GEO-PHYSI-CON

DEPTH TO BEDROCK INVESTIGATION
USING REFRACTION SEISMIC
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

Prepared For

PROCAN EXPLORATION COMPANY
CALGARY, ALBERTA

Prepared By

GEO-PHYSI-CON CO. LTD.
CALGARY, ALBERTA

December 1982
82-46

GEO-PHYSI-CON

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	LOGISTICS AND DATA ACQUISITION	2
3.0	DATA PROCESSING	6
4.0	RESULTS	8
5.0	EXPECTED ACCURACY	10

1.0 INTRODUCTION

This report presents the results of a shallow surface refraction seismic survey to map overburden thickness and the location of a fault on Graham Island, part of the Queen Charlotte Island property, B.C. Figure 1 shows the location of the property.

The fault was located along all lines surveyed. To the west of the fault terrain consisted of a thin overburden over bedrock. To the east of the fault substantial thicknesses of unconsolidated sediments were encountered.

Field data was collected and interpreted using well established procedures, as described in Section 3.0 of this report. Results are presented as line profiles in Figures 5 to 11.

The survey was requested by Mr. R. J. Joy of Procan Exploration Company by contract agreement form dated September 22, 1982.

2.0 LOGISTICS AND DATA ACQUISITION

The field work was undertaken during the period October 7 to 22, 1982. Two days were required for mobilization and demobilizaton of the Calgary based staff to Sandspit, B.C. Twelve field days were required for completion of the survey and two standby days were necessary due to inclement weather.

A four man crew carried out the survey. Accommodation was arranged by Geo-Physi-Con Co. Ltd. Helicopter access was required for all sites.

Explosives and storage magazines were obtained from Conex Explosives, Richmond, B.C. and shipped to the survey site. During the course of the survey 8 cases of Forcite (75%) and 11 cases of electrical blasting caps (25 per case) were consumed. Thirty-five spreads were completed in 12 days. The average productivity was 3 spreads per day. This productivity was less than that proposed due to difficult working conditions. Table 1 shows the location and amount of work accomplished for each field day.

Seven lines were surveyed. The lines run roughly northeast to southwest. The lines were surveyed in order of priority. The location of these lines and the number and position of the seimsic spreads on each line are indicated in Figure 2.

The typical shooting arrangement for two adjacent spreads is shown in Figure 3. Each spread has twelve equally spaced geophone take-outs. The spacing between geophones was 20 metres. The extent of each spread along the survey lines is indicated on the line profiles.

Along each line data was recorded for shots placed at the end and 240 metres beyond the end of all spreads. Data was also recorded for three shots placed in-line along each spread. The purpose of the shots fired beyond the ends of the spreads was to increase the depth of exploration to obtain arrivals refracted from bedrock at most geophones. The in-line shots were placed to adequately define overburden velocity and variation in this velocity along each spread.

Flagging, identifying the contractor (GPC), the site, line, spread and shot was left at each blast location in the field. The shots were named acccording to the scheme shown in Figure 3. Relative ground elevations were determined through use of a hand-held level.

Compression type seismic energy was generated with explosives placed in shallow (0.1 metre) holes. The amount of explosives used for any shot was less than 20 sticks of Forcite

(75%). The largest of the blast holes was about 2 metres in diameter and 1 metre in depth.

Seismic data was recorded with a GeoMetrics ES1210-F, 12 channel, signal enhancement seismograph. The manufacturer's specifications for this instrument are included in Appendix A.

TABLE 1

DAILY LOG OF WORK COMPLETED

Date October 1982	Line	Spreads	Length Surveyed	% Complete
8	3	1, 2, 3	700	8.7
9	standby			
10	6	1, 2, 3	680	17.3
11	6	4, 5	440	22.8
12	6	6, 7, 8, 9	900	34.2
13	3	4, 5, 6	680	42.7
14	standby			
15	4	1, 2, 3	680	51.3
16	4	4, 5	460	57.0
17	7	1, 2, 3	680	65.6
18	7	4, 5, 6	680	74.1
19	5	1, 2, 3	700	82.9
20	2	1, 2, 3	680	91.4
21	1	1, 2, 3	680	100.0
	totals	35 spreads	7960 metres	100 %

Mobilization	October 7, 1982	Calgary to Sandspit
Demobilization	October 22, 1982	Sandspit to Calgary

3.0 DATA PROCESSING

The data was processed using the plus-minus (delay-time) method of analysis. The method is briefly illustrated in Figure 4 for the two-layer case. The first arrival times, corrected for any large elevation differences along the spread, are plotted as a function of distance (4a). The differences in arrival times for each geophone from shots offset from the ends of each spread (in-line and end shots for each partial spread) are then plotted versus distance (4b). On this plot geophones recording arrivals refracted from the bedrock fall on a straight line with a slope of $2/V_2$, where V_2 is the compressional seismic velocity of the bedrock. For each geophone that recorded arrivals refracted from the bedrock, the delay time (defined and plotted in Figure 4d) is computed. The depth to bedrock is related to the delay-time by the function shown in Figure 4c.

Critical to the accurate determination of depth to refractors are the delay-time, the values of overburden velocity, V_1, and the travel time from the shot to the furthest geophone, T-total. These parameters are derived from the time distance plot (4a). All results shown in Section 4.0 have been derived from the interpretation of refraction seismic data only.

On each line the fault was located. On the west side of the fault arrivals refracted from the bedrock were recorded and depth to bedrock calculated.

For the shallow refraction seismic method there is a practical limit to the depth of exploration. On the east side of the fault bedrock exists below this limit (deeper than 60 metres). In this situation only a minimum depth to bedrock was calculated. The minimum depth calculation assumed that refraction along the bedrock would be encountered at the next geophone station beyond the end of the spread. The value for bedrock velocity observed on the west side of the fault is used in the calculation. This is a minimum depth calculation only, and bedrock may be encountered at any depth below this limit.

4.0 RESULTS

The line profiles are presented as Figures 5 to 11. Each profile is drawn west to east to scales of 1:1000 vertical and 1:2000 horizontal. The location of geophone take-outs along the spreads provided horizontal control. Elevations along the lines have been determined using a hand held level. A fixed elevation point has been taken from a topographic reference point on the contour map. All other elevations shown on the line profiles for a site are relative to this point.

On each line the fault was located. West of the fault bedrock was overlain by a thin soils layer with a depth to bedrock less than 20 metres. On lines 2 and 4 a second layer of unconsolidated materials with a velocity of 2200 m/sec overlies the bedrock and depth to bedrock reaches a maximum of 45 metres.

Two distinct bedrock velocities were observed. On lines 2, 5 and 7 a velocity of 4500 to 4800 m/sec was calculated for bedrock. On lines 1, 3, 4 and 6 bedrock velocity was between 3600 to 3700 m/sec.

In each case to the east of the fault zone the depth to bedrock was too great to be economically mapped. Minimum depths to bedrock between 60 and 70 metres were determined.

Beyond the fault bedrock lies below thick unconsolidated and likely saturated sediments of average velocity 2000 to 2400 m/sec. No arrivals from the bedrock were recorded east of the fault.

5.0 EXPECTED ACCURACY

Since there is a marked difference between overburden and bedrock velocity it was possible to locate the position of the fault with an accuracy of 20 metres on either side.

The main source of errors in determining depth to bedrock in refraction seismic surveying is due to the limited knowledge of the overburden velocities. Good control over overburden velocity was maintained in this survey by shooting three intermediate shots along each spread. The similarity in these velocities indicates that the expected accuracy in the calculated position of the bedrock surface is in the order of 15 percent.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS and GEOPHYSICISTS OF ALBERTA
PERMIT NUMBER
P 2302
Geo Physi Con Co. Ltd.

Respectfully submitted,

GEO-PHYSI-CON CO. LTD.

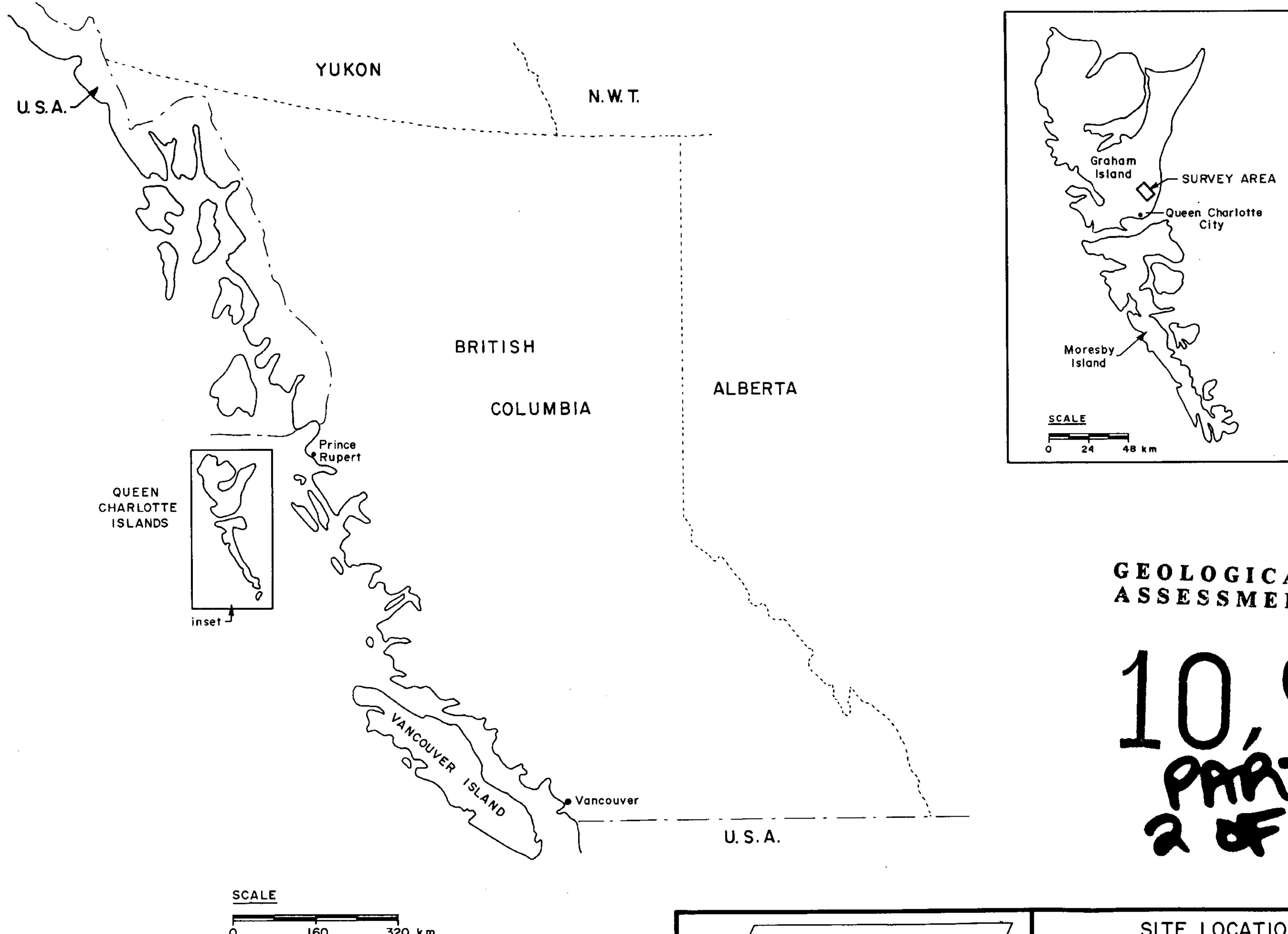
Per: Jane Palfreyman.

Jane Palfreyman, B.Sc.,
Project Geophysicist

Reviewed by: A. N. Sartorelli

A. N. Sartorelli, P.Eng.,
Senior Geophysicist

Calgary, Alberta
December 1982
82-46



GEOLOGICAL BRANCH
ASSESSMENT REPORT

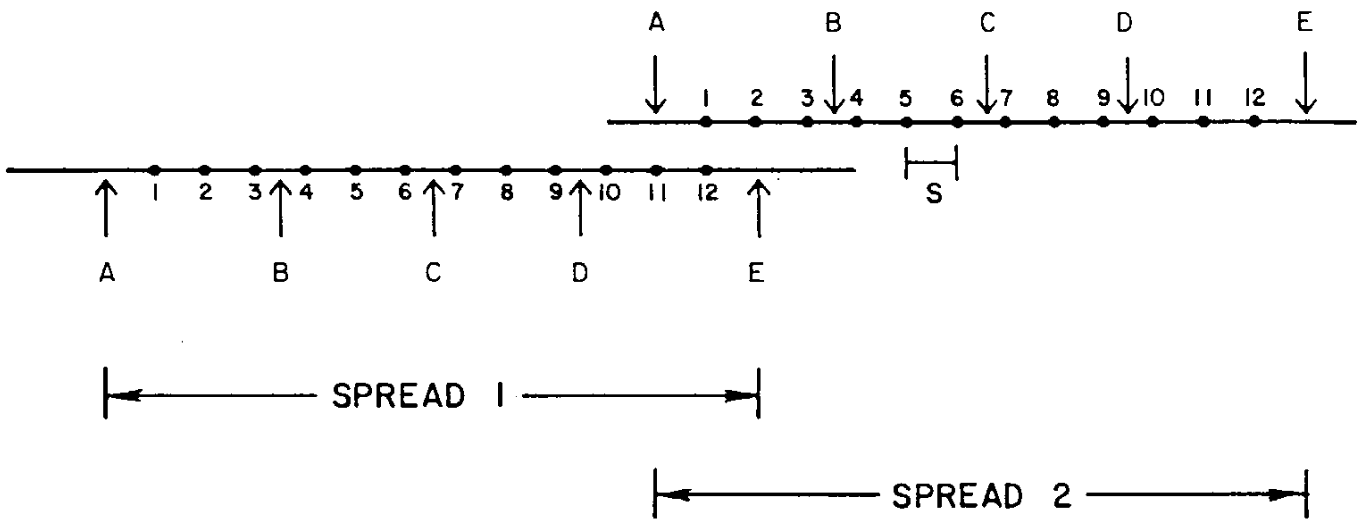
10,933
PART
2 OF 2

GEO·PHYSI·CON
ENGINEERING GEOPHYSICAL CONSULTANTS

SITE LOCATION MAP
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46 Figure 1



LEGEND

2 • Geophone location

↑, ↓ Shot locations - Spread 1, 2

A Normal shot

B Normal centreline shot

E Reverse shot

D Reverse centreline shot

C Centreline shot

S Geophone spacing (20 metres)

GEO-PHYSI-CON

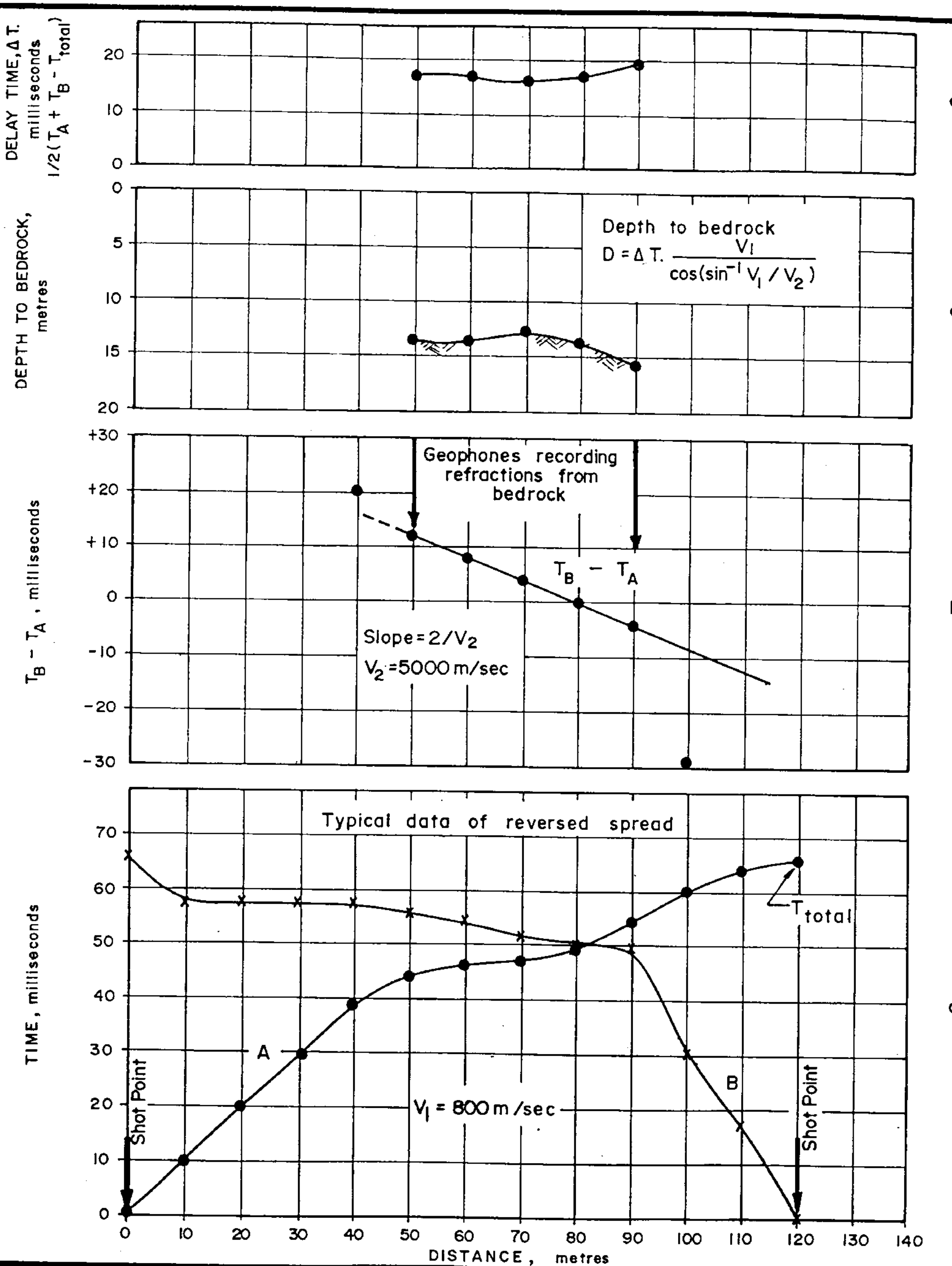
ENGINEERING GEOPHYSICAL CONSULTANTS

SHOT AND GEOPHONE LAYOUT
-ADJACENT SPREADS

PROCAN EXPLORATION COMPANY

82- 46

Figure 3



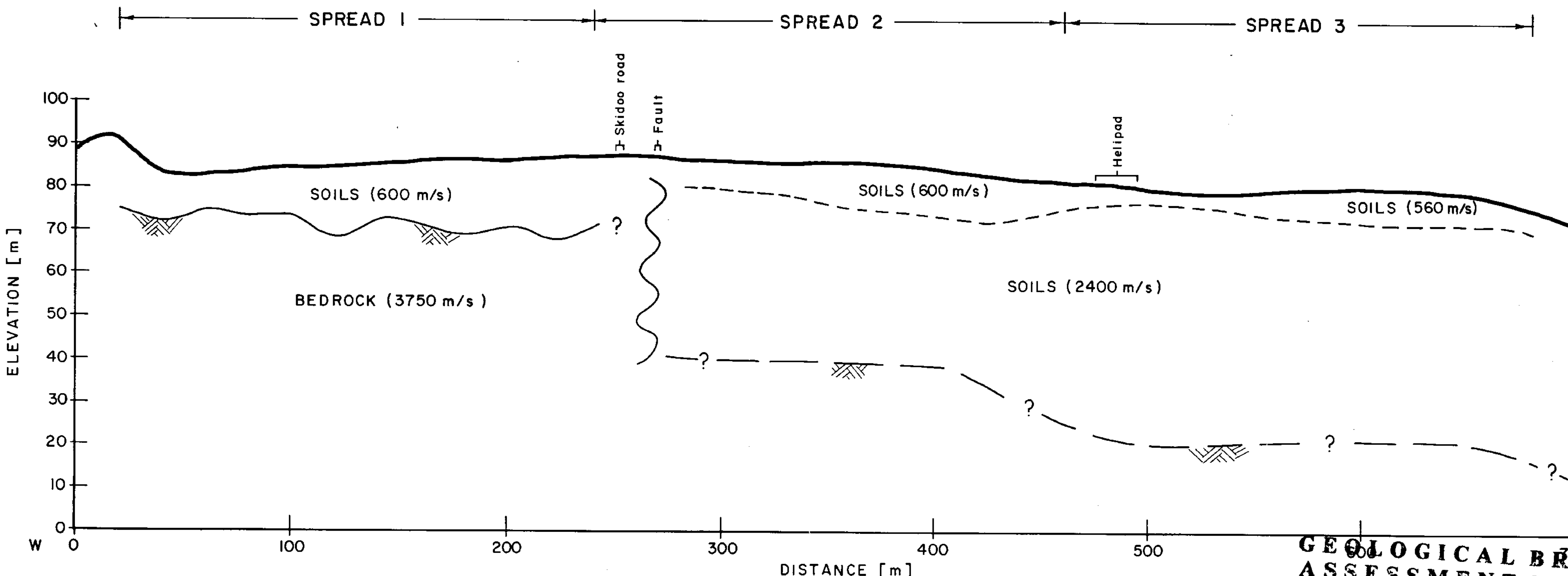
GEO·PHYSI·CON

ENGINEERING GEOPHYSICAL CONSULTANTS

TYPICAL REVERSE SEISMIC REFRACTION DATA AND ANALYSIS

82-46

Figure 4



LEGEND

- Ground Surface
- Intermediate Surface
- Bedrock Surface
- ? Minimum Bedrock Depth (calculated)
- (600 m/s) Velocity in metres per second
- Fault

SCALE

Horizontal 1:2000
Vertical 1:1000

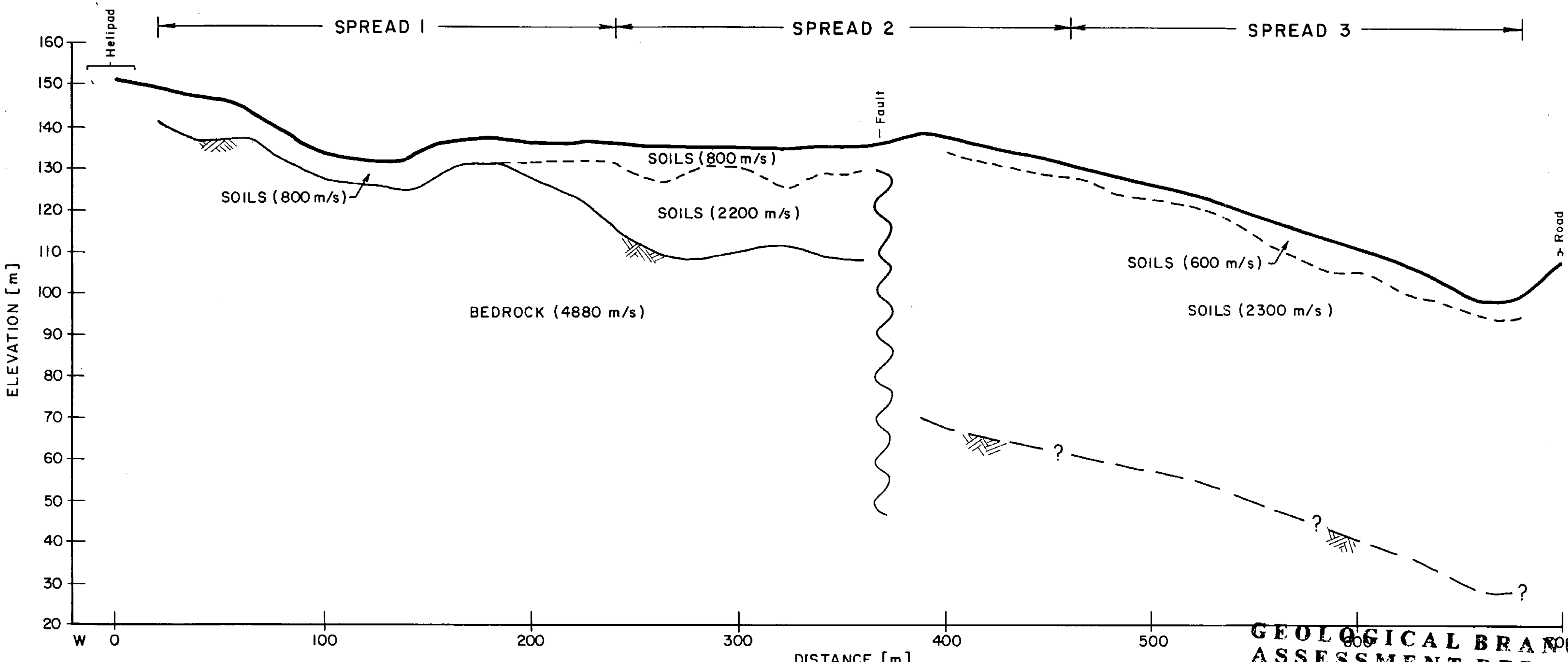
GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS

PROFILE ALONG SEISMIC LINE 1
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46

Figure 5



LEGEND

- Ground Surface
- Intermediate Surface
- Bedrock Surface
- ? Minimum Bedrock Depth (calculated)
- (600 m/s) Velocity in metres per second
- Fault

SCALE

Horizontal 1:2000
Vertical 1:1000

GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS

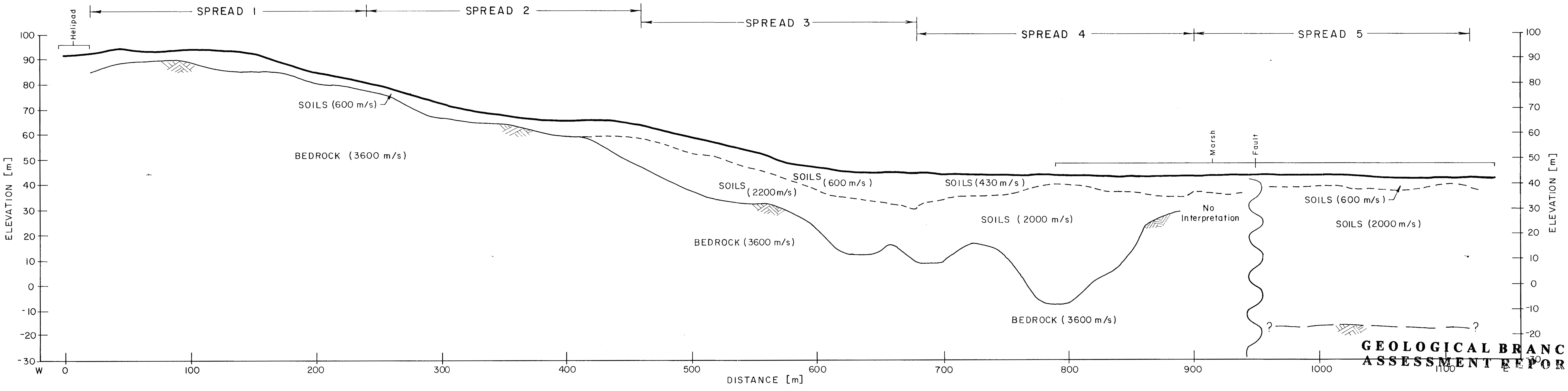
PROFILE ALONG SEISMIC LINE 2
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46 Figure 6

PART 2 OF 2


SPREAD 1
SPREAD 2
SPREAD 3
SPREAD 4
SPREAD 5
SPREAD 6
Marsh
Helipad
Fault
Creek
Creek
Creek
Creek
SOILS (720 m/s)
SOILS (720 m/s)
SOILS (740 m/s)
SOILS (600 m/s)
SOILS (2350 m/s)
BEDROCK (3700 m/s)
BEDROCK (3700 m/s)
BEDROCK (3700 m/s)
ELEVATION [m]
DISTANCE [m]
W
E
GEOLOGICAL BRANCH
ASSESSMENT REPORT
10,933
PART 2 OF 2
LEGEND
Ground Surface
Intermediate Surface
Bedrock Surface
Minimum Bedrock Depth (calculated)
(600 m/s) Velocity in metres per second
Fault
SCALE
Horizontal 1:2000
Vertical 1:1000
GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS
PROFILE ALONG SEISMIC LINE 3
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.
PROCAN EXPLORATION COMPANY
82-46
Figure 7



GEOLOGICAL BRANCH
ASSESSMENT REPORT

10,933

PART 2 OF 2

LEGEND

- Ground Surface
- Intermediate Surface
- Bedrock Surface
- —? Minimum Bedrock Depth (calculated)
- (600 m/s) Velocity in metres per second
- Fault

SCALE

Horizontal 1: 2000
Vertical 1: 1000

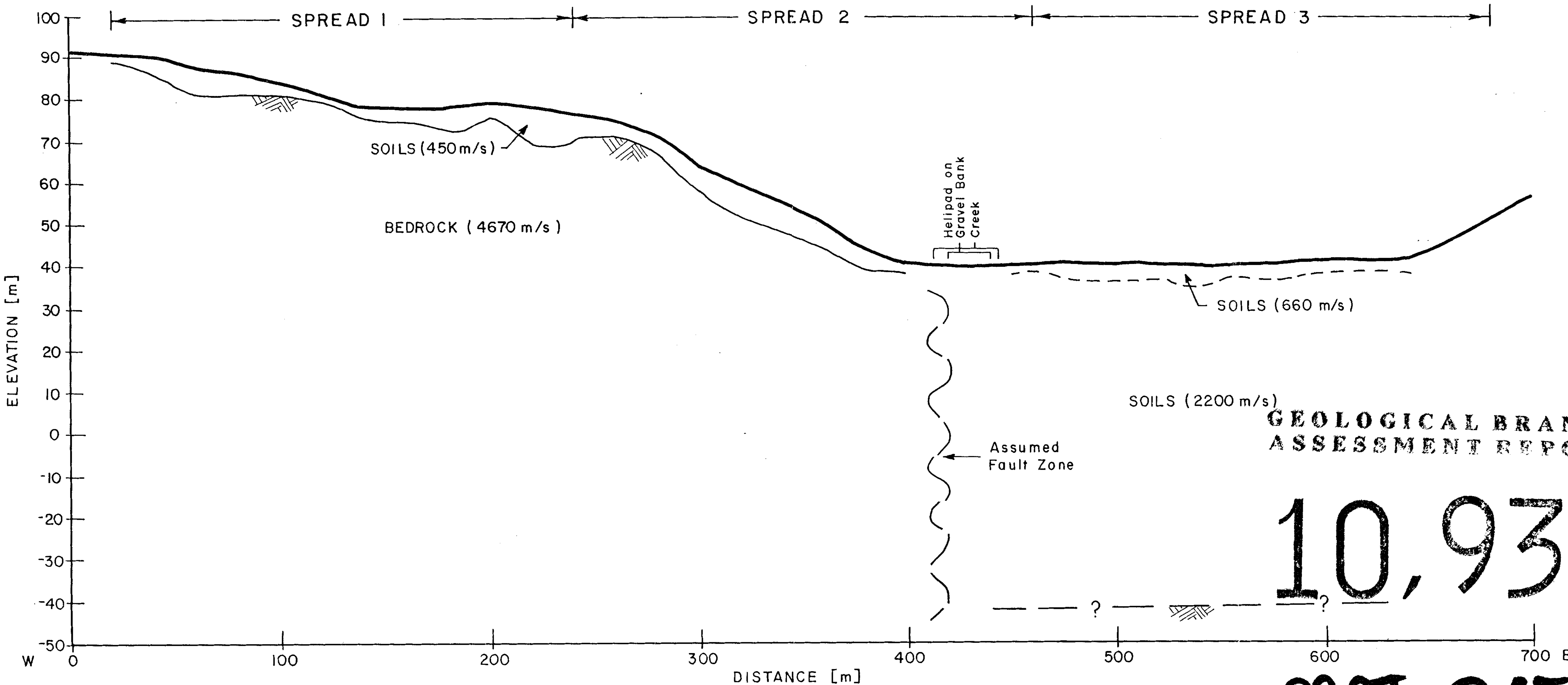
GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS

PROFILE ALONG SEISMIC LINE 4
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46

Figure 8



LEGEND

Ground Surface

Intermediate Surface

Bedrock Surface

—? Minimum Bedrock Depth (calculated)

(600 m/s) Velocity in metres per second

SCALE

Horizontal 1: 2000

Vertical 1: 1000

GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS

PROFILE ALONG SEISMIC LINE 5
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46

Figure 9

LEGEND

- Ground Surface
- Intermediate Surface
- Bedrock Surface
- Minimum Bedrock Depth (calculated)
- (600 m/s) Velocity in metres per second
- Fault

SCALE

Horizontal 1:2000
Vertical 1:1000

GEO·PHYSI·CON
ENGINEERING GEOPHYSICAL CONSULTANTS

PROFILE ALONG SEISMIC LINE 6
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46 Figure 10

LEGEND

Ground Surface

Intermediate Surface

Bedrock Surface

? Minimum Bedrock Depth (calculated)

(600 m/s) Velocity in metres per second

Fault

SCALE

Horizontal 1:2000

Vertical 1:1000

GEO-PHYSI-CON
ENGINEERING GEOPHYSICAL CONSULTANTS

PROFILE ALONG SEISMIC LINE 7
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

82-46 Figure 11

LEGEND

- Seismic Survey Line
- Spd 1 — Spread Number
- Marsh
- Seasonal Drainage
- Fault

SCALE 1:20,000

0 400 800 metres

GEO·PHYSI·CON
ENGINEERING GEOPHYSICAL CONSULTANTS

SEISMIC LINE LOCATION MAP
QUEEN CHARLOTTE ISLAND PROPERTY
GRAHAM ISLAND, B.C.

PROCAN EXPLORATION COMPANY

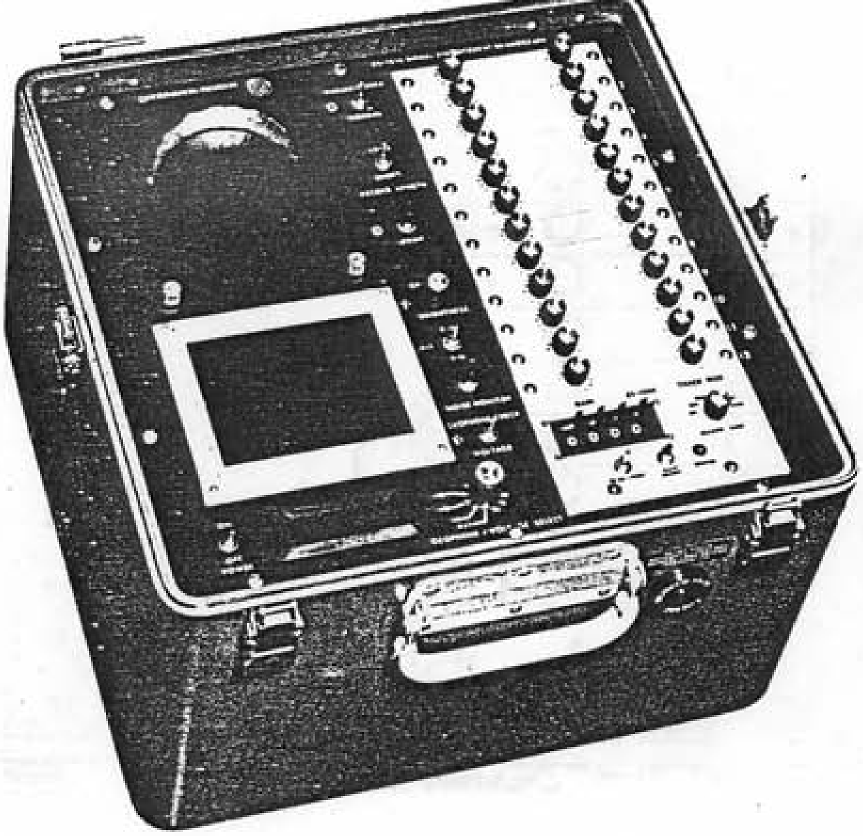
82-46 Figure 2

APPENDIX A

geoMetrics/nimbus

MULTICHANNEL SIGNAL
ENHANCEMENT SEISMOGRAPH
MODEL ES-1210

Preliminary Data Sheet



* *Signal enhancement* for greater sensitivity, improved waveform definition, and more accurate time measurements. Operates under high noise conditions and surveys to greater depths without explosives.

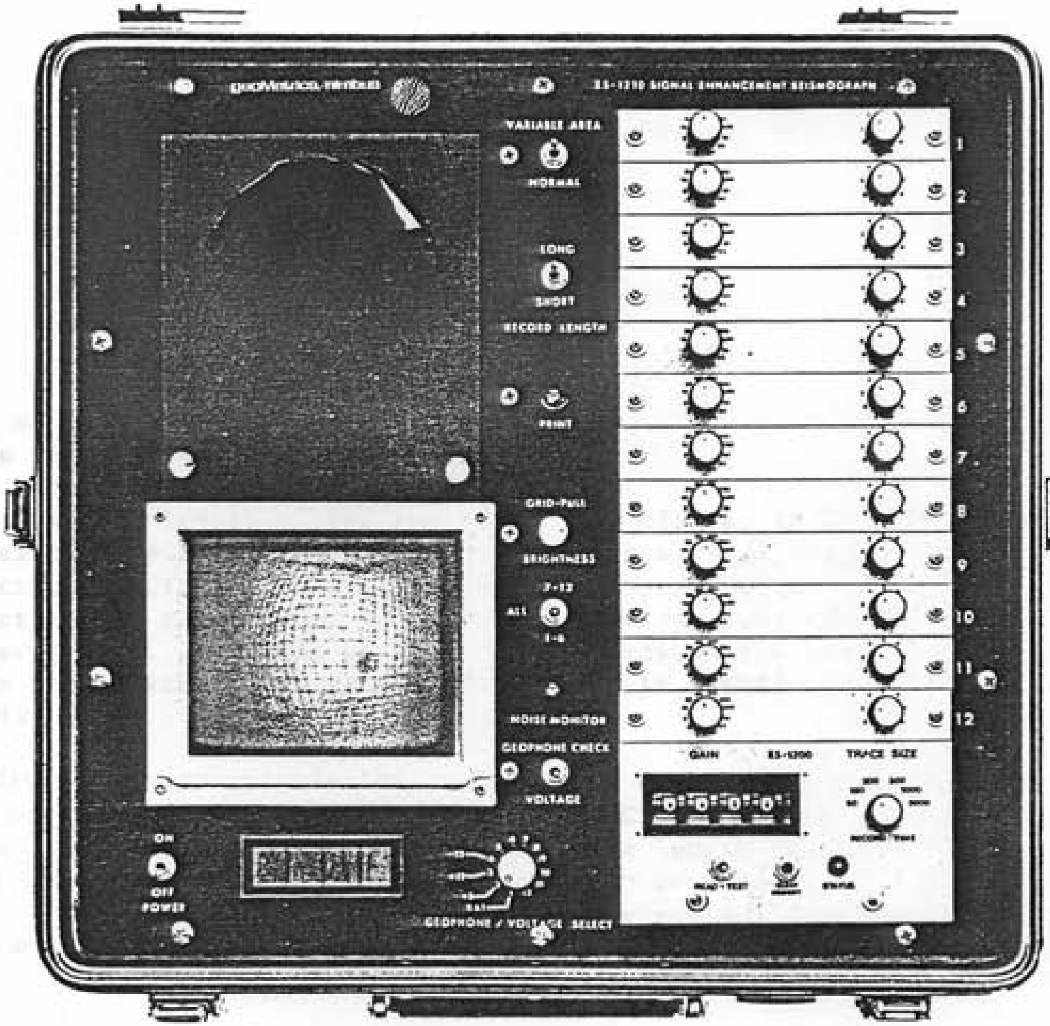
* *Multichannel oscillograph* provides permanent records on high-contrast, sunlight proof, reproducible paper with wiggle trace or variable area format.

* *Daylight-visible CRT monitor* displays the signal stored in memory.

* Compact, lightweight and portable. Ruggedly packaged in weatherproof case.

* Optional digital magnetic tape recorder for computer compatible data storage.

The Nimbus ES-1210 Multichannel Signal Enhancement Seismograph is unique in its combination of CRT display, signal enhancement and oscillograph recording in a single small field instrument. Simple to use yet powerful in performance, this new instrument is ideally suited for all shallow geologic investigations for mining, construction and geologic exploration.



CONTROLS AND FEATURES

Amplifier (input) GAIN is controlled by a 12-position switch, selectable from relative gain of 1 to 5000 in steps of 1-2-5-10 etc. Each amplifier has a 10 bit by 1024 sample memory which stores the digitized signal. Playback gain is controlled over a 20 to 1 range by the TRACE SIZE control. Pulling up the trace size control freezes the memory on that particular channel so that it will not further enhance or erase, thus saving the data while allowing operation on the other channels. Playback or display are not affected by memory freeze.

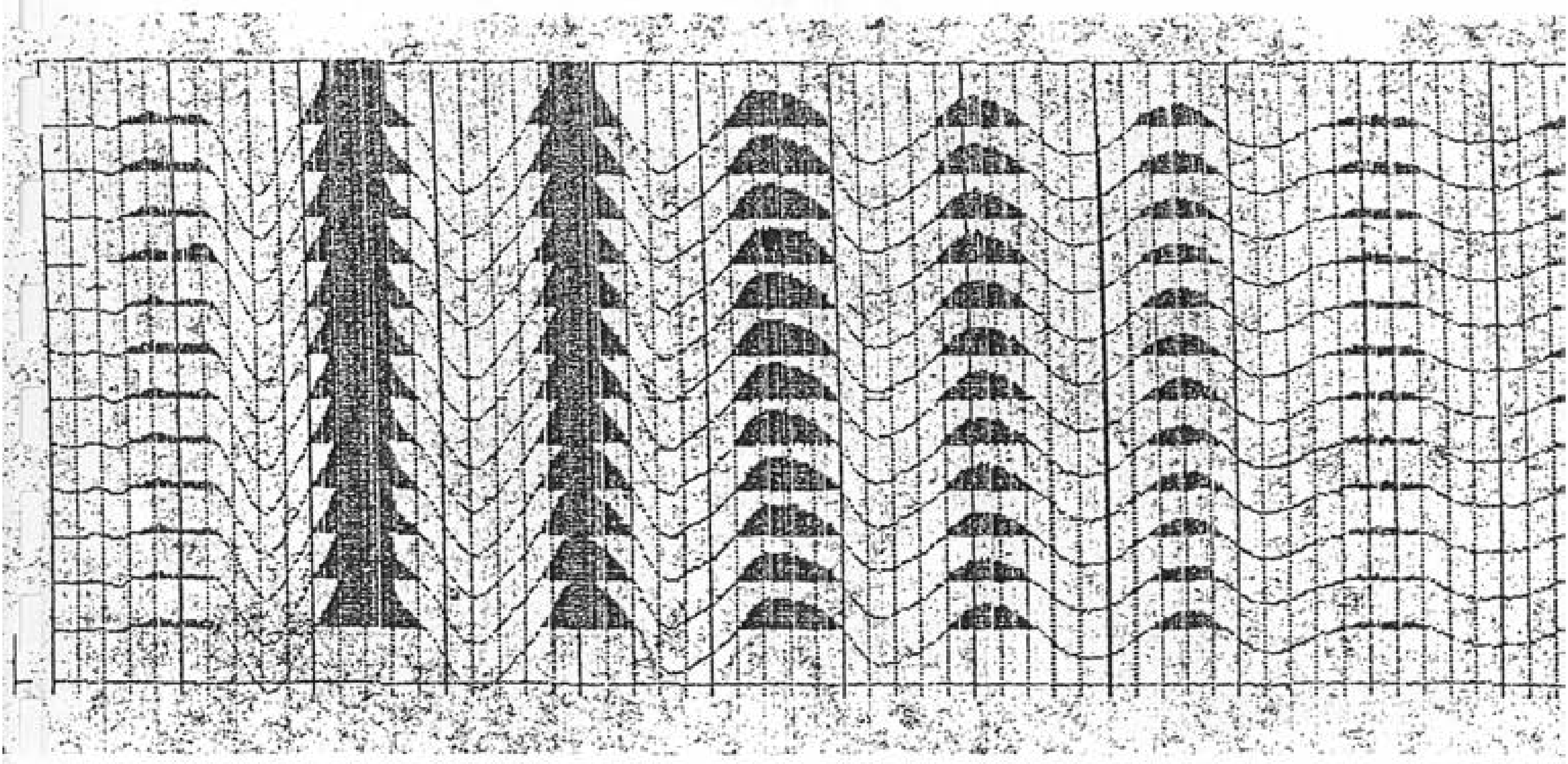
Enhancement control electronics include the RECORD LENGTH control, which selects total time of the record among 50, 100, 200, 500, 1000 or 2000 milliseconds. The record DELAY postpones the start of the record up to 9.999 seconds in one milli-seconds increments, allowing you to look later in time, delete unnecessary leading portions of the signal, and maintain faster sampling rates for later events. CLEAR MEMORY controls erases the data stored in the memory. An interlock is provided (both READ and CLEAR must be used) to prevent accidental erasure of valid data. TEST provides a start command to take a record in lieu of hammer switch or blaster.

The oscillograph is a rotary scanning dot matrix recorder. The record is composed of a number of closely spaced dots with a resolution of 70 dots per inch (3 dots/mm). The paper width is four inches (10 cm). The record is formed by electrically removing a thin metal layer on the surface of the paper, exposing a black underlayer. The resultant record is of high contrast, and is insensitive to aging or sunlight. It can be reproduced on office copiers, usually better than the original. Because of the way the recorder operates, it is easy to fill in the positive cycles of the signal, thus providing what is known as "variable area" recording. This type of signal presentation produces a record particularly useful in reflection surveys. It makes it easier to recognize reflection signals, and the resultant record resembles geologic structure.

The physical length of the record may be selected as 7½" (19 cm) or 15" (38 cm). In either case, the CRT display changes to a corresponding full record display or an expanded first half with higher resolution. If one of the six channel display functions is selected on the CRT, the corresponding six channels will be on the paper record, providing greater spacing between the lines. Alternate copies of wide space records may be pieced together to provide an effective paper width of 8" (20 cm).

Timing lines are recorded on the paper in either high resolution or low resolution format, depending on the position of the CRT time line switch. The interval between the lines varys with the record time length so that best combinations of time resolution and clutter are maintained. An additional edge time record shows intervals of 100 milliseconds regardless of any control settings. Using this marker, it is easy to determine the time length of the record and the time line intervals.

ES-1210 Record



Signal enhancement is a term used to describe the stacking process used in the ES-1210. The seismic signals for each hammer blow or shot are digitized and stored in a computer-like memory in the instrument. Unlike conventional analog seismographs, the record is not made at the instant of the hammer impact or explosion. Instead, it is held indefinitely and printed at the operator's convenience. If the impact or explosion is repeated, the seismograph will add the new signal and the old one, storing the sum back in the memory. As this process is repeated, the signal will grow larger and larger, thus enhancing its appearance on the display or oscillograph record. Seismic noise in the earth, which provides the most significant limitation in depth penetration, is random and does not add in the signal enhancement process at the same rate that the true signal does. As a result, surveys can be performed to about three times the depth that could be realized without enhancement using an equivalent energy source.

Signal enhancement is also a significant improvement in making shear wave velocity measurements. These types of surveys are important because of the dynamic parameters of foundations can be calculated from shear wave velocities, liquid saturation can be discriminated from other conditions with equivalent P-wave velocities, and shear strength can be estimated. The most reliable shear wave studies are made with mechanical sources, which means that signal enhancement is often a requirement.

Signal enhancement provides other, less obvious advantages, even when using explosive sources. Since the playback gain of the signal stored in memory is adjustable, there is less guess work involved in getting good records. Multiple copies can be made without reshooting the blast. Since the frequency response is not limited by galvanometers and paper speed, a higher time resolution is available, an important factor when working in high-velocity materials.

The signal stored in the memory is displayed on the built-in CRT monitor, and the display will have the same appearance as the paper record. A paper record can be made as often as necessary, at will, without disturbing the data stored in memory. The trace size control can be changed to optimize the record for an application. The gain may be set high for sharp breaks on the P-wave arrivals, and a hard copy made. Then the gain can be turned down for better shear waves or reflections and another copy made.

Both the CRT and oscillograph record in conventional wiggle trace and variable area. A wiggle trace record, like that of a conventional seismograph, would be selected for refraction and shear wave studies. Variable area recording (often seen on examples of petroleum reflection records) is best for reflection because that presentation emphasizes coherent events and resembles geologic structure.

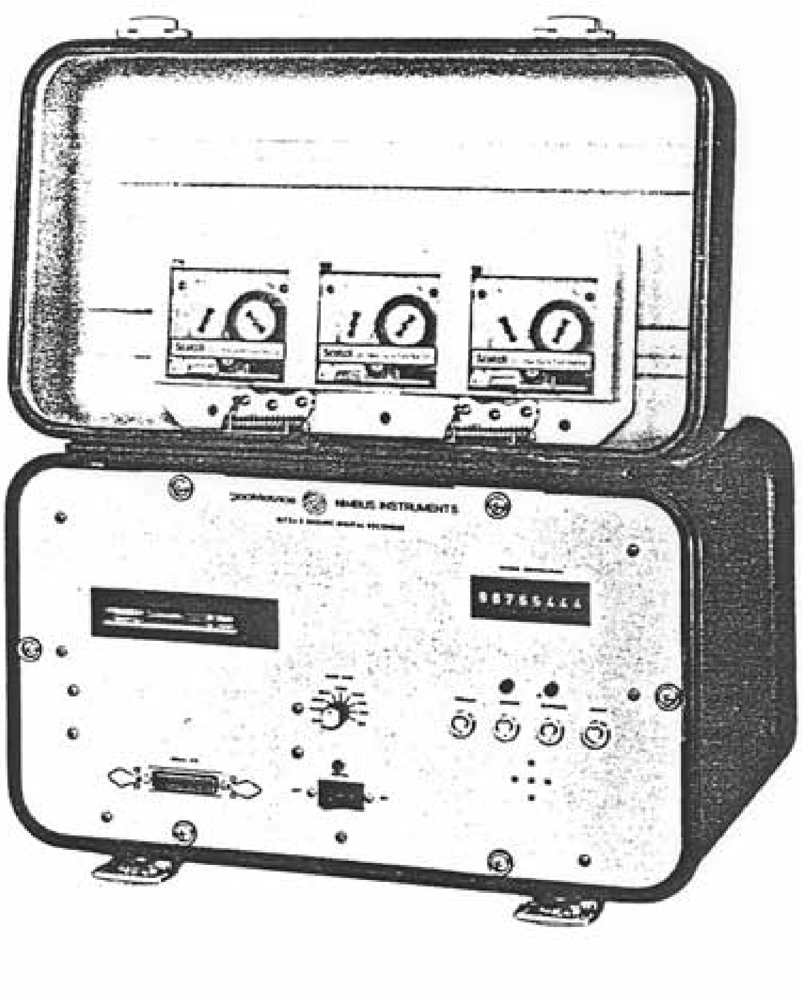
The CRT display is especially important in three other situations. When working in areas with significant background noise, the display gives an instant observation of the signal quality so that it is immediately known whether to repeat impacts, freeze specific channels, or erase and start over. The other use is in shallow reflections. The instant examination of all the channels simultaneously is important in recognizing these events in the record. The third use of the CRT display is in gain selection. With the NOISE MONITOR switch depressed real time signals are shown on the CRT and the gain setting for each channel can be chosen appropriately.

The CRT display is five inches (13 cm) diagonal measurement. It displays all 12 channels simultaneously or switch selected combinations of six channels as desired. It has a special light filter to allow direct viewing in sunlight without special hoods. The bezel will fit standard oscilloscope cameras so that photographs may be made of the display if desired. Timing lines may be superimposed on the CRT at will by pulling up on the BRIGHTNESS control. The timing line intervals vary, depending on the record length, so that appropriate resolution and clarity is maintained.

A digital voltmeter is provided to measure the battery voltage, internal power voltages, and individual geophone resistances. The NOISE MONITOR, when selected, couples the amplified geophone signals to the CRT display. This allows monitoring the instantaneous background noise so that records may be made during quiet periods.

The data stored in the memory may be accessed externally. An optional digital tape recorder, the G-724S, is available to provide computer compatible storage of the data. The G-724S will store 10 full records (120 channels) in a reduced resolution, 8-bit format, or you can store 5 records (60 channels) in the full 10-bit format. The G-724S serves as its own playback device, outputting the data in an RS-232 format which is directly interfaceable to most computers including desk top models.

G-724S Digital Recorder



Nimbus ES-1210

SPECIFICATIONS

Basic refraction and reflection system includes: 12-channel exploration seismograph, 12-volt battery pack, 110/220 volt charger, power cord, hammer switch, and instruction manual.

Signal Enhancement:	samples, digitizes, and stores signal in a random access memory. Repeated signals are added while random noise is cancelled or limited.
Memory Size:	10 bits by 1024 words on each channel.
Sample Interval:	switch selectable 50, 100, 200, 500, 1000, or 2000 microsecon
Record Length:	switch selectable 50, 100, 200, 500, 1000, or 2000 millisecon
CRT Display:	5" diagonal measurement CRT, daylight visible without hoods, switch selectable time lines, camera compatible, and displays wiggle trace or variable area record display.
Oscillograph:	permanent record of all 12 channels simultaneously on 4" wide electrosensitive paper. Record will not fade in light, and reproduces on copying machines.
Noise Monitor:	ambient vibrations displayed on CRT allowing timing of energy source during quiescent periods and the optimization of gain adjustments.
Timing:	crystal controlled, .01% accurate, time lines are switch selectable on CRT and high or low resolution on oscillographic record.
Precision Delay:	postpones start of record up to 9.999 seconds in one millisecond increments.
Digital Meter:	indicates battery voltage, geophone resistance on each channe power supply voltages.
Digital Output:	a panel connector to allow digital recording of signal stored in memory on optional digital recorder Model G-724S.
Record Initiation:	by contact closure, saturated NPN transistor, or negative 5-volt pulse.
Standard Size/Weight: (seismograph)	14 X 15 X 15 inches (36 X 38 X 40 cm) lid closed 38 pounds (17 kg)
Power Requirements:	12 volts, 3.5 amperes
Seismograph Case:	Heavy duty aluminum with lid and water tight seal.

geoMetrics, INC. A SUBSIDIARY OF EG&G
395 JAVA DRIVE
SUNNYVALE, CA. 94086 U.S.A.
TEL: (408) 734-4616
CABLE: "GEOMETRICS"
TELEX NO: 357-435

geoMetrics SERVICES (CANADA) LTD.
436 LIMESTONE CRESCENT
DOWNSVIEW (TORONTO),
ONTARIO, CANADA
TEL: (416) 661-1966
TELEX NO: 06-22694

geoMetrics INTERNATIONAL CORP.
80 ALFRED ST.,
MILSON'S POINT
SYDNEY NSW 2061
AUSTRALIA
TEL: 929-9942
TELEX NO: 790-226