

Sept.

R

LEON POMERANCE  
SEVEN AMHERST ROAD  
GREAT NECK, NEW YORK

January 30, 1966

Dr. Sheldon Breiner  
Quantum Electronics Division  
Varian Associates,  
Palo Alto, California.

Dear Dr. Breiner:

I have recently read with great interest your article in SCIENCE entitled "The Rubidium Magnetometer in Archeological Exploration."

I am an amateur archaeologist with a great interest in Crete. Beginning in 1962 and for four years, we have sponsored with the Greek Archaeological Society under the direction of Dr. Nicholas Platon, the extraordinary find of the fourth Minoan palace of Crete at Kato Zakro. In addition I have helped to sponsor the find of the royal tomb at Archanes in Crete last fall by the archaeologist J. Sakallarakis.

Last September I examined the tomb area of Katsaba with Dr. S. Alexiou, director of the Herakleion Museum. The enclosed photostat of the Illustrated London News article, gives the results of one of his tomb finds in this area.

The site it seems to us would be an excellent testing ground for a magnetometer experiment. The site is now used by the government as an experimental agricultural project and so is free of buildings. The tombs found by Alexiou have been the result of subsidence of the soil where the watering of the experimental plants has taken place. But because of the depth (30 feet) and the sandy nature of the soil it has been dangerous to dig trial trenches at random.

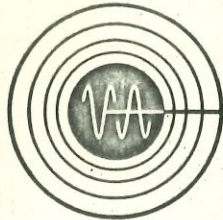
Katsaba is only ten minutes from the major town of Herakleion and was the harbor town of the great palace at Knossos. From the finds already made here it is clear that there can be a "break-through" in the knowledge of Minoan Crete of the 13th Century B. C. if we can find the rest of the tombs in this area. This time period is now the subject of much heated controversy in archaeological circles.

My purpose in writing is to determine if it would be possible to borrow or rent the Varian magnetometer for use at Katsaba under the direction of Dr. Alexiou. We would have available also Mr. Michael Schulhof, a graduate student in applied physics at Cornell University. The experiments could take place in September 1966.

I would be pleased to hear from you at your earliest convenience.

Sincerely,

*Leon Pomerance*



# VARIAN associates

611 HANSEN WAY • PALO ALTO, CALIFORNIA • 326-4000

February 4, 1966

Mr. Leon Pomerance  
Seven Amherst Road  
Great Neck, New York

Dear Mr. Pomerance:

Thank you for your most interesting letter of January 30, regarding the application of a magnetometer to the detection of tombs in Crete. We read with interest your description of the work performed thus far and the newspaper articles on the tomb findings.

In order to detect a buried tomb by itself, one must have a somewhat uniformly magnetic rock or soil out of which the tomb has been carved, the more magnetic the medium the larger the disturbance. In weakly magnetized rock or soil the contrast between the zero magnetic susceptibility of the air in the tomb and the soil itself may represent an undetectably small anomaly. If the tomb contains artifacts, however, such as earthenware, roof tiles, or large quantities of sherds, its detection would be considerably easier. Under very general conditions in soil or rock of average magnetic susceptibility, the maximum depth to the top of a detectable tomb is something on the order of the diameter of the tomb itself. Therefore, if there is any chance of detecting a tomb at a depth of 30 feet, it would first require a very sensitive magnetometer.

Since the time of writing of the article in Science, an instrument was developed for use by the University of Pennsylvania that performs the same functions as that described in the above article but which is now completely portable. This instrument is the 4920 Precision Portable Magnetometer with a digital readout and effective sensitivity between 1/10 and 1/100 of a  $\gamma$ . The instrument was developed for the Applied Science Center for Archaeology of the University Museum of the University of Pennsylvania and was used with great success this past Fall Season on the plain of Sybaris. They succeeded in mapping out very extensive areas of buried buildings and shall return to Sybaris and Greece this coming Spring and Summer.

The only instruments available at this time are those committed to the archaeological work of the University Museum; therefore, I recommend that you contact Dr. Froelich Rainey or Miss Elizabeth Ralph of this University Museum to make arrangements for an experiment to detect these tombs or



Mr. L. Pomerance

Page 2.

February 4, 1966

associated disturbances. They are on a very full schedule but do plan on using the instrument in Greece and may therefore be interested in applying the instrument for this purpose. All arrangements will have to be made through the University Museum for any experiments to be attempted this year. I have already taken the liberty of recommending to Miss Ralph that she look into this request and have also forwarded her a copy of your letter.

We have enclosed descriptions of the instrument described above and a reprint of the article in Science. We thank you very much for your interest and recommend that you keep in contact regarding the lease of an instrument, perhaps next season.

Sincerely,

Sheldon Breiner  
Geophysicist  
Quantum Electronics Division

SB:GT

Enc. Science Article  
4920  
Flyer

cc: Dr. Froelich Rainey

Miss Elizabeth Ralph

roof tiles  $\chi \sim 40 \times 10^{-4} \text{ emu/cc}$

$$M_r = \left[ 1 + \left( \frac{\mu_2 - \mu_1}{\mu_2 + 2\mu_1} \right) \frac{a^3}{r^3} \right] H_v \cos \theta$$

1.000044

.37

7000308  
3000132  
-----  
.37001628

1.00038

.37

700266  
300114  
-----  
.3701406

$\frac{320 \times 10^{-4}}{64} = 5 \times 10^{-4}$

.37

1.000044

148

370000148

64  
8  
-----  
512

$.032 = 32 \times 10^{-3}$   
 $3200 \times 10^{-5}$

.08

.4

.032

.03  
3 .10

1.04

5

5.20

Edgerton ~  
Hotel Bellevue  
Corinth

Galaxias

Academics

Meet at Hotel Plaka  
7:00 P.M.

Call Whittelsey 608

ec 4  
May

PRESERVATION COPY  
(8/11/2014)

COPY OF HANDWRITTEN LETTER

University of Athens  
Department of Archaeology  
February 4th, 1966

Dear Dr. Bass,

I reply with pleasure to both of your last letters and I beg you warmly to communicate my news both to Dr. Rainey and to Dr. John Huston, a cable of whom I had yesterday, but I have not his address at this moment.

1) Yes, a trip to Australia is now decided, though it is a considerable trouble to my plans. I will leave about June 1st and will be back not earlier than the first week of November.

2) Perhaps I will not avoid a week's trip to Italy and Hungary during the 2nd week of March.

3) If you or Dr. Rainey or Dr. Huston's personal can manage to appear in Greece till June 1st I will manage to leave any other work aside in order to give priority to Helice. Enough to have news of you as early as possible.

4) You must have always in mind, that both political and archaeological situations change constantly here, so that the formalities necessary need time, even for myself. For the moment I have in my hands the paper of the Arch. Services to let you work at Helice under my presence and I should like to be here, whenever you start in Helice and I desire to have well in my hands the Helice-efforts till you have - as I hope - some nice result. Then we will try the big work, for which I have friends to help us. Please tell it to our friends. If you can not come at time, we must postpone the work for next year. Helice lies buried exactly 2,339 years. Let it complete the next round number of years, if we can not do something before June! Otherwise, if you believe that we can work after October of this year, (which I believe), I will be in Greece and free to your disposition.

For the next question....[here Dr. Marinatos answers a question about ancient ships' rams, which does not pertain to Helice].

With best wishes and greetings,  
Yours truly

Sp. Marinatos

I am forwarding copies of this letter to Dr. Rainey, Dr. Edgerton, Mr. Huston, and Dr. Payne. I will be most interested to hear about how the dates may work out for possible underground and underwater surveys. This letter is the first which has suggested that we might be involved in the actual excavation of the site, if it is found, and that is good news, indeed. C.F.B.

Sohn Pomeroy

AEC Bldg.

EXPW. to Fredericksburg  
~15 m

Sym on Sayre  
2.00

February 25, 1966

Dr. Spiridon Marinatos  
47 Polyia St.  
Athens 903, Greece

Dear Dr. Marinatos:

Dr. Rainey has asked me to reply to your letter of February 4th to Dr. Bass. I am planning to be in Calabria, Italy with our new portable cesium magnetometer starting on April 1st. If convenient for you, I could come with it to Helice in May. If so, please let me know what time is best for you. Perhaps, one or two weeks would be sufficient for a preliminary underground survey. Dr. Rainey will be excavating at Sybaris in May and so will not be able to come.

Two assistants (either intelligent workmen or students) will be required to help with the running of the instrument. If you do not have two available, I could bring my two trained Italian assistants unless there would be difficulties for them to obtain passports.

Since I shall have a lot of equipment to transport, I shall plan to come by boat with my car. I imagine that the most direct route is from Brindisi to Patras. Since I don't know any Greek, I shall feel a bit lost when I arrive.

If you reply after March 20th, please address your letter to me c/o Enrico Mueller, Casano Ionio (Cosenza), Italy. I shall look forward to hearing from you. If next year is more convenient for you, please do not hesitate to tell me.

Sincerely yours,

Elizabeth K. Ralph  
Associate Director

ΔΙΕΥΘΥΝΣΙΣ ΜΟΥΣΕΙΟΥ  
ΗΡΑΚΛΕΙΟΥ

ΗΡΑΚΛΕΙΟΝ March 12, 1966

Dear Dr. Rainey

I am very grateful for  
your kind letter of 26 Fe-  
bruary. I think the month  
of September is very satis-  
factory for the magneto-  
meter probe of the Ka-  
[KATSABA] ← tsabi site. Mr. Pomerance  
tells me that he would  
like to assist to the work  
and that for him the  
middle or late September  
would be the best time.

I am happy that you are  
interested in this work and  
that we shall have your  
precious assistance. I should  
like to know the exact time  
of arrival of Sr. Ralph  
and the number of her crew,  
so that ~~we~~ I may find  
rooms for them in a hotel

with all best wishes  
sincerely yours

J. Alexim

ΕΘΝΙΚΟΝ ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ  
ΑΡΧΑΙΟΛΟΓΙΚΟΝ ΣΠΟΥΔΑΣΤΗΡΙΟΝ ΚΑΙ ΜΟΥΣΕΙΟΝ  
UNIVERSITY OF ATHENS  
DEPARTMENT OF ARCHAEOLOGY

Athens, March 13th 1966.

Mrs. Elisabeth Ralph,  
Associate Director.

Dear Mrs. Ralph,

Thank you for your letter of Febr. 25. Dr. Rainey wrote me about your plans. I think, that during the first two weeks of May we could try in Helice with your devices. Please write me at time about your exacte plans. Surely it is best to come with your car from Brindisi to Patras. Do not bring assistants. We shall have two diligent students or workmen. If it is impossible to me to come to Patras, somebody will be there to wellcome you on board. I think, I will be personally. Enough to know exactly when you arrive. For the rest we will discuss on the spot. There is great interest about our plans in Helice and the Prime Minister has been interested personally and vividly. I am looking forward for your news.

Yours sincerely.

Sp. Marinatos

March 22, 1966

Dr. S. Alexiou  
General Directorate  
Herakleion Museum  
Herakleion, Crete  
Greece

Dear Dr. Alexiou:

Dr. Rainey has asked me to reply to your letter of March 12th. I am glad that middle or late September is a satisfactory time for you.

I am planning to attend a NATO conference on thermoluminescence in Spoleto, Italy from September 5th to 16th, and after that I will need 2 days to pick up some of my equipment in Calabria where I shall leave it this spring (unless I have time to do this before the conference).

Since I shall have a lot of equipment, would it be easier if I bring my car and come by boat, or is it easier to fly to Crete?

Two assistants--either intelligent workmen or students-- are needed to assist with the magnetometer work. Can you supply them, or should I bring my two trained assistants from Italy? There may be some difficulty in their obtaining passports.

There is a possibility that Sheldon Breiner from Varian Associates will come with me, but he cannot be certain at this time. If not, I shall come alone unless you want me to bring the Italian assistants.

I am leaving for Italy tomorrow, and can be reached c/o Enrico Mueller, Cassano Ionio (Cosenza). During the first two weeks of May, I plan to search for Helike with Dr. Martinatos, and will then return to Italy.

Sincerely yours,

Elizabeth K. Ralph  
Associate Director

DIRECTION DU MUSÉE DE HÉRACLION  
CRÈTE - GRÈCE

Héraclion, le 29-3-66

Dear Miss Ralph,

Many thanks for your letter of March 22.  
I think it will be easier for you to come to Crete by one of the  
ferry-boats, which go every day from Athens to Héraclion.

I hope I will be able to supply two intelligent workmen  
to help you, if not a specialised personnel is needed.

With all best wishes

Sincerely yours



Dr. ST. ALEXIOU

Wrote 7/17/66  
Suggested Aug. 1-2

ΕΘΝΙΚΟΝ ΠΑΝΕΠΙΣΤΗΜΙΟΝ ΑΘΗΝΩΝ  
ΑΡΧΑΙΟΛΟΓΙΚΟΝ ΣΠΟΥΔΑΣΤΗΡΙΟΝ ΚΑΙ ΜΟΥΣΕΙΟΝ  
UNIVERSITY OF ATHENS  
DEPARTMENT OF ARCHAEOLOGY

47, Polyla St.  
Athens 903, Greece

Athens, April 3<sup>rd</sup> 1966.

Dear Miss Ralph,

Thank you for your lines of 25 March. I am just arriving from Egypt. On May 3<sup>rd</sup>. I shall be in Patras and I am looking forward to see you with great pleasure. If there is something to do in the meantime (for instance finding a boat or anything else) please let me know at time. There is great excitement in this country about our efforts for Helix owing to the interest of His Exc. the Prime Minister, who happens to be a Peloponnesian.

Yours very sincerely,  
Prof. S. Marinatos

wrote 4/15/66  
Roma 923256  
Fiat 850

May 8, 1970

Prof. H. E. Edgerton  
Dept. of Electrical Engineering  
Massachusetts Institute of Technology  
Cambridge, Massachusetts, 02139

Dear Prof. Edgerton:

The report of my magnetometer experiences at Helice is enclosed. The extraneous explanations included were written for the benefit of Prof. Marinatos.

I should like very much to see your article and learn of your experiences at Helice.

Sincerely yours,

Elizabeth K. Ralph

room 4405

DEPARTMENT OF ELECTRICAL ENGINEERING

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CAMBRIDGE, MASSACHUSETTS 02139

May 5, 1970

Dr. Elizabeth Ralph  
The University Museum  
University of Pennsylvania  
33rd & Spruce Streets  
Philadelphia, Pa.

Dear Dr. Ralph:

Did you write up your magnetometer experiences at the Helice site?

If so, I would like to list it at the end of an article that I am writing about a sonar search.

Sincerely,



Harold E. Edgerton

HEE:m

MAGNETOMETER TESTS IN SEARCH OF HELIKE

May 3-7, 1966

by

Elizabeth K. Ralph  
Applied Science Center for Archaeology  
University Museum  
University of Pennsylvania

cc. sent to  
Prof. Sp. Marinatos  
Angelos Delivorrias

At the invitation of Prof. Sp. Marinatos, a precision portable cesium magnetometer was brought to Greece by the writer for an initial trial in the search for Helike.

This instrument was designed and constructed for the University Museum by Varian Associates (Palo Alto, California). Preliminary tests with the Varian Associates' rubidium magnetometer in October 1965 on the plain of Sybaris in Southern Italy indicated that the greater sensitivity of optical absorption magnetometers (as compared with proton and fluxgate magnetometers) could be utilized for archaeological prospecting. Therefore, this new precision portable cesium magnetometer was designed expressly for this purpose. It is readily portable and has a maximum sensitivity of 0.05 gamma ( $0.05 \times 10^{-5}$  oersted). With this sensitivity, anomalies representative of archaeological deposits at depths of 4 to 6 meters have been detected on the plain of Sybaris.

The basic principle of the rubidium, cesium, and of other optical absorption magnetometers is that, due to the Zeeman effect, the energy levels of an atom become split into various sublevels whose separations are dependent upon the total intensity of the ambient magnetic field. To detect this proportional splitting, optical pumping is required. The operation of optical pumping involves the excitation of electrons into metastable states by the absorption of appropriate electromagnetic radiation. When "pumping" is completed, redistribution of the pumped electrons to lower levels is accomplished by stimulation from a radio frequency corresponding to the difference in energy between the split levels. For the isotope  $Rb^{85}$  the separation between sublevels is approximately 4.667 cycles per second per gamma. In comparison, the change in precession frequency of the proton

2

magnetometer is approximately 0.04 cycles per second per gamma. This is the basic reason why the  $Rb^{85}$  and similar optical absorption magnetometers are capable of detecting changes in magnetic intensity with approximately one-hundred-fold greater sensitivity.

In order to make effective use of the most sensitive range of the instrument, two sensors (the detecting elements) are required. One may be carried vertically above the other or one may be left in a fixed position in the center of the field to be covered. In either case, the higher (or fixed) sensor serves to cancel out diurnal and some other extraneous magnetic variations.

In the search for Helike, preliminary lines were made with one sensor in order to proceed more rapidly and to assess the types of anomalies (readings which differ from the normal) to be detected. The first trial was made in the bed of the Selinous River (see Fig.1). Very large variations were detected immediately — too large to be representative of deeply buried archaeological features. It was soon discovered that both the river banks and the bed of the river were covered with wire mesh fencing. This was the cause of the large anomalies and its presence negated the use of a magnetometer in the river bed.

We then moved down the river to the beach and continued Line 1 (see Fig.1) from the mouth of the river approximately 600 meters to the north. Here again, large anomalies were detected due to the presence of modern iron objects — "tin" cans and other litter on the beach. The next trial was made from a small landing area (house where we subsequently had lunch) approximately one kilometer south of the Selinous River. Line 2 was made from this spot to 600 meters north in the direction of the river and then back again, a short distance inland (Line 3). Again large variations in magnetic intensity were caused by modern iron debris on or near the surface of the beach. As seen in the plot of Line 2 (Fig. 2), some areas were worse than others as indicated by the rapid fluctuations in magnetometer readings. In a few spots, consistently regular magnetometer readings were obtained, but there were no indications of deeply buried structures.

In order to utilize the maximum sensitivity of the cesium magnetometer, it is necessary to make a grid -- a series of parallel lines that form a rectangle or square -- with two sensors -- one fixed in the middle of the grid. For this, an open space was found, about 50 meters west of the beach and 200 meters north of the "landing". In this area Grids 1 and 2 were made (see Fig. 1 for their locations). In the plot of magnetic contours (lines of equal magnetic intensity) for these grids, one sees a strong reaction in the northeast and northwest corners (of Grid 1, Fig. 3), another along the southern edge near a ditch (of Grid 1), and another along the western sides of both grids, but more pronounced in Grid 2. All of these were caused by modern iron -- principally the posts and rails of the grape arbors. The undisturbed central portions of the grids are too small to determine whether or not there are any archaeological features in this area.

Since it was apparent in these grids that the grape arbors caused a magnetic disturbance that extended at least 10 meters from their limits, Grid 3 was made with the second sensor mounted vertically above the usual movable sensor. The thought was that with the two sensors fairly close together, one  $1\frac{1}{2}$  meters above the other, that the upper one would serve to cancel out the external disturbances due to modern iron objects (from a smaller distance than with the fixed sensor) while the lower one would reveal possible features under the ground. Unfortunately, since the grape arbors were about as high as the upper sensor, changes were detected due to iron rails that were closer to the upper or "monitor" sensor. In other words, this system did not serve at this site to cancel out external variations. In the portion of the grid, not too close to the grape arbors, many small variations were detected due to small pieces of iron debris on or near the surface of the earth. Because of these, it was impossible to ascertain whether or not there were any buried archaeological deposits in the area of this grid.

The next trials were made in a boat with one sensor mounted in the bow and extending one meter ahead of the boat. If the boat had been "non-magnetic", this would have provided a means of making lines along the shore, about two

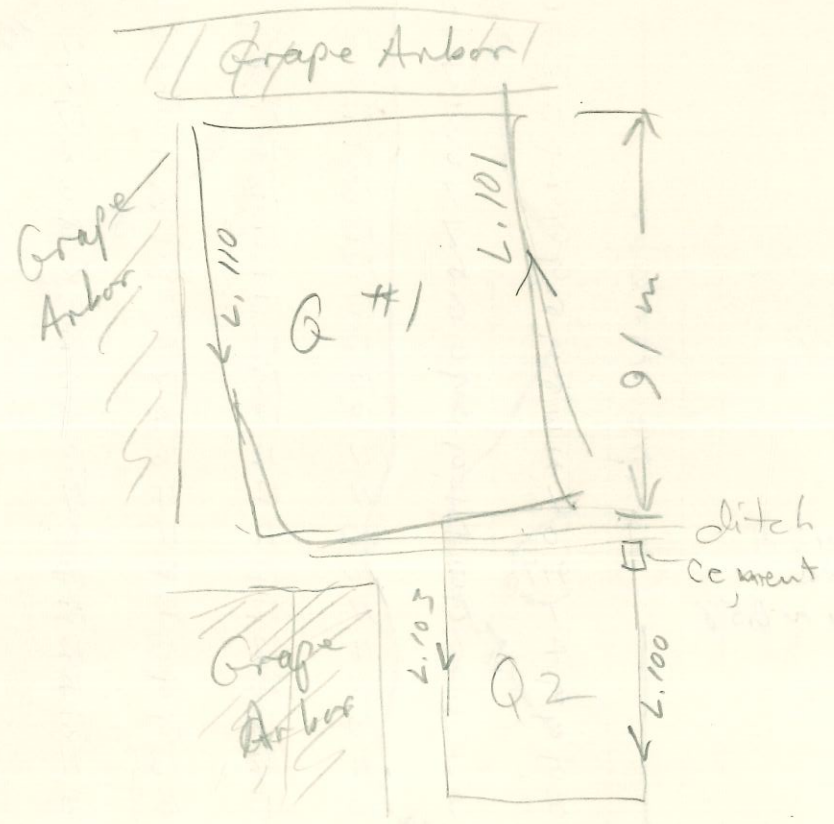
meters out where the water is approximately 1 meter deep. The boat provided, however, and a rowboat provided the next day, were not "non-magnetic". The first had a motor in its center and both had iron strips lining the keels. Therefore, even with the sensor mounted in a fixed position extending from the bow, anomalous readings were detected due to the rotation of the boat. This is because the position of the sensor in relation to the magnetic north pole and the magnetic material in the boat changed with rotation of the boat. Therefore, the readings were uniform (except for areas due to modern magnetic disturbances which corresponded with those found on land) until the boat changed direction. An apparent anomaly was detected as the delta was rounded, but it was not caused by buried features -- only <sup>by</sup> the change in direction of the boat. As a test the boat was rotated  $360^{\circ}$  in one spot, and the readings changed by 200 gammas.

It was unfortunate that the land surveys were inhibited by modern iron structures and debris, but some useful information might have been obtained along the shore if a non-magnetic boat had been provided. It was apparent, however, that a magnetometer is not an appropriate instrument in the search for Helike due to the presence of so much modern iron.

Perhaps, a sonic device such as Prof. Edgerton's Boomer will be more successful. Whether or not the stones on the beach and off-shore will interfere with this technique is yet to be determined.

I am grateful to for the kind hospitality and cooperation of Prof. Sp. Marinatos, Mr. Angelos Delivorrias, and the many others who gave so generously of their time while I was in Greece.





HELICE SITE SURVEY WITH SONAR

Peter Throckmorton  
Harold Edgerton  
Fred Feyling

May 22, 1970

HELICE SITE SURVEY WITH SONAR

Peter Throckmorton  
Harold Edgerton  
Fred Feyling

This preliminary report describes briefly a sonar survey of an area on the south shore of the Bay of Corinth, Greece between the Selinous river mouth and the harbor of Aiyion, where Helice may be concealed. Prof. Spiro Marinatos<sup>1</sup> has written the story of the catastrophe of 372 B. C. concerning the historical destruction of Helice.

A previous sonar survey,<sup>2</sup> in 1966, was made using a 16 kHz and a 2 kHz continuous sonic profiling equipment in this area. The records showed interesting "holes" and "bumps" in the bottom and sub-bottom. The present survey is an effort to extend the area of the 1966 survey and to add further information about the bottom and sub-bottom features. A sonar system (5 kHz) was used with a pulse length of about one-half a millisecond. Divers have not been used to explore the area and no excavations have been performed.

It is possible that the Helice site is under land<sup>3</sup> and not under the sea due to sedimentation and land subsidence. From the results of the present study, we cannot definitely state that Helice is, or is not, under the sea. Further results are needed.

An area of especial interest is shown in Fig. 1 as a circle. The diameter of the area is roughly 500 meters. The edges of the above area appear higher, similar to an encircling wall. If so, they are about 100 meters in thickness which seems too large. However, they could be flattened and also the sonar tends to give

a wide dimension due to side signals. Angles to the three buoys in the area are given at the end of the list of houses (Table 1). Fig. 5 shows two sonar records of the area in question, each taken on a course differing by about 90 degrees to portray the under sediment features. Further sonar profiling studies with improved navigation control are needed to pinpoint the various features of the sub-bottom targets.

The depth in water to the top of the so-called wall is about 50 meters. A covering of 3 to 7 meters of sediment is over the entire site. An excavation would be difficult by divers, due to the water depth, poor visibility, and associated problems. We recommend a mud-moving jet or other devices operated from the surface to clear the sediment. This is an engineering problem which can be solved. Sonar should be used as a monitoring device to supervise the mud moving effort.

We emphasize that the nature of the targets that produce the sonar signals is unknown to us. It could be a geological formation. We do not know what the sonar reflections are caused by, but we would like to know. Coring or dredging from the surface could give some answers. A magnetometer survey might be interesting and informative.

Dr. Edward Zarudzki, of the Woods Hole Oceanographic Institution, has studied briefly our sonar records and agrees that they reveal interesting sub-bottom echoes. He has suggested that we attempt to rectify the navigation of some of our records and prepare an accurate hydrographic chart. This we have not done, because we feel that this preliminary report should be produced as promptly as

possible. Also, with accurate navigation more sonar records should be made to extend our work, in case some one attempts to work seriously at the uncovering and exploration of the areas in question.

The chart (Fig. 1) enlarged from chart H.O. 3963, was prepared by one of us (Feyling). Buildings along the shore were pinpointed on this chart for reference points for the ship-carried sonar equipment. Distances were measured by means of a metering wheel along the shore. Fig. 1 shows this chart with the estimated courses of the ship when surveying and the location of the buildings as numbered. Table 1 lists the buildings along the shore, describes them numerically and graphically, and gives the distance between them in meters. These marks and charts will be useful for future surveys.

A side scan survey, opposite building # 25, with an EG&G, Inc. type 259 sonar is shown in Fig. 3 at positions indicated on the Fig. 1 chart. Note the white spots on Fig. 3. These are shadows of holes which we believe to be fresh water springs through the gravel which once may have been the river bed of the Selinous river.

Fig. 4 shows a side-scan sonar record opposite house # 15, where "bumps" without sediment covering have been seen. We do not understand the geological reasons for these bottom features.

The vertical records were made by an EG&G, Inc., type 254 recorder, with a 5 kHz sonar Massa transducer.

The ship, R/V STORMIE SEAS, served as a base for living and as a platform for the sonar equipment. She is 50 feet long with sail and auxiliary motor power. Nights were spent anchored at Aiyion.

Personnel, R/V STORMIE SEAS, (Mar/Apr, 1970)

Throckmorton, Peter - Expedition director  
Throckmorton, Joan - Administrative Assistant  
Rankin, Gus - First mate  
Traxel, David - Sailor  
Grinnel, Jim - Engineer  
Wortmann, Juergen - Technician  
Choremis, Angelos - Greek Archaeological Service, Athens  
West, Jehane - Sailor and surveyor  
Feyling, Fred - Sonar operator and surveyor  
Edgerton, Harold - Sonar operator and surveyor

The Research Committee of the National Geographic Society supported this effort. Travel expenses for Edgerton and Feyling were met personally and also the transportation of the sonar exploration equipment. The Geodyne Division of EG&G, Inc., Bedford, Mass. and the Massachusetts Institute of Technology furnished the side scan sonar and the 5 kHz sediment prober.

References





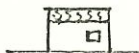
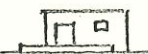
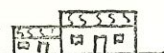



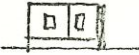

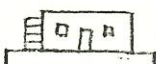
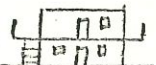
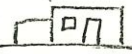


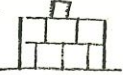


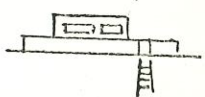




1. Marinatos, S., "Helice: A Submerged Town of Classical Greece," Archaeology, Vol. 13, No. 3, (Autumn 1960), pp. 186-193.
2. Marinatos, S., "Helike - Thera - Thebai," Athens Annals of Archaeology, A', I, Athens, 1968, pp. 12-17.
3. Ralph, Elizabeth, "Magnetometer Tests in Search of Helike, May 3-7, 1966," University Museum, University of Penn., Philadelphia, Penn. (Private communication)

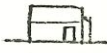

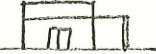

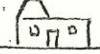

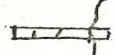
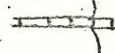





ILLUSTRATIONS

- Fig. 1 Chart between Aiyion and the Selinous river, showing 5 kHz sediment penetration sonar tracks (Figs. 2a,b,c) and side scan tracks (Figs. 3 & 4) and an area of interest.
- Fig. 2 A continuous seismic profile parallel to the shore at average depth of 45 meters. Note an area of especial interest at building #'s. 31 to 33, "holes" at building # 26, and "bumps" at building #'s. 14 to 20.
- Fig. 3 Side scan sonar records (1000 feet to both sides) showing "holes" opposite building #'s. 22 to 27.
- Fig. 4 Side scan sonar records showing "bumps" opposite building # 15.
- Fig. 5a Sonar record near house # 32, from shore to 60 meter drop off location.
- Fig. 5b East-to-west sonar record (5 kHz) at 50 meter depth. Note area at building #'s. 28 to 33 and fault (?), or ancient river edge (?), at building #'s. 21 to 22.

(P. Throckmorton, H. Edgerton, & F. Feyling)

Table: 1-Survey Notes on Bench Marks Along Beach East of Aiyion to the Selinous River, March 1970

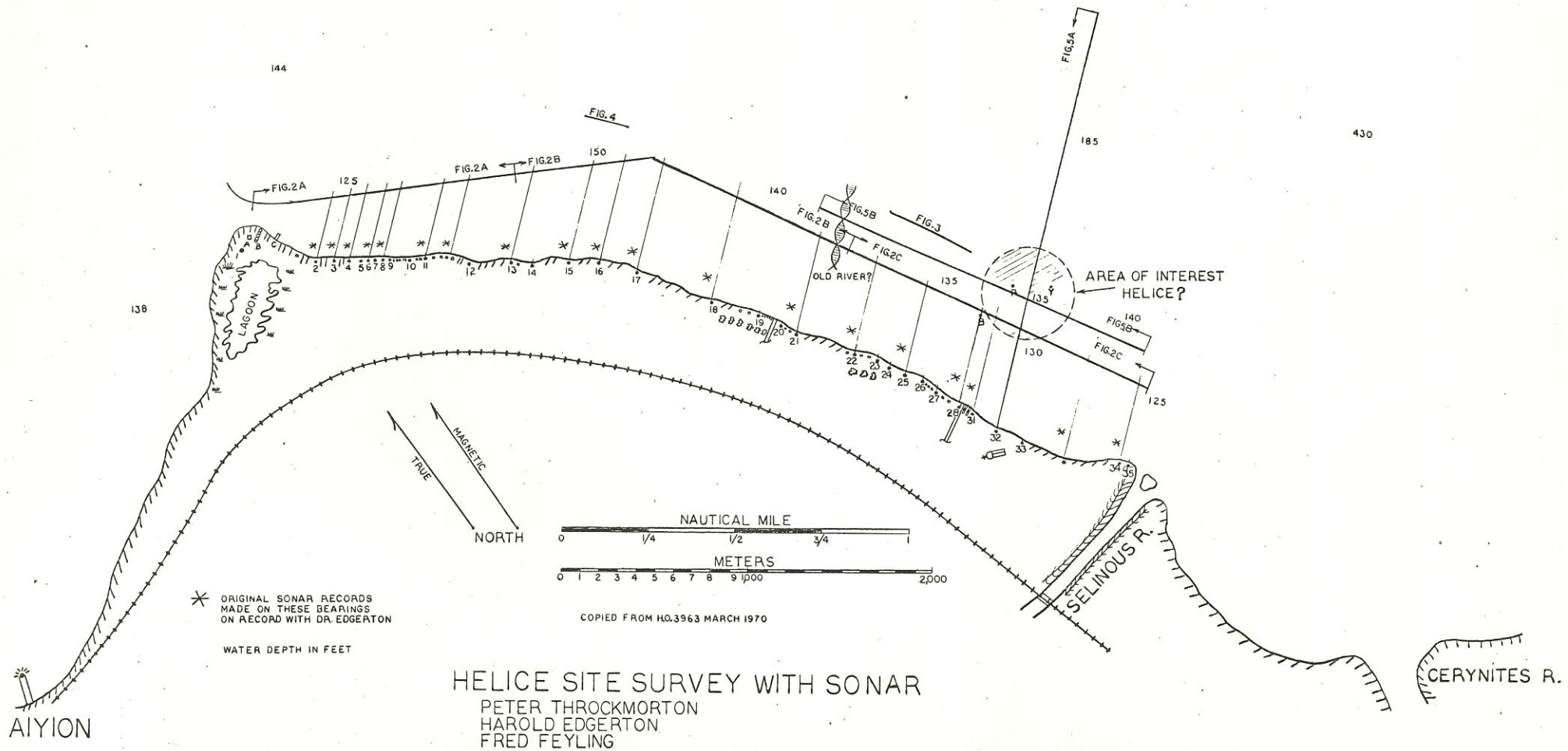
No.	Meters Between Marks	Description
1	70.0	monument with stone post 
A	58.9	base of old nav. light, dated 29/5/43 
B	211.8	stone wall 
C	346.1	stone culvert 
2	80.6	cabin with window west side 
3	78.6	cabin with blue shutter 
4	74.1	cabin with yellow shutters 
5	44.1	cabin with two small windows 
6	42.8	cabin with three posts 
7	39.3	cabin with flat roof 
8	28.1	cabin with post on west side 
9	113.6	cabin with four posts 
10	83.1	concrete house with two windows 
11	251.3	two-story house with blue and yellow shutters 
12	243.4	low white cabin with window and door 
13	95.8	white cabin with blue trim 
14	208.4	yellow cabin with flat roof 
15	155.7	two-story restaurant 
16	227.8	unfinished two-story concrete house 
17	419.3	cabin with flat roof, door, two windows 
18	275.2	two-story house with wall and marine railway 
19	140.3	cabin with flat roof, 8 posts 
20	95.9	restaurant with flat roof, red trim 
21	324.0	cabin with penthouse 
22	126.9	green cabin with red door 

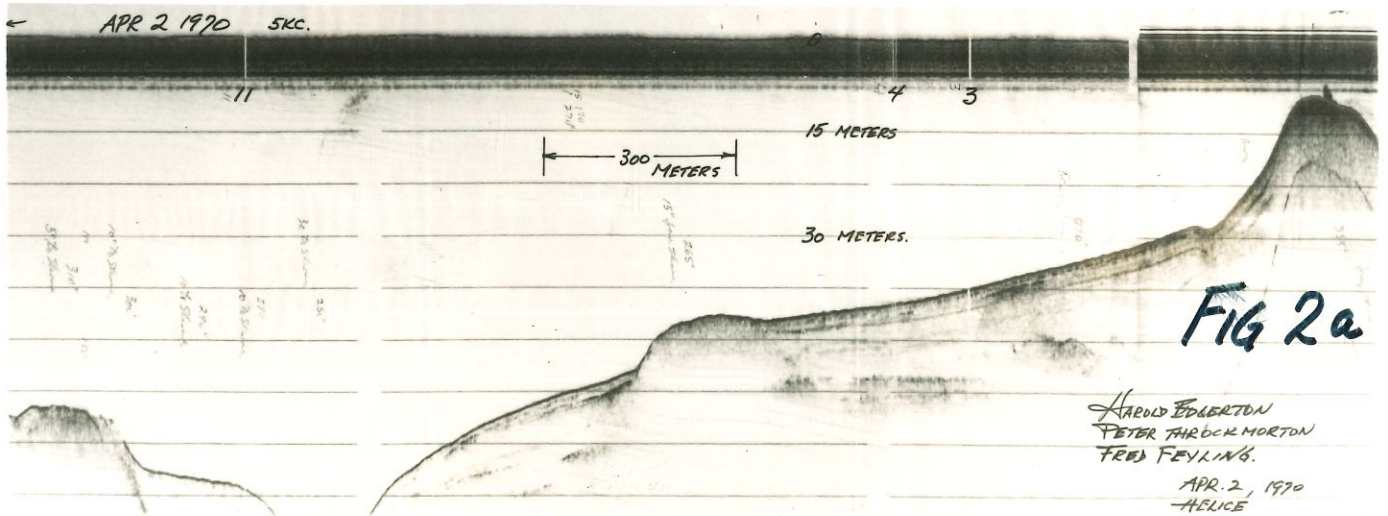
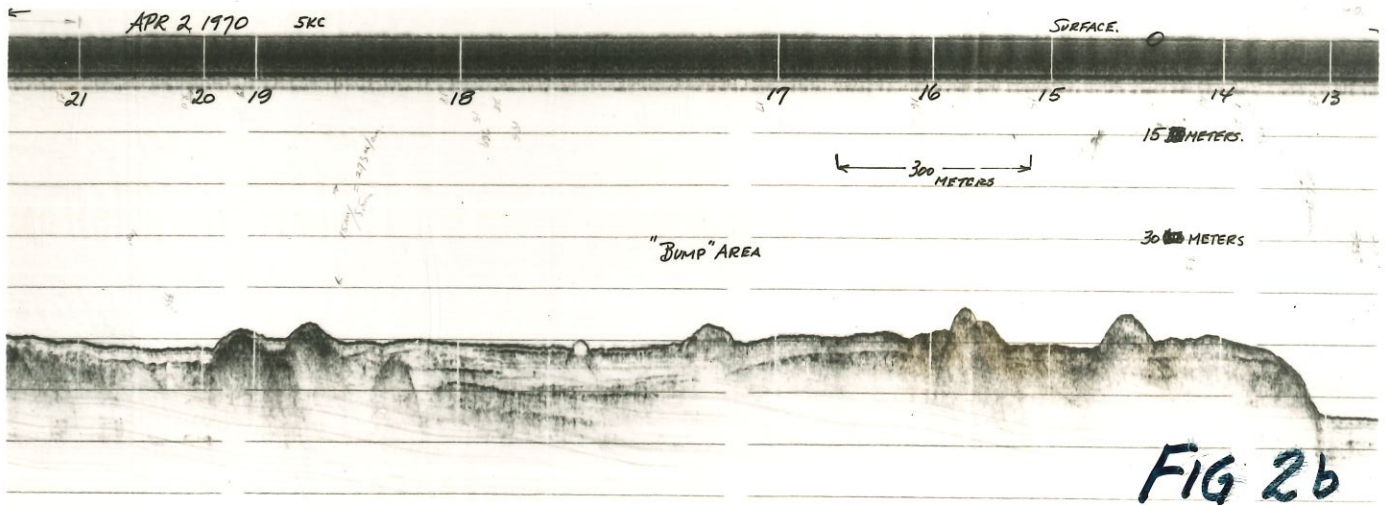
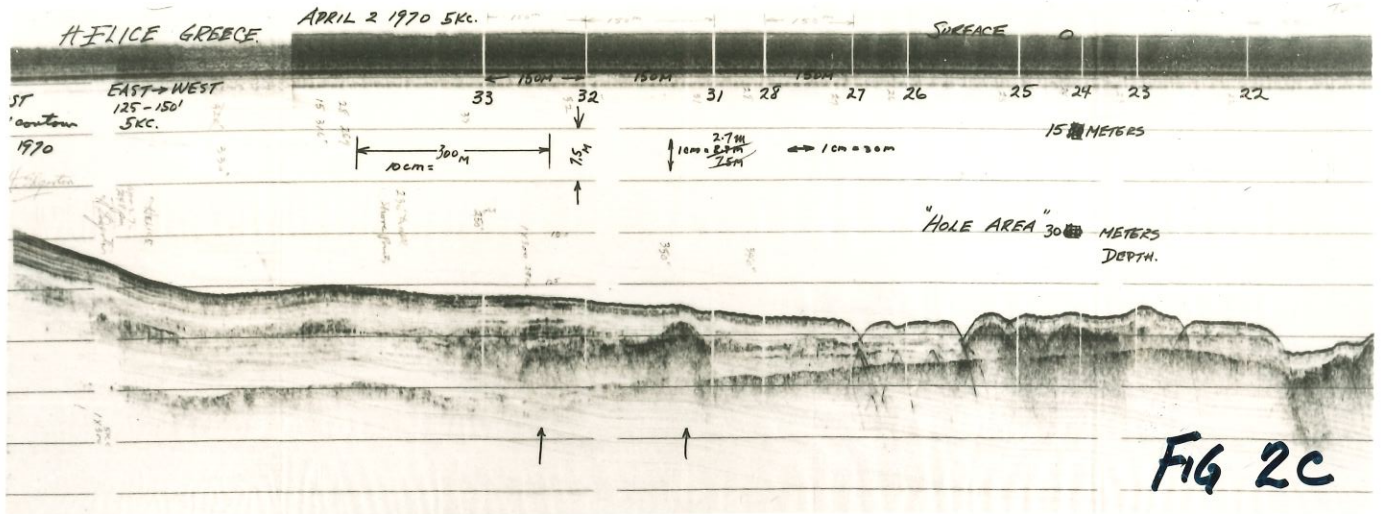
<u>No.</u>	<u>Meters Between Marks</u>	<u>Description</u>
23	79.8	small blue/green cabin 
24	94.1	cabin with blue door, orange shutters 
25	105.8	restaurant with double doors, porch 
26	83.0	house on posts with front porch 
27	148.5	house with green penthouse 
28	23.3	two-story house with peaked roof 
29	9.6	west side of old pier 
30	10.0	east side of old pier 
31	154.0	blue restaurant with red roof 
32	152.0	white cabin 
33	540.0	very small white cabin 
34	25.0	stone house with hipped roof 
35	0	west gravel bank of river 

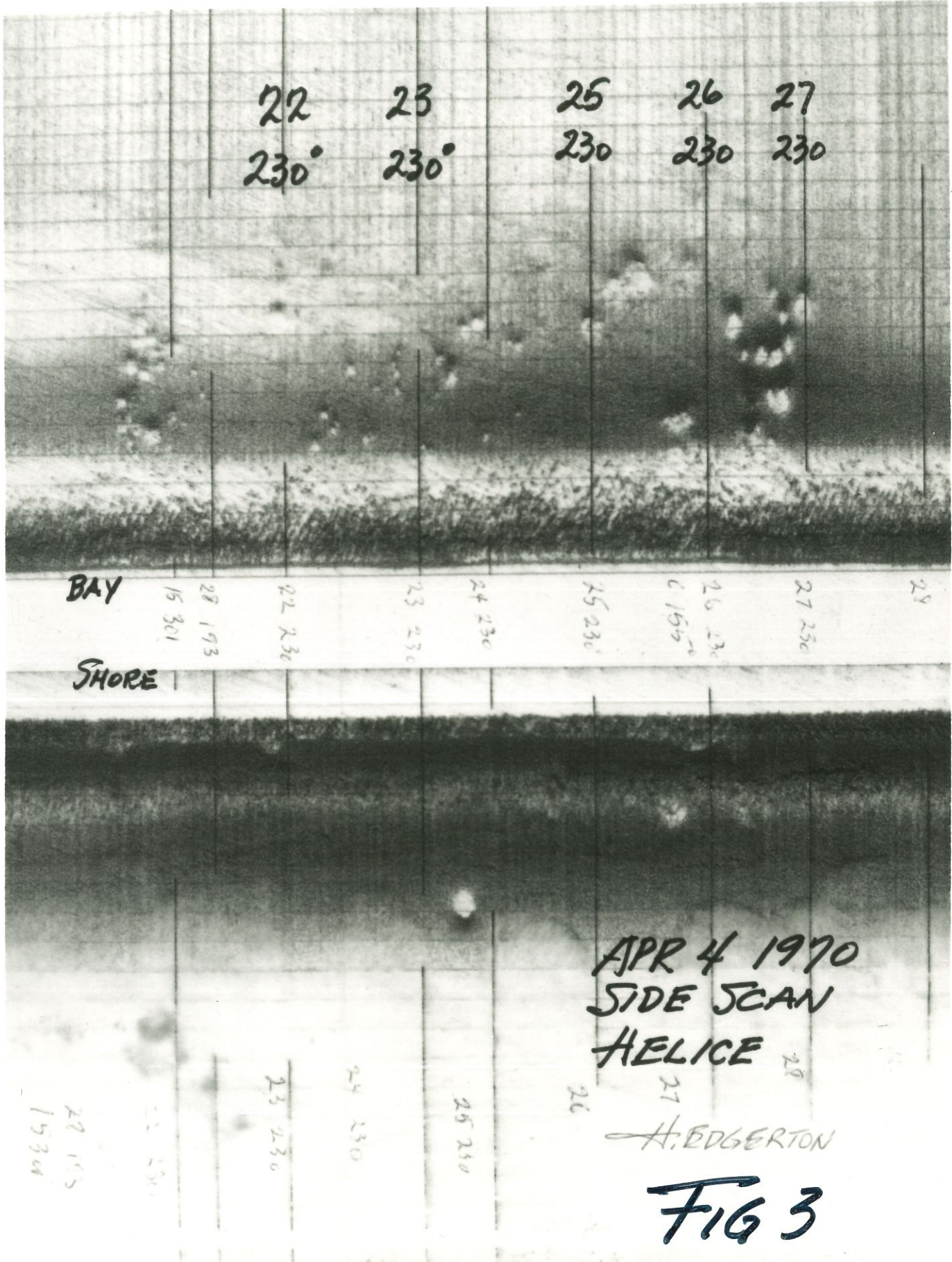
Bearings to Marker Buoys from Bench Marks

<u>Bench Mark</u>	<u>Buoy Flags</u>		
	<u>Yellow/Blue</u>	<u>Yellow/Yellow</u>	<u>Yellow/Red</u>
	(B)	(Y)	(R)
34	353°	12°	5°
32	26°	56°	40°
29	48°	70°	58°

GULF OF CORINTH







22      23      25      26      27  
 230°    230°    230    230    230

BAY      28      29  
 15301    193    230  
 22 230  
 23 230  
 24 230  
 25 230  
 26 230  
 27 230  
 29

SHORE

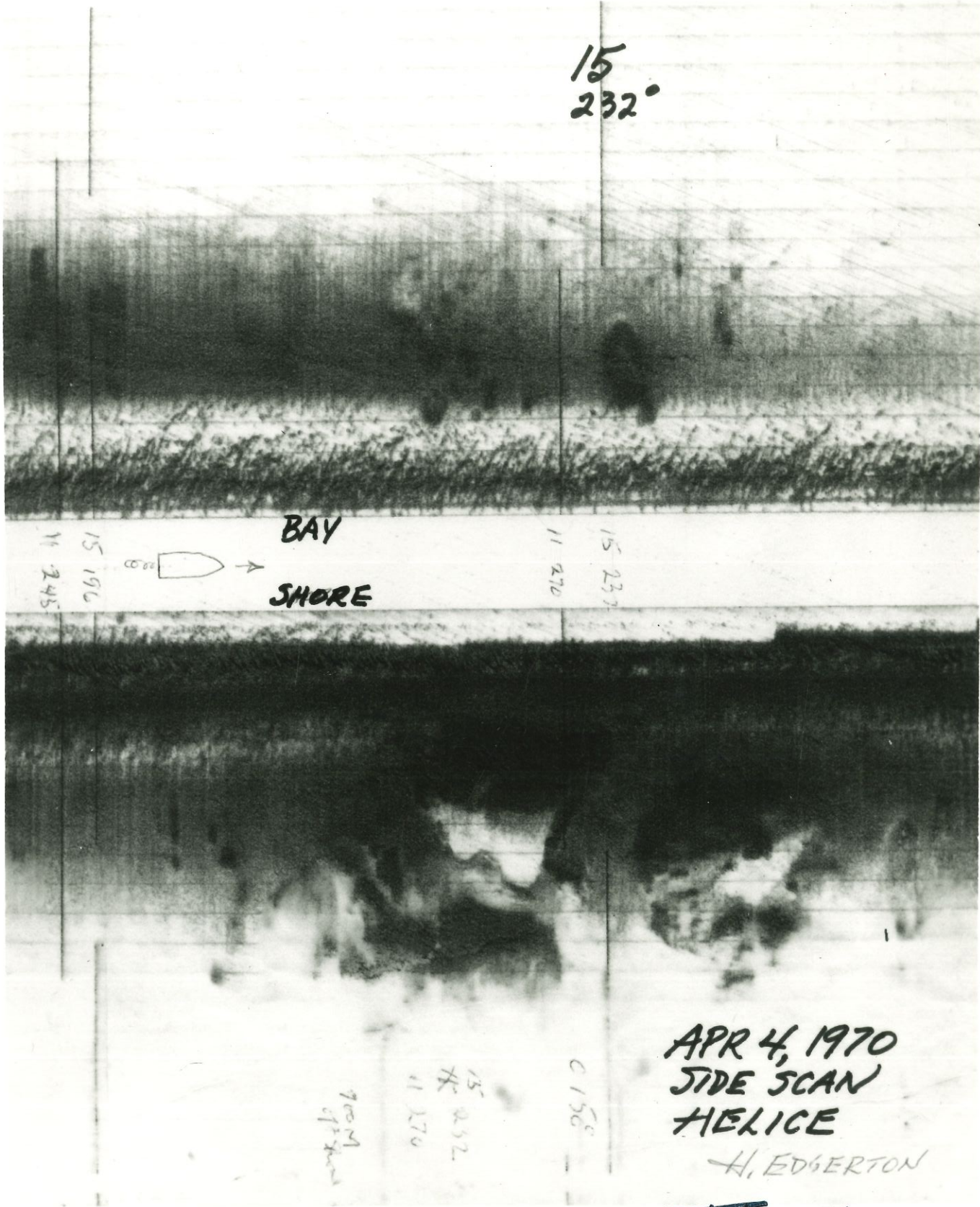
APR 4 1970  
 SIDE SCAN  
 HELICE

26  
 27  
 H. EDGERTON

FIG 3

23 230  
 24 230  
 25 230  
 26 230  
 27 230  
 28 193  
 15301

15  
232°



APR 4, 1970  
SIDE SCAN  
HELICE  
H. EDGERTON

FIG 4.

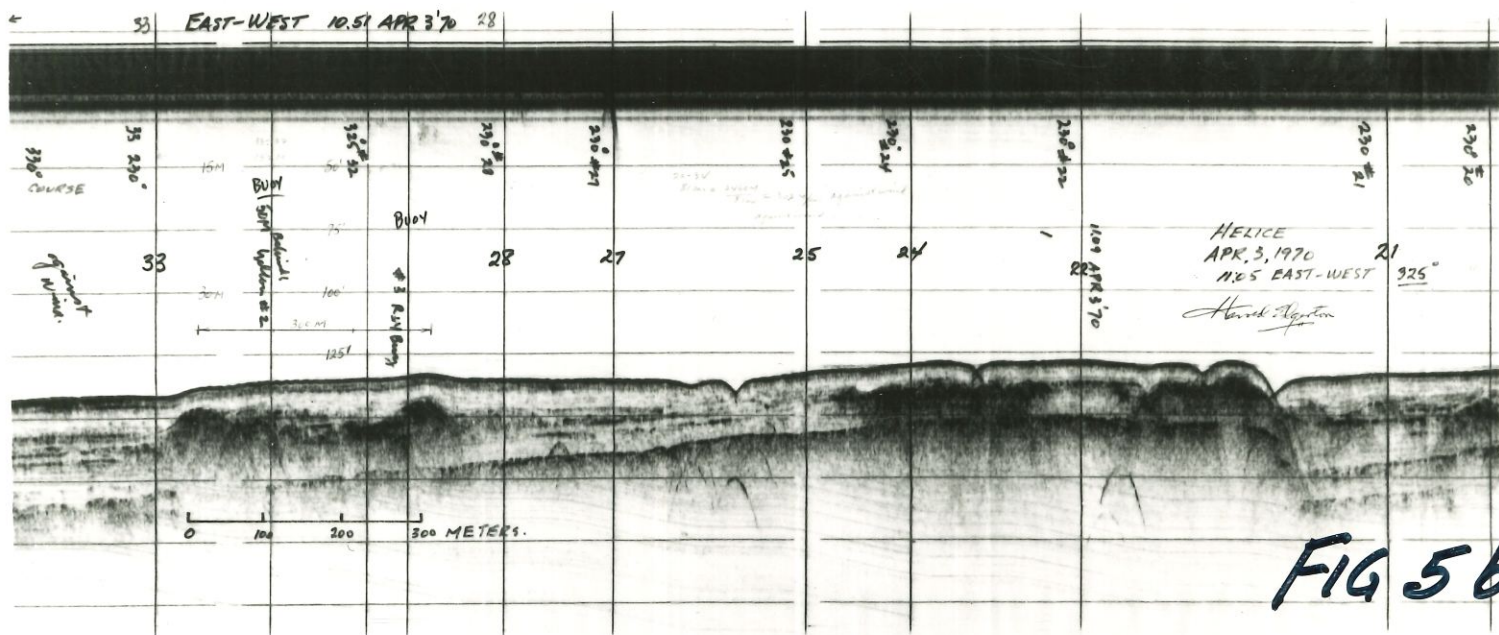


FIG 5b

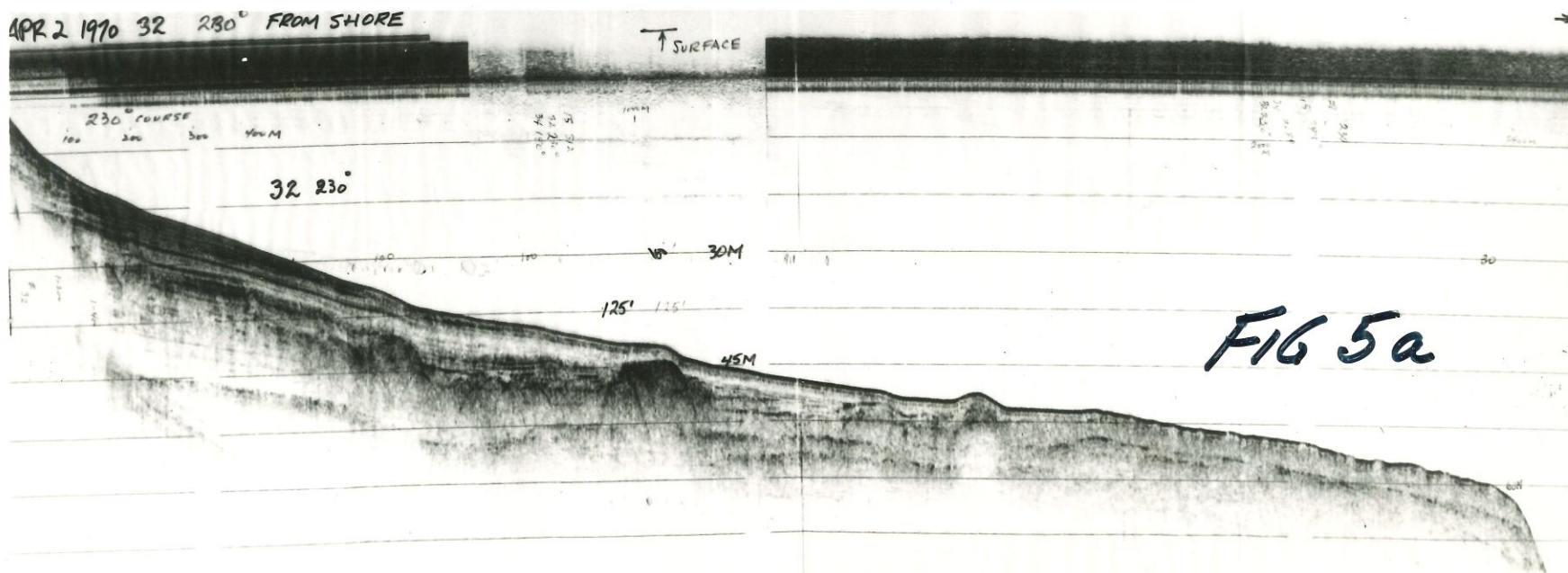


FIG 5a

Dear Mr. Pomerance

While I was in Greece for another purpose, I ~~visited the site~~ went to Crete, and with the kind help of Dr. Alexiou, <sup>Frank Morrison (a geophysicist from the Univ. of Calif.) &</sup> I looked at the tomb area of Katsaba. I am sorry to report that it is not an appropriate area for a magnetometer survey. First of all, there are two <sup>groups of</sup> power lines that produce <sup>extensive</sup> extraneous magnetic disturbances. And, in other places there are vineyards with reinforced concrete posts & iron rails — these produce magnetic disturbances which extend, at least, 30 meters away.

Subsequent tests of the soil & rock which we sampled indicate that there is no magnetic contrast between the two. For detection of the tombs, the greatest magnetic contrast is offered by the ceramic sarcophagi & the associated (but smaller) vases, etc. For an estimate of the effect of a sarcophagus such as Larnax 2 (dimensions:  $L = 0.1.04 \text{ M}$ ,  $W = 0.44 \text{ M}$ ,  $H = 0.78 \text{ M}$ , thickness of walls =  $0.04 \text{ M}$ ) found at a depth of  $820 \text{ M}$ , I have treated the volume

I am sorry that I do not have better news to report.

Sincerely yours,

of fired clay as a sphere and ~~with~~ <sup>used</sup> the formula

$$H_r = \left[ 1 + \left( \frac{\mu_2 - \mu_1}{\mu_2 + 2\mu_1} \right) \frac{a^3}{r^3} \right] H_v \cos \theta$$

where  $H_r$

$r$

$a$

$\cos \theta =$

$$\mu_2 = 1 + 4\pi \chi_2$$

$$\chi_2 \sim 40 \times 10^{-4} \frac{\text{emu}}{\text{cc}} \text{ for fired clay}$$

$$\mu_1 = 1 + 4\pi \chi_1$$

$$\chi_1 \sim 4 \times 10^{-4} \frac{\text{emu}}{\text{cc}} \text{ for clay or sand with low magnetization}$$

$$H_v \cong 0.37 \text{ oersted in southern Greece}$$

From this ~~with~~ formula & with these approximate values, I calculate that the anomaly from the sarcophagus at a depth of 8.2 meters is only 0.03 gamma, & at 4 meters depth, 0.3 gamma.

Both are too small to be detected in a field survey with a magnetometer even in a "magnetically quiet" area, which, Katsaba unfortunately is not.

Calc. anomaly of Larnax 2, Katsaba Crete

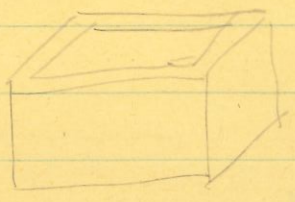
W W W

98) b6 Rb A - bet. rivers no ans

For sphere

$$H_r = \left[ 1 + \left( \frac{\mu_2 - \mu_1}{\mu_2 + 2\mu_1} \right) \frac{a^3}{r^3} \right] H_v \cos \theta$$

# 2



$$2 \times 1.04 \times .44 \times .04 = .0355$$

$$2 \times 1.04 \times .78 \times .04 = .0710$$

$$2 \times .44 \times .78 \times .04 = .0275$$

$$\text{Vol.} = \frac{.0275}{.21} \text{ m}^3$$

$$V = \frac{4}{3} \pi a^3$$

$$a^3 = \frac{3V}{4\pi} = \frac{.4}{4\pi} = 0.032 \text{ m}^3$$

$$\mu_2 \sim 40 \times 10^{-4}, \cos \theta = 1$$

$$\mu_1 \sim 4 \times 10^{-4}$$

$$H_v \sim 0.37, r = 8.2 \text{ m}, r^3 = 550$$

$$H_r = \left[ 1 + \left( \frac{36 \times 10^{-4}}{48 \times 10^{-4}} \right) \frac{.032}{550} \right] .37$$

$$H_r = \left[ 1 + (.75) 5.8 \times 10^{-5} \right] .37$$

$$H_r = \left[ 1 + 4.4 \times 10^{-5} \right] .37 = .370016 \sim 1.6 \%$$

If  $r = 4 \text{ m}, r^3 = 64$

$$H_r = \left[ 1 + (.75) 5 \times 10^{-4} \right] .37 = \left[ 1 + 3.8 \times 10^{-4} \right] .37$$

$$H_r = .37014 \sim 1.4 \%$$

1.00000085  
  .37

---

700000595  
300000255

---

.3700003145

.0452

1.00000073  
  .37

---

700000511  
300000219

---

3700002701

~~Roof tiles~~

~~1 x 1 x .4~~

160  
0502  $\times 10^{-4}$  1050

$$\begin{aligned} \mu_2 &= 1 + 4\pi \times 40 \times 10^{-4} = 1.0502 & \begin{array}{r} 2.1004 \\ 1.0050 \\ \hline 3.1054 \end{array} \\ \mu_1 &= 1 + 4\pi \times 4 \times 10^{-4} = 1.0050 & \begin{array}{r} .0452 \end{array} \end{aligned}$$

$$H_r = \left[ 1 + \left( \frac{.0452}{3.105} \right) \frac{.032}{550} \right] .37$$

$$H_r = \left[ 1 + (1.46 \times 10^{-2}) 5.8 \times 10^{-5} \right] .37$$

$$H_r = \left[ 1 + 8.5 \times 10^{-7} \right] .37 = .3700003 \sim 0.03 \%$$

If  $r = 4 \text{ m}$ ,

$$H_r = \left[ 1 + (1.46 \times 10^{-2}) 5 \times 10^{-4} \right] .37 = .370003 \sim 0.3 \%$$

LINE 2

S → N

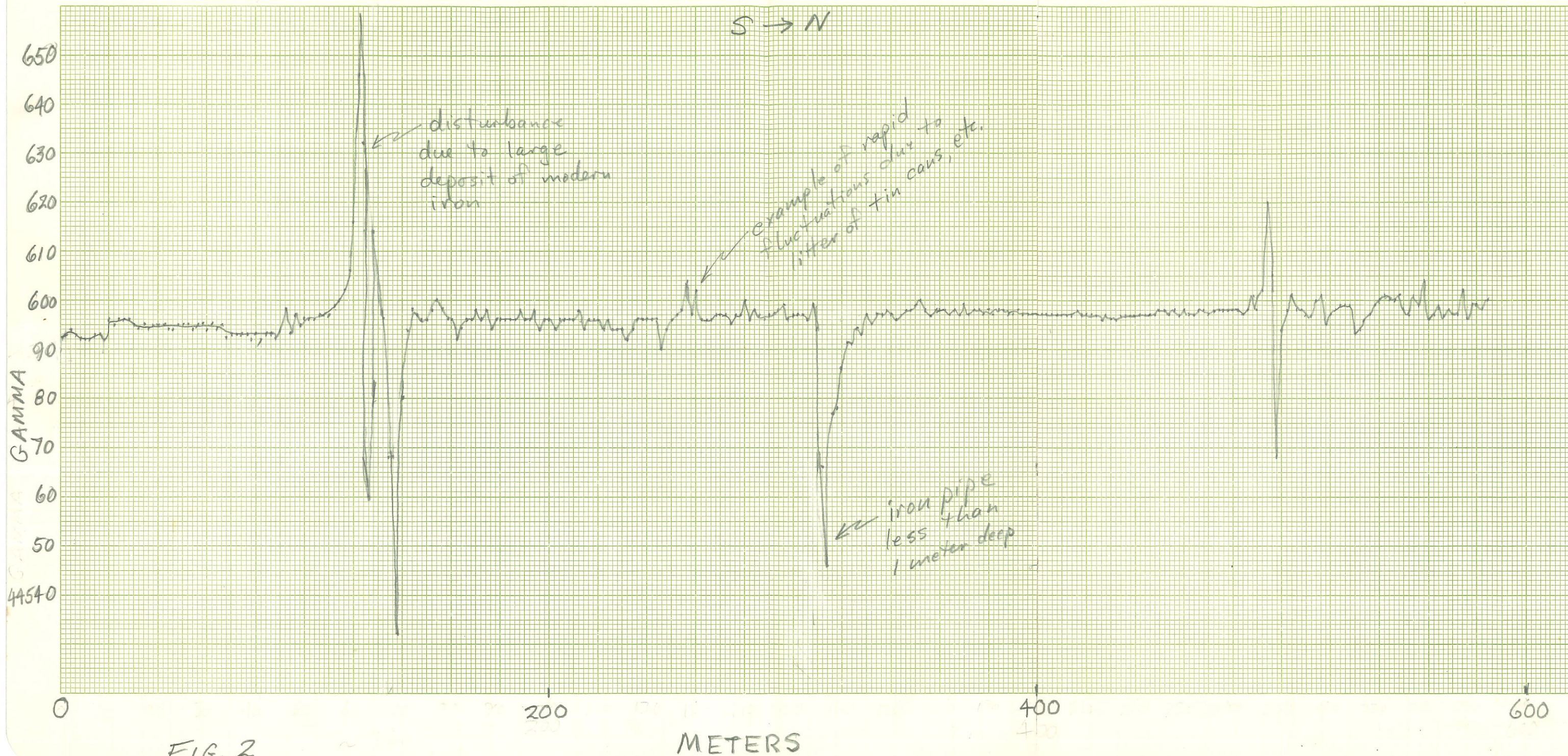


FIG. 2

TO  
EGHION

THE UNIVERSITY MUSEUM • UNIVERSITY OF PENNSYLVANIA  
33rd & SPRUCE STREETS • PHILADELPHIA 4, PENNSYLVANIA  
Fredrich Rainey, Director, Evergreen 8-7400 (Area code 215)  
Elizabeth K. Ralph, Associate Director, Evergreen 8-0100 Ext. 8188 (Area code 215)  
Cable Address "Antique"

WVETH



32

Applied Science Center for Archaeology

THE UNIVERSITY MUSEUM • UNIVERSITY OF PENNSYLVANIA  
33rd & SPRUCE STREETS • PHILADELPHIA 4, PENNSYLVANIA  
Fredrich Rainey, Director, Evergreen 8-7400 (Area code 215)  
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Cable Address "Antique"



Βαϊμύτιο

Selinous River →

Patras ←  
Main Road → Corinth  
Route 8

ΕΑΗΚΗ

Grid 1  
Grid 2  
Grid 3  
boat landing  
9

CORINTHIAN GULF

FIG. 1  
SCALE  
0 125 250 M  
1 CM = 125 M