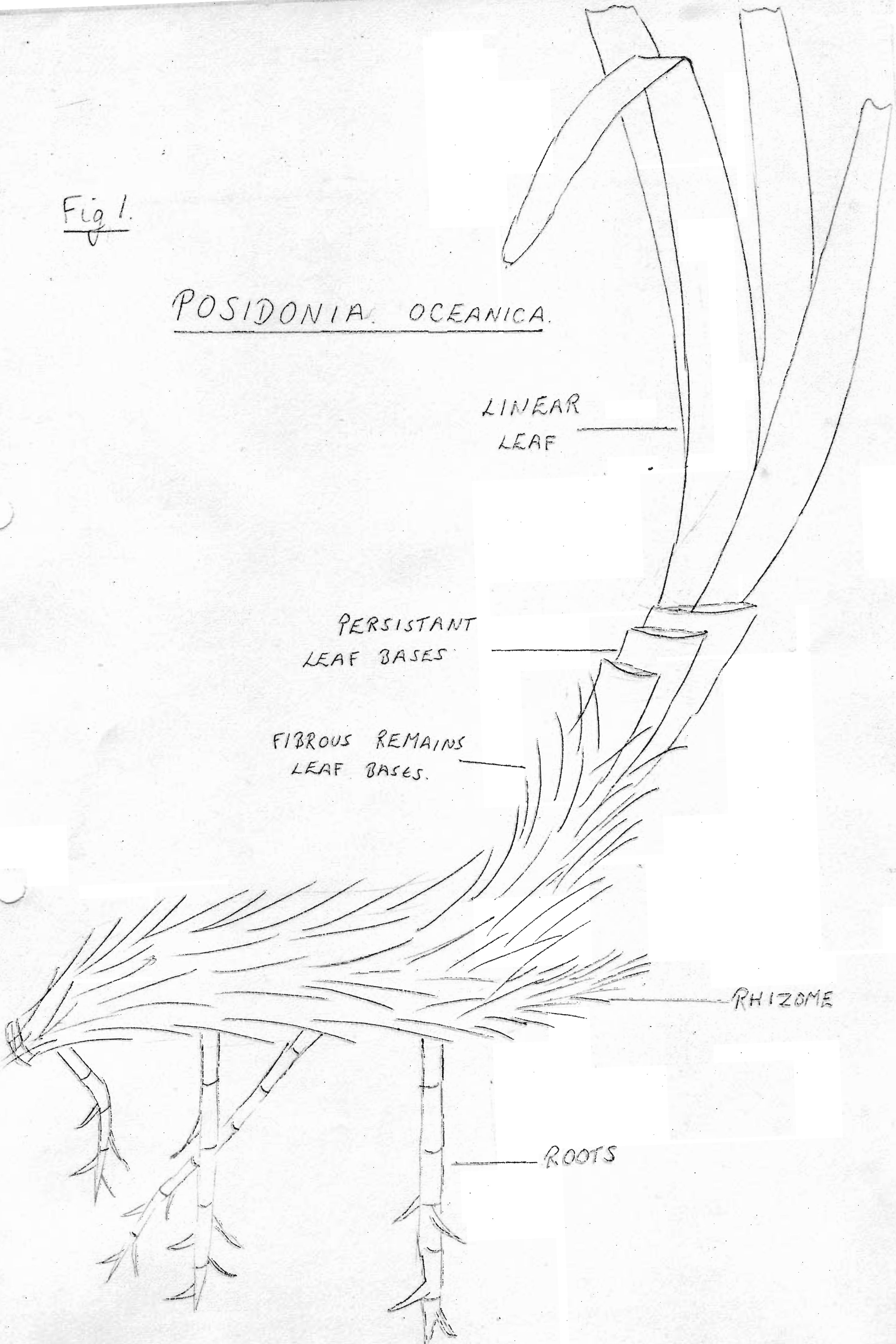
4. From your heap of discarded rhizomes select six which were growing vertically - their shoots grew straight out of the top and six in which the shoot had grown at right angles to the rhizome - the horizontal ones. Dry these also, and throw the other rhizomes back in the sea.

5. When the leaves and rhizome samples are really dry (turn them over several times to ensure this), pack them in the bags provided and enclose the relevant record sheet with each sample in a brown paper parcel and send to the Gatty Marine Laboratories.

The data collected is given in the sample sheets P24/1 to P24/6. Details about Site Location, Date etc. is given in Table 1. This information was sent to the Gatty Marine Laboratories and collated with previous studies and the sample shoots were likewise studied by their skilled staff. The results of all this work are held by the Gatty Laboratories.

Fig 1.

POSIDONIA OCEANICA.



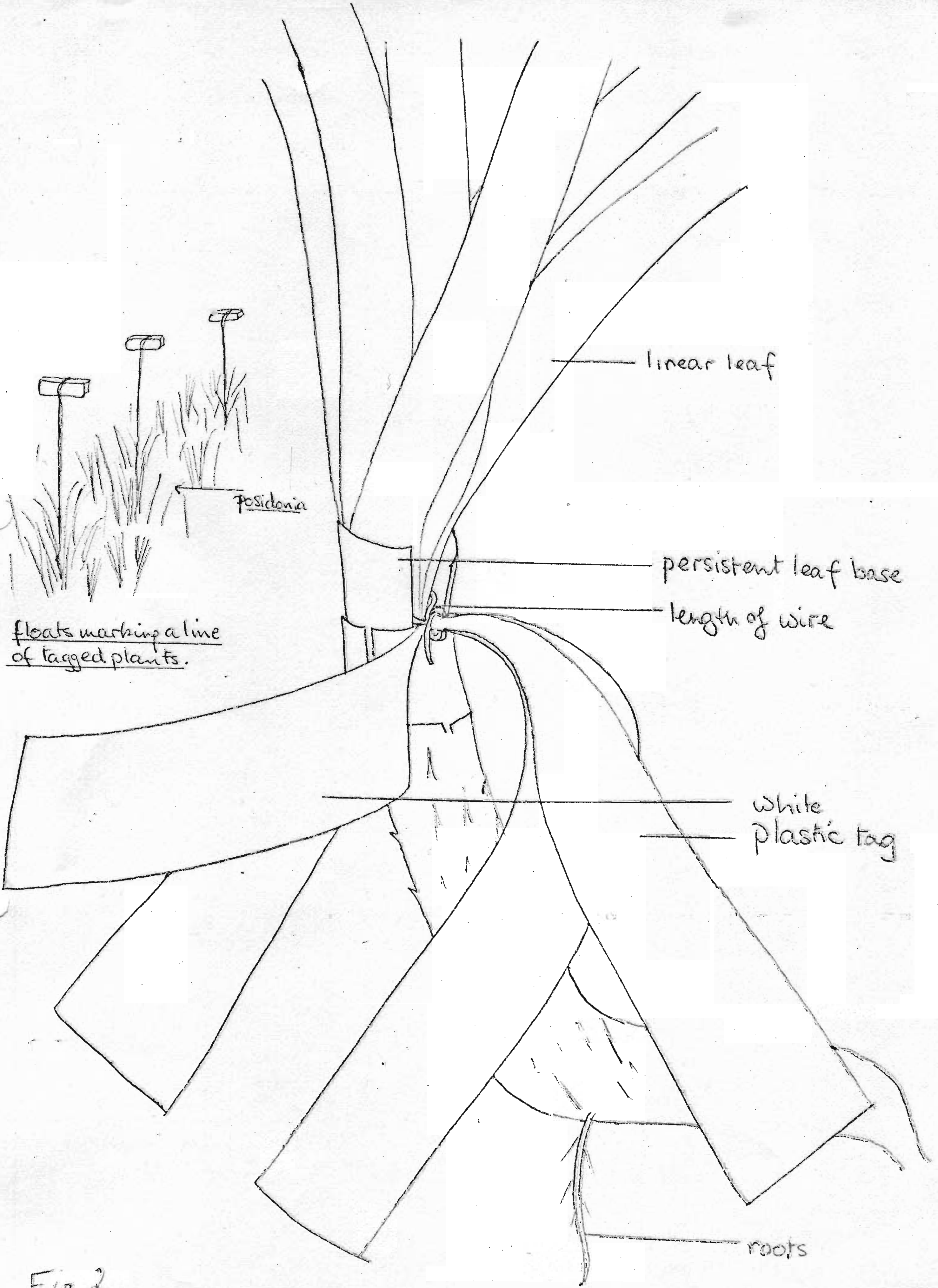


Fig 2.

Posidonia. Sketch showing important features.

TABLE 1

RECORD SHEET

QUADRAT AREA 0.25m^2
SIDE 50m

DATE	SAMPLE SERIAL NUMBER	LOCALITY	DEPTH IN METRES	TOTAL No. OF SHOOTS	No. OF SEA URCHINS
10/8/72	P24/1	MARFA QUAY	8-10m	258	2
12/8/72	P24/2	MISTRA BAY	4m	153	0
13/8/72	P24/3	BENGHISA POINT	13m	117	0
14/8/72	P24/4	QUARA POINT	22.5m	60	0
19/8/72	P24/5	WIED-IZ-ZURRIEQ	31m	113	1
20/8/72	P24/6	DELIMARA POINT	14m	63	0

[illegible] LEAF ANALYSIS RECORD

5% SAMPLE

Sample serial no. P24/[illegible]

All dimensions in cms. to one decimal place

Shoot No.	width	length total	length white	length green
1	0.9	56.0	3.9	35.0
	1.0	74.0	3.9	32.0
	1.0	29.5	4.0	25.0
	1.0	15.0	4.1	10.0
	0.9	8.8	3.0	5.8
	1.0	61.0	3.5	33.0
	1.0	59.0	4.0	27.0
	0.9	42.5	4.0	15.0
2	0.9	7.7*	3.9	3.8
	0.9	61.0	4.1	30.0
	0.9	53.0	3.5	49.0
	0.9	17.4	3.3	14.1
	0.8	45.5	3.1	40.0
3	0.8	50.4	4.6	30.0
	0.8	50.0	4.7	28.0
	0.8	23.0	4.1	17.0
	0.8	14.4	4.2	10.2
	0.8	33.5	5.5	21.0
	0.8	53.0	5.3	43.0
4	1.0	50.5	3.9	37.0
	1.0	69.4	3.8	41.0
	1.0	21.0	4.0	17.0
	1.0	7.6	3.5	4.1
	1.0	61.0	3.8	47.0
	1.0	79.0	3.9	44.0
5	0.8	36.5	3.7	DEAD
	0.9	75.5	3.6	44.5
	0.8	61.5	4.2	44.0
	0.8	8.2	3.5	4.7
	0.9	18.8	3.6	13.0
	0.9	73.0	3.3	46.0
6	0.9	49.5	3.3	40.0
	0.9	55.0*	3.1	43.0
	0.9	58.8	3.3	55.0
	0.8	13.7	3.8	9.9
	0.8	31.6	3.6	28.0

Shoot No.	width	length total	length white	length green
7	0.9	53.9	4.0	29.5
	0.9	54.8	3.7	44.0
	0.9	70.1	3.7	56.0
	0.9	4.6	~~4.0~~ 3.9	0.7
	0.9	19.6	4.0	15.6
	0.9	79.3	3.6	50.0
8	0.8	63.0	4.0	34.0
	0.9	57.5	3.9	47.6
	0.8	28.0*	4.2	23.0
	0.8	6.6	4.0	DEAD
	0.9	20.0	4.0	16.0
	0.8	80.2*	3.9	48.0
9	0.9	84.2	3.8	60.0
	1.0	51.4	2.3	47.0
	0.9	14.4	3—4	12—13
	0.8	5.1	3.0	2.1
	0.9	23.5	3.5	20.0
	1.0	81.9	3.8	47.0
10	0.8	47.0*	3.4	28.0
	0.9	53.0*	3.1	31.0
	0.9	56.0*	2.2	45.0
	0.8	13.7	3.0	10.7
	0.9	34.4	3.4	29.5
	0.9	75.2	3.3	50.0
11	0.9	71.0*	4.0	41.0
	0.9	82.0*	4.1	51.0
	0.9	58.1	2.2	48.0
	0.9	8.0	3.0	5.0
	1.0	25.7	4.0	21.0
	0.9	72.0*	3.9	45.0
12	1.0	62.0	4.0	47.0
	1.0	78.3	3.6	68.0
	1.0	23.5	3.0	21.0
	0.9	7.8	3.5	4.3
	1.0	69.2	3.3	50.0
	1.0	71.9	3.7	45.0

* ≡ BROKEN LEAF

[illegible] POSIDONIA LEAF ANALYSIS RECORD

Sample serial no. P24/1

Shoot No.	width	length total	length white	length green	Shoot No.	Width	length total	length white	length green
	0.9	40.5	4.5	31.0					
	1.0	67.0*	4.2	42.0					
13	1.0	66.9	4.4	45.0					
	1.0	12.8	4.0	8.0					
	1.0	67.0*	4.0	49.0					
	*≡ BROKEN LEAF								

All dimensions in cms. to one decimal place

/

OPERATION POSIDONIA LEAF ANALYSIS RECORD

5% sample

Sample serial no. P24/2

Shoot No.	width	length total	length white	length green	Shoot No.	Width	length total	length white	length green
1	1.1	69.1	3.6	65.5					
	0.9	3.7	3.7	—					
	1.0	12.8	3.7	9.1					
	1.0	35.8	3.4	32.4					
	1.0	49.7	3.7	46.0					
	1.1	74.4	3.6	70.8					
2	0.9	5.1	3.6	1.5					
	1.1	54.1	3.5	50.6					
	0.9	1.4	1.4	—					
	1.0	7.9	3.4	4.5					
3	1.0	23.4	3.7	19.7					
	1.0	73.8	3.7	55.0					
	1.0	50.9	3.6	41.0					
	1.1	69	3.5	56.0					
	0.9	2.0	2.0	—					
4	1.0	7.9	3.6	6.3					
	1.1	76.6	3.6	65.5					
	1.0	60.1	3.7	52.0					
	1.1	76.1	3.2	72.9					
	0.8	1.8	1.8	—					
	1.0	3.0	3.0	—					
	1.0	6.2	3.5	2.7					
	1.0	7.0	3.5	3.5					
5	1.0	18.7	3.5	15.2					
	1.0	18.4	3.1	15.3					
	1.1	49.9	4.1	45.8					
	1.2	74.0	3.8	70.2					
	1.0	3.3	3.3	—					
6	1.0	62.2	3.5	58.7					
	1.0	83.3	3.8	75.6					
	1.1	4.2	2.9	1.3					
7	1.0	21.7	2.7	18.0					
	0.9	12.7	2.9	9.8					
	1.0	46.0	3.2	42.8					
8	1.0	60.2	3.5	—					
	1.2	71.0	4.0	55.0					
	1.0	53.1	3.5	49.6					
	1.1	76.9	3.9	59.0					
	1.1	49.8	3.8	46.0					

All dimensions in cms. to one decimal place

OPERATION POSIDONIA LEAF ANALYSIS RECORD

5% sample

Sample serial no. P24/3

Shoot No.	width	length total	length white	length green	Shoot No.	Width	length total	length white	length green
1	1.0	64.0	3.7	59	6	0.9	43.0	4.0	36.0
1	1.0	44.1	4.3	36.5					
1	1.0	74.2	3.9	60.3					
1	0.95	59.6	2.8	52.4					
1	1.0	33.5	3.5	25.0					
1	0.9	3.6	3.6	0					
1	0.9	11.0	3.3	7.7					
2	0.9	9.6	3.5	6.1					
2	1.0	14.9	4.1	10.8					
2	1.0	29.0	3.1	25.0					
2	0.9	82.4	3.7	61.0					
2	0.95	33.2	4.0	29.1					
2	0.95	59.1	1.6	42.1					
3	0.9	54.3	3.5	33.0					
3	0.9	6.7	3.0	3.7					
3	0.9	20.3	3.6	16.1					
3	0.9	46.0	2.9	37.6					
4	1.0	76.0	4.2	45.0					
4	1.0	4.8	4.7	0.1					
4	0.9	10.1	3.3	6.8					
4	0.9	32.0	3.2	25.2					
4	0.9	53.7	3.9	47.0					
4	1.0	46.0	3.4	41.1					
4	1.0	4.0	4.0	0					
4	0.95	13.9	3.2	10.7					
4	1.0	20.0	4.1	15.8					
4	0.9	70.2	3.4	54.0					
4	1.0	69.0	4.0	27.5					
5	1.0	31.2	4.2	20.1					
5	0.95	40.0	2.2	35.0					
5	1.0	85.5	3.6	47.0					
5	0.95	13.7	3.6	10.1					
5	1.0	25.8	3.6	22.2					
5	1.0	5.6	5.1	0.5					
5	1.0	42.6	3.5	37.5					
6	0.9	42.2	3.7	17.4					
6	0.9	6.5	3.5	3.0					
6	1.0	16.4	3.5	12.1					
6	0.95	39.5	3.5	34.1					
6	0.95	70.3	3.5	63.5					

All dim

All dimensions in cms. to one decimal place

24 Rhyzomes apparently dead no shoots attached.

[illegible] LEAF ANALYSIS RECORD

10% sample

Sample serial no. P24/4

Shoot No.	width	length total	length white	length green	Shoot No.	Width	length total	length white	length green
1	1.1	79.3	2.8	76.5					
	1.0	94.5	4.3	77.5					
	1.1	8.0	1.5	6.5					
	1.0	70.0	5.2	41.0					
	1.0	93.0	4.3	53.5					
2	0.9	77.0	3.8	65.0					
	0.9	63.2	5.7	46.0					
	0.9	92.0	5.1	67.0					
	0.9	83.8	5.0	44.0					
3	1.1	99.5	5.2	60.0					
	1.1	65.0	1.5	42.0					
4	1.0	98.5	4.7	66.0					
	0.9	21.4	0.4	21.0					
	1.0	90.0	4.8	74.0					
5	1.0	99.0	4.6	67.					
	1.0	7.2	1.6	5.6					
	1.0	73.0	5.2	50					
	1.0	85.0	2.9	59.5					
	1.0	65.3	4.9	48.8					
6	1.0	40.5	5.2	29.0					
	1.0	54.0	5.1	48.0					
	1.1	57.0	4.8	52.2					
	1.0	11.3	3.1	8.2					
	1.1	10.0	4.7	55.3					
	1.0	48.0	0.6	47.4					
		↑ 60.0							

All dimensions in cms. to one decimal place

[illegible] LEAF ANALYSIS RECORD
10% sample

Sample serial no. P24/5

All dimensions in cms. to one decimal place

Shoot No.	width	length total	length white	length green	Shoot No.	Width	length total	length white	length green
	1.0	21 8	4.7	16.9		0.9	63.3	1.6	61.5
	1.1	19.8	4.5	15.2		0.9	16.6	4.2	31.4
1	0.9	20.9	3.5	14.0		1.0	68.9	3.5	45.6
	0.8	4.8	3.7	1.1	8	0.8	3.2	3.2	0.0
	1.0	66.4	4.8	33.0		0.9	10.7	3.1	7.6
	0.9	71.6	4.2	55.2		0.9	14.0	2.1	9.1
	0.9	26.5	2.7	23.0		0.8	69.4	4.0	31.8
	0.8	2.5	2.5	0.0		0.8	31.8	4.5	0.0
	0.7	8.7	2.7	6.0		0.9	46.7	4.8	19.9
	1.0	100.0	4.7	60.5		0.9	82.9	4.5	44.5
	1.0	47.4	5.4	0.0	9	0.9	47.6	4.2	40.0
2	0.9	2.8	2.0	0.0		1.0	12.5	4.0	8.5
	1.0	15.5	4.0	9.5		0.8	4.2	4.2	0.0
	1.1	31.1	4.2	26.4		1.0	90.8	4.0	21
	1.0	82.3	5.3	35.6		0.9	75.2	4.7	26.2
	0.4	66.6	4.0	43 6	10	0.9	12.1	5.3	6.8
	0.8	6.9	3.7	1.2		0.8	62.4	4.8	31.3
3	0.8	12.2	3.4	8.8		0.8	60.2	4.2	35.7
	0.8	89.8	4.4	65.3		0.9	5.3	3.4	0.0
	0.9	84.5	5.1	68.8		1.0	18.1	3.9	14.2
	0.4	15.8	4.0	11.8		0.8	19.4	3.2	15.2
	0.8	4.2	4.2	0.0		0.7	19.7	4.5	15.2
4	0.9	93.8	4.8	45.6		0.9	71.3	5.1	21.0
	1.0	71.8	4.0	46.5		0.9	87.1	4.8	27.1
	0.4	84.8	5.2	44.6	11	0.8	7.8	5.1	2.7
	0.8	4.3	3.8	0.5		0.9	46.0	4.8	8.8
	0.9	12.2	3.4	8.8		0.4	67.9	4.9	57.0
5	0.6	0.5	0.5	0.0		0.9	26.0	3.9	20.1
	0.9	31.3	3.3	28.0					
	0.9	45.5	4.3	26.0					
	1.0	70.8	3.3	57.2					
	0.9	85.5	4.6	56.2					
	0.9	75.5	4.8	0.0					
	0.9	84.7	5.0	0.0					
6	0.9	89.8	4.3	36.2					
	0.8	4.0	4.0	0.0					
	0.9	10.8	4.3	6.5					
	0.9	53.6	4.6	43.2					
	0.8	79.6	4.9	41.9					
	0.8	56.3	4.6	47.0					
	[illegible]	70.1	4.9	39.9					
	1.0	9.3	5.0	4.3					
7	0.9	36.9	3.9	18.3					
	0.9	1.9	1.9	0.0					
	0.9	1.9	1.9	0.0					

/

[illegible] LEAF ANALYSIS RECORD

Sample serial no. P24/6

10 % sample

All dimensions in cms. to one decimal place

Shoot No.	width	length total	length white	length green
1	1·0	60·0	4·3	34·0
	1·0	83·0	4·0	65·0
	0·9	12·9	3·6	9·3
	1·0	82·0	2·8	79·2
	1·0	83	3·7	79·3
2	1·0	55	3·7	50·1
	0·9	4·9	3·0	1·9
	0·9	76·0	3·9	41·0
	0·9	29·5	2·8	26·2
	1·0	72·5	3·2	73·3
3	0·9	54·0	3·6	26·5
	1·0	76·5	3·4	67
	0·9	18·0	2·8	15·2
	0·9	5·4	2·5	2·9
	1·0	63·5	2·8	60·1
	0·9	63·5	3·3	4·9
4	1·1	79·5	4·0	75·5
	1·0	68·5	3·7	64·8
	0·9	3·3	3·3	—
	1·0	15·0	3·0	12·0
	1·0	83	3·7	77
	0·7	9·5	2·6	6·9
	1·0	66·0	4·0	44·5
5	1·0	71·0	3·9	77·1
	0·8	11·5	3·5	8·0
	0·9	87·5	4·2	77
	0·9	84	3·8	75·8
6	1·0	81	2·9	73
	0·9	5·9	2·7	3·2
	1·0	29	3·2	25·8
	1·0	83	3·5	79·5
	1·0	21	4·0	17·0

A Study of the Techniques to Measure the Growth rate of Posidonia

Part 2

1. Introduction

Part 1 describes the work we performed as a continuation of some studies to collect information on the sea plant Posidonia. However the results are of limited value. They lack precise information on the growth rate of the plant leaves and how this rate is affected by such variables as depth, bottom type, current, temperature, to mention a few. We realised that to obtain this sort of information a precise experimental technique had to be evolved and that, following that stage, a long term study had to be undertaken. We felt that we could play an important role in the first part of this work. We therefore went to Malta with the aim of trying several different techniques and attempting to evaluate and optimise the exact experimental method so that future workers had suitable guidelines to follow.

2. The Problems

The areas to be studied broke into two main sections:-

(a) The accurate location of the test site underwater from the land, and

(b) The method of locating the plants under test and measuring the growth of any new leaves.

This was working on the assumption of a study where individual plants would be marked one year and re-located in subsequent years to measure the growth of new leaves.

2.1 Site Location

To accurately locate a test site underwater, repeatedly, from year to year, by different divers, requires a system that is both simple to use and of reasonable accuracy. To start, there must be some reference point or points on land. From these reference points it must be possible to locate a site up to several hundred yards out to sea. As many of the sites are remote and in many cases the land is very rugged, the equipment must be ruggedised and the quantity must be minimised. To mazamise the use of reference points more than one test site should be associated with each. Each test site will consist of a group of points with some form of markers. The optimum size of the site is considered to be 5 metres in which up to 12 tags can be spaced and will be marked by 3 small markers that can be easily fouled. This does mean that the accuracy of site location should be better than 5 metres.

The diver is capable of performing many functions underwater but when his efficiency is compared with a man doing the same job on land he comes a very poor second. It is also true that a diver swimming on the surface of the water, unless the conditions are extremely favourable, is less efficient and in many cases in greater dangers than a diver working on the sea bed. This means that the diver's work must be minimised and all aids for his work must be employed. With this in mind, a technique has to be evolved to locate the diver near the test site.

The water in the Mediterranean is usually very clear and in most cases the sea bottom can be viewed from the surface if the depth is not too ~~great,~~ (30 metres). We aimed for safety sake to limit most of our working dives to be less than 20 metres (we did attempt one test site at 30 metres). Under normal conditions this would mean that a test site would be visible or at least formation of sand rock or seaweed can be identified from the surface. It was unfortunate that during our stay in Malta the weather was very poor and in consequence the visibility was very low. If a diver can locate a landmark on the sea bed from the surface, it only remains to position him directly over the test site. If he can be accurately positioned it is not absolutely necessary that he sees the site. What is needed is that he can swim to a landmark on the sea bed that is reasonably close to the test site. He can then perform a standard search to locate the site markers.

The methods employed to locate dive sites during normal diving are several, they include

(1) photographs from the dive site to give location of landmarks

(2) instructions such as "line up the telegraph pole on the brow of the hill with the chimney on the White Horse".

(3) compass bearing of landmarks, or

(4) bearing between two landmarks (using sextant).

There are many more techniques but they are not of any significance here. It can be seen that all these methods use some form of reference point, or points and then either line these up or measure angles between them.

In most cases the land marks are not very reliable (i.e. they are not exactly in line or they are not the same height and some guess work is required). This would mean that a diver could not be positioned exactly over an experimental site. It is therefore necessary to produce an artificial landmark or landmarks and to use these to locate the site.

To accurately position a diver over the test site there are a selection of basic techniques. They involve either the measurements of distance from datum points, the measurement of angle from a datum line (or earths magnetic field) or a combination of the two.

Figure 2.1 shows a selection of the possible methods.

To establish the optimum technique we must study the relative merits of the available options.

It must first be established whether the diver should position himself over the test site or whether his assistants on land should guide him.

The advantage of the diver positioning himself is that there is less likely to be communication problems and less shore staff will be required. However, as even the most complicated land measurement techniques only require three assistants and as any normal dive party would have this size of shore party, acting as cover, this invalidates thesecond advantage.

To establish the feasibility of the diver positioning himself we performed the following experiment. We equiped a series of divers with a plastic sectant as used on small boats and had them position themselves at sea over a fixed target. They then had to measure the angle (see fig.2.2) of separation of the two landmarks. If this technique were to be employed a backmarker would also have to be located by an assistant. We found that under perfect conditions it was possible for the diver to make repeatable readings but that the slightest disturbance of the surface made these results impossible. It was therefore decided that all reading would have to be taken on land and the diver would have to be guided by his assistants.

Having established that all measurements will be made on land, it is then possible to say that standard survey equipment and techniques can be employed.

However there are still several choices to be made. Is it preferable to use standard triangulation techniques or to use distance measuring equpment and compass theodolites?

There are three basic means of measuring distance directly.

(1) Tape Measure

(2) Dual Path Optical Range finder

(3) Radio/Laser Range finder.

A tape cannot be used because of obvious reasons,all associated with the errors induced by the sea's surface currents and changing water heights.

The dual optical path system is a well established technique as used in naval gunnery. To obtain a comparative accuracy to the standard triangulation techniques, using a medium or low precision theodolite, the equipment would be large and difficult to handle under the typical working conditions on a sea shore.

The radio or laser range finders are more modern equipments that basically measure the distance by the time delay for a signal to go from the range finder to a target and back. The equipment is inherently far more accurate than methods 1 or 2 and can have, in theory, far greater accuracy than any triangulation method. However during the research stage for this project the equipment was just beginning to appear on the market, it was very expensive and in some cases difficult to use, but there is the added advantage that the equipment often has a built in voice communications link to the target. It was therefore felt that for this particular work the equipment was not applicable. However, it is predicted that with the advancement of this technology future expeditions should consider this option if the equipment cost has been reduced and the ease of operation has been improved.

It must be remembered that if distance measurment is to be used to position a diver the method shown in fig.2.1b would not be employed because of the requirement for two measure units. Instead method fig.2.1a or d would be used. The accuracy obtained by using a compassing bearing is far less than the accuracy obtained by using two landmarks provided the landmarks are spaced sufficiently apart.

It is fortunately the case that on most diving sites there are sufficient suitable sites where artificial landmarks can be made on or close to the shore. It is rarely the case that there is much suitable flat ground on the inland side of the landmarks.

The remaining option is the standard triangulation method fig.2.1c, where a baseline is established between 2 landmarks. Two angles are measured, PAB and PBA, using theodolites and the test site 'P' located at the intersection of the two lines.

Site Fixing

The following procedure was performed for all the sites recorded in this report. Preliminary work was performed to establish the most efficient method and to ensure that our whole team was fully aware of their individual roles.

In most cases a team of 2 divers with a shore team of 3 was required but to speed up our work we often deployed several teams of divers at the same time.

The divers were allocated a certain portion of the sea bed and were instructed to tag a certain number of sites. The dive leader was responsible for the choice of site, no specific criteria was used for the choice except depth. It was hoped that this would, combined with the wide choice of diving areas, provide a good random selection of plant conditions.

Once a site had been selected, 2 end markers were positioned 2 to 3 metres apart and one middle marker. These markers were constructed of rectangular blocks of polystyrene connected to a length of cord. They were fixed directly to the rhizomes of the Posidonia so that the block floats clear of the Posidonia leaves. The floats were to assist with the relocation of sites. S ome difficulty was encountered to decide the coptimum type of marker. Because of the numbers of divers around Malta we could guarantee that most of our sites would be found by someone between the tagging and the re-surveying of the sites. We therefore decided that the floats should have no intrinsic value to minimise the chance of theft. This ruled out almost all types of manufactured floats. The only easily available options were either used plastic bottles or polystyrene. We felt that any float used would have to be replaced every time the site was vistited. This is beacuse they would become covered in growths and difficult to locate and they would also loose their bouyancy. The bottles would fill with water and even the polystyrene could become slowly saturated due to cell collapse. Polystyrene was used because large quantities were readily available. (Marker size 8 x 5 x 25 cm).

Once the markers were fixed the divers would select plants on the line connecting the 3 markers (usually 12 or less) and connected the tags to these plants (detailed separately). Divers were asked to record the numbers of tags fixed and the orientation of the markers. This would assist the teams searching for the tags should only one marker be found.

Once work on the site was complete, the 2 divers would surface and because of the good visibility they could still identify the markers. One diver floated flat on the surface and the other remained upright. The horizontal divers held the other firmly and positioned the pair of them directly over the site. This was particularly difficult when a surface current or wind existed. When they were directly over the site the upright diver would raise his arm to indicate to the shore party to record the position. In some cases we used separate snorkel divers to perform this location task as it was found to be quite exhausting. This task was made more difficult by the poor sea and weather conditions we experienced.

The shore party were responsible to locate and mark the 2 landmarks required to locate the tagging site. The landmarks were chosen so that there was sufficient flat ground around the mark so that it could be found again without too much difficulty and also so that a theodolite could be positioned reasonably easily. The exact position of the landmark was marked by chiselling a cross into the rock and covering this with white paint. Alongside was painted "1C72". To obtain the maximum possible accuracy the 2 landmarks should be as far apart as possible to ensure that the angles of the triangle ABP (see fig.2.2) should be as close to 60° as possible. In most cases this situation is unobtainable. This situation was agravated by our desire to do as varied a selection of tagging sites at each dive location as possible. We felt that to increase the number of landmarks at each dive location would lead to confusion on any return visit. The theodolite was placed at 'A' and levelled in the normal way. The position of the centre of the theodolite was marked into the rock. A ranging rod was positioned at B and the theodolite is zeroed onto it. When the diver surfaced and indicated he was positioned correctly the shore party measured the angle BAP with the theodolite and positioned a second ranging rod (B_1) in line with B and P. Further sightings were taken of all the tagging sites and further ranging rod positions were indentified (B_2, B_3 etc).

Once the sites had been completed the zeroing of the theodolite was checked and the instrument then moved to position B. It was set up in the same way as at A except this time zeroing on A. The angles of ABB_1, ABB_2 etc. were recorded and the angle ABP, ABP_1 etc. calculated. Again before the theodolite was dismantled the zeroing was checked. The site markers were then completed and photographs taken if they had not already been completed during the surveying.

This procedure was adhered to with some minor variations throughout our experiments.

The use of backmarkers reduced the accuracy of our measurements considerably and was made necessary because of our failure to obtain a second theodolite.

Site Relocation

We would recommend the following procedure to relocate the sites.

Once the landmarks A and B have been relocated with the aid of the photographs and maps a theodolite should be placed at A and zeroed on a ranging rod at B.

A backmarker is then set at A_1 so that the angle BAA_1 is the required value. This is repeated for all the necessary backmarkers. The same operation is repeated at B measureing the angle ABB_1 to establish the B backmarkers. The dive party is then positioned in line with the marker poles. To assist with this we woulde advise that the shore party either wear very distinctive bright clothes or use coloured flags because of the difficulty of contrast against the shore. The shore party can, by an agreed form of signalling, indicate to the divers the correct direction to swim. Once the diver is correctly positioned he should attempt to identify some landmark immediately below him and should perform normal search routines until the markers are found. If only one marker is visible he should use the orientation specified in the tables of results to locate the tags.

2.2. Plant Tagging

To establish the growth rate of the Posidonia plant, it is necessary to define some basic measuring technique. Short term experiments can be made that measure the rate of particular chemical reactions. From coparative studies on different plants in different locations certain conclusions can be reached on the relative importance of different parameters on the rate of growth of the plants. This however is a very time consuming and difficult experimental technique to perform and the approach that it was suggested that we took was for long term measurments of growth. The need therefore was to define some basic measurements for the individual plants and to repeat this measument at suitable time intervals. The Posidonia plant grows by new leaves being formed at the tip of the terminal shoot.

As the leaves mature, they are replaced at the tip by newer shoots and eventually the leaves age and die. They then fall away from the body of the plant. The plant therefore seems to progress across the sea bed. We therefore had to establish a method of tagging the plant in a known way so that for visits in one, two or three years time it is possible to measure the number of additional leaves.

By examination of the plant we felt that the only means by which this could be done was by defining the change from an immature leaf to a mature one as our datum. We then placed markers 6 mature leaves further down the plant.

When the plants are re-examined the divers will have to count the new number of mature and dead leaves between the tag and the datum (change from immature to mature leaves). By subtracting six from this number they can find the number of leaves within the relevant time period.

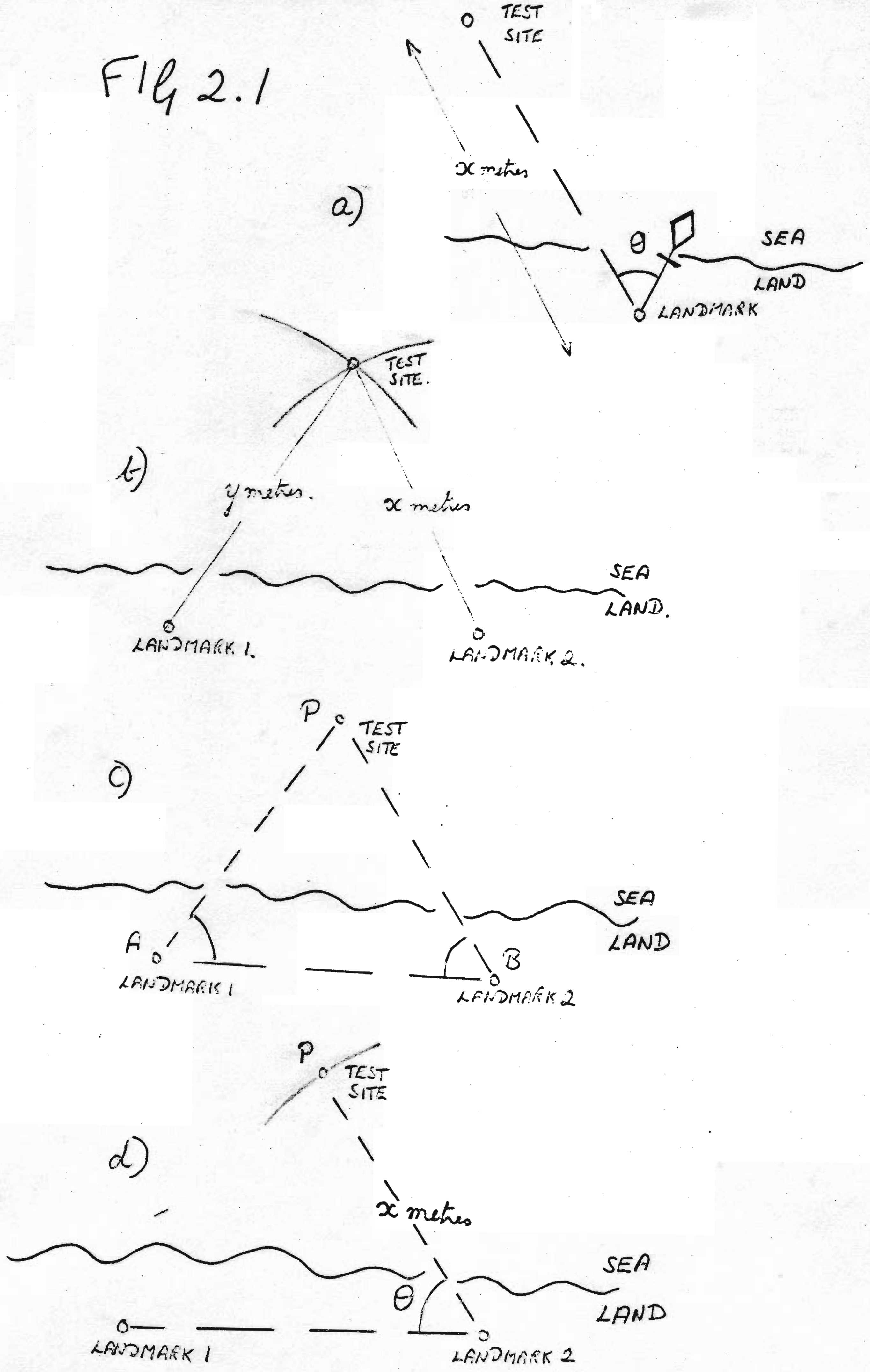
The tags used for the plant had to be securely fixed so that the normal movement of the plants and water did not destroy or remove them. However, the tag could not be such that it might in some way damage the plant or impede its growth.

We finally agreed on using a wire to wrap around the plant leaf base. The wire had to be fixed tightly and forced well down between the sixth and seventh leaf bases. To this there was attached a small white plastic flag about 3cm by 30 cm long. It is hoped that this will help in the relocation of the individual plants. It must be remembered that the white material will become contaminated by sea growth in the same way as the floats.

The means of tagging the plants and bouying the individual sites is far from ideal but as is always the case in a marine environment, the ideal is rarely attainable. Even the most potent anti fouling paints or surfaces eventually succumb to some form of contamination if left unattended for too long a period of time. The means of tagging is such that a certain percentage of the tags or sites will be impossible to relocate and so any experiment will have to work on a redundancy principal. If the sites are visited after six months probably 95% of the tags would be located, after 1 year 85%, 2 years 70% and so on. It is therefore important that if any really important conclusions are to be reached from this experiment, the sites should be visited as regularly as possible.

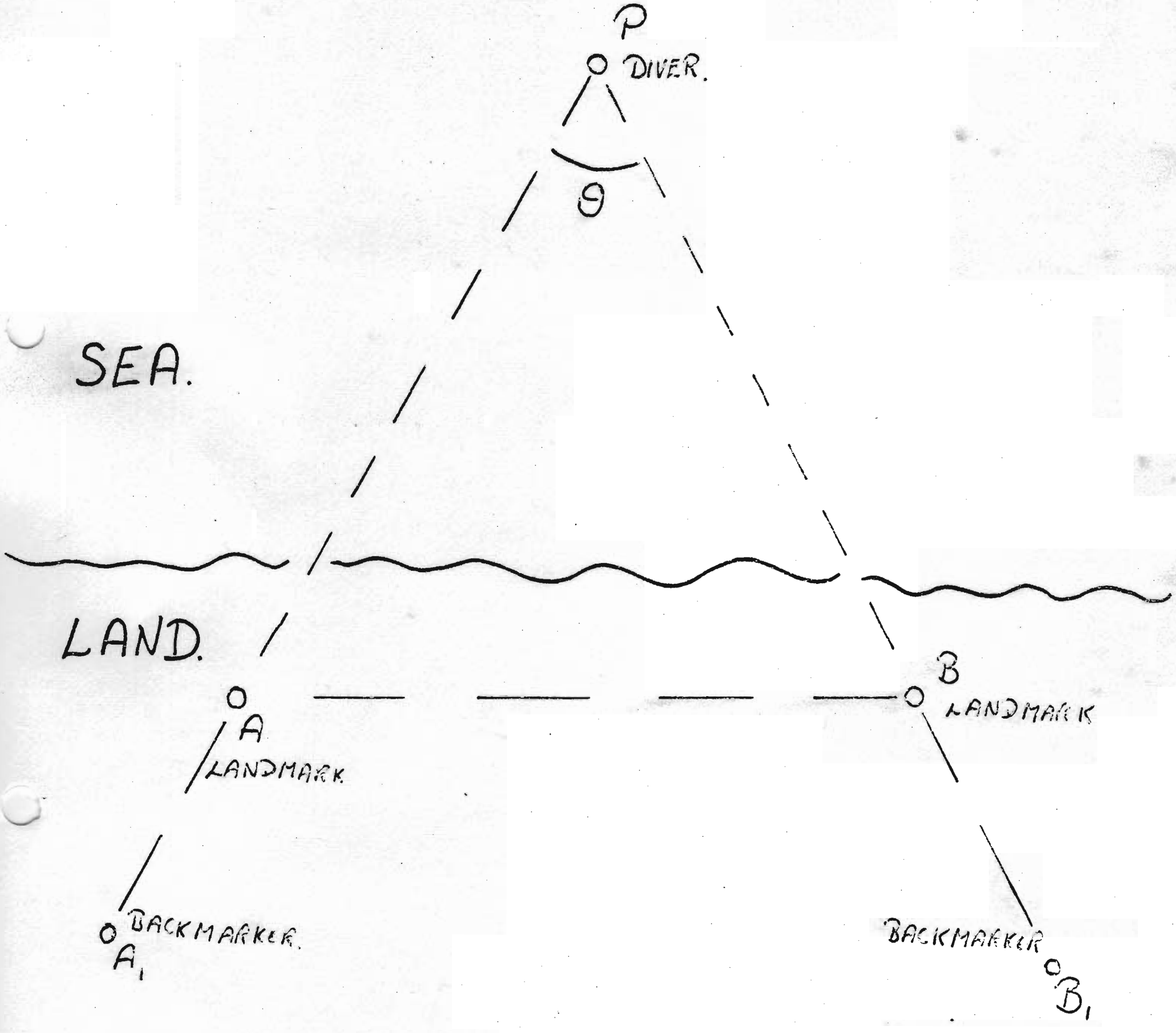
It is important that any diving team that revisits the sites should replace all the markers and tags, this will make the long term continuation of the experiment far more realistic.

FIG 2.1



a)
TEST SITE
x metres
θ
SEA
LAND
LANDMARK
b)
TEST SITE.
y metres.
x metres
SEA
LAND.
LANDMARK 1.
LANDMARK 2.
c)
P
TEST SITE
SEA
LAND
A
B
LANDMARK 1
LANDMARK 2
d)
P
TEST SITE
x metres
SEA
LAND
θ
LANDMARK 1
LANDMARK 2

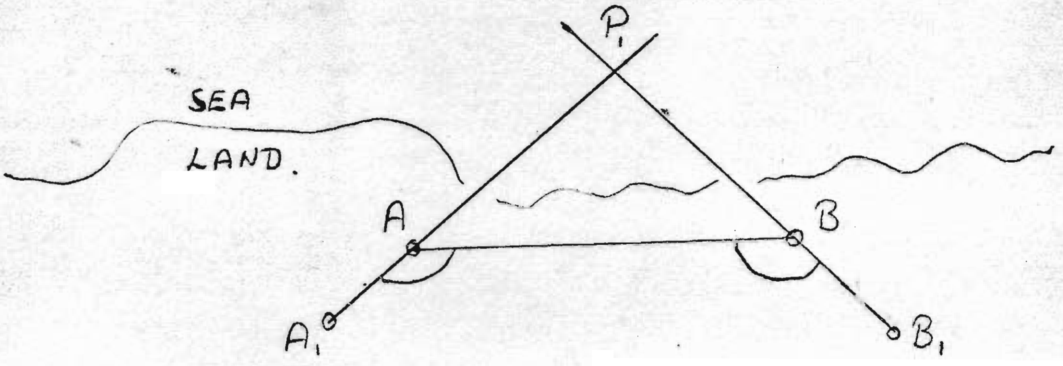
Fig. 2.2


P
DIVER.
θ
SEA.
LAND.
A
LANDMARK
B
LANDMARK
BACKMARKER.
A_1
BACKMARKER
B_1

POSIDONIA EXPERIMENT

(Abbreviated Technique)

Surveying technique for fixing land-based markers to enable location of sites of tagged posidonia plants at sea.



The distances of A and B to A and B respectively are considerably reduce in this sketch.

At a given site, two forward poits A and B were established a few yards from the sea and several hundred yards apart depending on local contions. A theodolite was established at A and a ranging rod at B. When a diver surfaced to mark his position directly above the sie of tagged Posidonia plants, at say P_1, the angle P_1AB was measured directly with the theodolite, (from this BAA_1 was deduced) and a temporary back marker B_1 was erected on the bearing P_1BB_1. At the end of the day the theodolite was established at B and the angle ABB_1 measured.

At each site, the points A and B were marked by chiselling a cross into the rock, filling it with white paint and painting 'IC 72' by the side. Photographs were taken of the marked points and the site in general.

Relocation of sites of tagged Posidonia plants at sea.

Four two-metre ranging rods, distinctively painted and with supports to keep them upright, and a theodolite are required. At any given site points A and B are located. The theodolite is established at A and a ranging rod set up at B. According to directions from the person manning the theodolite, a ranging rod is set up as a back marker for B at the recorded angle of ABB_1. The theodolite is then established at B, a ranging rod set up at A, and a ranging rod set up as a back marker for A at the recorded angle of BAA_1.

Divers on the surface at sea must now position themselves so that the ranging rods acting as back markers appear directly behind the appropriate ranging rods at both A and B. The divers will then be exactly above the site of tagged Posidonia plants on the sea bed.

At some sites the divers may require people to stand by the ranging rods, as these may be difficult to locate visually when out at sea.

Once the divers have located a line of tagged plants, people on land may reset the back marker ranging rods for location of the other line of tagged plants. Up to ten lines of plants were tagged at one site, using the same front markers at A and B.

Method of tagging and marking tagged plants.

A length of wire was secured round the persistent leaf bases of six mature leaves on a Posidonia plant rhizome. A long length of white, plastic material about 30 cm long and 3 cm wide was attached to each wire. A group of leaves on up to twelve plants were tagged, plants chosen being fairly close together and in a straight line. The line of tagged plants was marked by anchoring polystyrene floats to Posidonia rhizomes so that they floated about 60 cm above the top of the leaf zone of the Posidonia plants. Floats were positioned one at each end of the line of tagged plants and one in the middle. Each float was of white polystyrene about 25 cm long, 8 cm wide and 5 cm thick.

It is intended that tagged plants will be examined on a 1 or 2 yearly basis to determine the nature of new leaf growth.

Site Data.

Delimara Point

Date: 4.8.'72 and 20.8.'72

Point A

Point A is at the seaward side of some salt pans and to the left of a large pool, approximately 5 feet from the pool edge and the same distance from the sea high water line. It is reached by walking on a bearing through the edge of the hut near the steps, and the edge of the cliff, towards the salt pans.

Point B

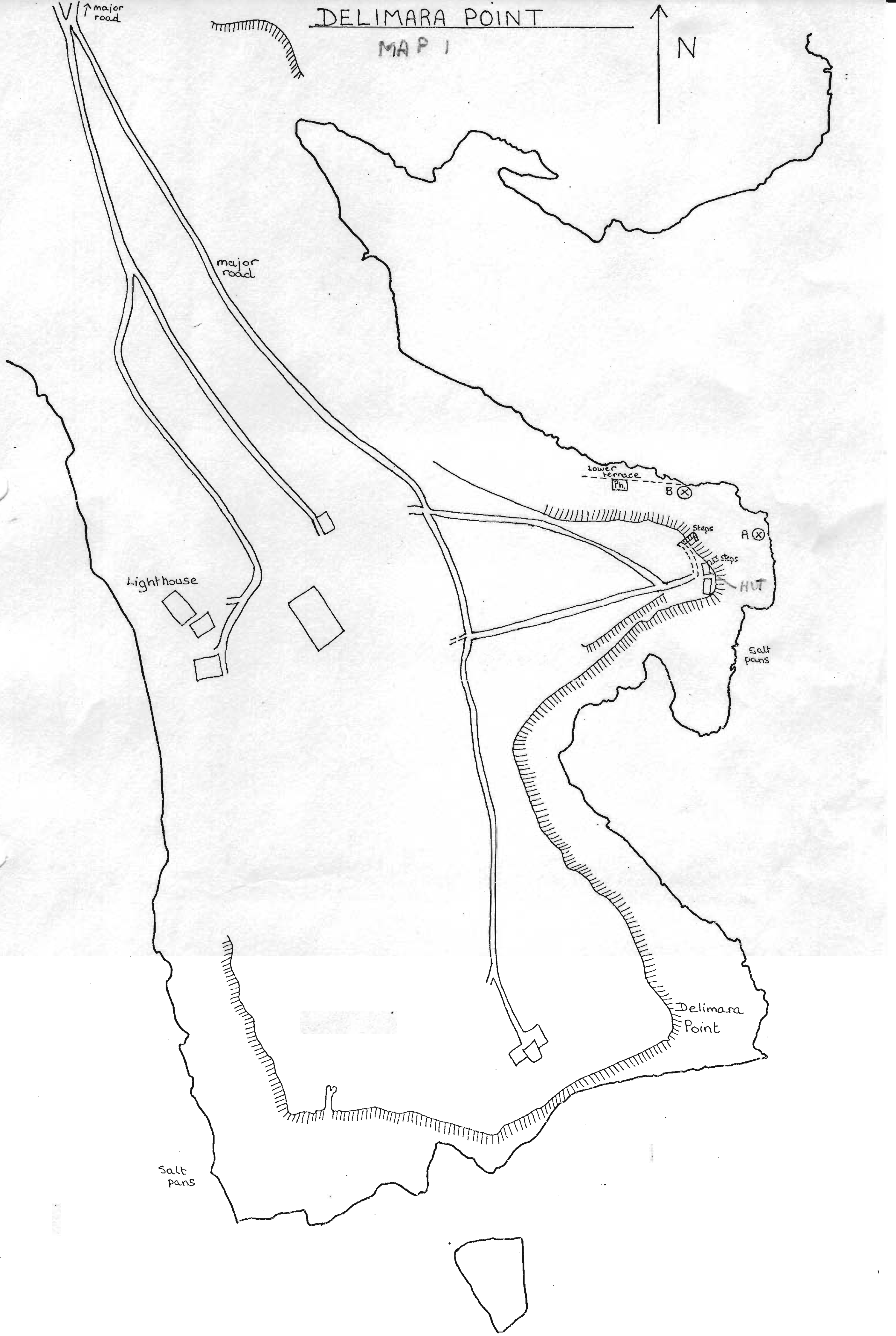
Point B is in the centre of a circular depression about 3 feet across at the edge of the upper terrace. It is approximately in line with the seaward end of the small salt driers' hut shown on the map. It is about 2 metres North of a large crack in the rock, running from the path to the sea.

A photograph of both points was taken from the position marked Ph. on the map.
Map 1. Ph 1, 2 and 3.

line	BAA_1	ABB_1	bearing of line	number of tags	depth (in feet)
1	135° 2'30''	80° 4'30''	–	10	< 60
2	111° 41' 00''	96° 23' 00''	–	10	< 60
3	107° 56' 00''	101° 7' 30''	–	10	< 60
4	144° 32' 00''	74° 52' 00''	–	10	< 60
5	45° 42' 00''	198° 55' 00''	N-S	10	30
6	71° 40' 00''	100° 58'00''	N-S	10	50
7	74° 6' 30''	123° 43' 00''	N-S	10	35
8	105° 30' 00''	128° 28' 00''	N-S	10	60

DELIMARA POINT

MAP 1



PH1

DELIMARA POINT

PH2

DELIMARA POINT

PH3

DELIMARA POINT

Site Data.

Mistra Bay.

Date: 12.8.'72

Point A

Point A is on a rock platform ±3 feet below and to the seaward side of the path (see map) as it rounds the headland. It is about 100 yards from the car park.

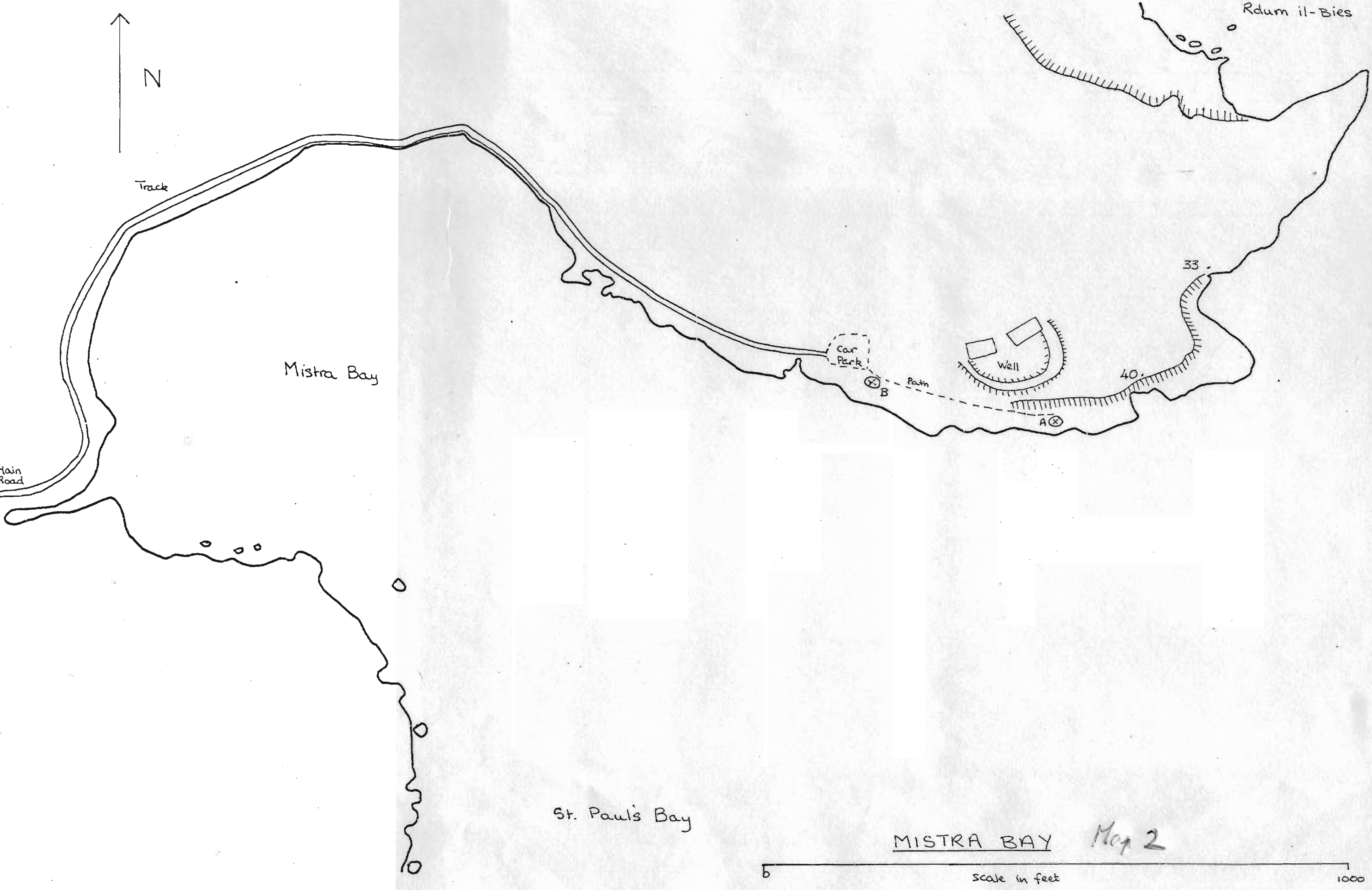
Point B

Point B is on a rock platform about 15 yards from the car park, just to the seaward side of the path. It is in line with a small rock outcrop, and a large buoy in the middle of St. Paul's Bay.

A photograph of both points was taken from the car park.

Map 2. PH4, 5 and 6.

line	BAA_1	ABB_1	number of tags	depth (in feet)
1	82° 58' 30''	120° 00' 00''	12	< 35
2	91° 5' 00''	123° 25' 00''	12	< 35
3	108° 6' 30''	122° 49' 30''	12	< 35



MISTRA BAY

Map 2

PH4

MISTRA BAY

PH5

MISTRA BAY (From path)

PH6

MISTRA BAY (From Car Park)

Site Data.

Benghisa Point.

Date: 13.8.'72

Point A

Point A is behind a large rock at the edge of flat rock slabs, 15 feet above the sea high water level.

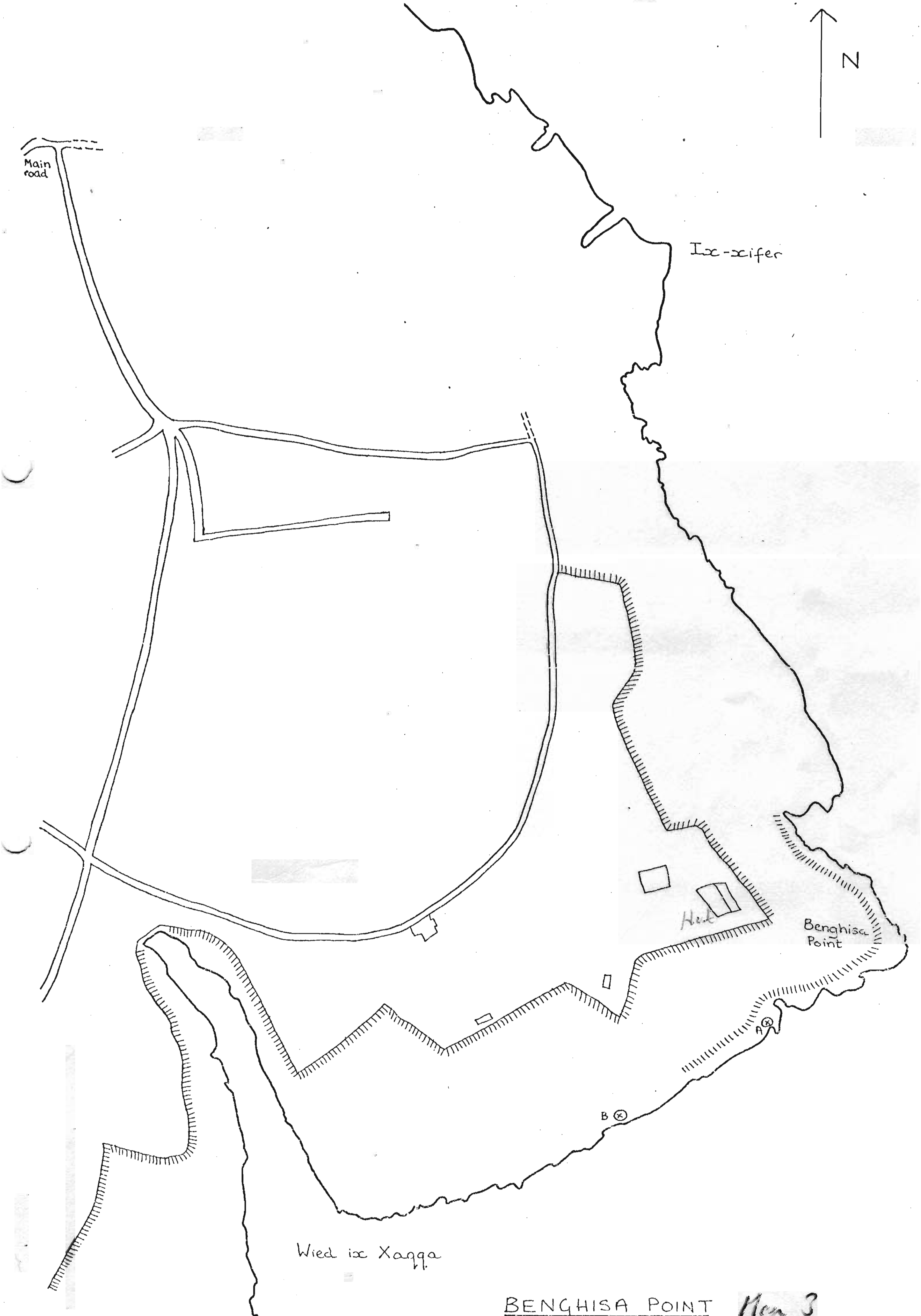
Point B

Point B is on a bearing of 230° from the hut (see map). It is on a small rock outcrop, just below a large flat area with deep cuttings. An arrow was engraved in this area, pointing towards point B.

A photograph was taken looking towards points A and B from the hut. A ranging rod was held above the rock surface at point B.

Map 3. Ph 7, 8 and 9.

Line	BAA_1	ABB_1	bearing of line	number of tags	depth (in Feet)
1	97° 18' 00"	94° 53' 00"	—	12	40
2	117° 25' 30"	96° 51' 30"	N–S	12	35
3	115° 1' 00"	126° 59' 00"	—	12	40
4	112° 58' 30"	111° 50' 30"	—	12	40



BENGHISA POINT Map 3

PH 7

BENGHISA POINT

PH 8

PH 9

BENGHISA POINT

(from Hut)

SITE DATA

Mignuna Point

Date: 17.8.72.

Point A

Point A is on a rock outcrop about 6 feet wide and 20 feet long and rising about 1 foot 6 inches above the main flat table. The outcrop is seaward of a long crack in the table.

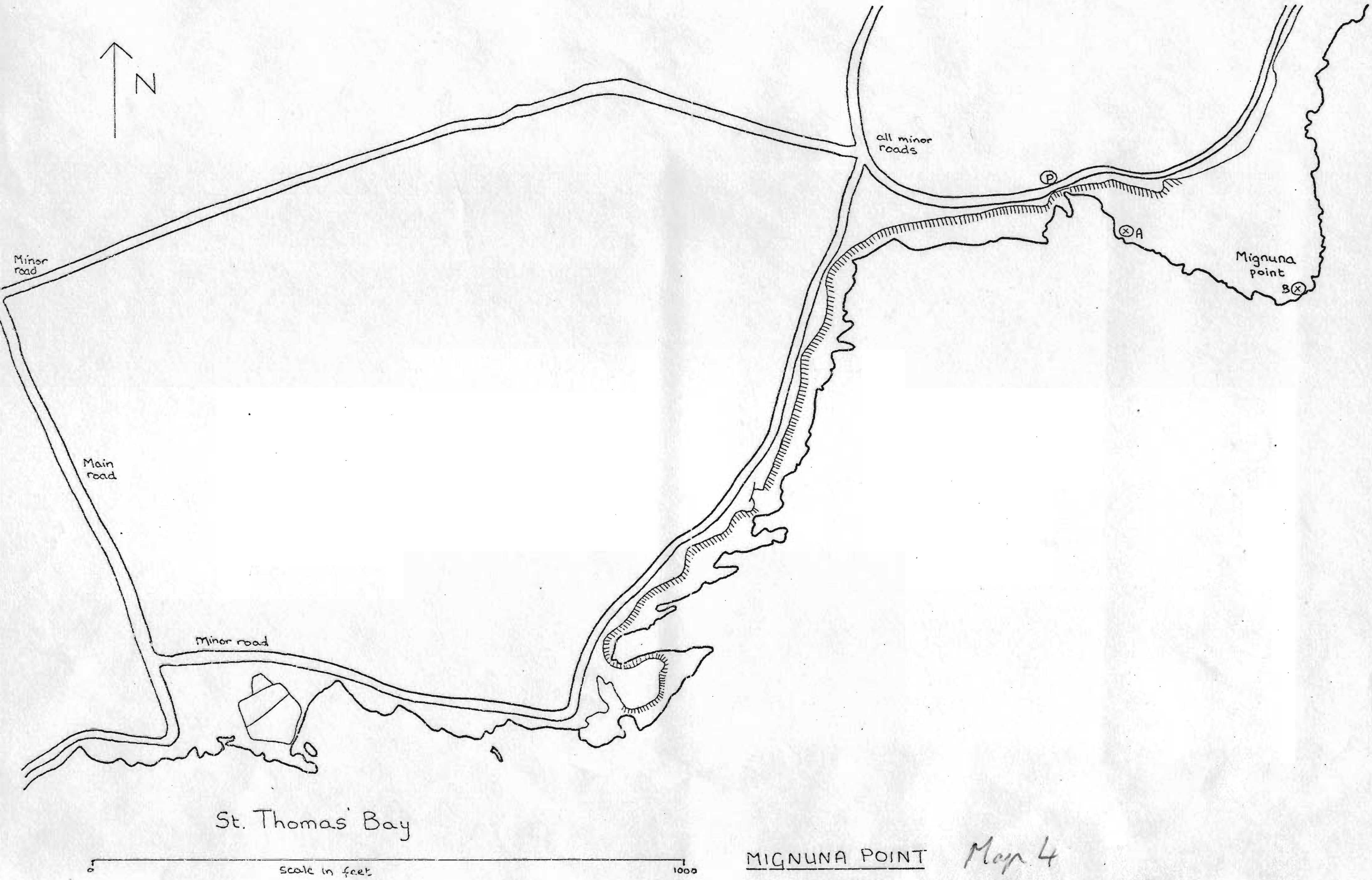
Point B

Point B is in the centre of an etched depression in the rock table and is right on the point. It is within fifteen feet of the sea on two sides. Not far away is a large crack in the rock, extending to the sea.

A photograph of both points was taken from the cliff top in addition to individual close up shots.

Map 4 Ph. 10, 11 and 12.

Line	BAA_1	ABB_1	Number of Tags	Depth (in feet)
1	147° 41' 00"	69° 49' 30"	10	20
2	151° 46' 30"	49° 30' 00"	10	20
3	139° 8' 30"	63° 03' 30"	10	20
4	153° 38' 30"	39° 1' 30"	10	20
5	135° 24' 30"	118° 41' 30"	10	20
6	121° 5' 30"	81° 3' 00"	10	20
7	114° 8' 00"	119° 11' 00"	10	20
8	106° 57' 00"	133° 47' 30"	10	20
9	100° 14' 30"	115° 31' 00"	11	20
10	86° 48' 30"	131° 21' 30"	12	20



MIGNUNA POINT Map 4

PH 10

MIGNUNA POINT

PH 11

MIGNUNA POINT

PH 12

SITE DATA

Qawra Point

Date: 14.8.72.

Point A

Point A is in the centre of the 4th platform in the middle of the pool (see photos).

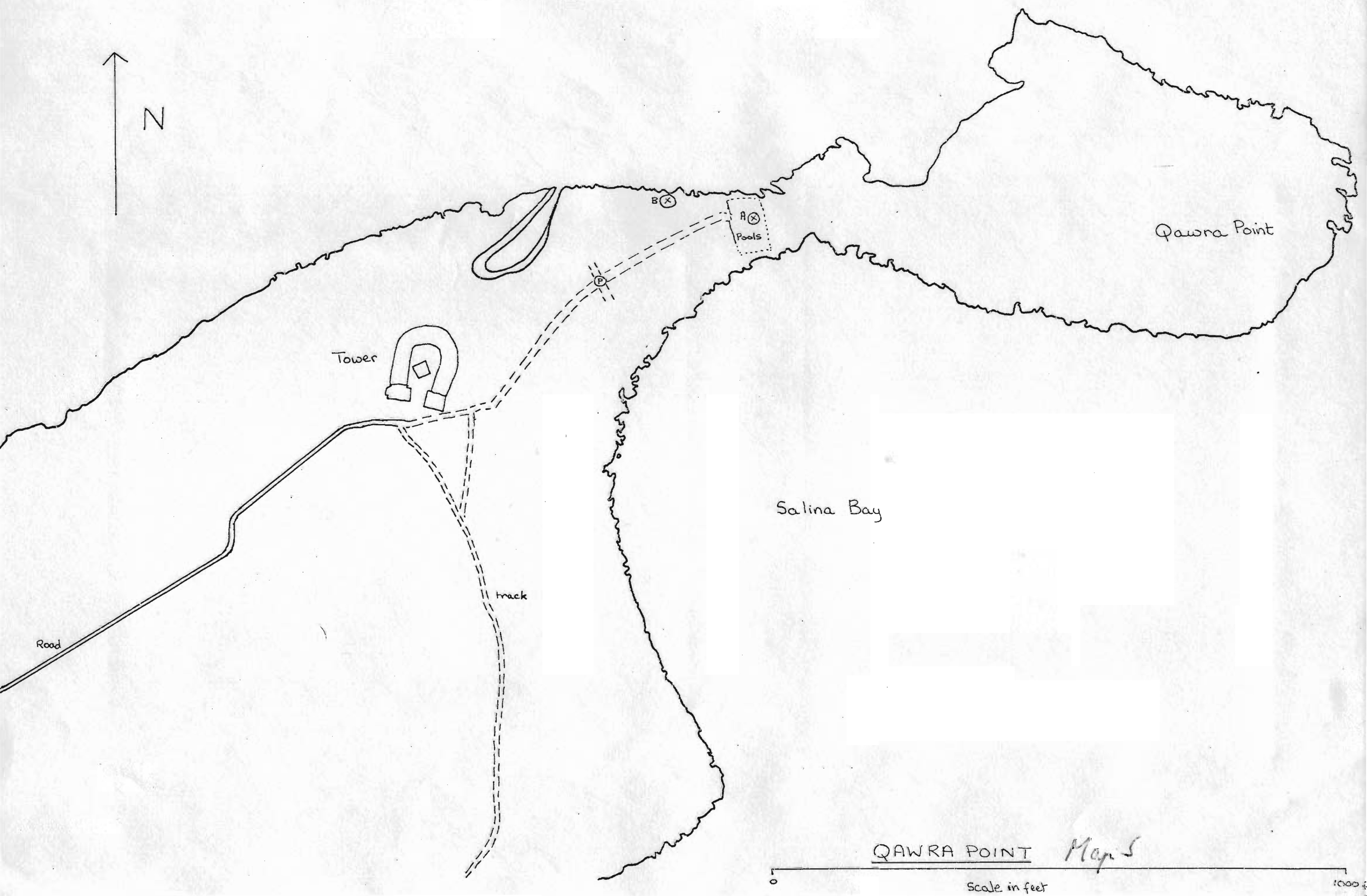
Point B

Point B is in the centre of a small depression in the rock some ten feet from the sea and about 50 feet from the edge of the pool.

A photograph was taken to give a general view of the site from the top left hand corner of the approach road.

Map 5 Ph. 13, 14 and 15.

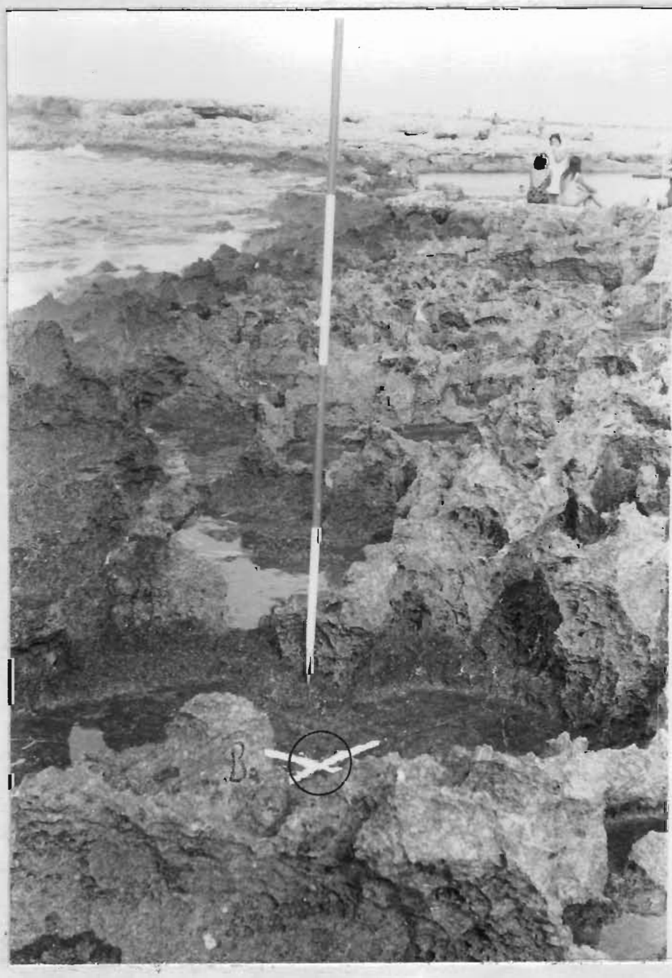
Line	BAA_1	ABB_1	Bearing of line	Number of Tags	Depth (in feet)
1	151° 13' 00"	89° 15' 00"	E - W	12	25'
2	120° 39' 00"	105° 17' 00"	E - W	12	55'
3	131° 37' 00"	76° 16' 00"	NE - SW	12	25'
4	122° 7' 30"	84° 44' 00"	E - W	12	45'
5	83° 50' 00"	113° 58' 00"	N - S	12	50'
6	95° 0' 00"	102° 50' 00"	N - S	12	75'


N
Qawra Point
B
A
Pools
P
Tower
Salina Bay
track
Road
QAWRA POINT
Map 5
0
Scale in feet
1000 ft

PH 13

QAWRA POINT

PH14



QAWRA POINT

PH15

QAWRA POINT

SITE DATA

Marfa Quay Site 1

Date 11.8.72.

Point A

Point A is a short distance beyond the end of the concrete Quay, close to the sea.

Point B

Point B is at the top of an outcrop at the other end of the Quay.

Photographs show the positions of the points relative to the quay.

Map 6 Ph. 16, 17 and 18.

Line	BAA_1	ABB_1	Number of Tags	Depth (in feet)
1	146° 5' 00"	100° 18' 00"	8	35'
2	125° 11' 30"	103° 51' 00"	10	35'
3	141° 23' 00"	81° 7' 00"	10	35'
4	130° 30' 30"	122° 33' 00"	10	35'

SITE DATA

Marfa Point   Site 2

Date: 29.8.72.

Point A

Point A is on the top of a rock outcrop overlooking a small platform next to the sea, and the larger sunken plateau that extends inland.

Point B

Point B is about three feet from the cliff edge and is roughly in line with paradise beach and the end of the large rock outcrop. (See sketch map)

Photographs showing the general position of the points were taken.

Map 6 Ph. 19, 20 and 21.

Line	BAA_1	ABB_1	Bearing of line	Number of Tags	Depth (in feet)
1	86° 46' 0"	137° 11' 00"	E - W	10	35
2	87° 58' 20"	127° 40' 00"	E - W	10	60
3	142° 38' 0"	58° 24' 00"	N - S	10	70
4	123° 12' 30"	105° 26' 30"	-	10	-
5	126° 50' 30"	91° 20' 00"	-	10	-

SITE DATA

Marfa Point   Site 3

Date: 29.8.72.

Point A

Point A is in the middle of a flattened depression about 5 yards from the sea in both a W and N direction. 5 yards south is an easy access to the sea.

Point B

Point B is on a smooth slab of rock. The rocks extend from the shore in a broken pattern and then change to shingle. The rock is the last before the shingle and is several yards in front of a square of concrete.

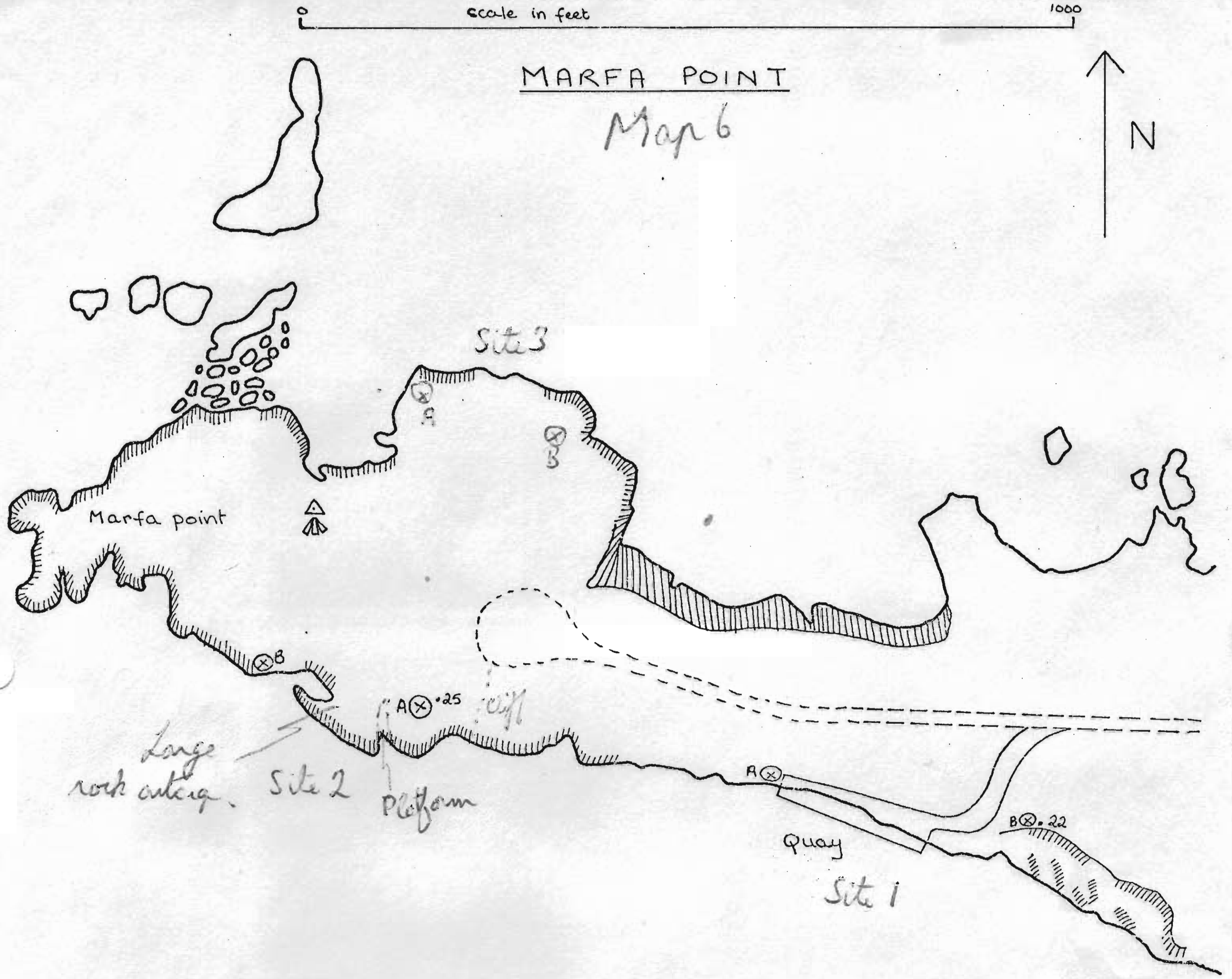
The photographs taken are enclosed.

Map 6 Ph. 22, 23 and 24.

Line	BAA_1	ABB_1	Bearing of line	Number of Tags	Depth (in feet)
1	98° 13' 30"	119° 43' 00"	N - S	10	10
2	91° 6' 30"	113° 43' 00"	N - S	10	18
3	90° 8' 00"	107° 9' 00"	N - S	10	25
4	113° 41' 00"	98° 33' 00"	N - S	10	15
5	118° 39' 00"	85° 23' 30"	N - S	10	10
6	107° 27' 20"	98° 7' 30"	N - S	10	15
7	104° 31' 00"	94° 53' 00"	NE - SW	10	20

MARFA POINT

Map 6



PH 16

MARFA QUAY

PH 17

MARFA QUAY

PH 18

MARFA QUAY

PH21

MARFA POINT SITE 2

PH22

MARFA POINT SITE 3

PH19

MARFA POINT

PH20

PH23

MARFA POINT SITE 3

PH24

MARFA POINT SITE 3

SECTION III

AN ACOUSTIC RANGEFINDER

FOR

LOCAL SURVEYS of the SEA FLOOR

By: P.G. FEARNHEAD

Page

1. INTRODUCTION

This report describes a simple, single-path acoustic rangefinder for use underwater and the results of field tests carried out with a prototype. When designing this instrument it was recognised that a fundamental limit to the accuracy of such a system exists due to the inhomogeneity of the operating medium. Hence, while the instrument was designed to have a resolution under ideal conditions which would be better than normal operating conditions were likely to permit, no attempt was made to make a redundant accuracy capability. In this way the design has been kept simple and costs minimised.

It is expected that the rangefinder could find wide application for detailed surveys in areas of limited (say, 100 metres) extent where a reasonable accuracy is required, but limited visibility and/or difficult topography prevent a tape measure from being effective. An obvious example is in the growing field of nautical archaeology where accurate plans of the sea floor must often be prepared despite poor working conditions.

2. DESIGN AND CONSTRUCTION

2.1 Principle of Operation

The principle of operation is that an ultrasonic pulse is generated at one end of the line to be measured and detected at the other end. Given the local speed of sound, the time of transit gives a measure of the length of the line. Provided that a direct acoustic path exists between transmitter and receiver, one can neglect any possible complications due to interference of direct and surface reflected (or other) signals because the only signal of interest at the receiver is the first to arrive which will have followed the most direct path (hopefully, a straight line). Hence, a reflector is only needed with the transmitter to focus the sound energy and increase the operating range; its function as a spatial filter is redundant unless there are several similar systems operating in close proximity. This has the obvious advantage that the beam width can be as large as is necessary to guarantee that the beam finds the receiver by a direct path. Thus the location of the receiver does not have to be known with any precision and the system can easily be used under conditions of very poor visibility.

Hence, the mode of operation is that the transmitter generates an ultrasonic pulse and simultaneously sends a signal by wire to start the counter. The receiver amplifies the incoming pulse to an acceptable level and stops the counter if the pulse exceeds a threshold level which is chosen to be above the ambient noise level.

2.2 Acoustic Considerations

We would like the operating frequency to be as high as possible since the best possible resolution is of the order of the wavelength used. However, we are not entirely free to choose any frequency since at higher frequencies the absorption starts to impose limitations on the ranges which are attainable. This can be counteracted to some extent by transmitting at a higher power. Unfortunately, there is a limit to how much power we can put into the water because at power densities greater than $P_o^2/2R$, where P_o = ambient pressure, R = acoustic impedence of medium - about 1 watt cm^{-2} at the surface - the sea water starts to cavitate resulting in a large drop in radiating efficiency. This latter effect becomes very important at high frequencies, because the dimensions of the transducer, if operated in a resonant mode, decreases with increasing frequency. This imposes a limit to the total amount of power which can be radiated from its surface.

We decided to use spherical transducers, since these will have the greatest total power transfer capability and were fortunate to be able to obtain two $BaTiO_3$ spheres resonant at about 80 KHz, from the National Institute of Oceanography. A full description of the transducers is given in the Appendix. These spheres not only have the required power handling capability, but also operate at a frequency where the natural ambient noise level (see Fig. 1) is low.

Although a system could be devised with very high accuracy and resolution under ideal conditions, it is rare that ideal conditions are encountered. There are two principal causes of uncertainty in this kind of measurement, both related to the local sound velocity and its variations. If there exists a variation of sound velocity along the acoustic path, then there will clearly be an uncertainty in converting the time lapse into a distance. Similarly, if there is a velocity gradient normal to the direction of propagation (as might commonly be caused by a vertical temperature gradient), then the acoustic path will be curved and the accuracy of the system impaired. In particularly bad temperature gradients it may not be possible to make any measurements at all.

A detailed treatment can be found in Albers (1) and a more advanced treatment of the theory in Tolstoy and Clay (2). To the best of my knowledge there exists no means of overcoming these problems, which might typically cause uncertainties of the order of 0.1%, although it is conceivable that a correction for path curvature could be applied if the velocity gradient is assumed to be constant.

2.3 Consideration of Circuit Design

From the above discussion it will be clear that the problem has been reduced to that of generating an acoustic pulse with a sharp leading edge, the detection of this edge after passage through the water, and timing the interval of travel. Although a simple system like this has a best resolution of the order of the operating wavelength, it would normally have a much lower resolution due to the finite response time of the circuit elements and the correspondingly uncertain triggering edge. In the following section is a description of how we overcame this problem and also managed to dispense with any need for tuned oscillators or amplifiers in the transmitter.

2.3.a The Transmitter

Our principal problem was the slow rise time (about 60 microseconds), of the transducers. Since we require only a certain power level from the transducer, but are not worried if we exceed it, it seemed reasonable to adopt the following technique for reducing the effective rise time of the transducer. The rise time is a fundamental property of any system, but we note that it is independent of the level which is ultimately reached, as shown in Fig. 2, (we assume that the system is being "fed" on a step function).

Notice that the time taken to pass a given level depends on the amplitude of the input signal. Thus it seemed reasonable in our case to generate a much higher (but rapidly decaying), signal than would normally be used to achieve the required minimum output level. Hence we would like to put a signal into the transducer whose envelope is that of Fig. 3(a), in order to produce an output function whose envelope is of the form of Fig. 3(b). Fig. 3(c) shows what the response would have been to a simple gated oscillator.

Since the transducer is a capacitive load, it must be tuned for resonance operation with an inductor (428 microHenries in this case). It was pointed out to us by Dr. B. Ray of Kingston Polytechnic, that the back e.m.f. from a current switched through the coil could be used to make the tuned circuit oscillate spontaneously at its resonant frequency if isolated. Fig. 4 shows the full circuit diagram of the system. It can be seen that the transmitter is simply an astable multivibrator driving a power transistor on for about 100 milliseconds every $2\frac{1}{2}$ seconds. This allows the current to build up to about 0.8 amps in the inductor. The transistor switching off generates a back e.m.f. in the coil, as shown in Fig. 5, with a peak value of about 150 volts. Since the required input voltage to the transducer for this system is only about 80 volts r.m.s., it can be seen that the objective has been achieved. The maximum current attained in the inductor can be controlled either by putting a resistor in the emitter of the power transistor or by altering the period for which the power transistor is switched on.

The explanation of the "flat" areas in the voltage waveform across the coil is not certain, but could be due to the generation of some frequency other than the fundamental which interferes with the fundamental.

2.3.b The Receiver

As shown in Fig. 4, the receiver was a simple amplifier with variable gain. The mode of operation was to use the Counter, (on loan from Marconi Instruments, type TF 2416), input threshold of 0.5 volts as our detection threshold, the amplifier gain being adjusted (from the surface), so that the signal level was above the threshold while the noise was below the acceptance level. Times were recorded from the digital counter by an observer using pen and paper. This had the advantage that spurious results could be discarded, an interpretation process which would be difficult to perform easily without a human observer. The counter input logic could be chosen by simple switches.

The received waveform as observed on an oscilloscope showed a rise time of less than one wavelength. However, varying the amplifier gain, (i.e. equivalently varying the threshold), varied the time interval recorded by up to about the period of the waveform, which was to be expected.

2.4 Mechanical Design and Construction

2.4.a The Transducer Mountings

In order to protect the transducers from the corrosive sea water and to provide electrical insulation for them, the transducers were mounted, (or more precisely, hung), inside a polythene container filled with castor oil. The latter substance was chosen because it is an insulator with an acoustic impedence similar to that of sea water. Fig. 6 shows a cross section through one of the polythene containers and an enlarged diagram to show how the electrical leads were sealed through the lid of the container. To ensure that no air remained in the containers, they were filled by totally immersing them in a large reservoir and then assembling while submerged. The reason for taking such care to eliminate even the smallest air bubbles is that they would introduce an additional admittance to the system causing possibly large energy losses.

2.4.b The Transmitter

The transmitter container was a simple box made of half inch Perspex with internal dimensions of 5 x 4 x 6 inches. The only reason for having it this large was that it enabled the transmitter to carry its own power supply in the form of a battery of five NiCd cells. The transducer was mounted on the lid, as shown in Fig. 7. The reflector was constructed from a standard eight inch car headlamp reflector with the back lined with expanded neoprene, the metal surfaces being coated with a plastic spray to prevent corrosion. The perspex disc which retains the transducer also serves to eliminate the direct acoustic path, thereby ensuring that all transmitted energy travels over the same path length to avoid any possible interference effects.

The container lid was held in place by six 4 B.A. bolts and sealed with an ordinary O-ring. The only wire coming out of the box was a single co-axial cable which carried the signal to start the counter. This was sealed through the lid by using a cable gland and a lot of Evo-Stick and fibreglass resin.

In order to minimise the number of waterproof seals required, a magnetic reed switch was used as a power switch with the magnet externally mounted.

2.4.c The Receiver

A scale drawing of the receiver's waterproof casing is given in Fig. 8. The method of attaching the transducer to the casing is the same as for the transmitter. In this case the wall thickness prevented the lid from being held in place with screws so we made the fit fairly tight and relied on the water pressure holding the lid on. It did. The reason for the enlarged top section is principally to contain the rather large inductor, but also serves as a convenient enlargement on which to attach the transducer. Note that in this case the instrument has an external power supply, (on the surface). The power, gain control, and amplified signal were transmitted between surface and instrument by a double co-axial cable which entered the waterproof casing through a cable gland with plastic tape for packing and Evo-Stick to complete the seal.

2.4.d Miscellaneous

Because we were using a one way system it was necessary to have a cable from each end to the surface. This we feared might produce problems with the cables snagging on obstructions but were pleased to find that by the simple expedient of putting plastic floats on the wires at appropriate intervals this problem was completely overcome.

In order to position the receiver easily with reasonable precision, it was attached to an eighteen inch spar with eight pounds of lead at the base. By this means the receiver could be stood vertically with the transducer above any immediate obstructions.

The one piece of equipment which was needed to ensure correct positioning of the transmitter was a suitable tripod, which unfortunately we lacked. Thus all measurements had to be made either with the transmitter resting on the bottom or else with it hand held. The problems with the former method will be self evident, while the latter proved that a diver cannot hold an instrument still underwater in even the best of conditions.

3. RESULTS OF FIELD TESTS

In order to obtain some idea of the reliability of the system as a measuring device, we used three techniques. Firstly, we attempted some simple distance determinations along a tape measure to try to get a feel for how the system was functioning. Secondly, we did a small number of tests to see how the device responded to small changes in the measured distance, and thirdly we carried out a large number of consistency tests between fixed points on the sea bed over a period of several days.

3.1 Simple Range Determinations

For this part of the experiment a 50 metre steel surveying tape was stretched between two prominent rocks on the sea bed at a depth of 6-7 metres, so as to be as straight as possible. By this means it was possible to keep the maximum catenary deviation to less than 0.5 metres, (which corresponds to a horizontal contraction of less than 1 cm.). During measurements the receiver was placed at one end of the tape and the transmitter held in place on the tape by a diver who tried to support the tape also in order to try and further minimise the effects of the catenary. The maximum range measured was about 64 metres, which was well beyond the visible range of about 20 metres. This result has a large standard deviation because the diver was free swimming. At this range we were able to detect the incoming signal with little difficulty and would expect that ranges of over 100 metres are perfectly feasible. Table 1 shows the results obtained.

TABLE 1 - Comparison of range estimates using a tape measure and the sonic rangefinder

Tape Range (m)	Mean Time Lapse (m.secs)	Standard Deviation (m.sec)	Sonic Range (m)
5.00	3.2268	0.0037	4.945
10.00	6.490	0.022	9.945
15.00	9.7501	0.0066	14.94
20.00	13.0178	0.0049	19.95
30.00	19.5428	0.0052	29.94
40.00	26.0844	0.0090	39.96
48.00	31.3022	0.0092	47.96
- (see text)	41.98	0.20	64.3

Local sound velocity used in this table is 1532.4 m/sec., obtained from the time difference between 5.00 and 10.00 metres ranges. Water temperature was 23.8°C.

From this table it appears that apart from a constant "end error" of about 5 centimetres, the acoustic rangefinder is accurate to a tolerance of ±1 cm, (approx.) in the range 5 to 48 metres.

The most difficult aspect to this part of the experiment was setting up the tape, which took two divers a whole hour.

3.2 Resolution of the Sonic Rangefinder

For these tests we decided to operate with the tape set up similarly to the preceding section, but more supported by the bottom to reduce the catenary. Also, we operated in much shallower water, (depth 0.4 - 1 metres), because this combined the worst acoustic conditions with the best control of the system, (the handlers could maintain close contact with both the instruments and surface control). The method used was to measure the "centre range" and then move the transmitter first forward and then backward by the appropriate distance, the receiver remaining fixed.

Although the tests do show that a movement of as little as 5 centimetres is in general detectable, the accuracy of the individual measurements was rather poor; typically of the order of 0.2 - 0.3%. With the exception of the 20 m group of figures, the spread of results does not indicate any obvious "end error". In the case of the 20 m group, the acoustic range determination is about 10 cm longer than the tape determination. This probably due to a recording or operating error as it is not consistent with the rest of the results in the group.

TABLE 2 - Resolution of sonic rangefinder

Tape Range (m)	Mean Time Lapse (m.secs)	Standard Deviation (m.secs)	Sonic Range (m)
4.95	3.203	0.019	4.94
5.00	3.2216	0.0099	4.97
5.05	3.275	0.019	5.05
9.90	6.4111	0.0070	9.89
10.00	6.502	0.087	10.03
10.10	6.5346	0.0059	10.08
14.95	9.6823	0.0058	14.97
15.00	9.7178	0.0050	14.99
15.05	9.7462	0.0023	15.03
10.90	12.964	0.030	19.99
20.00	13.011	0.011	20.07
20.10	13.113	0.028	20.22

The ranges given in Table 2 were obtained using a sound speed of 1542.3 m/sec, derived from the time difference between 15.00 and 5.00 metres. Water tamperature was 25.8°C.

3.3 Consistency Tests

In order to obtain some idea of the consistency of our system we marked some fixed points on the bottom as depicted in Fig. 9, using "Obo" nails hammered into the rock with small polystyrene floats attached to them by a string about 0.5 metre long for ease of re-location. The sea bed in the area chosen was composed of rocks up to 3 metres "diameter", (typically 1 - 2 metres), scattered about with shingle and smaller rocks in the gaps. Over a period of five days, various parts of the test area were measured by several different groups of divers. The test lengths were also measured by tape for comparison. Visibility was generally sufficient to see at least one other point from any given point, but not usually good enough to see the full length of the long arms. Hence to ensure that the tape was straight, only single point to point distances were measured with the tape.

TABLE 3 - Tape measurements of test area for consistency tests (See Fig. 9).

Line	Length One (m)	Length Two (m)	Length Three (m)
OA	14.90	14.60	14.77
OB	15.01	15.01	14.94
OC	18.81	18.80	18.68
AB	15.05	15.06	15.05
AX	18.34	18.33	18.34
XB	29.04	29.06	29.03
XY	31.98	32.08	32.00
YB	14.06	14.08	14.08
YC	20.33	20.40	20.34
YZ	25.74	25.75	25.78
ZC	17.55	17.55	17.55
CB	13.20	13.22	13.20

The three sets of measurements given in Table 3 were obtained independently by three different groups of divers. In general they show reasonable consistency and are probably as good as one could normally expect to obtain from free divers using a hand stretched tape. Line OA shows a lack of consistency due to the presence of a large rock between the two points which eliminates the possibility of a straight line measurement. The values given represent what the divers felt to be the best approximation.

Each set of results in Table 3 was obtained in a period of about 50 minutes. However, it should be borne in mind that the working conditions were exceptionally good (by British standards), with visibility of 20-30 metres and no current. I would expect similar measurements in the North Sea or English Channel to take much longer and probably to be less accurate.

TABLE 4 - Acoustic measurements of test area for consistency tests

Line	Date	Mean Time Lapse (m.secs)	Standard Deviation (m.secs)
OA	1.09.72	9.758	0.016
OA	1.09.72	9.7571	0.0064
OB	1.09.72	9.8864	0.0022
OB	2.09.72	9.8052	0.0059
OS	4.09.72	9.948	0.013
OB	4.09.72	9.9474	0.0074
OB	5.09.72	9.84190	0.00055
OB	5.09.72	9.875	0.011
OB	5.09.72	9.8958	0.0038
OC	1.09.72	12.3630	0.0056
OC	2.09.72	12.2002	0.0042
OC	3.09.72	12.36660	0.00050
OC	4.09.72	12.3078	0.0050
OC	5.09.72	12.2941	0.0019
OC	5.09.72	12.3297	0.0043
OC	5.09.72	12.3730	0.0042
AB	2.09.72	9.86263	0.00062
AB	4.09.72	9.86075	0.00045
XY	2.09.72	20.915	0.024
YZ	2.09.72	16.600	0.054
YZ	4.09.72	16.738	0.015
CB	1.09.72	8.586000	0.000001
CB	1.09.72	8.59860	0.00052
CB	2.09.72	8.7212	0.0081
CB	3.09.72	8.596	0.018
CB	4.09.72	8.6308	0.0059
OX	1.09.72	21.6296	0.0025
OX	2.09.72	23.064 *	0.03
CX	2.09.72	21.8019	0.0073
OX	2.09.72	21.7077	0.0037
OX	4.09.72	21.6533	0.0012
OX	5.09.72	22.97 *	0.48
OX	5.09.72	21.010	0.041

TABLE 4 (Cont./ ...)

Line	Date	Mean Time Lapse (m.secs)	Standard Deviation (m.secs)
OY	1.09.72	19.0430	0.0026
OY	2.09.72	18.879	0.079
OY	2.09.72	18.83443	0.00075
OY	4.09.72	19.062	0.011
OY	5.09.72	18.97980	0.00041
OZ	1.09.72	23.813	0.023
OZ	2.09.72	23.677	0.028
OZ	4.09.72	23.6826	0.0070
OZ	5.09.72	23.69550	0.00051
OZ	5.09.72	25.311 *	0.029

* These results are believed to be inconsistent due to the acoustic path including a surface reflection.

Table 4 shows the results of measurements made in the test area using the acoustic rangefinder. The following points emerge from the table.

(i) The consistency of the results, uncorrected for local sound velocity, is in general good enough to obtain an accuracy of the order of 0.1 m over a period of several days.

(ii) No improvement is shown by taking results from a single day.

(iii) The table contains obvious systematic errors. For example, notice the progressive increase of the mean time lapse for OB and OC during the 5th of September. (The results are given in chronological order).

(iv) The accuracy of the individual measurements as given by the standard deviation is, in general, between one and four orders of magnitude better than the long term accuracy given in (i).

In considering these observations we have to bear in mind that in (iv) we are considering the accuracy of the instrument, not the range determination which could be affected by refraction effects, etc. It is also instructive to consider the sea conditions during the period of the measurements. For about two weeks preceding the 29th of August, there had been continuous strong winds resulting in wave amplitudes up to about two metres (trough to crest), which would have mixed the surface layer thoroughly down to at least the 10 metres depth which prevailed in the test area. This would account for the very good results shown in Table 1. However, from the 31st August until the end of the experiments we experienced light winds and longs periods of sunshine. It seems very likely that this led to stratification of the water column and some limited measurements suggest that possibly we were affected by a thermocline which built up during the day and then dispersed at night.

Temperature measurements showed the increasing water temperature quite clearly. On the 1st of September, the water temperature was fairly uniform at about 22.5°C between 5 and 8 metres; similarly on the 2nd. On the 3rd, however, we recorded afternoon temperatures of 24.5°C at the surface and 24.3°C at eight metres. On the 4th the water temperature was again around 24.4°C, but during the afternoon of the 5th there was a strong negative gradient with a surface temperature of 24.1°C, and a temperature of 23.7°C at a depth of 8 metres. This temperature gradient had built up during the day as divers reported no sensible temperature gradient at the beginning of the day (09.00), though they felt the gradient quite strongly during the afternoon, and it was at the diver's suggestion that an investigation was made.

It seems likely that the systematic variation of the results recorded on the 5th of September can be attributed to the build up of the temperature gradient just described.

4. CONCLUSIONS AND RECOMMENDATIONS

From our observations it seems that the simple system described is capable of considerable accuracy (of the order of 1 centimetre at ranges between 5 and 50 metres) under good acoustic conditions. The standard deviation of all the measurements was typically of the order of 1 microsecond, suggesting that an instrument resolution of one wavelength (about 12 microseconds), is likely to be obtained fairly readily. This corresponds to a range of less than 2 centimetres and is upheld by the results of Table 1.

In order to obtain an accurate estimate of absolute ranges, it is essential that the local sound velocity is known with some precision. We found that it was quite adequate to estimate the sound velocity from two precise measurements of known distances and use the difference to eliminate any end errors. This required the two fixed distances to be separated by several metres, (we used 5 metres successfully), to minimise the error in the final result due to uncertainties in the individual measurements. Unfortunately this method requires one to use tapes and is very time consuming. I would recommend the use of either a commercially available velocimeter or a rod of length at least three metres on which the transmitter and receiver can be accurately positioned to measure the sound velocity. It appears from the estimates of OB and OC made on 5th September (see Table 4), that one could not reasonably expect to obtain an accuracy of better than about 0.5% in regions with strong thermal gradients unless a series of detailed corrections is applied.

As far as practical applications are concerned, I think there are some useful ideas which have come from this work. Firstly, it should be possible under reasonable conditions to use a system very similar to the prototype described in this report. If a completely battery powered submergible system were required it could be constructed fairly easily now that solid state numeric displays are commonly available. Alternatively, one might wish to use an automatic system to monitor sand waves, for example. In this case one could store the measurements on magnetic tape in the same box as the transmitter.

If this were to be done one would of course use a coaxial cable along the sea bed for the returning signal and not go via any kind of surface system. This has the advantage of reducing the amount of wire around, but there are still many instances where one would prefer a transponder to eliminate the need for any wires at all. Unfortunately, it was not possible for us to design a transponder with sufficient stability using the simple transmitter which was employed in the single path device. This was due to a combined shortage of time and expertise. The main features of a transponder to operate with this system are that it should introduce a delay of the order of 100 milliseconds, so that an effective range gating can be used to eliminate unwanted echoes and that it should transmit a signal with a fast rise time. The form of the delay should be such that it si reproducible with an accuracy of about 1 microsecond, which we were unable to achieve.

5. ACKNOWLEDGEMENTS

Many people gave assistance to this project and it would be impractical to name them all. However, I would like to mention particularly Marconi Instruments, who kindly loaned us the electronic counter whose "added extras" made our work in the field much easier; the National Institute of Oceanography who loaned the transducers without which we could not have managed and especially Mike Summers who patiently explained much of what should have been obvious; the staff of the 3rd Year Laboratory in the Physics Department at Imperial College who were so helpful in providing valuable facilities; Dr. B. Ray of Kingston Polytechnic who gave much helpful advice; Frank Green who so painstakingly assisted in the early stages of the project, and all the Expedition members who worked for long periods both on land and underwater to enable the project to get as far as it did. Others who assisted either financially or through gifts of materials are listed at the end of the main report.

6. REFERENCES

1. Albers, V.M. Underwater Acoustic Handbook, Pennsylvania State University Press (1960).

2. Tolstoy and Clay. Ocean Acoustics: Theory and Experiment in Underwater Sound, McGraw-Hill (1966)

APPENDIX - TRANSDUCER PARAMETERS

The following data was supplied to us by the National Institute of Oceanography with the transducers which they loaned us.

DIAMETER:	$1\frac{1}{4}$ inches
CONSTRUCTION:	Barium Titanate (Ba Ti O_3), spherical
EXCITATION:	Radial
RESONANT FREQUENCY:	81.2 KHz
BANDWIDTH:	8.8 KHz
Q IN WATER:	9.2
IMPEDENCE AT RESONANCE (DYNAMIC):	400 ohms
OPEN CIRCUIT SENSITIVITY AT RESONANCE:	45 microvolts/microbar
CLAMPED CAPACITANCE:	0.0089 microfarads

EXPEDITION ACCOUNTS

Treasurer: J.R. Nicholls

INCOME

	£	p	£	p
1. Personal Contributions				
9 x £75.00	675	00		
2 x £60.00	120	00		
2 x £25.00	50	00		
	845	00	845	00
2. Donations				
Imperial College Exploration Board	500	00		
Royal Geographical Society	150	00		
World Expeditionary Association	80	00		
Comex Diving Ltd.	200	00		
British Petroleum Ltd.	50	00		
	980	00	980	00
3. Other Income	17	93	17	93
Total Income			1842	93

EXPENDITURE

	£	p	£	p
1. Travel				
Air Flights (London-Malta-London)	496	65		
Ferries: Ramsgate-Calais	45	00		
Syracuse-Malta	46	11		
Road Tolls in Italy	9	83		
Hire of 22 cwt Transit Van	146	31		
Petrol	92	49		
Other Travel Expenditure	57	24		
	893	63	893	63
2. Accommodation				
In Malta	162	67	167	67
3. Food	251	71	251	71
4. Equipment				
Particular to Surveying/Sonar Exp.	173	51		
Particular to Posidonia Exp.	6	21		
Other Equipment	134	81		
	314	53	314	53
5. Diving				
Running Costs/Maintenance of the Compressor	17	18		
Running Costs/Maintenance of the Boat and Engine	61	28		
Other Diving Expenditure		58		
	79	04	79	04
6. Other Expenditure				
Medical Supplies and expenses	5	26		
Stationary	7	11		
Sundry expenses	27	25		
	39	62	39	62
Total Expenditure			1741	20

	£	p	£	p
Petty Cash in Hand	15	87		
Small Foreign Coinage		36		
Balance Remaining in the Bank	85	50		
	101	73	101	73
TOTAL			1842	93