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SOME OBSERVATIONS ON THE USE OF THE -VIBROSEIS- METHOD

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by

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ILLUSTRATIONS

SUMMARY

The Commonwealth of Australia, Bureau of Mineral Resources employed a contractor from May to October 1964 to demonstrate the effectiveness of the "Vibroseis" method of seismic exploration in areas where conventional shot-hole methods were impractical or where they had previously experienced difficulties in obtaining good quality reflections.

The test areas chosen were in the Sydney and Otway Basins and included the built-up area of the City of Maitland; areas of outcrop of the Hawkesbury Sandstone Formation; areas of volcanics cover; an area of cavernous Gambier Limestone outcrops; and sand covered areas. These areas have problems mainly of drilling and energy transmission.

The experimental procedure consisted of recording noise tests and testing by varying "Vibroseis" parameters, one at a time, to arrive at the best recording technique with the facilities available to the contractor; production tests were done with the best recording technique for each area. The parameters of the "Vibroseis" method and some characteristics which contribute to its flexibility are discussed and compared with the parameters and some characteristics of shot-hole methods.

The method proved successful in the built-up area where reflections were obtained to 1.1 seconds. It was not always possible to use the best recording technique found because of restrictions to the positioning of vibrators and geophones. On Hawkesbury Sandstone outcrops the method was successful in obtaining fair quality reflection information to 2 seconds. Fair quality shallow reflections were obtained in the

volcanics, Gambier Limestone and sand-covered areas, but difficulties were found in obtaining continuous deep reflections in these areas.

The tests demonstrated the flexibility of the "Vibroseis" method whereby the parameters could be rapidly changed for carrying out a series of experiments to arrive at "optimum" techniques. Fair quality reflections were obtained in the test areas, which were previously designated as poor reflection areas.

INTRODUCTION

The "Vibroseis" method of seismic exploration, which uses as an energy source, a signal of relatively long duration with a smoothly varying frequency, was described by Crawford, Doty and Lee in "Geophysics" Vol XXV, No. 1. The method was introduced into Australia early in 1963.

In Vol. 1, Part 2ca of the "Proceedings of the Second Symposium", O'Donnell referred to the use of vibrators as new sources of energy in seismic exploration work. In the section on "Petroleum Exploration Techniques and Methods" in the "Report of the Second Symposium", a recommendation was made suggesting the use of contractors to stimulate new advances in the industry and to show the applicability of new methods for adaptation to areas with unusual terrain and particular seismic problems.

In accordance with its policies for accelerated oil search, the Commonwealth of Australia Bureau of Mineral Resources employed a contractor, from May to October 1964, to demonstrate the applicability of the "Vibroseis" method by conducting experimental surveys in several areas chosen because of their specific seismic problems. The test areas selected lie within the Otway and Sydney Basins. The objective of the surveys was to show if reasonable quality results could be achieved in the problem areas by making use of the inherent flexibility of the "Vibroseis" method. A further objective was to assess the costs of

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"Vibroseis" operations as compared with those of shot hole methods.

THE "VIBROSEIS" METHOD

Principles of the method

Plate 1 shows the "Vibroseis" system.

The method uses vibrators operating at the surface of the ground as contolled energy sources, as an alternative to explosives in shot holes. A signal of continuously varying frequencies, called a sweep, is injected into the ground over a period of 7 seconds by the vibrators, which are activated by servo-controlled hydraulic rams that follow a signal transmitted by radio from the recording truck.

The maximum bandwidth of this signal is 10 c/s to 120 c/s. However, generally, an input with a range of about two octaves is chosen. The bandwidth is selected to contain frequencies that form the spectrum of a normal reflection pulse; no energy is wasted by injecting frequencies which it is known the earth will not efficiently transmit.

The signal picked up by the geophone is recorded on magnetic tape. By a process of continuous correlation of this magnetic tape against the recorded input signal, a record similar to a conventional shot-hole record is obtained, i.e. the final result is the same as if all frequencies had been injected into the ground simultaneously.

Field techniques

The field procedures are extremely flexible, mainly owing to the fact that no predetermined drilling programme is required. The vibrators are extremely mobile but there are limits to their positioning as they require relatively flat surfaces for good vibrator-to-ground coupling. The recording techniques used depend on desired spatial noise filtering, penetration required, and degree of compositing.

In the standard in-line method, geophones are laid out in groups at locations along the spreads as in normal shot-hole seismic operations and vibrators operate at the conventional shot-point positions. In poor reflection areas where a high effort involving large numbers of geophones and vibrations is required, this may be tedious. However, in good reflection areas where a low effort is required, this method gives the highest production rates.

The transposed method was used more generally in the experimental surveys. With this method the geophones are grouped in two nests, one at either end of the spread, and the vibrators operate between the nests at the positions normally occupied by the geophones in shot-hole methods.

Both these methods allow the use of large geophone and/or vibration patterns for cancellation of noise and for the compositing of large numbers of independent ray paths. However, the transposed method is more felxible to use and a greater degree of compositing and speed of operation can be more readily attained by using this method in poor reflection areas. An additional advantage of this method is that recordings made on each trace are made at different times from those made on adjacent traces. This tends to increase the random nature of the noise between final traces.

The "Vibroseis" method is particularly well suited to the use of a "rollalong" common depth point (C.D.P.) method using standard in-line geophone spreads. Recordings at different offset distances, from the same subsurface point, are stacked. This increases the relative amplitudes of signal to background noise and also produces cancellation of any multiple reflections recorded.

Variable Parameters

The flexibility of the "Vibroseis" method is due mainly to the ease in which most parameters can be varied. The main parameters are as follows:

Sweep frequency range Several sweep frequency ranges are available and a choice is made to suit the particular area and the problem being investigated.

No. of vibrations (sweeps). The results of numbers of sweeps can be added because of the relatively uniform duplication of the energy from successive transmissions. The time independence of recordings aids noise cancellation when sweeps are added. The number of sweeps used is varied normally in steps from 5, 10, 20, 40 to 80 sweeps. The theoretical signal-to-background noise ratio improves as the square root of the number of sweeps.

Vibrator thrust This can be varied, but the energy from a vibrator must not exceed the elastic limits of the surface formations. A maximum vibrator thrust of 10,000 lb is normally applied and no damage is caused to surfaces on which the vibrators operate.

<u>No. of vibrators</u> The number can be varied since vibrators are synchronised. Three are normally used on a party with another vibrator available as a spare. The theoretical signal-to-background noise ratio is improved proportionally to the number of vibrators used.

<u>Vibration patterns</u> These may be transposed to occupy the positions of geophone patterns in shot-hole methods. The length and width of the patterns and spacing of vibration points within the patterns are determined from the spatial noise filtering and random noise cancellation requirements, the objectives of the survey, the number of vibrators used, and sweeps required.

<u>No. of geophones</u> 2000 geophones were available on the experimental party. For the transposed method large numbers of geophones (up to 800) are laid in individual groups.

<u>Geophone pattern</u> The characteristics of the patterns are determined by the same principles that define the vibration patterns.

<u>Offset distance</u> "Vibroseis" work requires the vibrators to be offset from the nearest geophones since recordings are made without automatic volume control and with gains set for 100% magnetic tape modulation on the highest amplitude event recorded; this may be refracted energy (as in the first breaks), coherent noise, or a reflection event. If no offset is used the relative amplitudes of noise interference from the vibrator and later reflection events are likely to exceed the dynamic range of the recording instruments (about 45 db.). A short offset distance is necessary (to avoid refraction

paths) for obtaining shallow reflection information and a long offset distance may be necessary to reduce the relative amplitudes of the refracted or coherent noise energy, which decays with distance from the source, and the later reflection events. Offset distances of 1, 2, and 3 spread lengths are normally used for systematic continuous recording.

Electrical filters on playbacks   Normal electrical filtering can be applied to the correlated magnetic tapes. Filtering is varied to give a final record with limited frequency pass band as is done with the processing of shot-hole recordings. However the correlation process normally also performs this function.

Automatic volume control (A.V.C.) on playback   This is applied to the correlated magnetic tapes. A.V.C. is varied to give uniform signal level as with playbacks from shot-hole recordings.

Comparison of various characteristics of "Vibroseis" and shot-hole methods

The following table compares these two seismic exploration methods.

"Vibroseis" method	Shot-hole Method
Sweep frequency range	-
Sweep	C.F. Explosion
No. of sweeps	No. of shots and/or size of charge
Vibration patterns	Shot-hole patterns
-	Depth of shot
No. of geophones - max. 800 for transposed recording	No. of geophones - max. approx. 96 per trace
Geophone pattern	As for "Vibroseis" in-line recording
Amplifier record filters - set at limits of the sweep frequency range.	Amplifier record filters - set as wide as possible at limits of seismic pulse spectrum
Cross correlation - sharp cut off filtering dependent on sweep frequency range	-
-	A.V.C. and/or programmed gain on record.
Offset distance - min. geophone-to-vibrator offset is dictated by instrument limitations and objectives.	Offset distance - no limit for geophone - to-shot offsets but not normally required.
Electrical playback filters - as for record filters.	Electrical playback filters narrower limits than for recording.
A.V.C. on playback	A.V.C. - rate dependent on reflection resolution.
Easy transposition of vibration points and geophones	Difficult transposition of shots and geophones.
Rapid variation of vibration point and geophone arrays between experiments.	Slow variation of arrays between experiments
Weathering information not generally available.	Weathering information generally available
No damage to ground surfaces	Damage to surfaces with drilling and shots

The "Vibroseis" method has clear advantages by:

1. limiting the sweep frequency range to contain frequencies which contribute to reflection resolution.
2. using the cross-correlation process to provide a sharp cut-off filter
3. using the correlation process to discriminate against random noise.
4. the ability to employ high multiplicity of vibration points and geophones for relatively low cost.

The "Vibroseis" method has some disadvantages by:

1. having no counterpart to varying depth of shot
2. requiring the use of an offset distance to record the signal within the dynamic range of the "Vibroseis" system (45 d.b.); in shot-hole methods A.V.C. or programmed gain on record is used for this purpose. For the "Vibroseis" recordings without A.V.C. it is necessary to ensure that the highest amplitude signal does not saturate the tape and cause distortion since this would affect other signals that it overlaps in the correlation process.

TEST AREAS & ASSOCIATED PROBLEMS

The project areas are shown in Plate 2. The areas, with particular problems selected to test the flexibility of the "Vibroseis" method, were as follows:

Built-up-area project. Fair quality seismic information had been recorded, using shot-hole methods on the east and west outskirts of the city of Maitland. It was considered that a test of "Vibroseis" recordings through this built-up area would illustrate the applicability of the method in an area where shot-hole methods could not be used.

Hawkesbury Sandstone project. The hard, somewhat quartzitic, Triassic Hawkesbury Sandstone, which covers large areas of the Sydney Basin, transmits seismic energy poorly.

Drilling is difficult and expensive. Access is poor and seismic traverse generally follow roads that run along the rugged Hawkesbury Sandstone ridges. Power lines also follow these roads and give troublesome 50 c/s. interference. The weathering on the highly eroded surface is extremely variable.

Volcanics project. Extensive volcanic activity during the Quaternary period partly covered the eastern part of the Otway Basin with basalt, tuff, and other volcanic residue. This cover, which varies not only in its composition but also in its thickness and depth, constitutes an energy transmission problem for seismic exploration. Other problems associated with the volcanics are an erratic weathering zone; probable variations in velocity distribution in the section due to basalt layers; general low average velocities in the section, which result in large dynamic corrections and limits the lengths of geophone and source patterns that can be used; and in some places hard drilling, which often makes shot-hole drilling difficult.

Gambier Limestone project. A large part of the western part of the Otway Basin is covered by the cavernous Tertiary Gambier Limestone, which is up to 500 ft thick in some areas. This limestone constitutes an energy transmission problem as well as having associated drilling problems with circulation losses, and often slow drilling rates due to hard flintstone bands in the formation.

Sand-cover project Other areas in the western part of the Otway Basin are covered by a sand sheet or sand dunes. These areas of loose sand are troublesome for shot-hole seismic work because of absorption of the seismic energy and difficult drilling.

EXPERIMENTAL PROCEDURE

The selection of areas in which to test the applicability of the method was based on knowledge of surface geology, information from wells drilled, and previous geophysical surveys including aeromagnetic, gravity, and seismic. The results of previous seismic experimental work were studied.

Noise tests were initially recorded as a guide to further experimentation. These were recorded using an in-line method with one vibrator, a 10 - 120 c/s sweep and a normal recording distance out to approx. 4000 ft with geophones at 20 ft. intervals. The number of sweeps was increased with distance from the source. The results were illustrated in graphs of Time v Distance. Amplitude v Wave Number and Frequency v Wave Number.

Initial recording parameters were selected from previous knowledge of recording conditions and from the interpretation of the noise tests for choosing offset distance, spatial filtering requirements, and sweep spectrum.

Experimentation proceeded with recordings made generally over several spreads with the initial technique selected. Parameters were then changed one at a time in order to assess the effectiveness of the changes. Recordings were generally repeated using the different techniques in order to assess revised techniques over more than one spread. The technique found to be best in a particular area was in most cases tried in another area with a similar problem. Up to six weeks was spent on each problem.

RESULTS

Parts only of some cross-sections recorded along the experimental traverses are included as illustrations (Plates 3-7) of the results of the "Vibroseis" tests. The recording techniques are noted in the plates.

Built-up-Area project

After initial testing using standard in-line recording with vibrator force-levels at 25% maximum, a high-effort transposed-recording technique was adopted for the test. Vibrators with maximum force-level operated on the bitumen roadways, and geophones were laid in nests as far from the roadways and power lines as possible in order to reduce extraneous noise due to traffic and 50 c/s interference. Traffic was very heavy.

A high-amplitude, high velocity, near surface refraction wave masked the reflections down to 0.5 second and limited the recording level for later reflection events, which are evident in Plate 3 at times of approx. 0.7 and 1.1 seconds.

The method has been demonstrated to operate successfully in a highly populated, built-up area without interfering with traffic. However, it may not be possible to attain an optimum recording technique in all built-up areas owing mainly to limitations on the offset distance and pattern lengths of vibrations and geophones that can be used.

Hawkesbury Sandstone project

The results of a noise test indicated a high-velocity, high amplitude, first-break interference event. Good quality shallow reflections down to 1.0 second were obtained using 600-feet-long vibrator and geophone patterns with a minimum one-spread offset and a 10-40 c/s sweep. Deeper reflections down to 2 seconds were obtained, with resulting deterioration of the quality of the shallow information, by increasing the pattern lengths to 1000 ft so that spatial filtering effects reduced the amplitudes of the first-break event relative to the reflection events. It was necessary to increase the number of sweeps and to use a minimum two spread offset. Comparisons with these recording techniques are shown in Plate 4.

The use of a 10-40 c/s sweep in "Vibroseis" recordings on Hawkesbury Sandstone cover is considered to be a major factor in the attainment of good quality reflections. It eliminates the generation of high frequency noise and the correlation process eliminates 50 c/s high-line pick-up. The test indicates that "Vibroseis" recording techniques can be successfully applied on the hard Hawkesbury Sandstone Formation.

Volcanics Project

Transposed recordings were made along the complete traverses and parts of the traverses were re-recorded using in-line and C.D.P. methods. Experimentation showed that the technique yielding the best results varied along the traverse; this was probably due to extreme variations in the surface and subsurface conditions. Fair quality reflections were recorded over most of the traverse using transposed methods. This was considered to be the result of effective compositing over 12,000 separate ray paths for each trace. A comparison of ten-fold C.D.P. recording and transposed recording is shown in Plate 5. The slower C.D.P. recording, one mile per day compared with almost two miles per day for transposed recording, was successful in improving the reflection quality. The improvement was probably due to the vertical stacking.

Gambier Limestone project

The noise tests indicated high-amplitude interference events with velocities of 2500, 3300, and 7200 ft/s. Fair quality reflection information was recorded at 0.8 to 1.0 second on the initial experimental work with a low-effort transposed method; no deep reflections were obtained and shallower poor quality events were obscured by the noise interference. After considerable experimentation, a transposed recording technique was developed using a minimum three-spread offset, 20 sweeps per trace, and a diamond shaped geophone pattern. The effective pattern length of vibrator and geophone patterns was 200 ft. All efforts made with transposed techniques were unsuccessful in substantially reducing the amplitude of the noise interference; however, some success was achieved with ten-fold C.D.P. recording as shown in Plate 6. The C.D.P. section shows better continuity than the transposed section but the quality of deeper reflection events was not improved, this was probably due to the reduction of ray paths composited with the particular C.D.P. technique used.

It would appear that the quality of "Vibroseis" recording is limited in this area by the high-amplitude interference waves. This noise problem would probably be less acute for shot-hole methods where the charges can be placed below the weathering layer.

Sand-cover project

The section shown for Traverse 1 in Plate 7 was recorded in an area of fair quality reflections off the sand cover. Apart from a noise test, only limited experimentation was carried out along Traverse 2 on the sand cover to the north of Traverse 1. The lengths of geophone and vibrator patterns represented a compromise for obtaining both shallow and deep reflections down to about 2 seconds.

The test showed that fair quality reflection information could be readily obtained on the sand cover using "Vibroseis" techniques by increasing the number of sweeps and the offset distance (Plate 7).

Effect of changing particular parameters

Records shown in Plate 8 have been selected to demonstrate the effects of changing particular recording parameters.

The transposed in-line comparison shows two recordings made on the same profile in approximately the same recording time. The transposed recording has a higher signal-to-background-noise ratio mainly because of increase in the number of ray paths composited per trace.

The sweep frequency comparison indicates that the 10-40 c/s sweep is superior to the 20-57 c/s sweep for recording on Hawkesbury Sandstone. Reflection events are discernible to 2.5 seconds on the 10-40 c/s sweep record compared with 0.9 second on the 20-57 c/s sweep record.

The number of sweeps comparison shows that although shallow reflections can be recorded to 0.7 second with 5 sweeps per trace, effective penetration to 2.5 seconds can be obtained with 10 sweeps per trace.

The offset comparison show high-amplitude good quality shallow events to 0.8 second and poor quality events deeper, with a one-spread offset. The shallow events deteriorate, whereas the deeper events are enhanced using the three-spread offset.

The pattern length comparison illustrates the use of 400 ft.-long vibrator and geophone patterns to suppress the high-amplitude first break arrivals. The recording tape was 100% modulated on these arrivals when 200-ft-long patterns were used and the later poorer quality reflection events are of too low level to be clearly seen.

CONCLUSIONS

The flexibility of the "Vibrosies" method was illustrated by the recording of fair quality seismic information in previously designated poor or no-reflection areas with unusual terrain.

Results were obtained in the built-up area with no resulting damage to roadways, water mains, houses, etc. However, the use of an optimum recording technique was not always possible owing to limitations imposed by the positions of houses, road intersections, water mains, railway lines, etc.

The test on the Hawkesbury Sandstone indicated that the "Vibroseis" method was capable of solving this area's problems; this was mainly due to the selection of a particular controlled sweep. The best methods for obtaining shallow and deep reflections differed.

The best recording technique was found to vary along the Volcanics traverses. Variations of technique were readily accomplished by "Vibroseis" methods since no predetermined extensive drilling programme was required.

C.D.P. recording techniques were used to improve the results in areas where poor quality results were obtained using transposed techniques; the "Vibroseis" is very adaptable to the use of C.D.P. methods. The high multiplicity of ray paths per trace inherent with "Vibroseis" recording techniques probably contributed largely to the success of the methods in this area.

High-energy noise, generated in the surface layers in the Gambier Limestone area by the "Vibroseis" method, limited the effectiveness of the method for obtaining good quality deep reflections. This noise was attenuated by C.D.P. recording, which improved the quality of the seismic data.

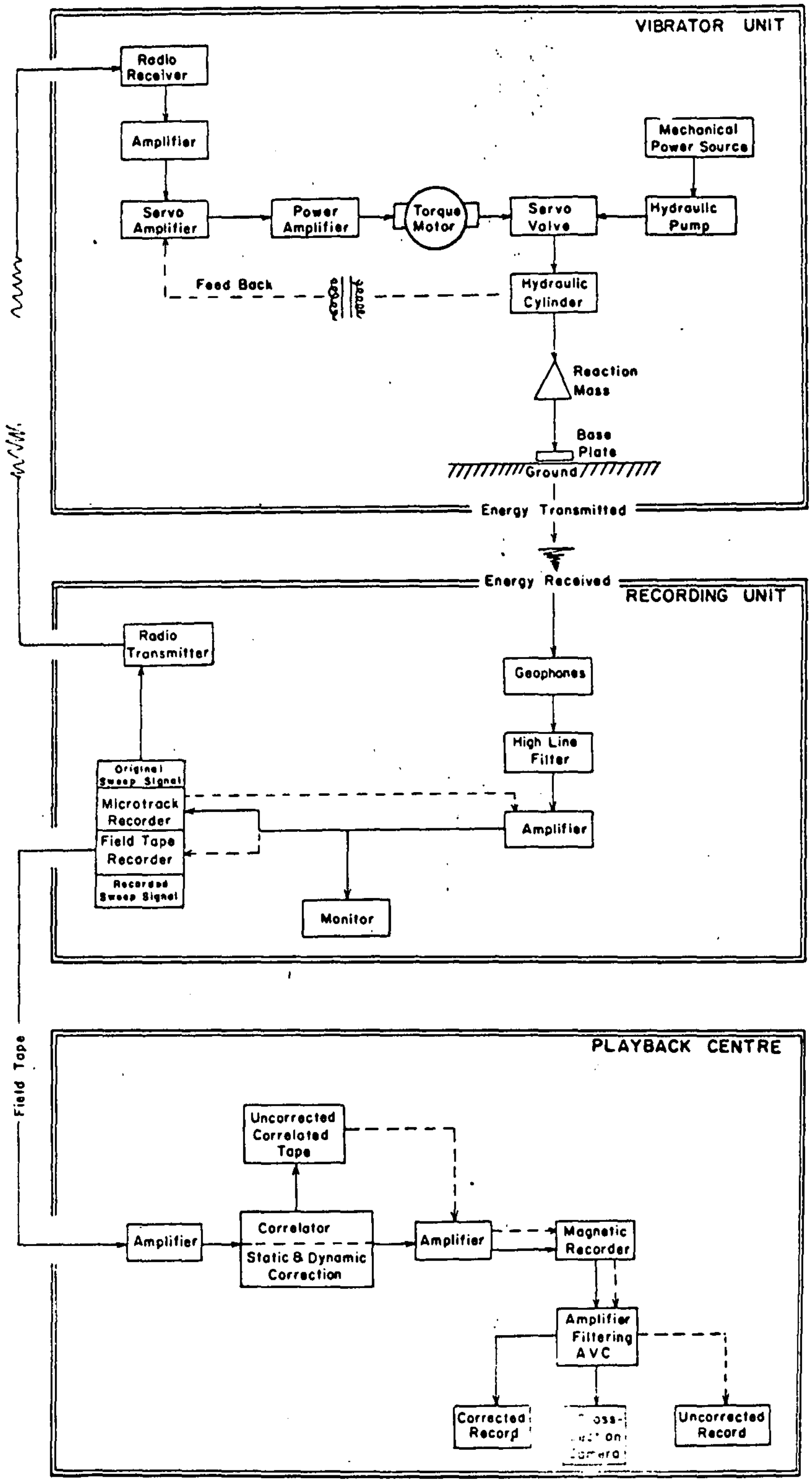
Penetration for recording deep reflections was achieved in the sand-cover area. However, a compromise of pattern length and offset distance was necessary for recording shallow and deep reflections.

The quality of results was generally not adversely affected by the assumption of uniform weathering layer thicknesses and velocities in the problem areas. This was probably due to the averaging of the effects of weathering variations by ground mixing and compositing. Some inconvenience was experienced in the delay necessary for correlation of the field recordings whereby the results of the experimental work could not be examined until some hours later; for production recording these delays are not important.

COMMENTS

The "Vibroseis" method, by virtue of its flexibility for rapidly carrying out a range of experiments, is able to approach an "optimum" technique much more quickly than shot-hole methods. Shot-hole methods, although they may employ different parameters from those of the "Vibroseis" method, are able to take advantage of experience gained when following a "Vibroseis" survey and may thus produce better records than a survey preceding the "Vibroseis". This has, in fact, proved to be the case in a current survey covering the Volcanics and Gambier Limestone areas mentioned above.

Since the "Vibroseis" test survey, further "Vibroseis" work has been carried out on Hawkesbury Sandstone in a built-up area on the outskirts of Sydney. Techniques adopted for the built-up area and Hawkesbury Sandstone projects in the test survey were combined for this survey. Other surveys have been carried out in the Gippsland Basin where C.D.P. methods were used to tackle a problem of multiple reflections, and in the Officer Basin where cartage of explosives, drilling water, etc. are problems, associated with the remoteness of the area.



"VIBROSEIS" SYSTEM

PLATE 2

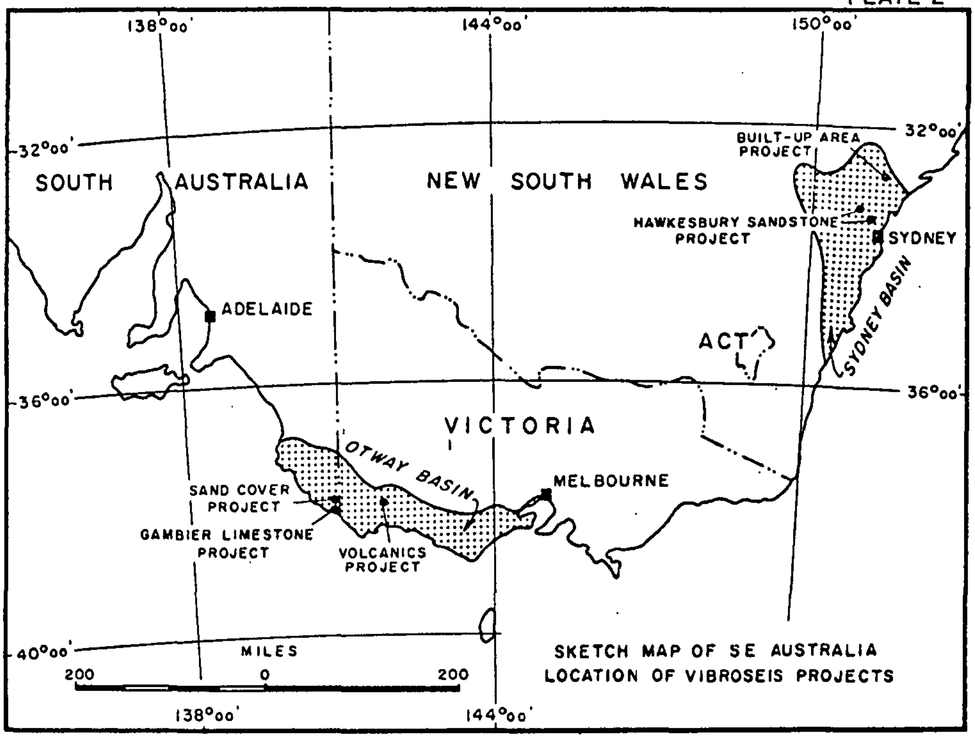
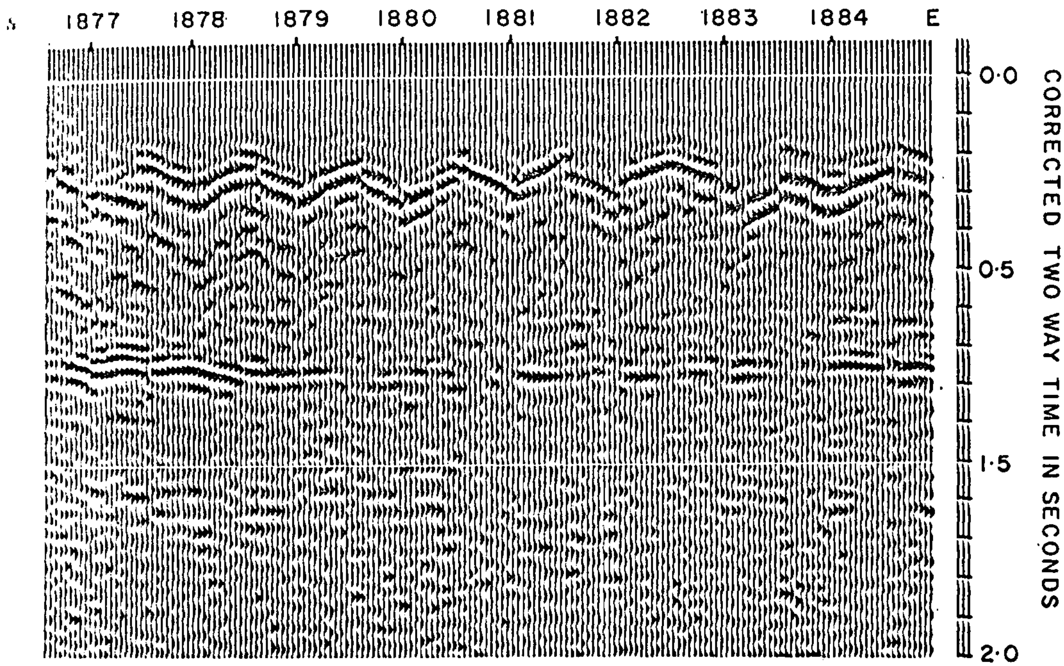

138°00'
144°00'
150°00'
32°00'
36°00'
40°00'
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
ACT
ADELAIDE
MELBOURNE
SYDNEY
BUILT-UP AREA PROJECT
HAWKESBURY SANDSTONE PROJECT
SYDNEY BASIN
OTWAY BASIN
SAND COVER PROJECT
GAMBIER LIMESTONE PROJECT
VOLCANICS PROJECT
MILES
200
0
200
SKETCH MAP OF SE AUSTRALIA
LOCATION OF VIBROSEIS PROJECTS

PLATE 3



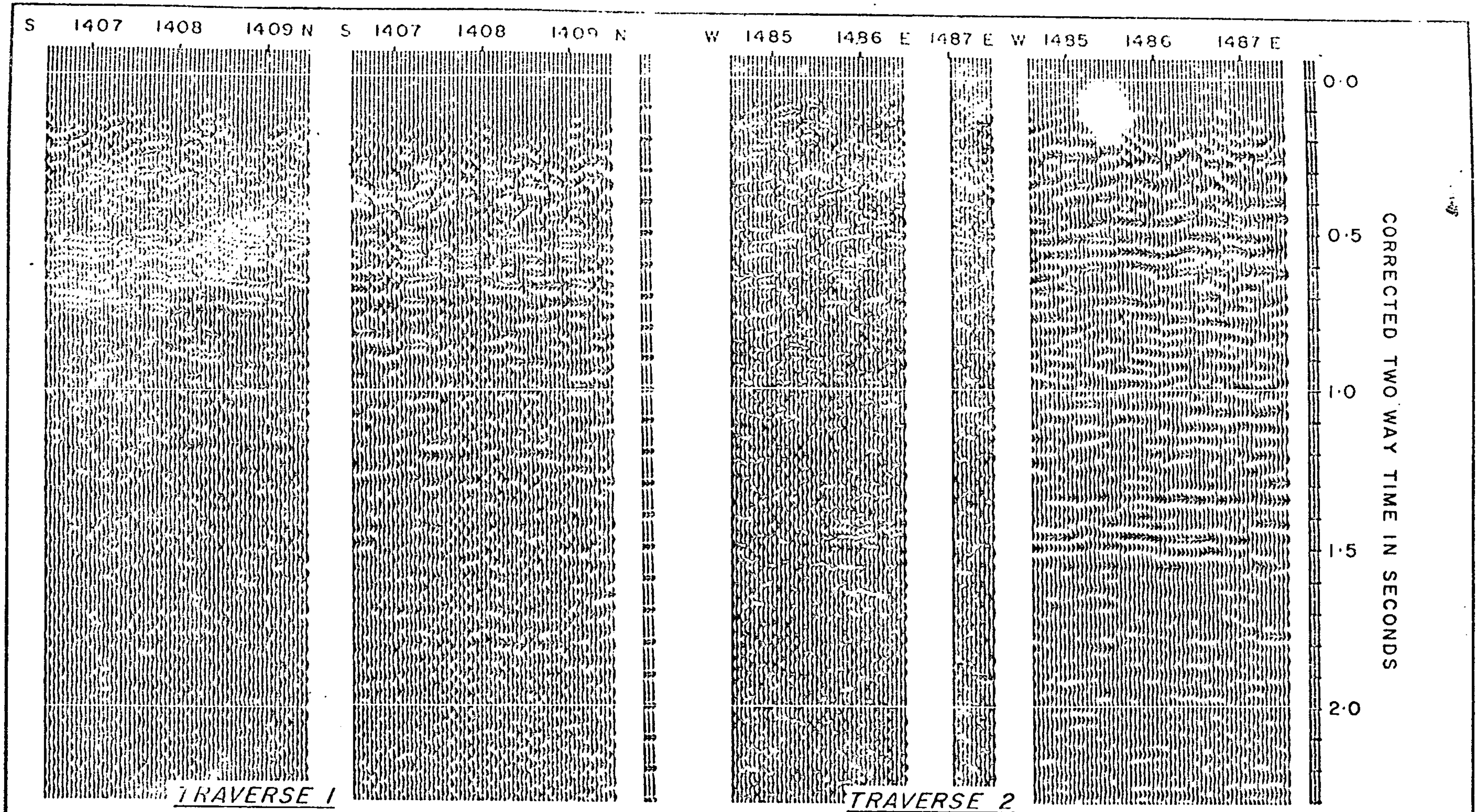
TRANSPOSED	RECORDING METHOD
10-40 c/s	SWEEP FREQUENCY
10	No. OF SWEEPS
1386-2574 ft	OFFSET DISTANCE
132 ft	VIBRATOR PATTERN LENGTH
400 ft L x 200 ft W (360 Geo) (Nominal)	GEOPHONE PATTERN

HORIZONTAL SCALE

0 1320 2640 3960 FEET

SECTION-BUILT-UP AREA PROJECT

G 438-22



TRAVERSE 1		TRAVERSE 2		
TRANSPOSED	TRANSPOSED	TRANSPOSED	TRANSPOSED	RECORDING METHOD
10 – 40 c / s	10 – 40 c / s	10 – 40 c / s	10 – 40 c / s	SWEEP FREQUENCY
10	20	20	20	No. OF SWEEPS
1386 - 2574 ft	2706 - 3894 ft	1386 - 2574 ft	2706 - 3894 ft	OFFSET DISTANCE
600 ft	1000 ft	1000 ft	1000 ft	VIBRATOR PATTERN LENGTH
600 ft L x 200 ft W	1000 ft L x 200 ft W	1000 ft L x 200 ft W	1000 ft L x 200 ft W	GEOPHONE PATTERN (360 Geo)

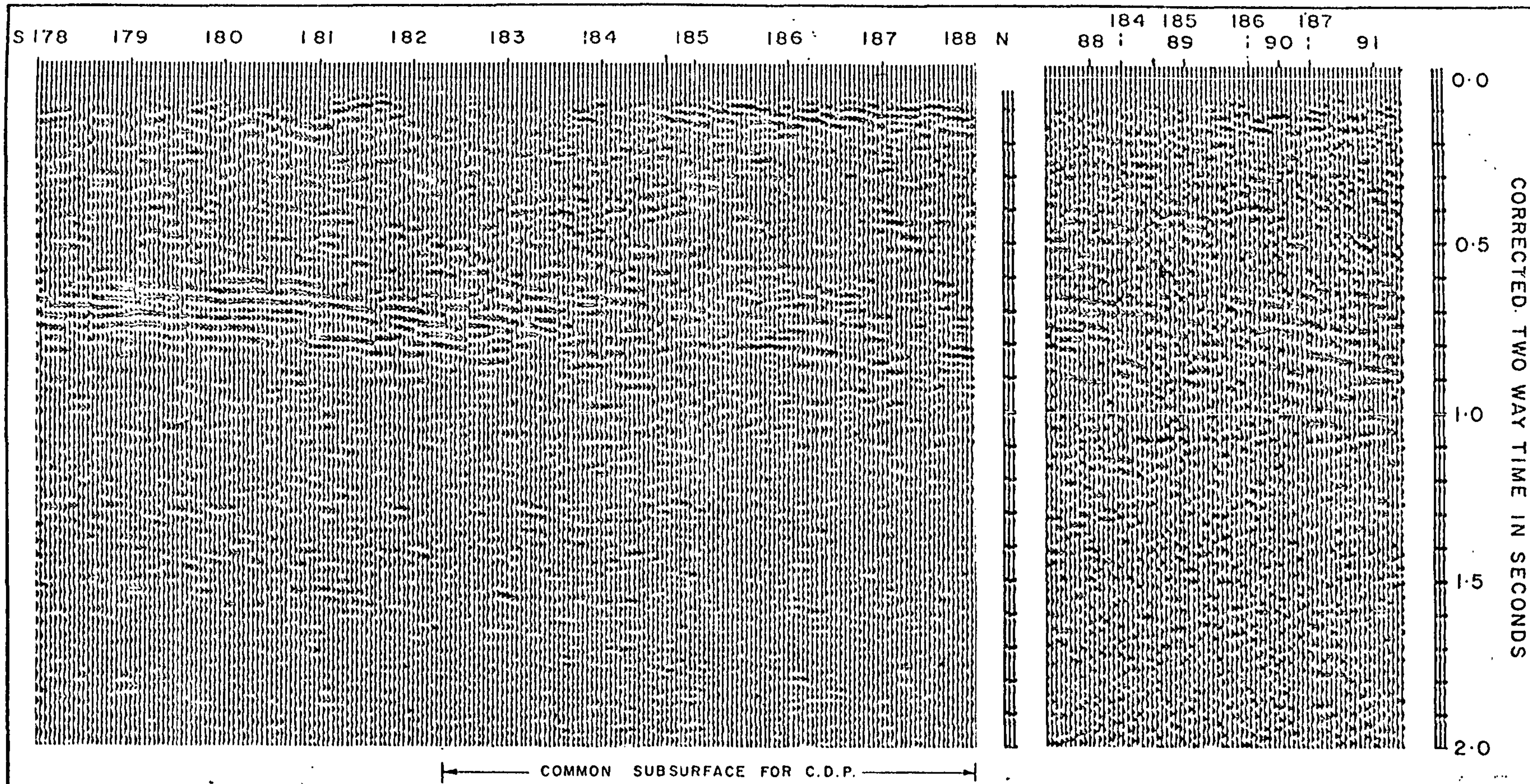
HORIZONTAL SCALE

0 1320 2640 3960 FEET

COMPARISON SECTIONS - HAWKESBURY SANDSTONE PROJECT

PLATE 4

G 43R-23



TRANSPOSED	10 FOLD C.D.P.	RECORDING METHOD
20-57 c/s.	20-57 c/s	SWEEP FREQUENCY
20	10	No. OF SWEEPS
924-1716 ft	726-3234 ft	OFFSET DISTANCE
400 ft	264 ft	VIBRATOR PATTERN LENGTH
400 ft L x 200 ft W (400 Geo)	264 ft (In line 40 Geo)	GEOPHONE PATTERN

HORIZONTAL SCALE

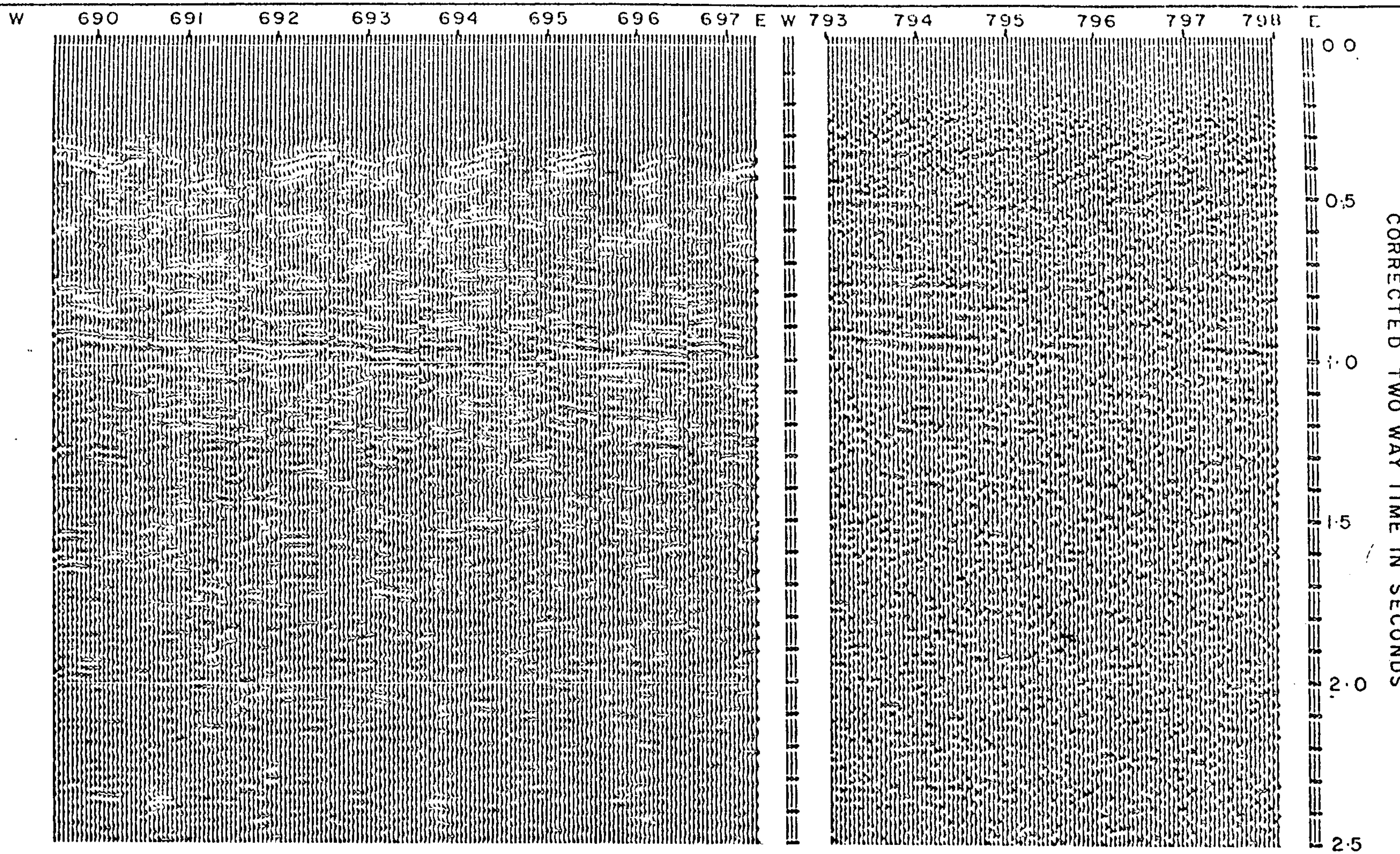
0 — 880 — 1760 — 2640 FEET TRANSPOSED

0 — 1320 — 2640 — 3960 FEET C.D.P.

COMPARISON SECTIONS—VOLCANICS PROJECT

G 438-24

PLATE 5



NOTE. SUBSURFACE COVERAGE SAME FOR BOTH SECTIONS

HORIZONTAL SCALE

0 — 880 — 1760 — 2640 FEET TRANSPOSED

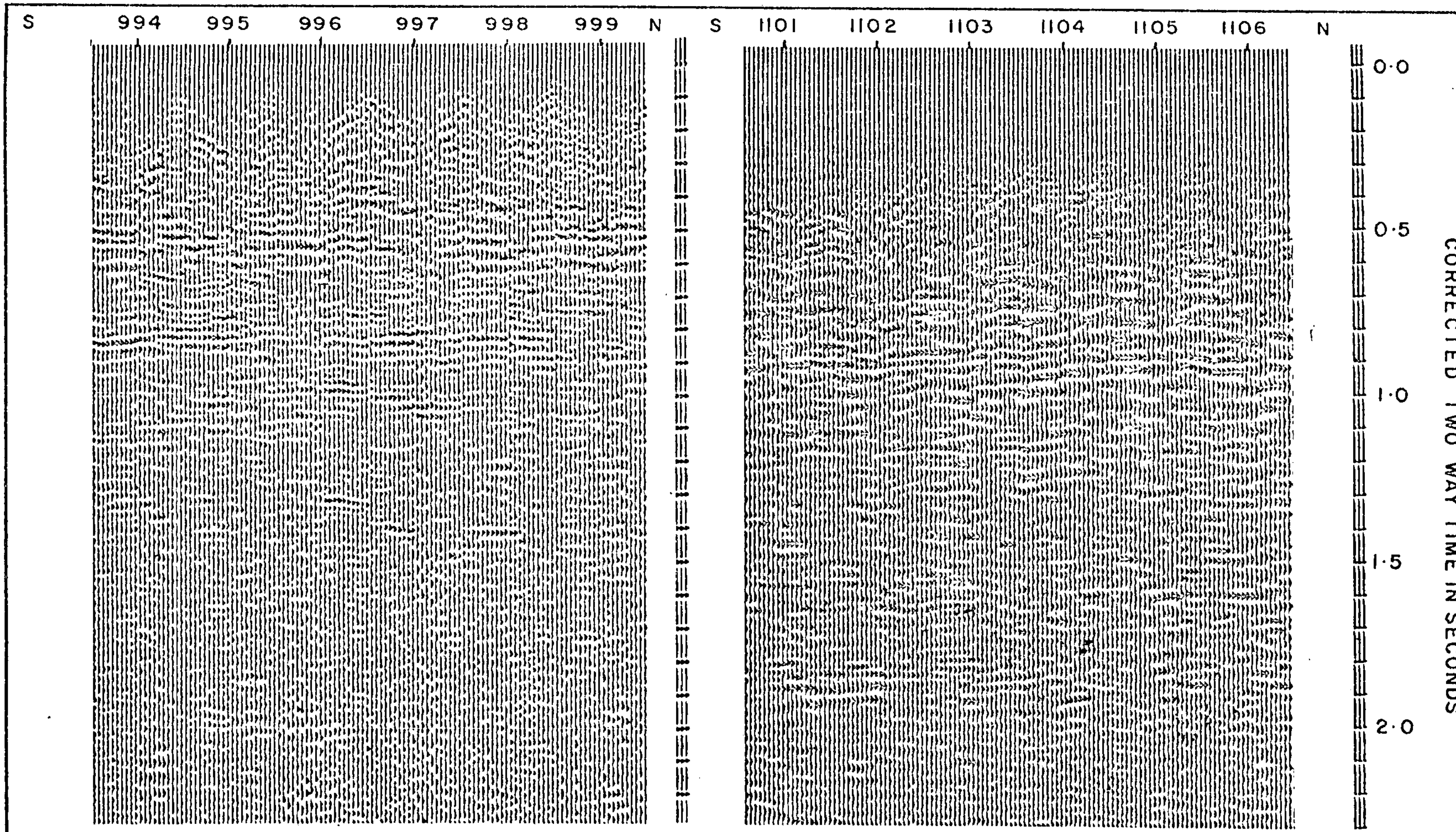
0 — 1320 — 2640 — 3960 FEET C.D.P.

TRANSPOSED	10 FOLD C.D.P	RECORDING METHOD
14–57 c/s	14–57 c/s	SWEEP FREQUENCY
20	10	No. OF SWEEPS
2684–3476 ft	1386–3894 ft	OFFSET DISTANCE
200 ft	200 ft	VIBRATOR PATTERN LENGTH
200 ft (Diamond 400 ft diagonal)(360 Geo)	200 ft (In line 40 Geo)	GEOPHONE PATTERN

COMPARISON SECTIONS–GAMBIER LIMESTONE PROJECT

G 438 - 25

PLATE 6



TRAVERSE 1

TRAVERSE 2

	Traverse 1	Traverse 2
RECORDING METHOD	TRANSPOSED	TRANSPOSED
SWEEP FREQUENCY	14 – 57 c / s	14 – 57 c / s
No. OF SWEEPS	10	20
OFFSET DISTANCE	924 – 1716 ft	1386 – 2574 ft
VIBRATOR PATTERN LENGTH	400 ft	400 ft
GEOPHONE PATTERN	400 ft L x 200 ft W (350 Geo)	400 ft L x 200 ft W (400 Geo)

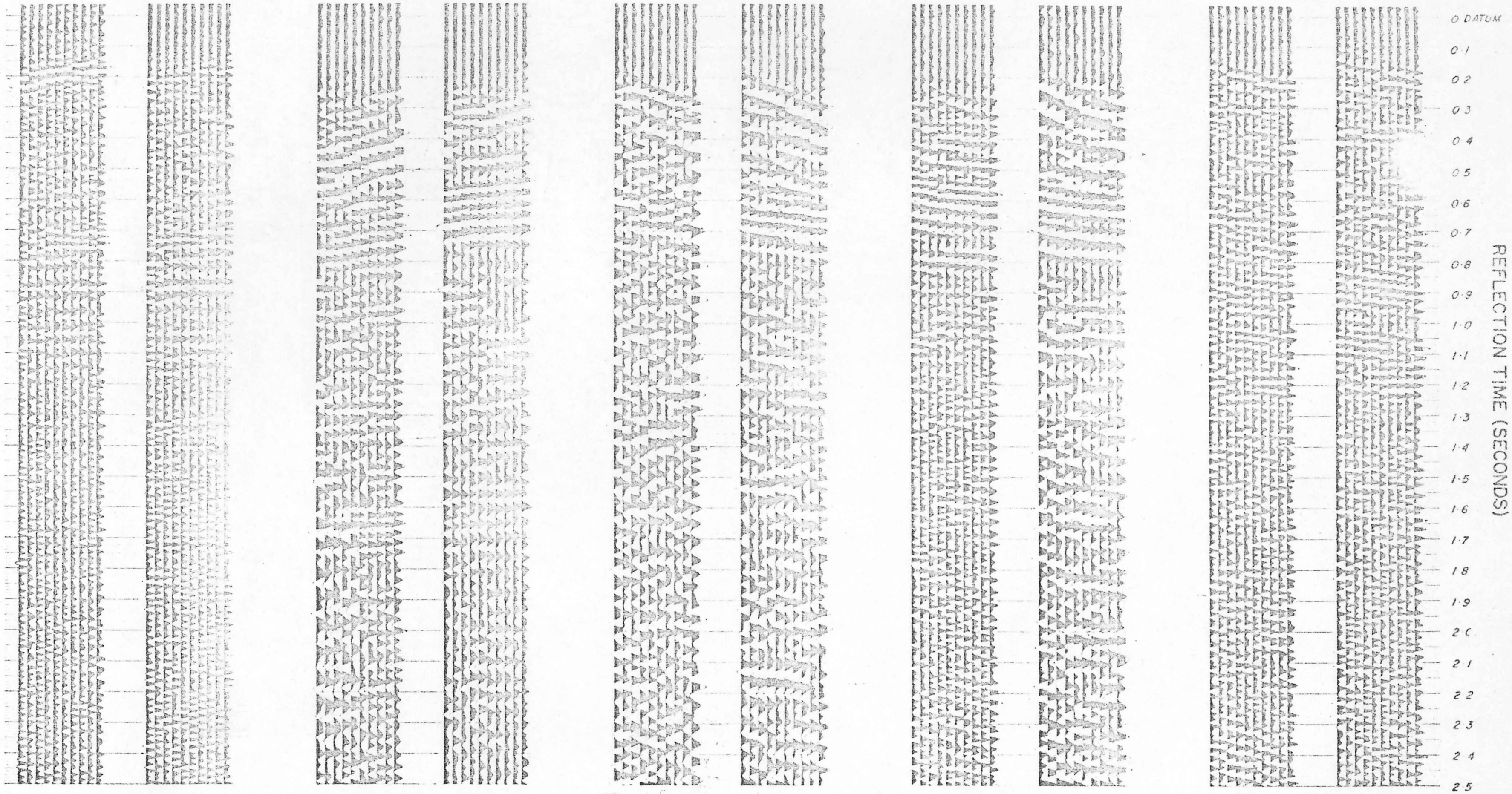
HORIZONTAL SCALE

0 880 1760 2640 FEET TRAVERSE 1
0 1320 2640 3960 FEET TRAVERSE 2

COMPARISON SECTIONS – SAND COVER PROJECT

G 438-26

PLATE 7



VOLCANICS 2 TRAVERSE
V.P. 186N
200' 400'
PATTERN LENGTH

HAWKESBURY SANDSTONE I TRAVERSE
V.P. 1403N
3 Spread 1 Spread
OFFSET

HAWKESBURY SANDSTONE I TRAVERSE
V.P. 1411S
5 Sweeps/trace 10 Sweeps/trace
No. OF SWEEPS

HAWKESBURY SANDSTONE I TRAVERSE
V.P. 1409S
20-57 c.p.s 10-40 c.p.s.
SWEEP FREQUENCY

VOLCANICS 2 TRAVERSE
V.P. 193S
In line Transposed
RECORDING METHOD

NOTE: Other parameters in comparison sets are identical

PARAMETER COMPARISONS

G 438 - 21

PLATE 8