

# Geophysical SPECIALTIES COMPANY

MANUFACTURE - SALES - CONTRACT SERVICE

15409 ROBINWOOD DRIVE HOPKINS, MINNESOTA

WEST 8-6877

June 9, 1960

Elizabeth K. Ralph  
Radiocarbon Laboratory  
Department of Physics  
University of Pennsylvania  
Philadelphia 4, Pennsylvania

Dear Madam:

Recently we sent to you the material which you requested concerning our MD-1 Engineering Seismograph and its use for determining depth to bedrock without drilling. We hope that it provided the information you require. You may also have seen the featured article in Engineering News Record for May 19, describing a series of subsurface problems to which the MD-1 Seismograph has been applied by the Michigan State Highway Department.

I am tentatively planning to be in your area toward the end of June or early July. I would like very much to show you the unit, discuss with you the applications which you might have for it, and demonstrate it in field operation if you wish. There would of course be no obligation on your part. If this would be of interest to you, please let me know as soon as possible by the enclosed card.

Very truly yours,

*Harold M. Mooney*  
K/S

Harold M. Mooney  
Vice President

HMM:d





# Geophysical SPECIALTIES COMPANY

MANUFACTURE - SALES - CONTRACT SERVICE

CABLE: "GEOSPEC"

15409 ROBINWOOD DRIVE HOPKINS, MINNESOTA

WEST 8-6877

May 29, 1961

Miss Elizabeth K. Ralph  
University of Pennsylvania  
Department of Physics  
Philadelphia 4, Pa.

Dear Miss Ralph:

Dr. Harold Mooney, Department of Geophysics, University of Minnesota, has requested that we forward a reprint of The Review of Scientific Instruments, 29 (April, 1958).

We have also enclosed a complete selection of literature describing the MD-1 Engineering Seismograph. The MD-1 is priced at \$1675 F.O.B. Hopkins, Minnesota. Delivery is from stock.

Very truly yours,

Robert A. Kaasa  
President

RAK/el

Enc. 1,6,7,8,10,11,13

↑ sent to G. McLaughlin 6/7/61



REPORT ON FIELD TESTS OF SEISMIC INSTRUMENT IN ITALY  
Sept. - Oct. 1961

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R. E. LININGTON, Research Associate in Archaeological Techniques  
University of Pennsylvania -

Instrument used

A refraction seismograph; model M D, produced by Geophysical Specialities Company, Hopkins, Minnesota and recently purchased by the University Museum, University of Pennsylvania for use in conjunction with a programme of field testing of instruments in Italy.

Brief descriptions of instrument

The instrument is fully transistorised and carries its own self contained battery supplies. Basically the instrument consists of a simple timing device to measure the time interval elapsing between shock wave production and arrival at a distant point; it was designed for shallow refraction surveys in connection with engineering projects, road construction etc.

Normally shock wave production is obtained by using a three or six pound hammer on a flat metal plate; if necessary an explosive source could be used. The instant of shock wave production is recorded by means of inertial switch mounted on the hammer handle. On closure of this switch counting circuits in the instrument are started.

The counting system employed consists of a 100 K c/s crystal controlled oscillator whose output is fed via gate circuits to a series of binary counters. Each counter operates a neonlight so that the time intervals concerned are measured to the nearest 1/4 millisecc. The initial pulse from the hammer circuit opens the gate circuit.

The shock wave arrival is recorded using a low frequency geophone, whose response extends down to 5 cycles, high frequency pick up is limited by filter circuits. *→ 100, drops; 200-300 cycles off*

After amplification the geophone output is used to shut the gate circuit thus stopping the counting. The amplifier circuitry includes a half wave detection circuit arranged so that for the normal geophone the gate is closed by a pulse associated with an upward earth motion at the geophone. For special uses a "reversed" geophone can be used which has reversed connections so that the gate is closed for a downward earth motion.

Field use of instrument

The instrument was used on the site of an Etruscan necropolis at Tarquinia, near Rome, Italy. Details of the features encountered are given below.

A hammer and flat metal plate were used throughout to produce the shock wave. It was found that the inertial switch appeared to introduce a small constant time increase, although this was difficult to prove.

For normal archaeological work it appeared that the reversed geophone would be superior owing to the increased size of the first negative pulse compared to the first positive one, and thus the lessened chance of confusion from a change to second arrivals. On the test lines both normal and reversed geophones were used. With the normal geophone both first and second arrivals could be recorded by altering the amplifier gain; for the reversed geophone, however, only the first arrivals were recorded at the short distances concerned. It was also found that in many cases it was difficult to record the normal first arrival owing to the level of local noise limiting the maximum gain that could be employed.

The time intervals recorded proved a consistency of within  $\pm 1/2$  millisecc. for repeated hammer blows, with the exception of the first blow at a given point, which often gave an anomalously long time interval; this was probably due to incomplete earth coupling.

For the test purposes envisaged lines of readings were taken across known archaeological features, readings being made each half meter and repeated until at least three consistent readings were obtained (to within  $\pm 1/2$  millisecc.). Average values, to the nearest  $1/4$  millisecc., were used in the production of the graphical results given below.

Archaeological features tested

The archaeological site concerned consisted of a series of rock cut tombs, either cut vertically down into the rock and then filled with mixed earth and stone or hollowed out below the rock surface at the end of a sloping entrance way. The entrance ways, now completely filled with earth or mixed earth and stone, were the main type of feature encountered. In general the entrance ways consist of a vertical cut into the natural limestone rock from  $1\frac{1}{2}$  to 3 meters wide and with a sloping floor from the rock surface down to a depth of from 3 to 5 meters below the present ground surface. The top portions of the entrance way walls have often been broken away, given below.

as in the test case

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Sample results quoted

Results from two entrance ways are given where readings were taken at a variety of geophone distances. In addition results over other features are included to show the range of anomalies encountered.

Tomb 1 - is given in fig. (1)

A plan and section is given in fig. 1) showing the position of the test line and nature of the entrance as proved by subsequent excavations. Fig. II) gives the results for the geophone at the 0m position. A and C were obtained using the normal geophone and represent the first and second arrivals respectively. B was obtained using the reversed geophone. Fig III) gives the results for the geophone at + 2 m on the test line. It is seen that in every case the earth fill in the entrance caused a time delay of appreciable magnitude.

Tomb of Olympiads

This tomb had been excavated so that the position of the entrance (since refilled) was known, although the exact section on the test line was uncertain. The position of the test line is shown in fig. IV), with an approximate section. The results revealed a second anomaly; upon a limited excavation this was found to be a collapsed tomb. It is possible that this second tomb extended considerably further towards the entrance if the tomb of Olympiads thus is shown. Fig V) gives three survey lines across the two features, A with the geophone at 0 m, B at - 2 m and C at - 4 m. Fig. VI) gives three other lines in the opposite direction the geophone being at 8 m for A, 6 m for B and 4 m for C. In every case the reversed geophone was used as noise pulses made the normal geophone readings uncertain.

Old excavations

Readings on one test line, shown in fig. VII), graph A showed an anomaly of different shape from these above; in particular it was of interest as that both the  $6\frac{1}{2}$  and 7 meters marks two consistent sets of readings could be obtained. Readings taken in the opposite direction showed no anomaly (graph B). The reversed geophone was used in both cases.

On excavating at the point of anomaly a wide shallow old excavation was discovered of irregular shape. Its depth was about 60 to 70 cms and it was filled with a mixed earth and stone deposit.

#### Further use of seismic instrument

Since the above portion of report was written further test work with the seismic instrument has been done. This occurred at the archaeological site of Sybaris, Calabria, in South Italy and consisted of several lines of readings across a massive stone wall buried in alluvial clay and silt deposits. The wall was constructed with one finished vertical face and extended in depth from about 1/2 m below the modern ground surface to a total depth of at least 3 m (see fig. VIII). Two sample sets of results are quoted, one away from the wall and the other on the wall. Away from the wall the normal result showed a distinct velocity change at a depth calculated to 1.7 meters (fig. IX), this seems to correspond to the level of the local watertable, as discovered in adjoint excavations. Fig. IX gives the graphs of first and second positive arrivals as well as the first negative arrival; these were obtained using the normal and reversed geophones. A relatively large dispersion of the pulse occurred, presumably also associated with the watertable.

The second set of results across the wall (fig. X) also show the change in pulse character with, in addition, a marked change in the general shape of the graphs; this effect is probably due to a velocity increase within the wall structure. It unfortunately proved impossible to continue the work on this test site owing to the pressure of other survey commitments.

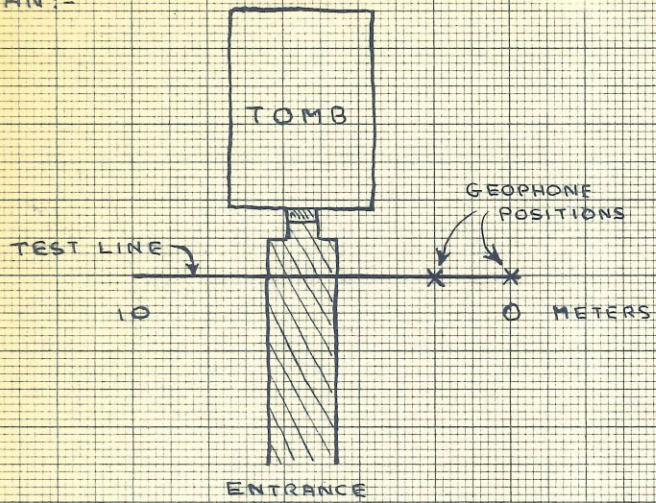
#### Comments

- 1) Despite the fact that the predominant frequencies produced by an impulse source are all very low for use with objects of the size likely to be encountered in archaeological work, it can be seen that relatively large time anomalies are produced by the sample features tested.
- 2) It is likely, however, that the size of any given time anomaly will not necessarily be directly proportioned to the size or significance of the features producing the anomalies. This is born out by previous results obtained by the writer, in collaboration with Texas Instruments, on test sites in Texas and Arizona, U. S. A. In one case a large time delay was discovered at a point where no significant archaeological feature existed. From a study of the photographic records taken it seemed possible that this time delay was produced by the interference of shock waves travelling along different paths in heterogeneous archaeological deposit.

5)

- 3) It is possible from <sup>the above</sup> that much confusion could be caused from interference effects on more complex archaeological features than those tested.
- 4) In general the dispersion, and thus differential attenuation with frequency, does not appear to be too serious except under special conditions as for the results from Sybaris quoted above.
- 5) A great defect of the ~~&~~ present equipment is in the energy source used. Anomalous time values could be obtained by varying the method of hammering; this appeared to be caused by incorrect closure of the inertial switch. Also variations in the strength of the hammer blow, or in coupling between the metal plate and the ground surface could cause either the recording of different arrivals or of different points on the same arrival pulse. For the pulse widths encountered this second effect could cause time errors of up 1 millisecond and was probably responsible of the observed spread in the recorded time values.
- 6) In most of the work so far accomplished using seismic methods the time anomalies produced by archaeological features have appeared to be the most significant out of all the possible effects. However it was noticed in the previous work in Texas and Arizona, when photographic records were obtained, that changes in the phase shape did occur. In particular changes in the pulse amplitude were noticed, as if from sudden increases in attenuation at the boundaries of the features tested.
- 7) From 6) it is thus possible that in addition to the proposed high frequency research it may prove worthwhile to investigate the possibility of comparing pulse shapes, for example by interference ("beat") methods, across archaeological features as a means of locating these features.

PLAN:-



SECTION:-

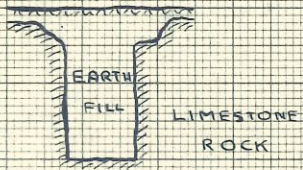
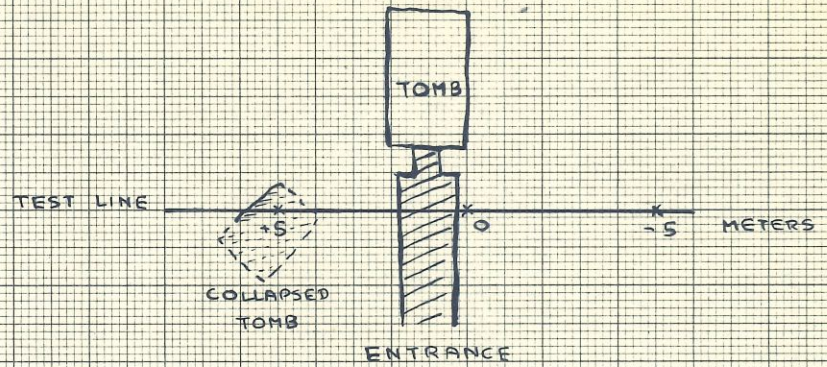


Fig i

PLAN:-



SECTION:-

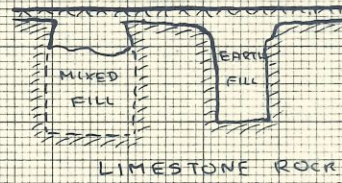


Fig iv

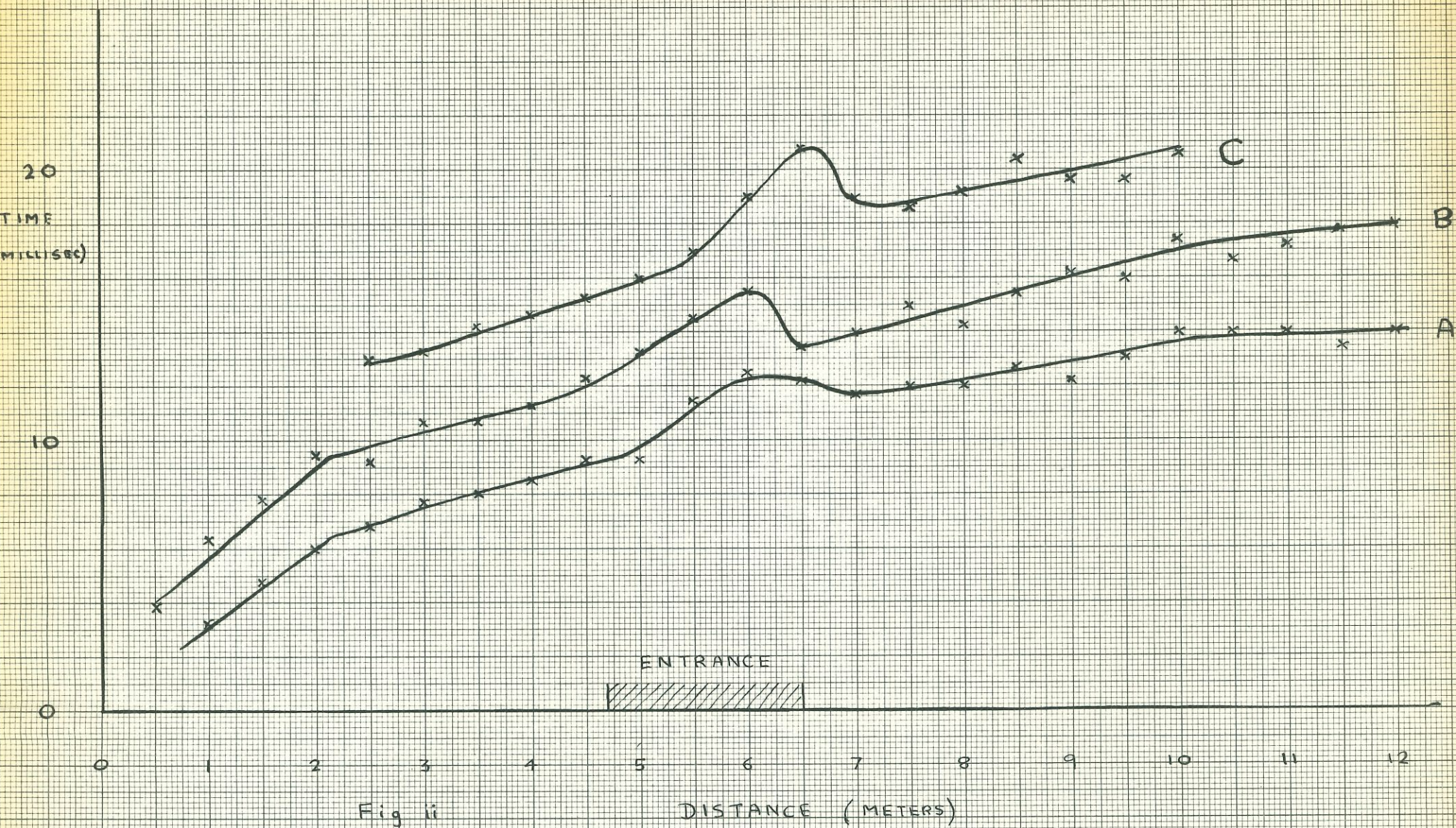


Fig ii

DISTANCE (METERS)

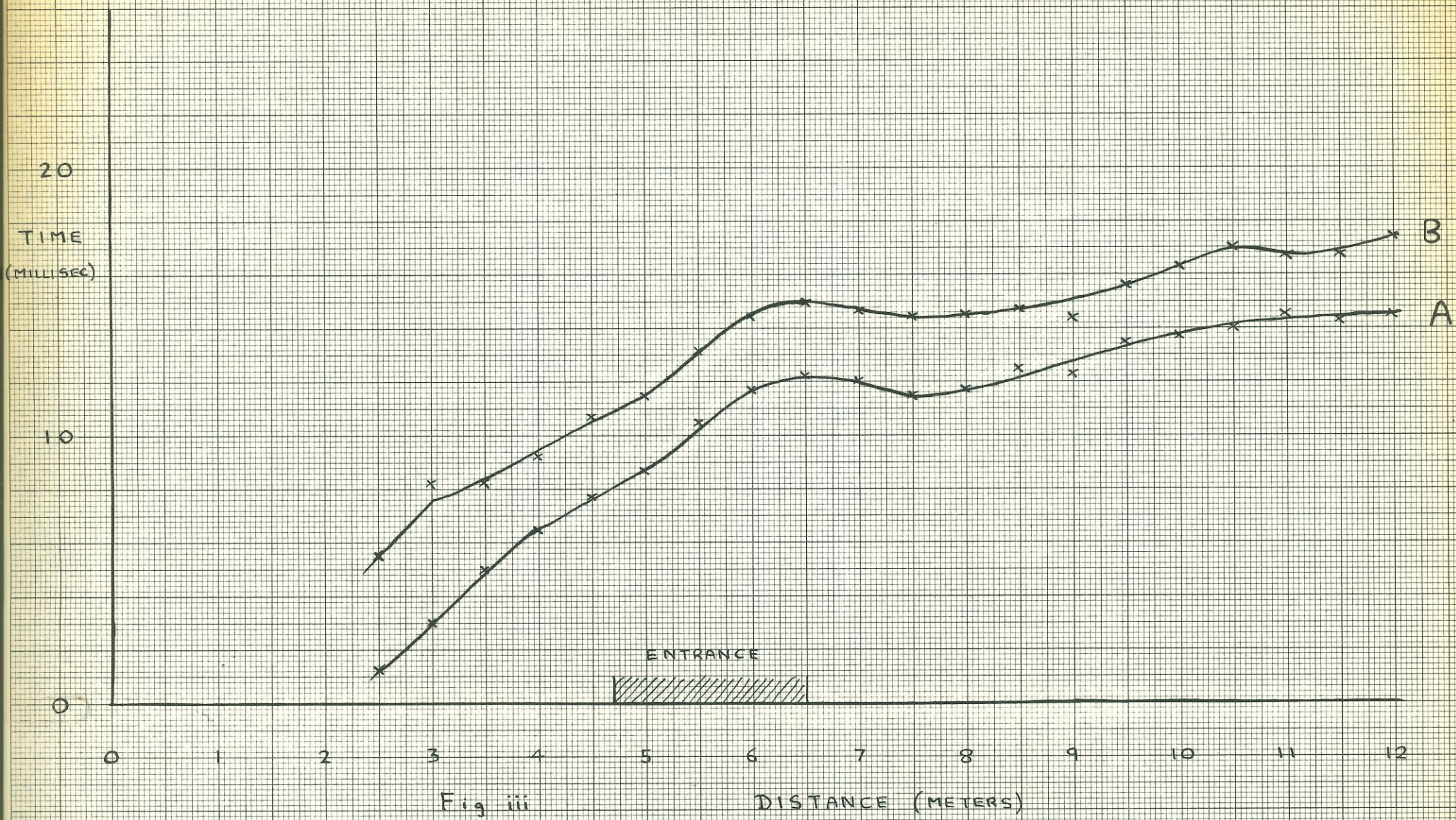


Fig iii

DISTANCE (METERS)

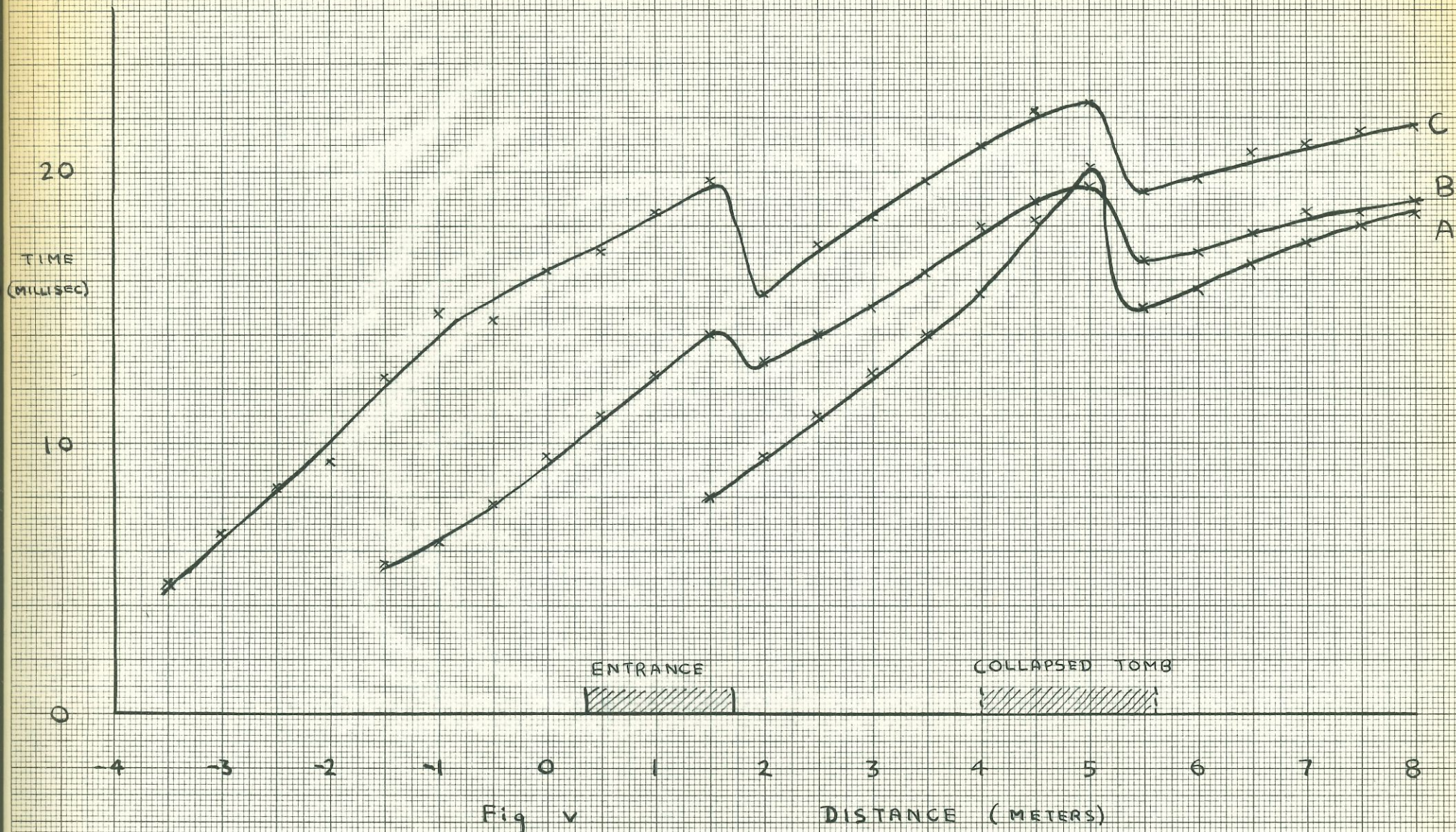


Fig v

DISTANCE (METERS)



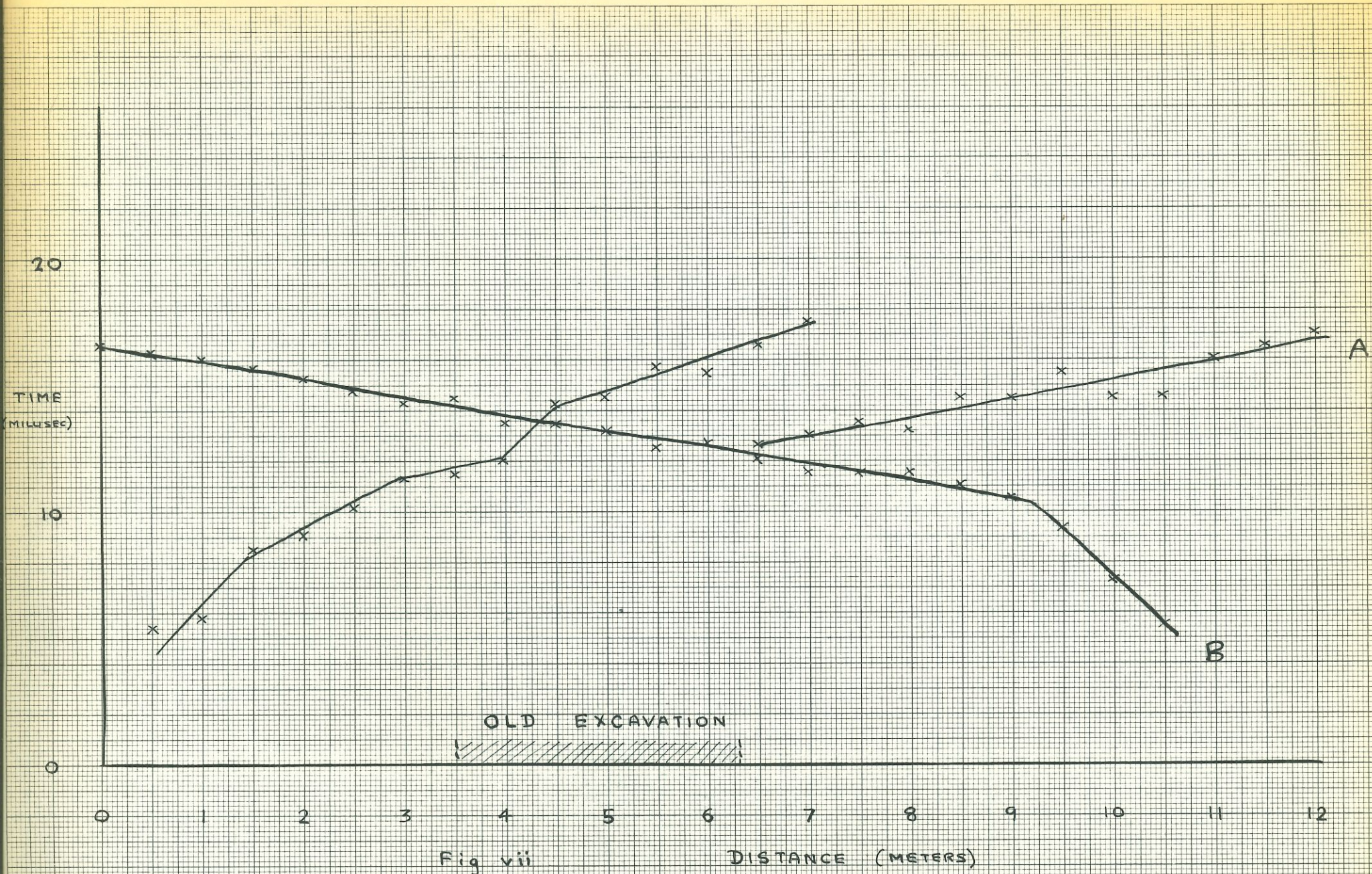
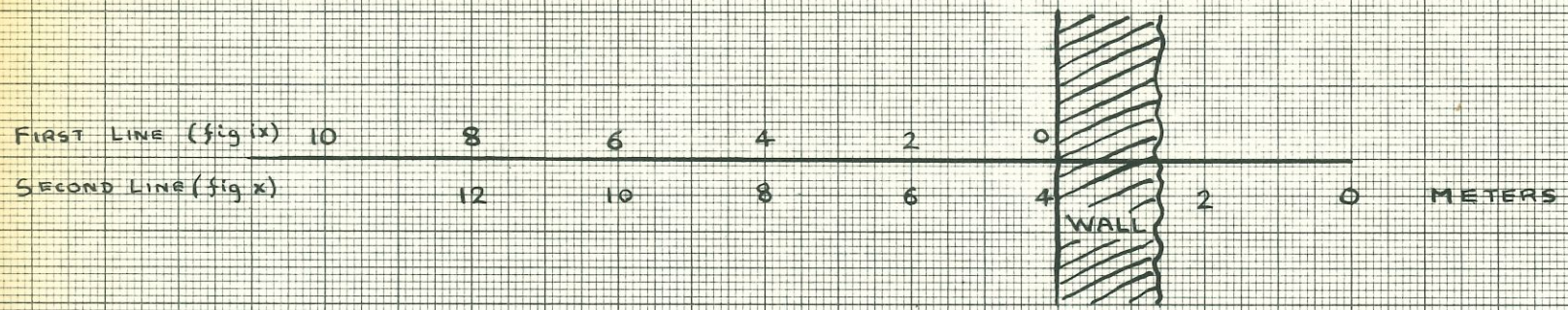


Fig vii

DISTANCE (METERS)

PLAN :-



SECTION :-

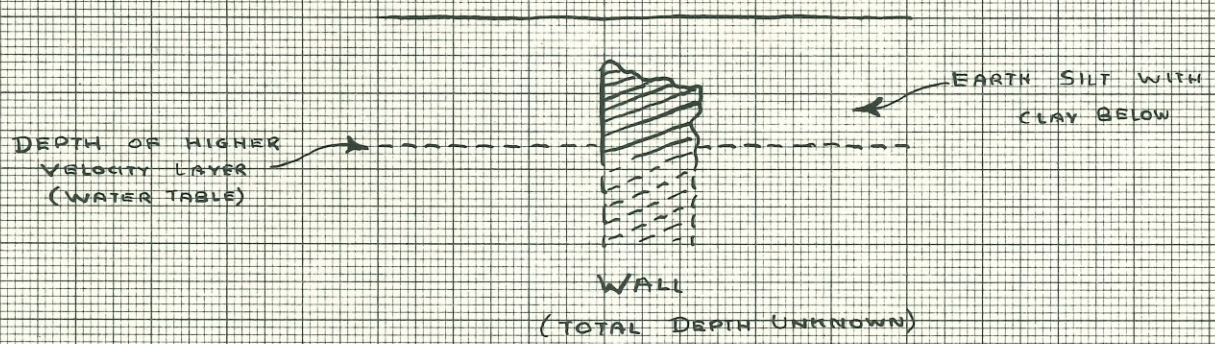


Fig viii

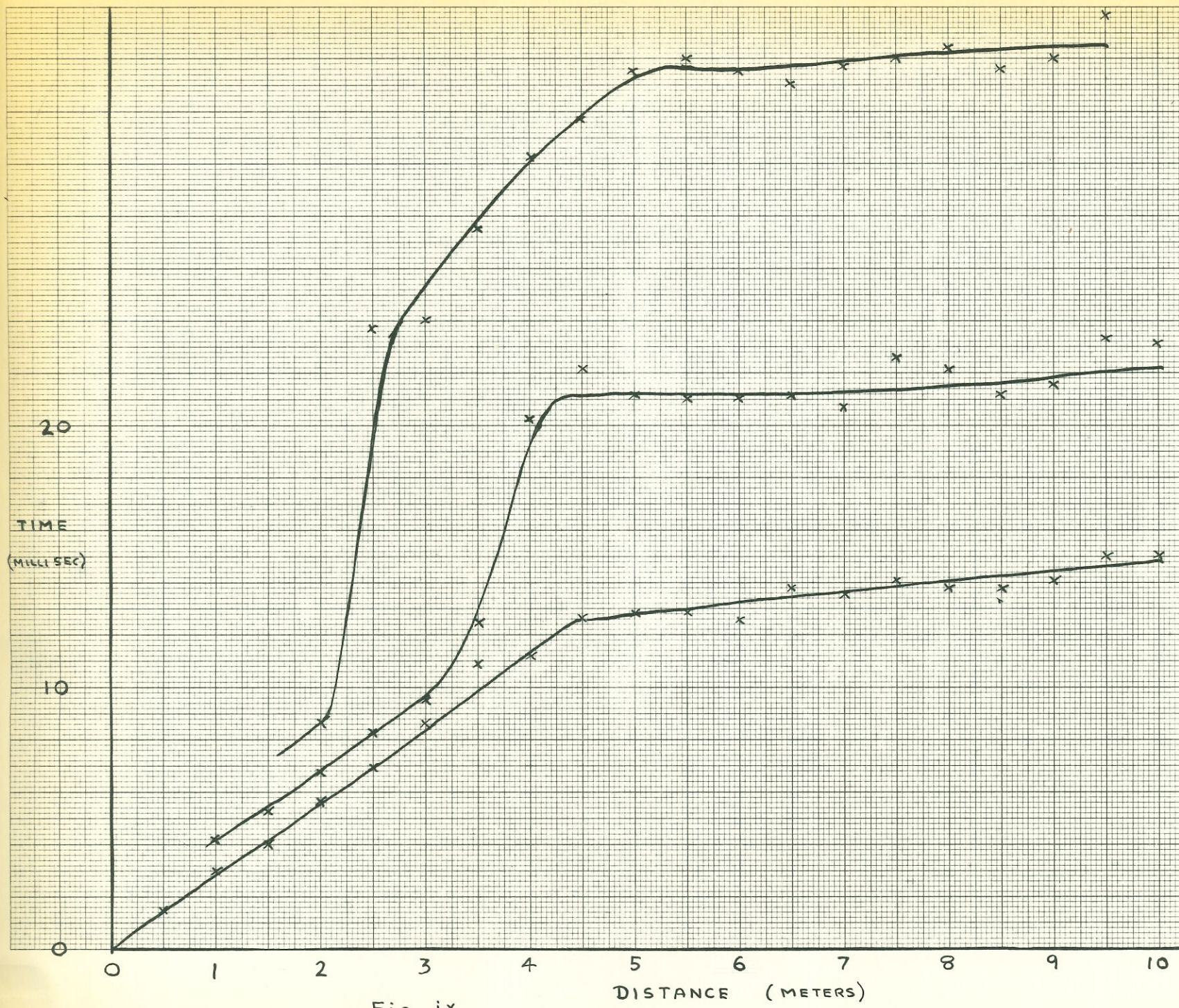


Fig ix

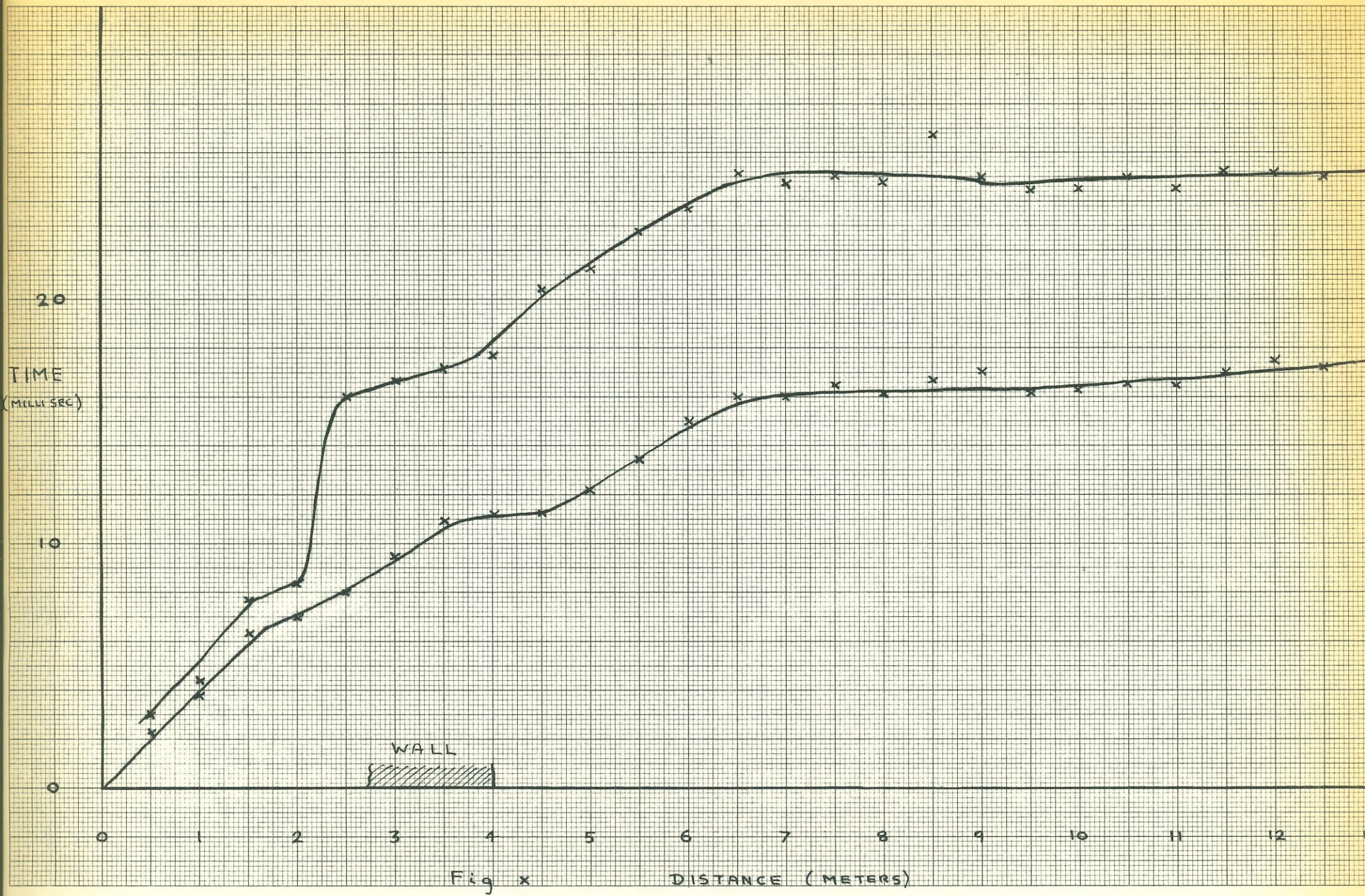
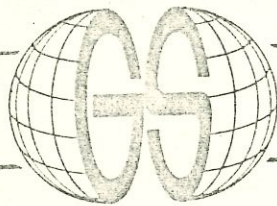


Fig x

DISTANCE (METERS)

Chart of  
Free time  
2nd wk  
Oct.

return to  
Beth Ralph



**GEOPHYSICAL SURVEY SYSTEMS, INC.**

P. O. BOX 154, NORTH SALEM, NEW HAMPSHIRE 03073 (603) 893-6041  
In Texas: 4 RAYDON LANE, HOUSTON, TEXAS 77024 (713) 468-9468

4 August 1970

copy to  
Beth Ralph

Professor Froelich Rainey  
University of Pennsylvania  
23rd and Spruce Street  
Philadelphia, Pa. 19104

Dear Professor Rainey:

After reading some of your exploration activities, I felt that you may have some interest in our new electromagnetic soil profiling system.

Our company has developed a broadband pulsed radar system which is capable of penetrating 10 to 20 feet in ordinary soil and, probably, to 50-foot depths in dry sandy soil. In the broadest sense our system is analogous to the marine bottom profiling systems which have been developed by Edgerton and others at MIT. In the marine system, a broadband acoustical pulse is transmitted into the river bottom and the time of arrival of reflected acoustical pulses is recorded on a strip chart recorder. I am sure you are familiar with the technique. I have enclosed a recent record, Figure 1, of the bottom of the Charles River. This survey was done by Dr. Edgerton.

Our system uses a broadband radar pulse which has a pulse width of 2 ns. The pulse contains all radar frequencies available from DC to about 150 MHz. The radar pulse has a rep rate of 100 kHz. We record the time of arrival of the radar pulse which is reflected at each dielectric interface. Our system consists of a transmitter, an antenna, a duplexer, a receiver, a sampler circuit, an "A" scan indicator, a "B" scan recorder and associated power supplies. The most unique component of the system is the antenna. A single antenna is used for transmission and reception. Much of the development work has concentrated on the antenna, since much of the prototype electronics are off-the-shelf items that have been modified and packaged for field operations. The output of the system can be a chart record of the dielectric interfaces detected by the radar signal as the antenna is moved across the ground. To date, the GSSI-developed Electromagnetic Soil Profiler has been useful in locating, for example, a buried telephone cable 2 ft deep and followed the curves in the cable path, a buried house water pipe 5 ft deep, both in the lawn and in the street; and a 30" diameter concrete storm drain 3 ft deep. Also, the system distinguished between chemically weathered bedrock and unweathered bedrock, indicating the direction of the fractures in the weathered bedrock. The system has been used to locate and map bedrock.

4 August 1970

I have enclosed two charts of the output of our system. Figure 2 is a copy of an early chart record taken over a culvert-like structure in our test bed. As the sepia tone recording did not Xerox well, I have taken the liberty of drawing an ink line on the record to show the approximate outline of the interfaces. Figure 3 is a record of individual radar traces as recorded on magnetic tape. The traces were approximately 6 in. apart on the surface and the site surveyed was the same tunnel located in our test bed. It is clear from an investigation of the radar returns that we are losing a great deal of information on interface location because of the narrow dynamic range of the field recorder. When, as is required for field operation, we clip the signal at one place in order to highlight a particular interface we lose other information from less pronounced interfaces. We hope to begin a computer shortly which will result in precisely drawn underground interface locations for the survey area.

At the present time, we are engaged in a calibration program with Anderson Nichols, a local civil engineering firm and USGS. During the course of these studies we will investigate the radar return and system resolution and penetration capability from a number of geologic sites.

I believe our system has great potential in archeological exploration. In dry area our depth of penetration should be up to 50 ft. In areas where the overburden is homogeneous, there should be considerably less radar scatter from rubble in the soil and the signal should be quite simple to record and interpret. I could anticipate the system, providing a complete map of buried structures and location of artifacts before any excavation work was accomplished. Incidentally, the resolution of the Electromagnetic Soil Profiler (ESP) system is approximately 3 in.

GSS is prepared to support your interest in our system in several ways. We would be pleased to quote on a demonstration of our equipment to support an exploration survey. GSS is also prepared to build, to your specifications, survey equipment for use in the area of archeological exploration.

Yours very truly,

GEOPHYSICAL SURVEY SYSTEMS, INC.

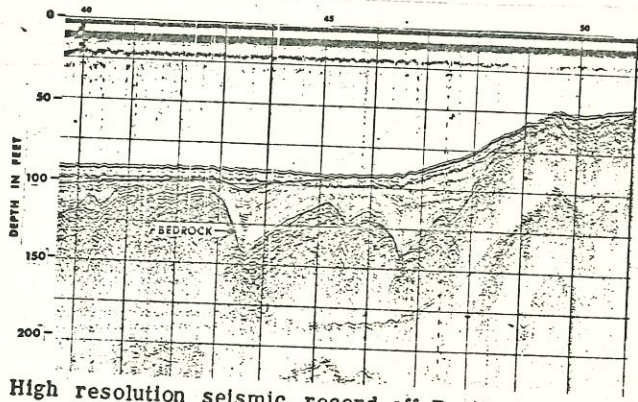
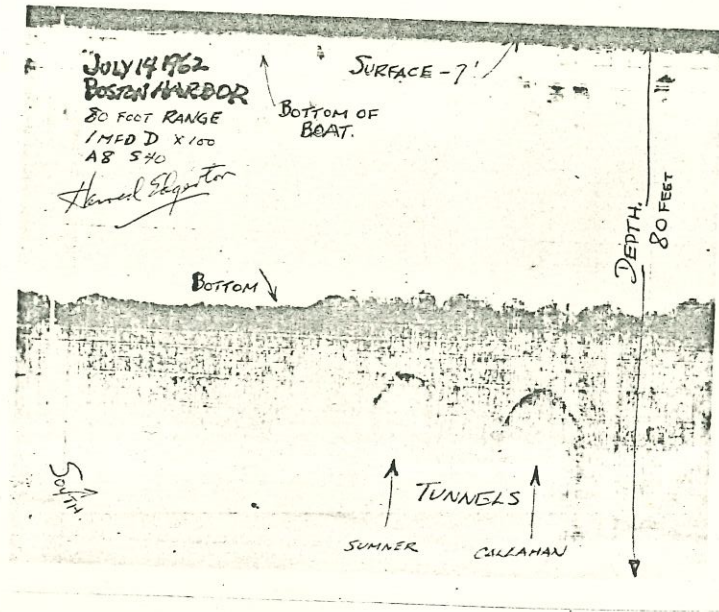


Dr. Ernest F. Blase

EFB:fp

Enclosures

High resolution marine bottom profiling  
using broad band pulsed acoustic  
Techniques



High resolution seismic record off Portland, Maine

Figure 1

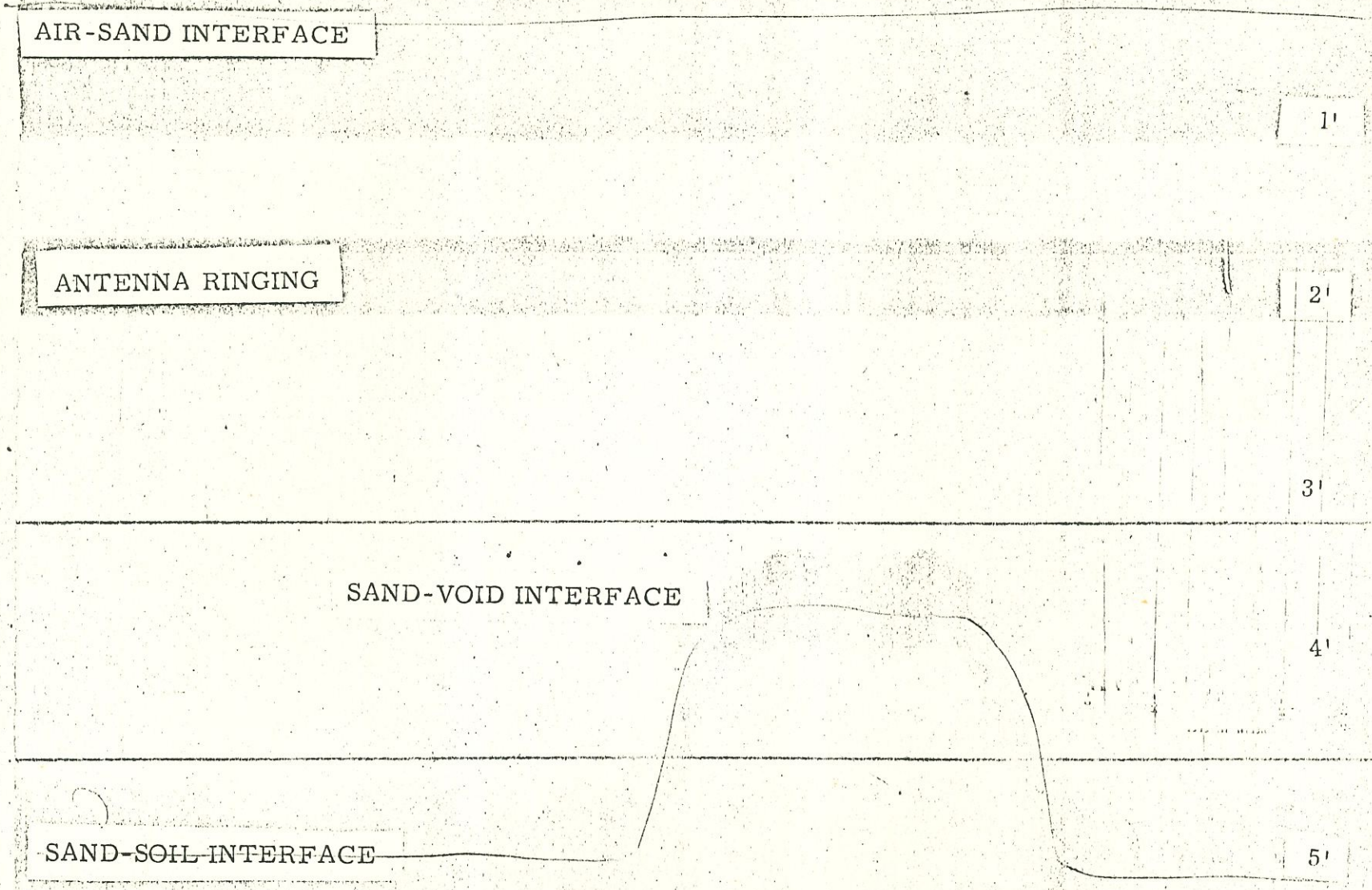
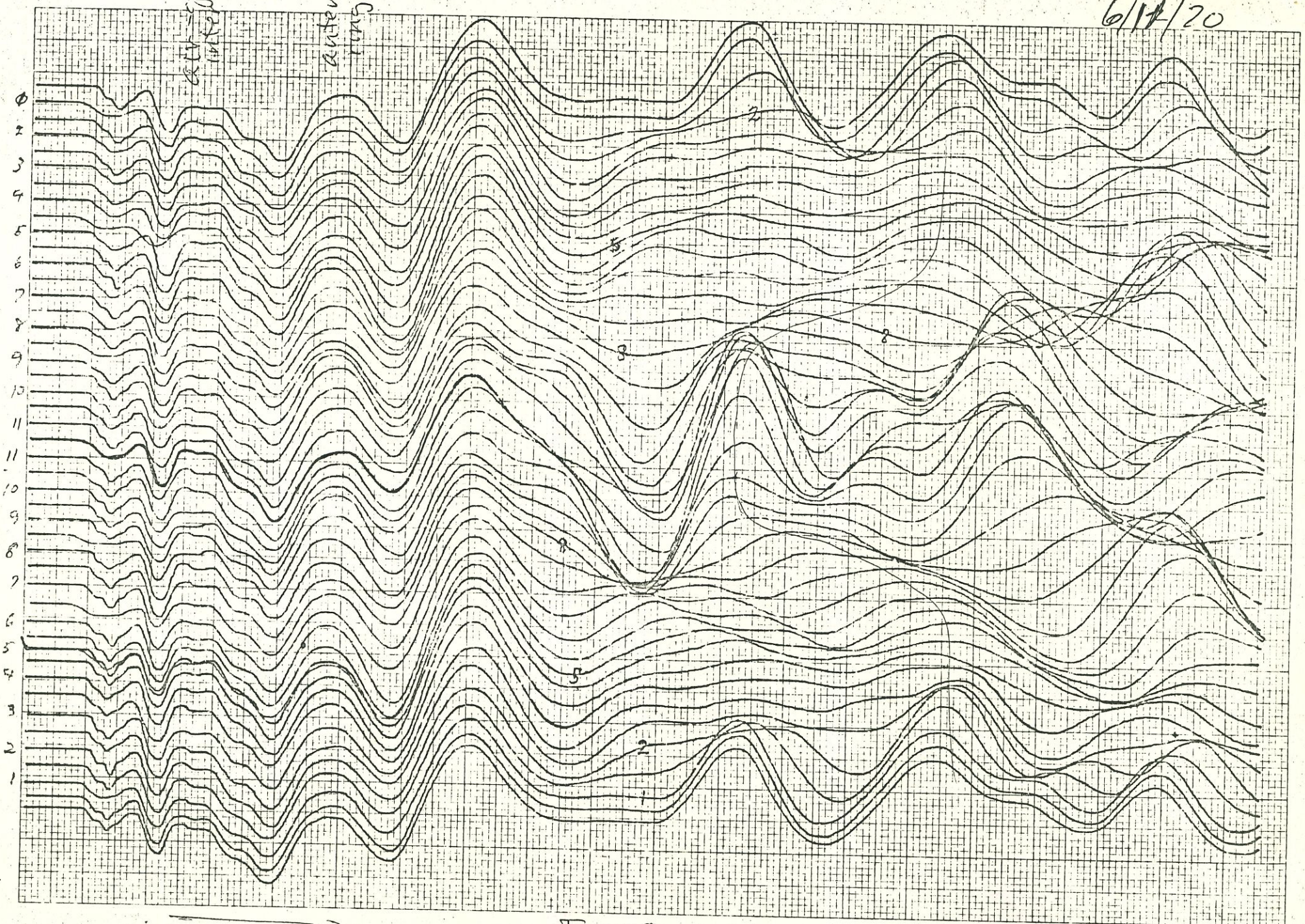


Figure 2

6/17/70



→  
increasing depth in soil

Figure 3