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A RE-EVALUATION OF SEISMIC VELOCITIES RECORDED IN CALCRETES FLINDERS HIGHWAY TALIA-PORT KENNY-STREAKY BAY SECTION

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DEPARTMENT OF MINES

SOUTH AUSTRALIA

A RE-EVALUATION OF SEISMIC VELOCITIES RECORDED IN CALCRETES: FLINDERS HIGHWAY TALIA - PORT KENNY - STREAKY BAY SECTION

by

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TALIA - PORT KENNY - STREAKY BAY SECTION

ABSTRACT

In a survey performed to test seismic velocities measured in 1972 on calcrete in cuttings along the new Flinders Highway, it was found that substantially the same velocities were recorded. It seems reasonable to adopt the following limits for seismic velocities regarding rippability of West Coast calcretes:

below 3500 ft/sec - rippable;

from 3500 ft/sec to 5000 ft/sec - marginal (depending on the nature of the material to be ripped); above 5000 ft/sec - unrippable (requires blasting). The use of larger machines may result in greater production, but it is suggested that these limits should be adhered to irrespective of machine size and power.

It is interesting to note that there is evidence that Australian calcretes may have different chemical characteristics than most calcretes found in other countries. Further work is required on the whole subject of the engineering properties of Australian calcretes.

INTRODUCTION

This survey was carried out to test the seismic velocities recorded in a previous survey in 1972 (Dixon & Nelson, 1972).

The 1972 survey was made in an attempt to gauge rippability conditions in cuttings along the proposed new Flinders Highway between Talia and Streaky Bay. Most of the cuts were expected to be made in aeolianite with calcrete layers, the calcrete varying from a weak calcareous sandstone to a strong cryptocrystalline limestone. At this stage no information was available to relate the rippability of calcretes on the West Coast of Eyre Peninsula to their seismic velocities. However, the formations are similar in age and characteristics to those found in the Upper South-East of South Australia where the Department of Mines has made extensive investigations on rippability conditions, and this knowledge was used in assessing the rippability of the West Coast calcretes. It was estimated that blasting would be required in about 50% of the cuts. A report was prepared listing seismic velocities, geological conditions, and general recommendations. Attention was drawn to certain limitations in the seismic method and to the fact that only sample velocities were measured at points on each cutting. It was pointed out that the results interpreted from the seismic records gave only approximate depths and velocities over the length of the spread (120 feet) but that it was considered that these could be extrapolated as a guide to likely conditions over the length of the cut.

In 1974 McDonald Earthmovers, the contractors engaged in making the cuttings, reported difficulties in ripping the calcrete and J. Selby (Senior Geologist, Engineering Geology) investigated on 10.4.74. He recommended seismic work to check the velocities in representative cuts where greatest difficulties had been encountered. These were cuttings at chainages

152.000

161.800

171.600

& 179.500

This work was done in the period 24.4.74 to 5.5.74 by R.G. Nelson, Geophysicist, R.S. Turner, Senior Technical Officer, & B.A.C. Brice, Staff Field Assistant.

GEOLOGY

The geology of the area is discussed in Dixon & Nelson, 1972. The attached table (Table I) derived from work done by the Regional Mapping Section, from borehole records and site inspection is from this report.

CALCRETE (AFTER GOUDIE, 1972)

The term "calcrete" is used in preference to "Caliche" because "caliche" in addition to describing calcium carbonate deposits, has been used for materials as diverse as nitrates and gypsum" (Goudie, 1972; see also Crawford, 1965, p. 41). Goudie defines calcrete as "terrestrial materials composed dominantly but not exclusively of calcium carbonate, and involving the cementation of, accumulation in and/or replacement of greater or lesser quantities of soil, rock or weathered material primarily within the vadose zone. It does not, however, embrace cave deposits (for which tufa or travertine are accepted terms) marine deposits (such as beachrock), or lacustrine algal stromatoliths".

On a global scale calcretes are composed predominantly of calcium carbonate as microcrystalline calcite with a world mean value of 79.28%. The only areas where a divergence from this value occurs are India (mean - 61.02%) and Australia (mean 87 to 97%). The world mean value of the CaO:MgO ratio is 14:1 but the magnesium carbonate value can vary widely (e.g. in South Australia: 1.89% at Tailem Bend, Hd. Seymour to 45.41% at Arno Bay, Hd. Boothby: Johns, 1963, p. 54).

To summarize, the general chemical characteristics of calcretes are:

(1) high calcium carbonate content (as microcrystalline calcite),

(2) low magnesium carbonate content except in special localities

(3) moderately high (about 12%) silica content, and

(4) low silt and clay content in Mediterranean climates. There is a relationship between the calcium carbonate content and the silt and clay content.

SEISMIC VELOCITIES AND RIPPABILITY

It must be understood that there is no direct relationship between "rippability", itself an ill-defined term, and the seismic velocity of a rock. Manufacturers of tractor-ripping units provide charts which relate empirically the rippabilities of various generalized rock types to their seismic velocities. However, it is considered best to test the specific rock involved, or at least its nearest local equivalent, before making firm assessments of its rippability.

Rippability depends not only on the elastic properties of the rock involved, but also on the presence or absence of fractures, cleavage lines and joints, and the degree of weathering or breakdown of the cementing material. Thus, it can be appreciated that granites, whose normal velocity is in the range 14000 to 18000 ft/sec, can be ripped when weathered at velocities as high as 9000 ft/sec. Young calcretes, on the other hand, are far from being weathered.

There is no firmly established code for the use of the term "seismic velocity" in this context, but the velocity referred to is the velocity of compressional elastic waves through the rock. Refer to Plan No. S10943. Equation (1) shows the relationship between this velocity and the elastic properties of the medium involved. It can be seen that not only is the tensile strength involved but also the shear strength, the density and the incompressibility of the material. Thus, low-density rock salt deposits give velocities of up to 20000 ft/sec, and low-shear-strength, high-incompressibility water-saturated soils give velocities of around 5000 ft/sec. Neither of these materials is particularly noted for its high competence.

It is only when the velocity of shear waves through the material has been determined that estimates can be made of its elastic moduli as equations (2) to (4) will show. This velocity, will not normally be seen on the seismic refraction record unless special horizontal geophones and recording techniques are used. An attempt was made in this survey to measure some representative shear velocities, but the work is considered as experimental only.

PREVIOUS EXPERIENCE

Although the Department of Mines has made extensive studies of rippability for many years, our experience as far as calcrete was concerned before this survey was limited to the South-East of the State. However, although confined to a specific part of the State, the area involved was considerable, covering the 2000 or so square miles which contain the Tailem Bend-Keith pipeline. After an experimental survey (Nelson, 1970) which was used to relate the velocity characteristics of the calcrete to subsequent ripping tests some 200 miles of closely-spaced seismic tests were made along the pipeline route.

Plan No. 74-589 shows a histogram of the seismic velocities recorded: velocities in the range 2000 ft/sec to 5000 ft/sec were found to be most common; velocities above 8000 ft/sec were most infrequent. The success of this seismic work was one of the factors which enabled the Engineering & Water Supply Department to complete the project ahead of schedule at an estimated saving of $1,120,000. See Morris (1972) for further details.

Ripping on the Tailem Bend-Keith pipeline was done by a Caterpillar D8 tractor - ripper combination, often with another D8 tractor in tandem.

The tractor used on the Flinders Highway work was an Allis-Chalmers HD41, which, the manufacturers claim, can rip "caliche" to velocities of up to 9000 ft/sec.

It is not the intention of this report to make comparisons between the ripping capabilities of different tractors; it is merely to record scientifically and objectively the seismic velocities measured.

INSTRUMENTATION

A discussion of the various types of instrumentation used in seismic surveys of this nature is appropriate. The Department of Mines possesses a number of seismographs which are used extensively in shallow refraction studies. These are of three types.

(1) Interval timer

This is simply a device for measuring elapsed time. The time base is a crystal-controlled oscillator which is fed into an electronic counter when a gate circuit is opened by a triggering pulse from an energy source. Arrival of wave motion from a geophone sends a signal to shut this gate so that the elapsed time interval can be recorded. A gain control amplifier in the geophone input circuit controls the strength of the signal required to close the gate. However, premature closing of the gate by sufficiently strong random noise may occur, or sometimes there may be a delay due to the first arrival of energy being below the required signal strength. The only time which can be measured is that for the first arrival of sufficiently strong energy at the geophone. Later events cannot be timed.

This type of instrument has proved so unreliable that it is seldom used by us nowadays.

(2) <u>Single channel recorder</u>

This instrument, a Bison Model 1570B signal enhancement seismograph, amplifies and displays the seismic waveform on a cathode ray screen. The waveform is also stored in a 256 point matrix memory. The time base is an internal crystal-controlled clock. Repeated impulses from the energy source add to the waveform in memory so that random noise is cancelled and the signal-to-noise ratio is increased. There are two geophone inputs, allowing both horizontal and vertical geophones to be used at the same measuring station. When a marker is moved to coincide with any particular event on the seismic waveform, its corresponding arrival time can be read on a digital readout.

This instrument was used for the present survey, one 100 ft traverse being made on each of the four cuttings listed. An attempt was made to measure shear wave arrival times by using a horizontal geophone, but this work is considered to be experimental only as more experience in picking shear wave arrival times is considered necessary.

(3) Multichannel recorders

Two such systems are presently in use for shallow refraction surveys. One is a Texas Instrument Co. 7000B 24-channel recording seismograph, the other a 12-channel P19 recording seismograph from the same manufacturer.

At present the 7000B uses a Geospace R1801 electrostatic camera to produce recordings. Its paper speed is normally 20 inches/sec and timing lines produced by an electronic counting system are printed at 10 millisecond intervals.

The P19 system uses a camera whose timing system is controlled by a tuning fork. Timing lines are produced at 10 millisecond intervals by a rotating slotted cylinder. Recordings are made photographically on Kodak Linagraph paper which has to be developed and fixed. Paper speed can be set to 37 inches/sec.

Both these instruments were used on the present survey, the P19 being used for traverses where the geophones were set 5 ft apart. These traverses were made at 100 ft intervals along each cutting, with generally two spreads per cutting being made at right angles to these to check for anisotropic effects. The 7000B system was used with a geophone spacing of 30 ft on the cuttings at chainages 152.500 and 179.500 where the depth of cut is quite large and where there is also a certain amount of soil cover. These spreads were designed to detect deeper higher-speed refractors which might come close to the surface in places.

The 7000B system was used in the 1972 survey with a geophone spacing of 5 ft. A different camera system, similar to that used in the P19, was however used in this survey.

The advantage of such multichannel systems lie in the fact that each input channel has its own separate amplification and filtering system giving output to a galvanometer coil which permits an analogue of the seismic waveform to be recorded photographically. A correlation is possible from trace to trace across the record; later events may be picked more readily; and it is possible to make a more complete study of the mechanism of the seismic propagation. Moreover, once a spread has been laid down it is possible to make multiple shots along the spread without changing geophone stations.

INTERPRETATION PROCEDURES

In this survey, seismic velocities have been recorded at various chainages along each cutting. Because each cutting had either been made, or was in the process of being made, it was impossible to recoccupy the sites used in the 1972 survey.

The recordings made using the P19 system and geophones at 5 ft spacing were from shots fired at each end of the spread. These reciprocal shots gave data amenable to analysis by the method reviewed by Hawkins (1961). The seismic records were timed and plotted as time-distance graphs and then Hawkins' analysis was applied. It is well-known that when shooting updip over a dipping bed the velocity measured is greater than the true velocity of the bed, and similarly, when shooting downdip, the apparent velocity is less than the true velocity. The true velocity can be calculated from the following relationship:

$$v = 2 \cos x \, (v+ . \, v- / (v+ + v-))$$

v+ = updip velocity

v- = downdip velocity

x = angle of dip.

Where bedrock is overlain by an irregular covering of soil it can be considered as consisting of a sequence of random dips, first updip and then downdip. When it is realized that a mere 6 inches of soil having a velocity of 500 ft/sec (which is of the order of soil velocities measured in this survey) can produce a time delay of 1 millisecond, it can be seen that such delays will lead to a time-distance curve consisting of an irregular set of points (see, for example, the hammer seismic data for ch 179.5, Plan No. 74-705). In order to obtain the true velocity of the bedrock it is necessary to correct these errors, and it is this that reciprocal analysis as outlined by Hawkins sets out to achieve.

Depth estimates were made, assuming either horizontally stratified or dipping layers using conventional methods.

RESULTS

(1) Cutting at drainage 152.500

Dense mulga scrub covered most of this cutting which reaches a maximum depth of 4.6 feet at 152.500. Sheet calcrete crops out in places, but there is generally 1 ft or so of soil cover.

The original survey showed the following:

at ch 152.500

1.7 ft of 1300 ft/sec material overlying 5000 ft/sec material;

at ch 152.800

3.1 ft of 1700 ft/sec material overlying 4950 ft/sec material.

The results of the P19 and 7000B work are shown in Plan No. 74-707. The near-surface sampling of velocities and thicknesses made using the P19 system can be seen to be in good agreement with that of the original survey. The 7000B work, which was designed to test for deeper-seated refractors, shows that a 14200 ft/sec refractor exists at depths estimated at from 55 ft near ch 152.700 to 123 ft near ch 152.100. This is assumed to be granite. The initial velocities in the 7000B recordings ranged from 5550 ft.sec to 6525 ft/sec and for the purposes of depth estimation to the 14200 ft/sec refractor it is assumed that these shallower layers are not underlain by lower velocity layers.

However, local borehole information (see below) indicates that the hard calcrete layer may be underlain by dry sands whose velocity is possibly only about 1500 to 2000 ft/sec. If this is the case then the depths are probably overestimated; if the calcrete layer is assumed to be 6 ft thick, as the borehole information would tend to suggest, then the depth estimates should be reduced by about 50%. Where the granite lies closer to the surface, the depth estimates assuming a continuous 5000 ft/sec refractor will be more accurate as the assumed 2000 ft/sec layer will become thinner.

Log of bore No. 1C, Section 142, Hd. Rownsevell

From	Depth to	Nature of strata
0'	2'	Chocolate brown topsoil
2'	8'	Light brown flinty travertine and some lateritic gravel
8'	20'	Brown clayey fine sand and a little coarse sand - calc
20'	28'	Yellow fine sand and some fine quartz gravel - calcar
28'	35'	Do, but light yellow - slightly calcareous

35'	61'	Off-white kaolinitic clay and smoky quartz
61'	63'	Smoky quartz gravel and some white clay
63'	64'	Grey granite

End of bore 64 ft

Logged by C.F. Wegenar 12.4.50

Static water level 43 ft.

Time-distance graphs for the Bison hammer seismic work done between ch 152.300 and 152.400 are shown in Plan No. 74-702. What seems to be a 16000 ft/sec refractor appears on one of the time-distance graphs. This could be due to a granite knob lying at a depth of 23 ft from the surface as shown in Interpretation II (and the 7000B work would tend to confirm this).

It could also be assumed that this effect could be due to a lithological change within the calcrete. This is considered unlikely because while there is an apparent velocity change to 16000 ft/sec on traverse A in the Bison results (see Plan No.74-702), there is no apparent change in the reciprocal shot (traverse B). However, Interpretation I is included to show that the effect could be caused by a 20 ft wide slab of 8000 ft/sec material lying between ch 152.370 and 152.390. Calcrete in the rest of the spread has a velocity of 4384 ft/sec according to the Bison work. This is in excellent agreement with the P19 work.

(2) <u>Cutting at chainage 161.800</u>

The variability of the calcrete in this cutting is shown by the fact that a borrow pit containing soft rubble has been dug on the western side within a few yards of the new road. It extends north from near ch 161.900 and yet difficulty was experienced in ripping this cutting over nearly all of its length.

This variability is shown in the seismic velocities measured (see Plan No. 74-708). For example in the spread located at ch 161.500 the maximum and minimum velocities recorded over a 60 ft traverse length were 7000 ft/sec and 3250 ft/sec. It is reflected in the histogram for calcrete velocites in this cutting (see Plan No. 74-590), which shows a broad maximum in the range 3000 ft/sec to 6000 ft/sec. It is the only possible explanation for the discrepancy between this survey and the 1972 survey which showed velocities of the order of 3200 ft/sec at ch 161.500 and 161.800. The notion of extrapolating the results of sample velocities obviously has not worked for this cutting. Nevertheless, velocities are well below 9000 ft/sec. An assessment using the criteria of the 1972 survey and the more detailed results of this survey would certainly have indicated that some blasting would be required. Such in fact was the geologist's recommendation (Dixon & Nelson, 1972; Table A1, p. 16).

No 7000B work was done on this cutting, but the Bison hammer seismic spread, made between ch 161.600 and 161.700 shows a velocity of 5688 ft/sec after reciprocal analysis has been applied. See Plan No. 74-703.

(3) <u>Cutting at chainage 171.600</u>

No seismic work was done over this cutting in the 1972 survey, the nearest spread being 400 ft away at ch 172.000 where a velocity of 3950 ft/sec was indicated.

The present survey shows that the calcrete over this cutting has a fairly high velocity range of generally 6000 ft/sec to 8000 ft/sec. The Bison hammer seismic spread (see Plan No. 74-704) between ch 171.500 and 171.600 gives a velocity of 6940 ft/sec which agrees closely with the P19 work (see Plan No. 74-709). No 7000B work was done here.

Although velocities are less than 9 000 ft/sec. this cutting would certainly have been classified as unrippable according to the criteria of the original survey. The geologists' original assessment was:

"0-? ft. rippable with difficulty. Some blasting".

(4) <u>Cutting at chainage 179.500</u>

Deep mulga scrub and a 3-4 ft. layer of sandy soil covered this cutting.

The 1972 survey gave the following figures:

at ch. 179.300

5.7 ft of 1 550 ft/sec. material

overlying 5 000 ft/sec. material;

at ch. 179.500

2.3 ft of 750 ft/sec. material,

followed by 13.0 ft of 2 900 ft/sec. material

overlying 7 800 ft/sec. material.

The present survey confirms this velocity distribution as inspection of Plan No. 74-710 will show. The locations of the spreads used in this survey are indicated on the same plan. These differ from the 1972 spread locations because the cut had at this stage been made. The rippable material would seem to have velocities in the range 4 540 ft/sec. to 6 275 ft/sec. (ch.179.500 and 178.900 respectively). This is confirmed by the Bison hammer seismic spread between ch. 179.500 and 179.600 which gives a velocity of 4 370 ft/sec. (see Plan No. 74-705).

a 690 ft traverse with geophones at 30 ft intervals and centres at ch. 179.500 was made here using the 7000B system. This shows an 8 279 ft/sec. refractor at depths of 15 ft. and greater, as indicated in the original survey. It is possible that this refractor may have been encountered in the deeper parts of the cut. Nevertheless, its velocity does not deviate much either way from 8279 ft/sec, as the reciprocal analysis shows. The 8279 ft/sec velocity is derived from linear regression of the corrected travel times vs. distance. The correlation coefficient is 0.9994. That the deviations of the corrected travel times from the mean do not have a linear trend is shown by a Spearman's rank correlation coefficient test: the value computed is a low 0.0667. That the deviations from the mean are random is shown by application of the theory of runs to the sequence of positive and negative deviations.

The probability that the sequence shown in Plan No. 74-706 is random is 0.214 which is accepted at the 95% level of confidence.

Thus, the majority of seismic velocities which should have been encountered in this cut are in the range 500 ft/sec to 6275 ft/sec. The greatest velocity encountered within a depth of forty or so feet is 8279 ft/sec which is calculated to be within 15 ft of the surface at ch 179.500. No velocity greater than 9000 ft/sec was found. Yet the cutting required blasting.

CONCLUSIONS

An overall appraisal of the results of this survey indicates that the distribution of velocities agrees with the findings of the 1972 survey. It would seem that where velocities of greater than 5000 ft/sec are encountered the material is rippable only with great difficulty and if one accepts that the definition of rippability must include a condition of economic productivity then it must be called unrippable. Where previously material of up to 4000 ft/sec was classed as rippable, with a marginal range of from 4000 ft/sec to 6000 ft/sec it now seems reasonable to reset the marginal range to from 3500 ft/sec to 5000 ft/sec. For a definition of the term "marginally rippable" see Dixon and Nelson, 1972, Appendix B., p. 4.

RECOMMENDATIONS

Further studies of calcrete velocities and rippabilities should be made. These should include investigations of

(1) the mechanism of seismic wave propagation

(2) the effect of grain size and character, and the properties of the cementing matrix on velocities

(3) the power spectrum of the waveform (is the velocity frequency-dispersive?)

(4) the velocities of individual samples (tests were made using reflected microwave techniques at AMDEL but scattering of the incident energy from individual grains rendered them useless; special apparatus would need to be constructed),

(5) anisotropy effects due to horizontal laminations within sheet calcrete,

(6) the elastic properties of individual samples.

In particular, an uphole seismic survey at ch 179.500 could yield interesting results.

2nd September, 1974
RGN:IA

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Plate I. Cutting at 152.100 looking East.

Plate II. Cutting at 161.800 looking West.

Note borrow pit in background.

Plate III. Cutting at 171.5 looking North.

Plate IV. Cutting at 179.500 looking south.

A P P E N D I X 1

SUMMARY OF GEOLOGY OF AREA BETWEEN TALIA AND STREAKY BAY

SUMMARY OF GEOLOGY OF AREA BETWEEN TALIA AND STREAKY BAY

APPROXIMATE THICKNESS (FEET)	AGE	UNIT AND ENVIRONMENT OF DEPOSITION	GEOLOGICAL DESCRIPTION AND TOPOGRAPHIC EXPRESSION	ENGINEERING DESCRIPTION
0 - 30(?)	CAINOZOIC Quaternary (Recent)	Semaphore Sand. Coastal aeolian sand dune.	White and pale brown calcareous sand and shell grit of modern beaches and dunes.	Gravelly sand, loose. Generally dry to humid but varies with rainfall. Occurs about chainage 72 000.
0 - 10	Quaternary (Pleistocene)	Calcrete in Bakara Soil. Ripon calcrete at base. Aeolian soil with chemically precipitated lime horizons	Cream to light brown limy soil with calcrete nodules from 2 mm to 15 cm diameter, or as platy deposits. Nodules and plates frequently cemented to form cream to pink "sheets" or blocky calcrete.	Silt soil, gravelly with rock horizons which vary in extent and thickness, and in strength from weak to strong rock. Humid. Occurs along most of the road.
0 - 100	Quaternary (Pleistocene)	Bridgewater Formation. Aeolian and lacustrine.	Yellow brown calcarenite with occasional clay beds. Outcrops in between ridges and sheets of calcrete.	Silty sand with some gravel. Mainly loose but sometimes cemented to weak sandstone. Occasional layers of clay soil, high plasticity, very stiff. Occurs in some places along road.
Unknown	PROTEROZOIC Adelaidean(?)	Pandurra Formation Equivalent. Marine sediments.	Brown conglomerate and arkosic sandstones. Outcrop along coast south of Venus Bay.	Medium strong to strong rock when fresh. Does not outcrop along road. Not likely to occur in proposed cuts.
Unknown	PROTEROZOIC Carpentarian	Crystalline basement.	Granite and granitic gneiss. Outcrops along coast and as isolated hills either side of road near chainage 150 000.	Vary from micaceous sands and silts to strong rock depending on degree of weathering. Not likely to occur in proposed cuts.

A P P E N D I X 2

Log of Bore No. A, Hd. Rounsevell, Section 192

Log of Bore No. A, Hd. Rounsevell, Section 192

(near ch 179.500)

Depth From	Depth To	Nature of Strata
0'	2'	TOPSOIL Sand, fine grained, very silty. Drains are mainly calcite and shell fragments from silt size to 0.2 mm. Organic rich, numerous plant root remains. Numerous sub-rounded fragments of calcrete to 10 mm. Grey to grey-brown.
2'	23'	AEOLIANITE. Fine to medium grained, uncemented to weakly cemented. Grains are calcite, shell fragments and grey carbonate to 0.5 mm., a few shell fragments to 1.5 mm. Some organic material towards top. Light greyish-brown at top grades to pale whitish brown at bottom.
23'	33'	CALCRETE Aeolianite, fine to medium grained. Very strongly cemented. Contains abundant angular fragments of dark grey carbonate to 2 mm. Less well cemented and slightly silty and clayey towards bottom. Red-brown to pinkish.
33'	43'	AEOLIANITE. Mainly medium-grained, moderately to weakly cemented. Grains are calcite and shell fragments, some grey carbonate 0.1 to 1 mm. Generally slightly silty and clayey. Pale reddish brown to whitish brown.
43'	52'	AEOLIANITE. Well graded, weakly to strongly cemented. Grains are mainly calcite and shell fragments, 0.1 to 2 mm. Silty and clayey. Pale whitish brown to whitish.
52'	55'	CLAY, slightly sandy. Grains mainly quartz sub-rounded, to 0.5 mm. Grey, red-brown and yellow-brown.
		END OF BORE: 55'
		No water cut

A P P E N D I X 3

Log of Bore 6A, Hd. Rounsevell, Section 193

Log of Bore 6A, Hd. Rounsevell, Section 193

(near ch 179.500)

Depth From	Depth To	Nature of Strata
0	30	Existing well
30	38	Mottled Clay
38	46	Light brown, dine soft sandstone (slightly calcareous)
46	58	Yellow sand with coarse gravel (slightly calcareous)
58	64	Grey, coarse quartz gravel and sand.

BORE ENDED AT 64'

LOGGED BY A. MASON

23.11.51

Static Water Level 25 ft

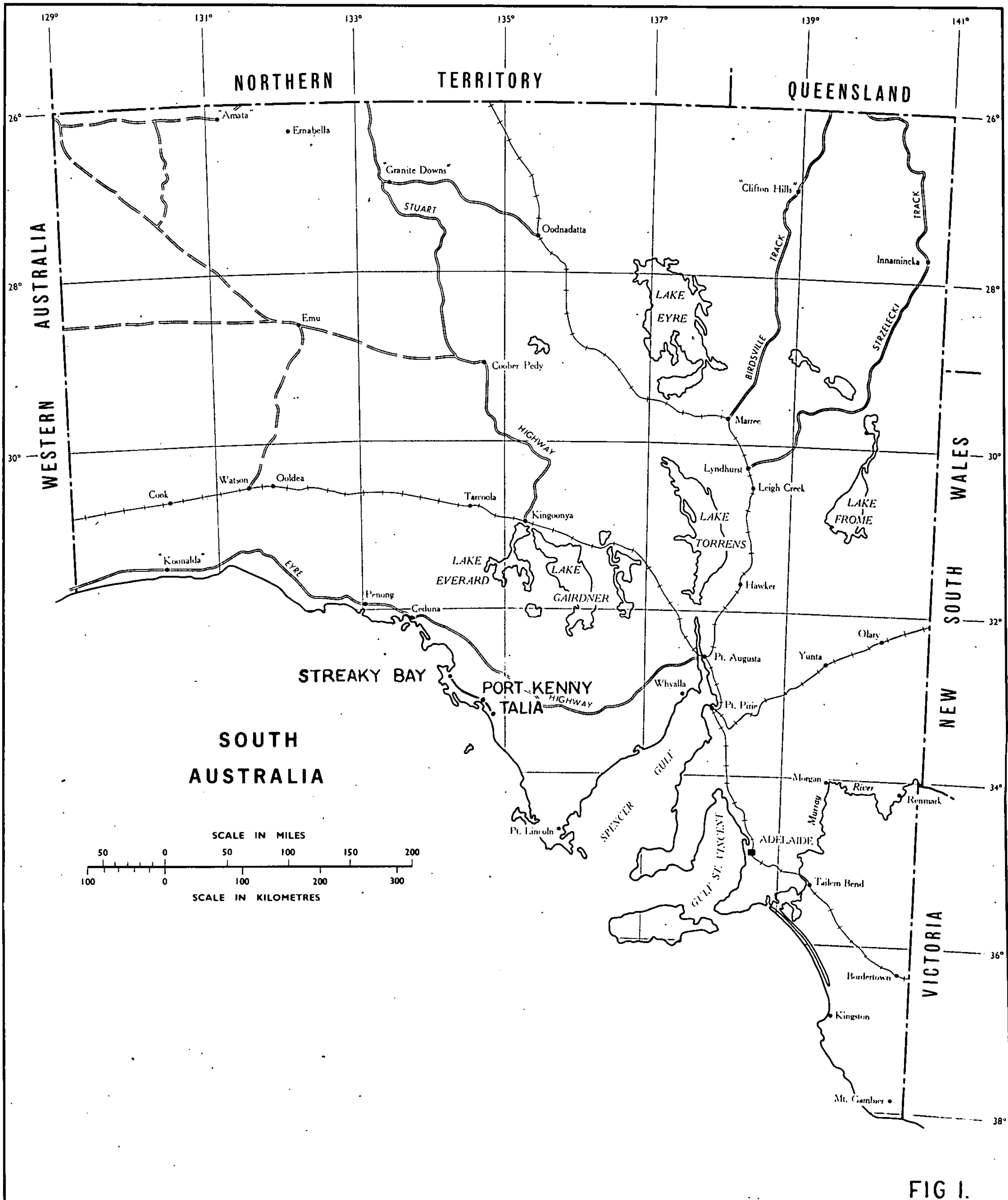


FIG I.

ENGINEERING GEOLOGY SECTION	DEPARTMENT OF MINES —— SOUTH AUSTRALIA	Scale : As shown.
Compiled. H. DIXON	FLINDERS HIGHWAY TALIA – PORT KENNY – STREAKY BAY SECTION LOCALITY PLAN	Date: 27 March 1972
Drn. J.M.B / Ckd.		Drg. No. S9780 Dgh+l

P.F. No. 55850 994.2

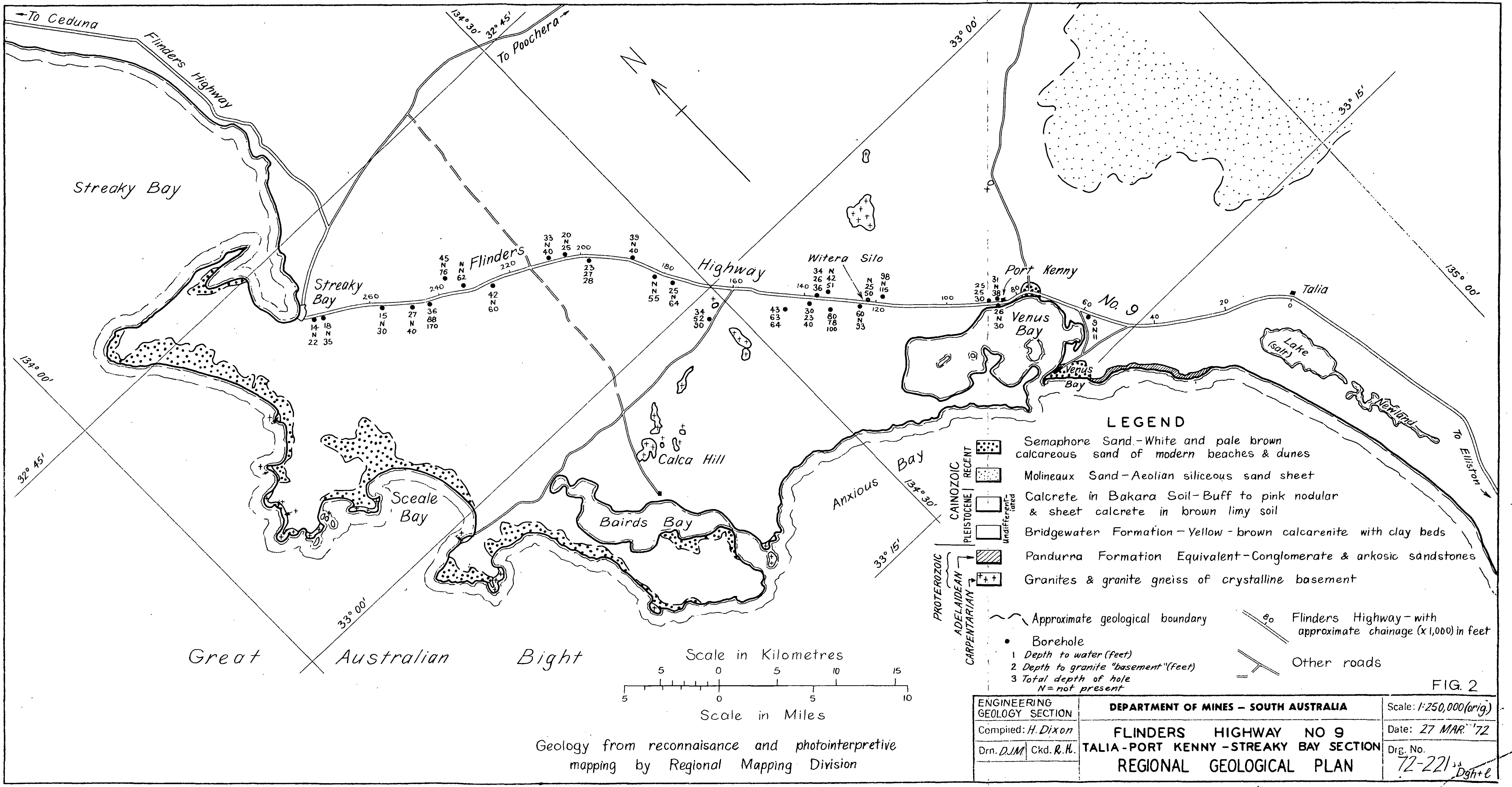


FIG. 2

ENGINEERING GEOLOGY SECTION	DEPARTMENT OF MINES – SOUTH AUSTRALIA	Scale: 1:250,000 (orig.)
Compiled: H. Dixon	FLINDERS HIGHWAY NO 9	Date: 27 MAR. '72
Drn. DJM Ckd. R.H.	TALIA-PORT KENNY-STREAKY BAY SECTION	Drg. No.
	REGIONAL GEOLOGICAL PLAN	72-221

V_p = Compressional wave velocity

V_s = Shear " "

E = Young's modulus

k = Bulk or incompressibility modulus

μ = Shear modulus

σ = Poisson's ratio

ρ = Density

$$V_p = \sqrt{\frac{E}{\rho} \cdot \frac{(1-\sigma)}{(1+\sigma)(1-2\sigma)}} = \sqrt{\frac{k + \frac{4}{3}\mu}{\rho}} \qquad (1)$$

$$V_s = \sqrt{\frac{\mu}{\rho}} = \sqrt{\frac{E}{\rho} \cdot \frac{1}{2(1+\sigma)}} \qquad (2)$$

$$\sigma = \frac{\frac{1}{2}\left(\frac{V_p}{V_s}\right)^2 - 1}{\left(\frac{V_p}{V_s}\right)^2 - 1} = \frac{1}{2}\left(\frac{\frac{k}{\mu} - \frac{2}{3}}{\frac{k}{\mu} + \frac{1}{3}}\right) \qquad (3)$$

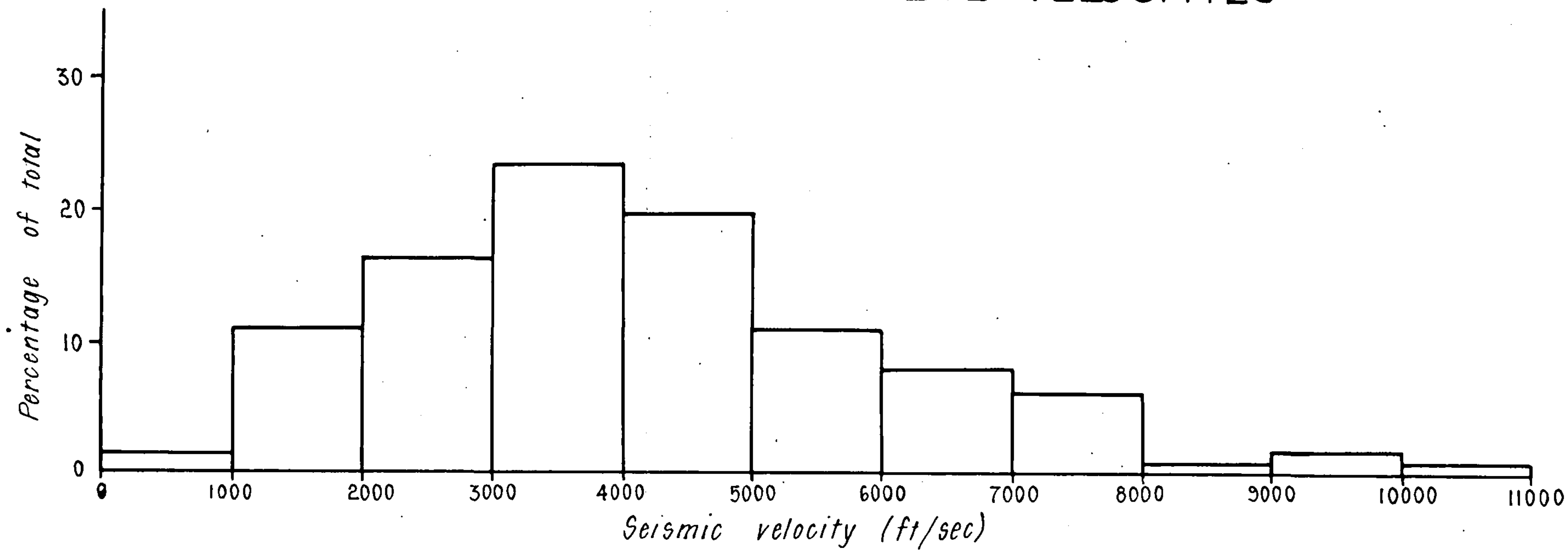
$$E = \rho V_s^2 \left(\frac{3V_p^2 - 4V_s^2}{V_p^2 - V_s^2}\right) \qquad (4)$$

Nb A homogeneous isotropic material is assumed

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
EXPLORATION GEOPHYSICS	Drn. R.N.	RELATIONS BETWEEN SEISMIC VELOCITIES AND ELASTIC CONSTANTS	SCALE:
	Tcd. B.W.		S10943 Dg + L
R. NELSON GEOPHYSICIST	Ckd.		
	Exd.		DATE: 8 Aug 1974

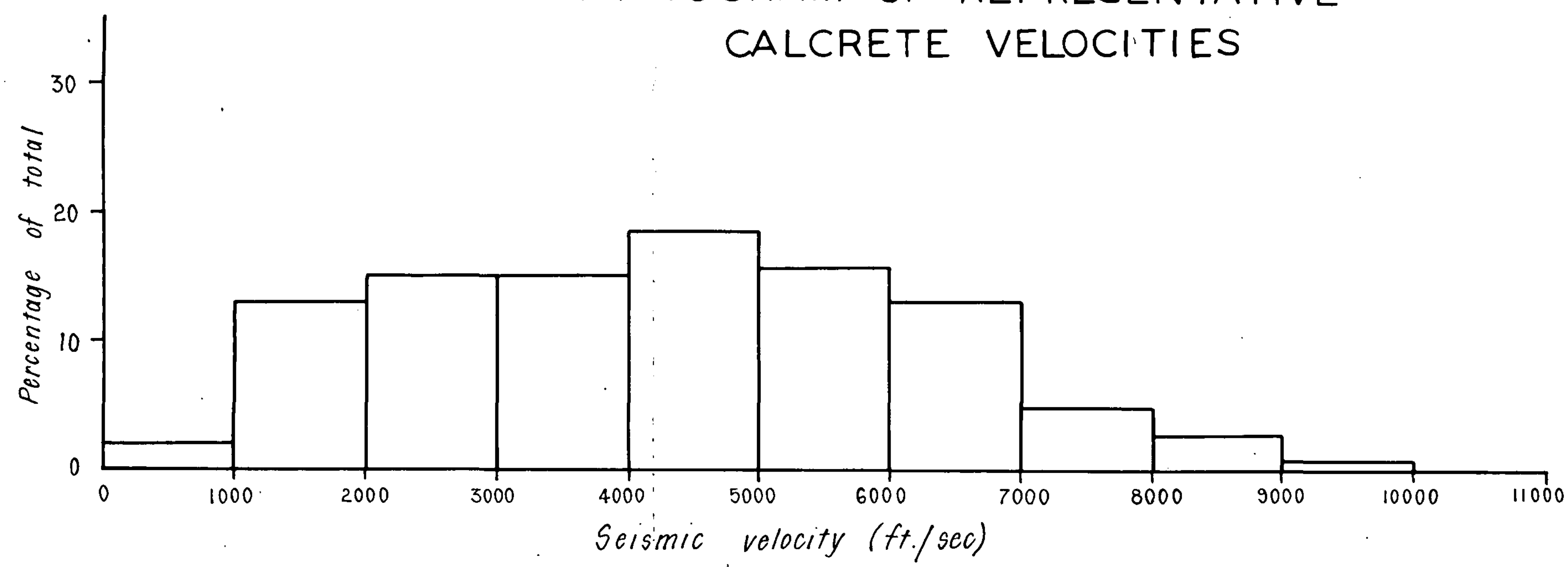
TAILEM BEND — KEITH PIPELINE

HISTOGRAM OF REPRESENTATIVE CALCRETE VELOCITIES

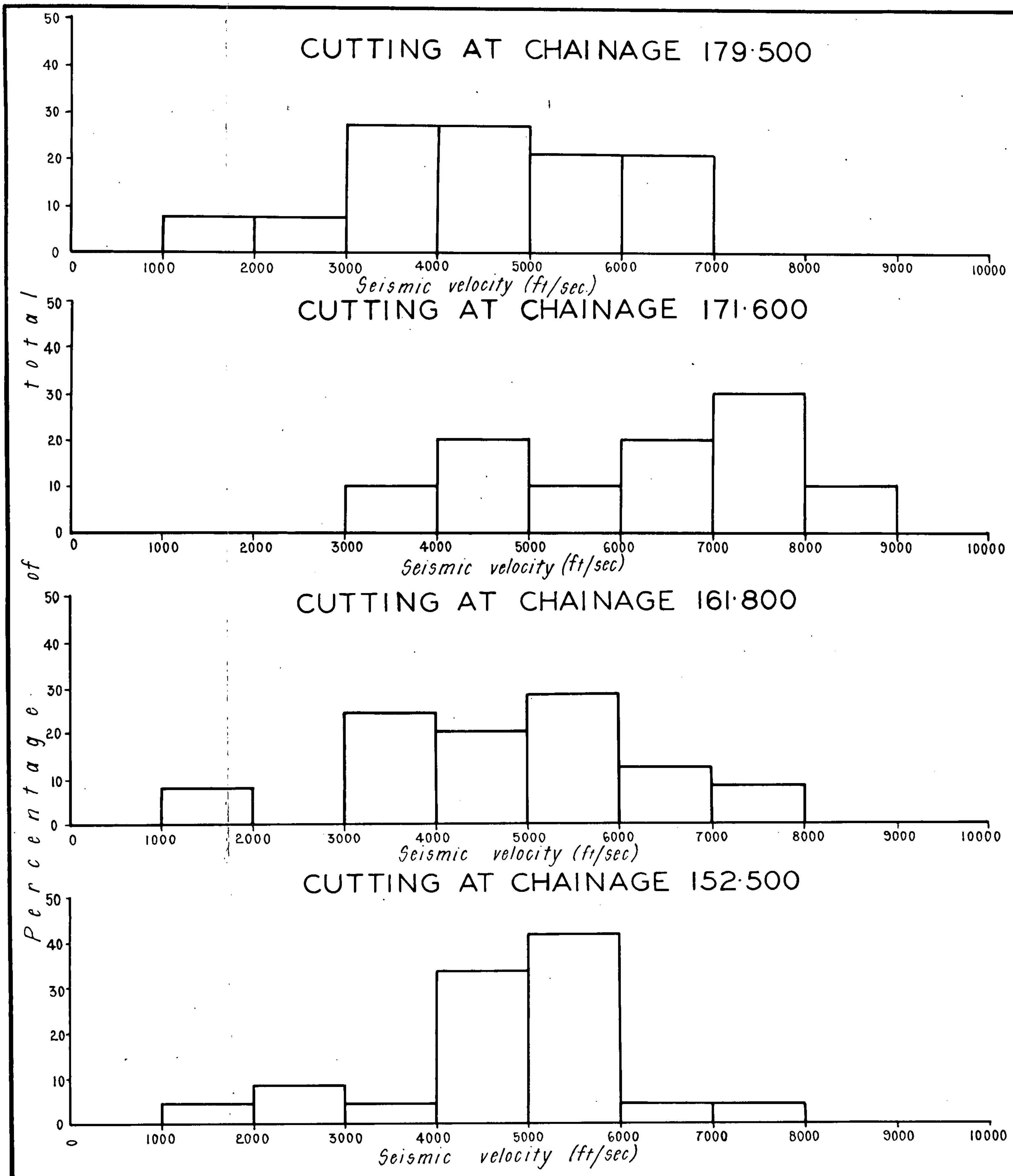


FLINDERS HIGHWAY TALIA — STREAKY BAY

HISTOGRAM OF REPRESENTATIVE CALCRETE VELOCITIES



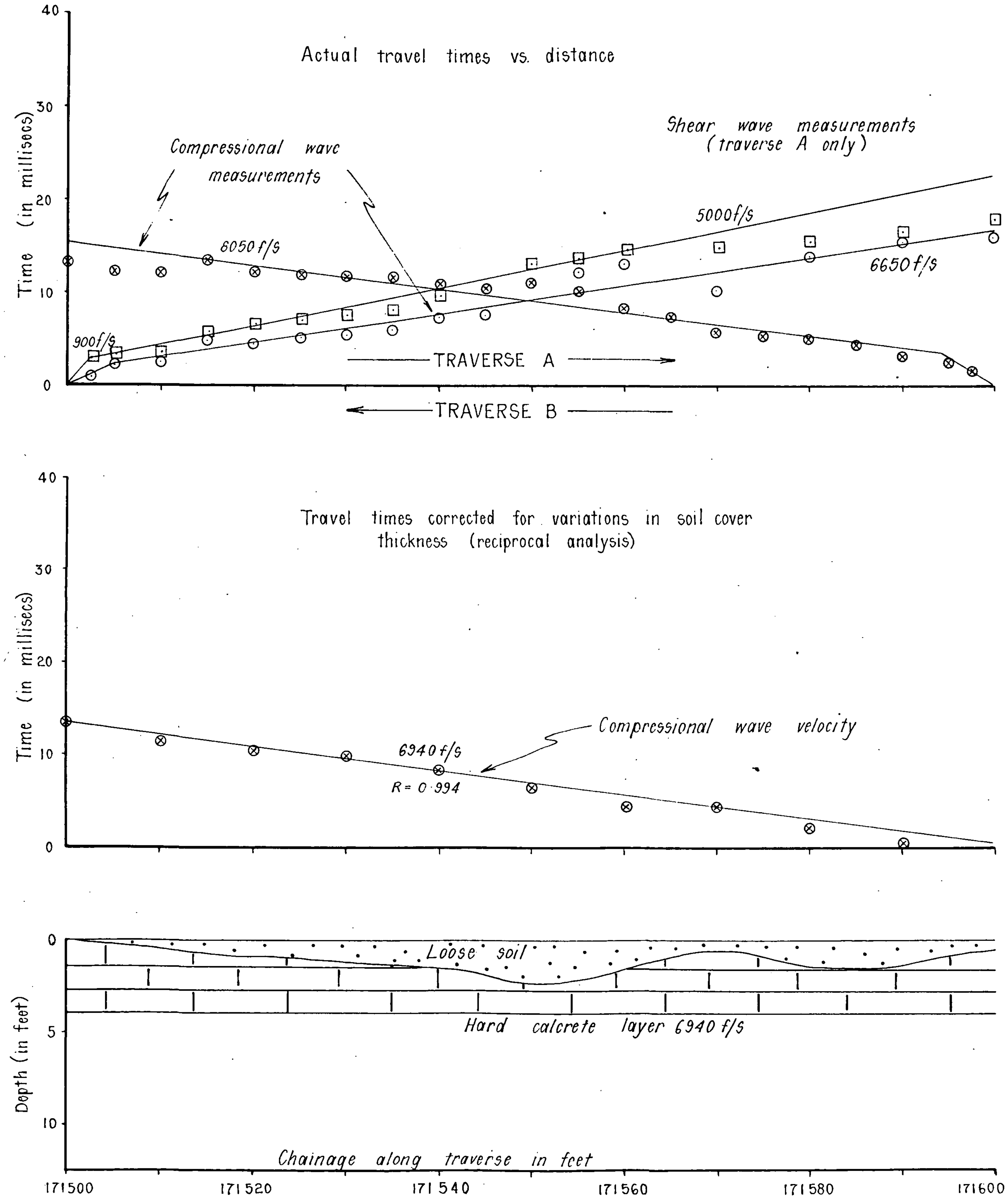
DEPARTMENT OF MINES — SOUTH AUSTRALIA			
HISTOGRAMS OF CALCRETE VELOCITIES FOR NEAR SURFACE CONDITIONS			
EXPLORATION GEOPHYSICS	R. NELSON GEOPHYSICIST	Drn. R.N.	SCALE:
		Tcd. B.W.	74-589
		Ckd.	Dg+l
Director of Mines		Exd.	DATE: 8 Aug 1974



DEPARTMENT OF MINES — SOUTH AUSTRALIA

FLINDERS HIGHWAY SEISMIC SURVEY
HISTOGRAMS OF CALCRETE VELOCITIES
ENCOUNTERED IN VARIOUS CUTTINGS

EXPLORATION GEOPHYSICS	R. NELSON GEOPHYSICIST	Drn. R.N.	SCALE:
		Tcd. B.W.	74-590
		Ckd.	Dg+l
Director of Mines		Exd.	DATE: 8 Aug 1974



NOTATION

○ Compressional wave travel times for traverse A

□ Shear wave " " " " "

⊗ Compressional wave " " " " B

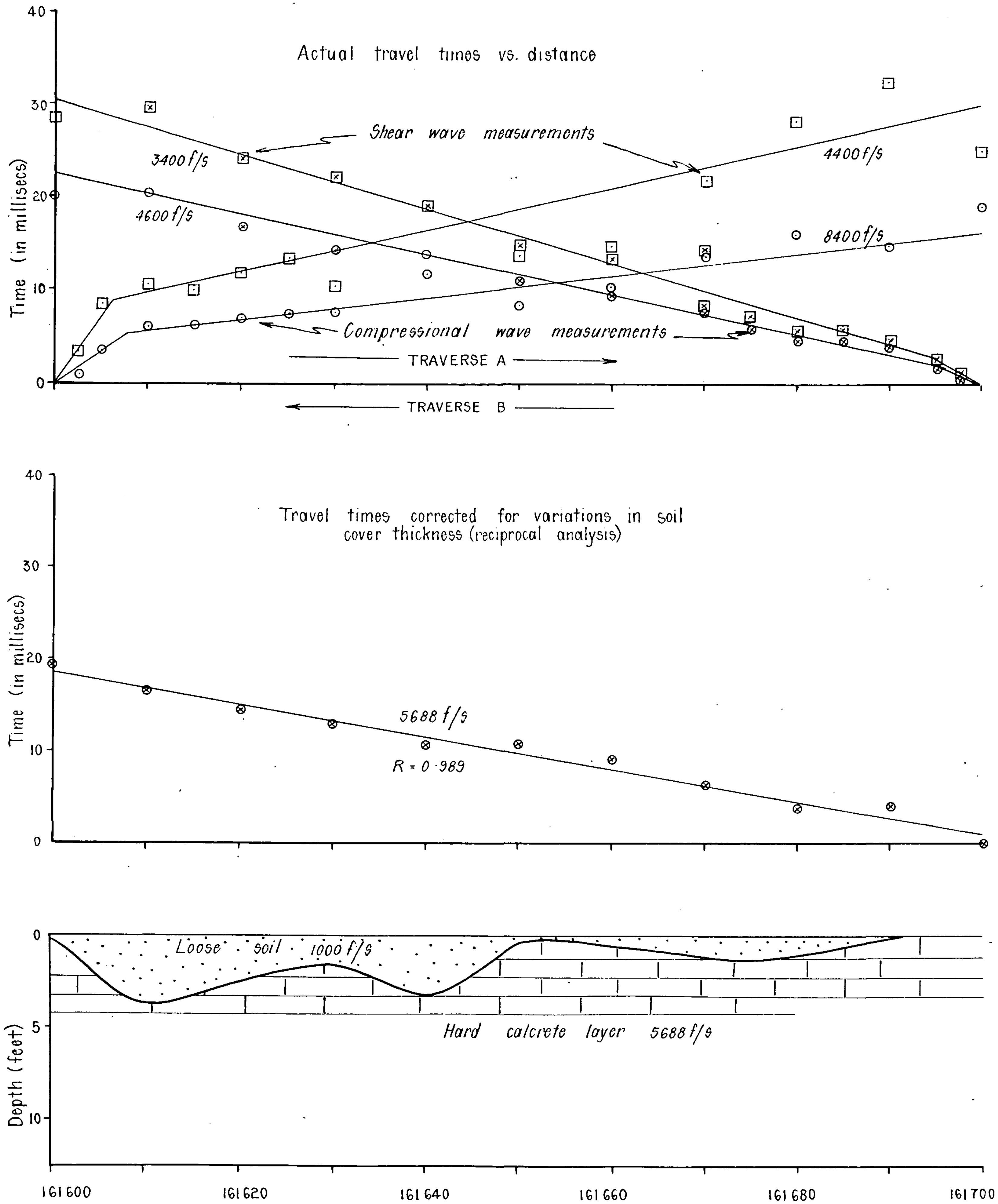
⊠ Shear wave " " " " "

R = Correlation coefficient for velocity regression

DEPARTMENT OF MINES — SOUTH AUSTRALIA

FLINDERS HIGHWAY – TALIA TO STREAKY BAY
SEISMIC SURVEY 1974
CUTTING AT CHAINAGE 171600

EXPLORATION GEOPHYSICS SECTION	R. NELSON	Drn. R.N.	SCALE :
	GEOPHYSICIST	Tcd. B.D.W.	74 – 704
		Ckd.	Dgh + ℓ
Director of Mines		Exd.	DATE : 30 Aug. 1974



NOTATION

- Compressional wave travel times for traverse A
- Shear " " " " " "
- Compressional " " " " " B
- Shear " " " " " "

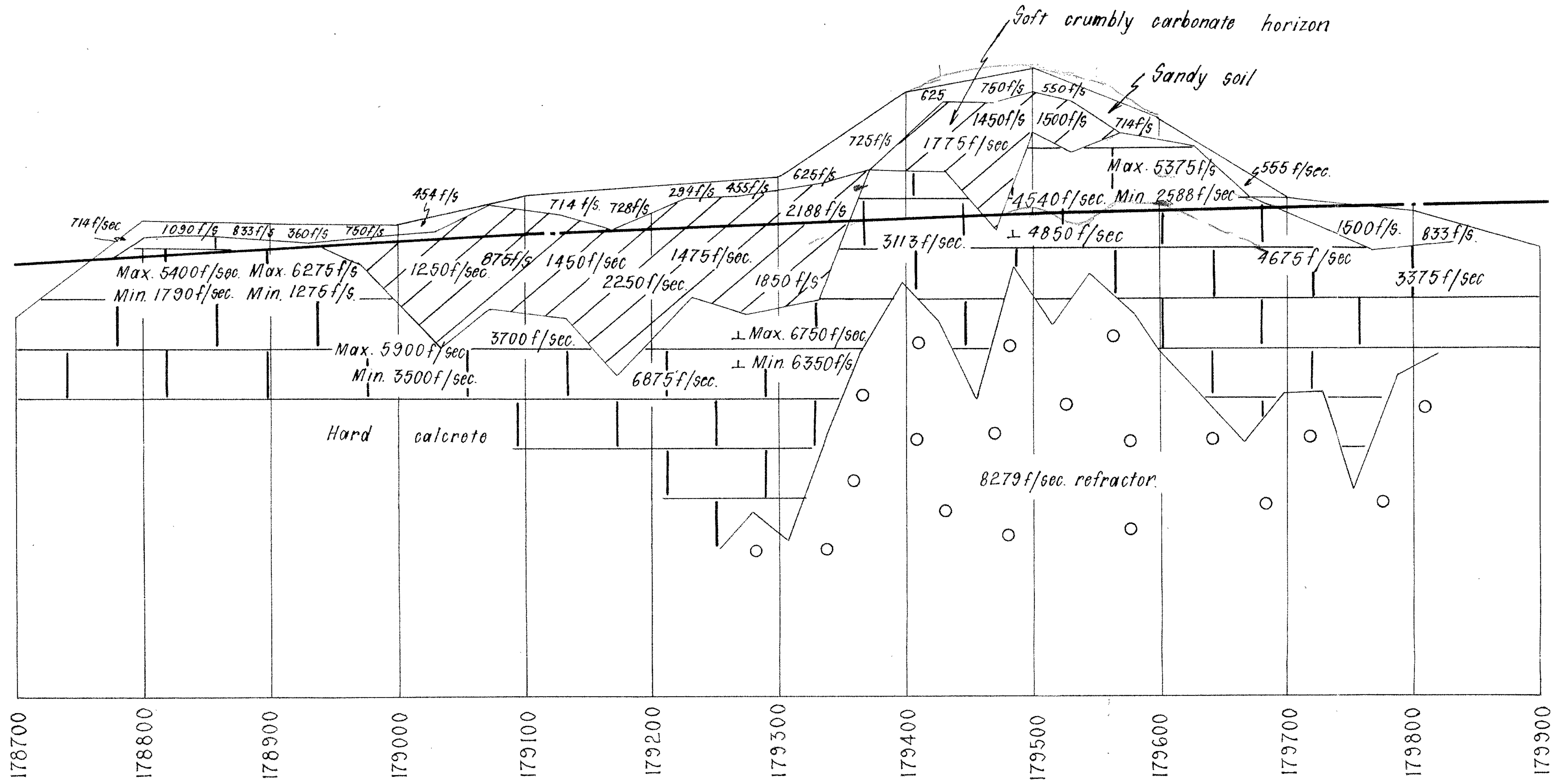
R = Correlation coefficient for velocity regression.

DEPARTMENT OF MINES — SOUTH AUSTRALIA

FLINDERS HIGHWAY—TALIA TO STREAKY BAY
SEISMIC SURVEY 1974
CUTTING AT CHAINAGE 161 600

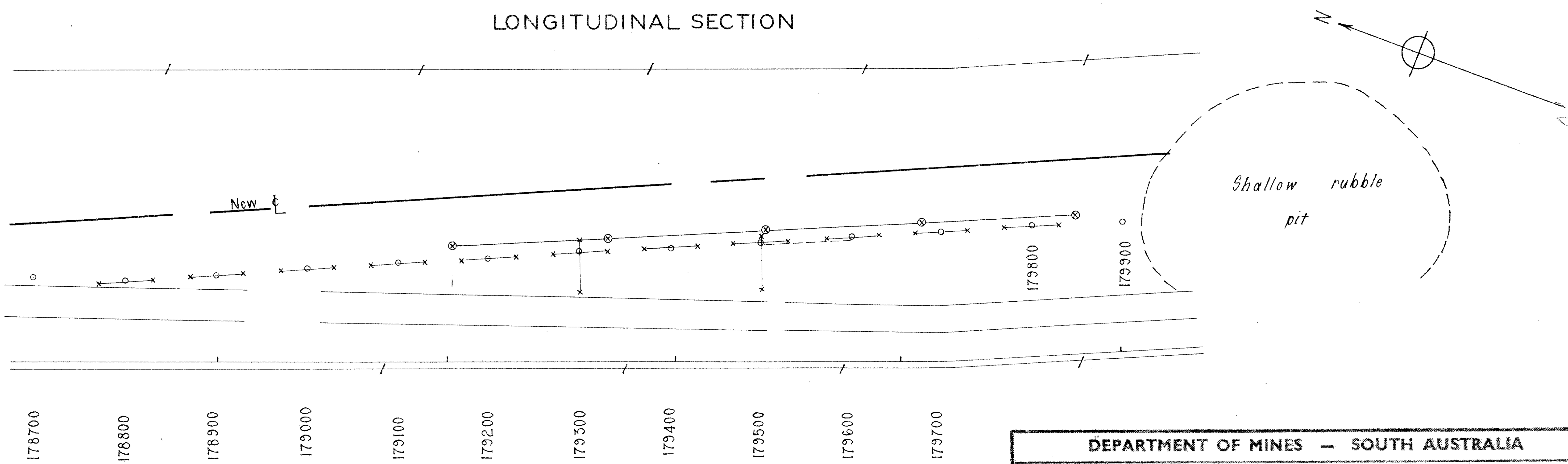
EXPLORATION GEOPHYSICS SECTION	R. NELSON	Drn. R.N.	SCALE :
	GEOPHYSICIST	Tcd. B.D.W.	74-703 Dgh+ℓ
		Ckd.	
Director of Mines		Exd.	DATE : 30 Aug. 1974

CUTTING AT CHAINAGE 179 500



Where stated, velocities are derived from north-south oriented spreads, unless prefixed by the symbol "⊥", which implies a west-east orientation. Max. and Min. refer to the maximum and minimum velocities respectively. recorded along the length (60 ft) of a particular spread (after applying reciprocal analysis).

LONGITUDINAL SECTION



LEGEND

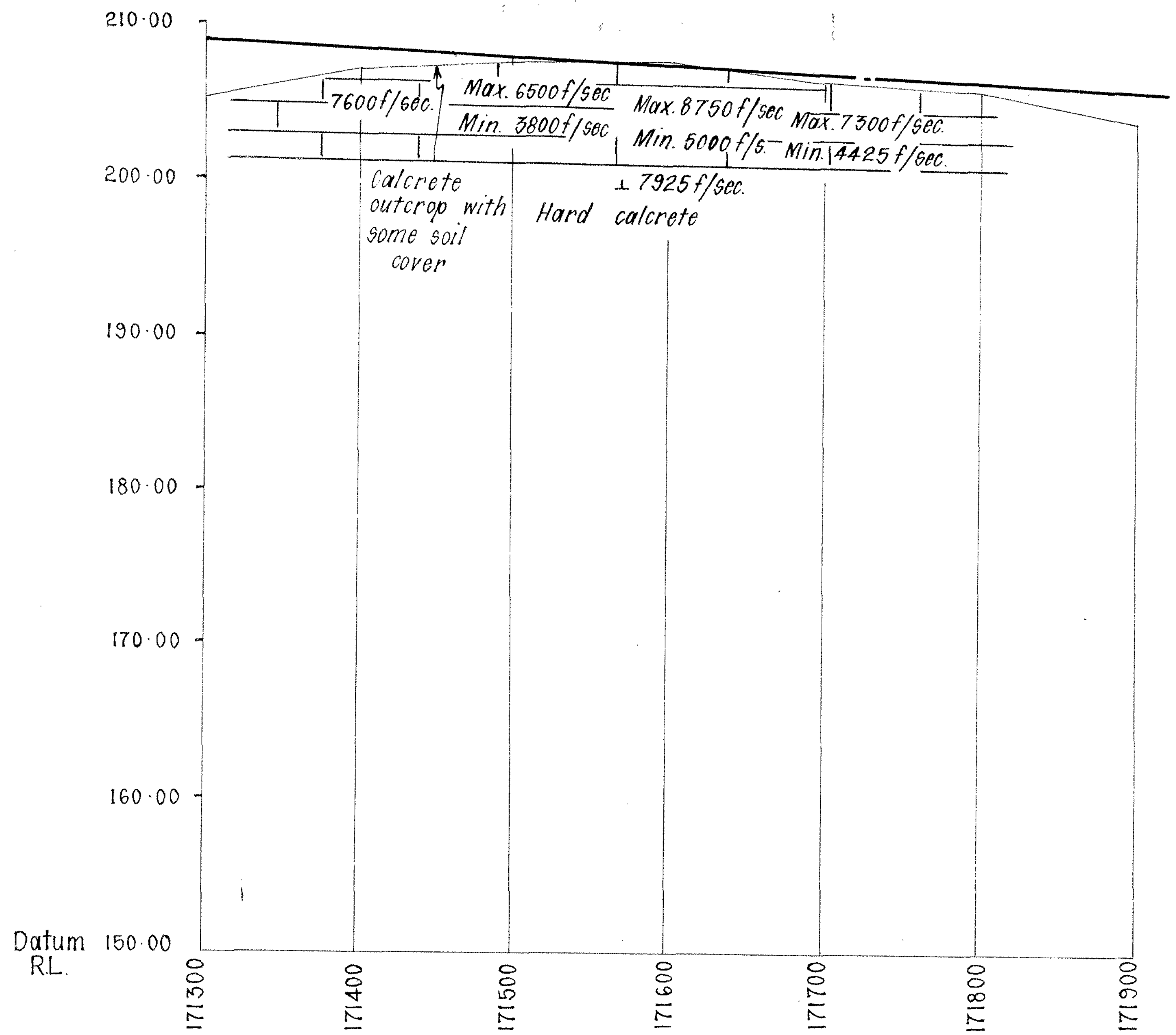
Spreads using geophones at 5' intervals.

Spreads using geophones at 30' intervals.

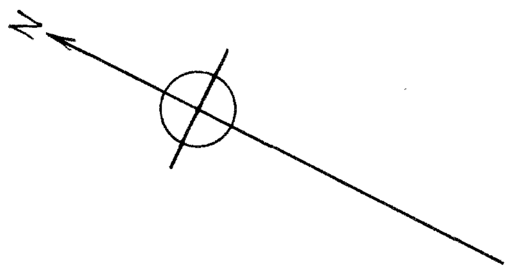
Hammer seismic spread

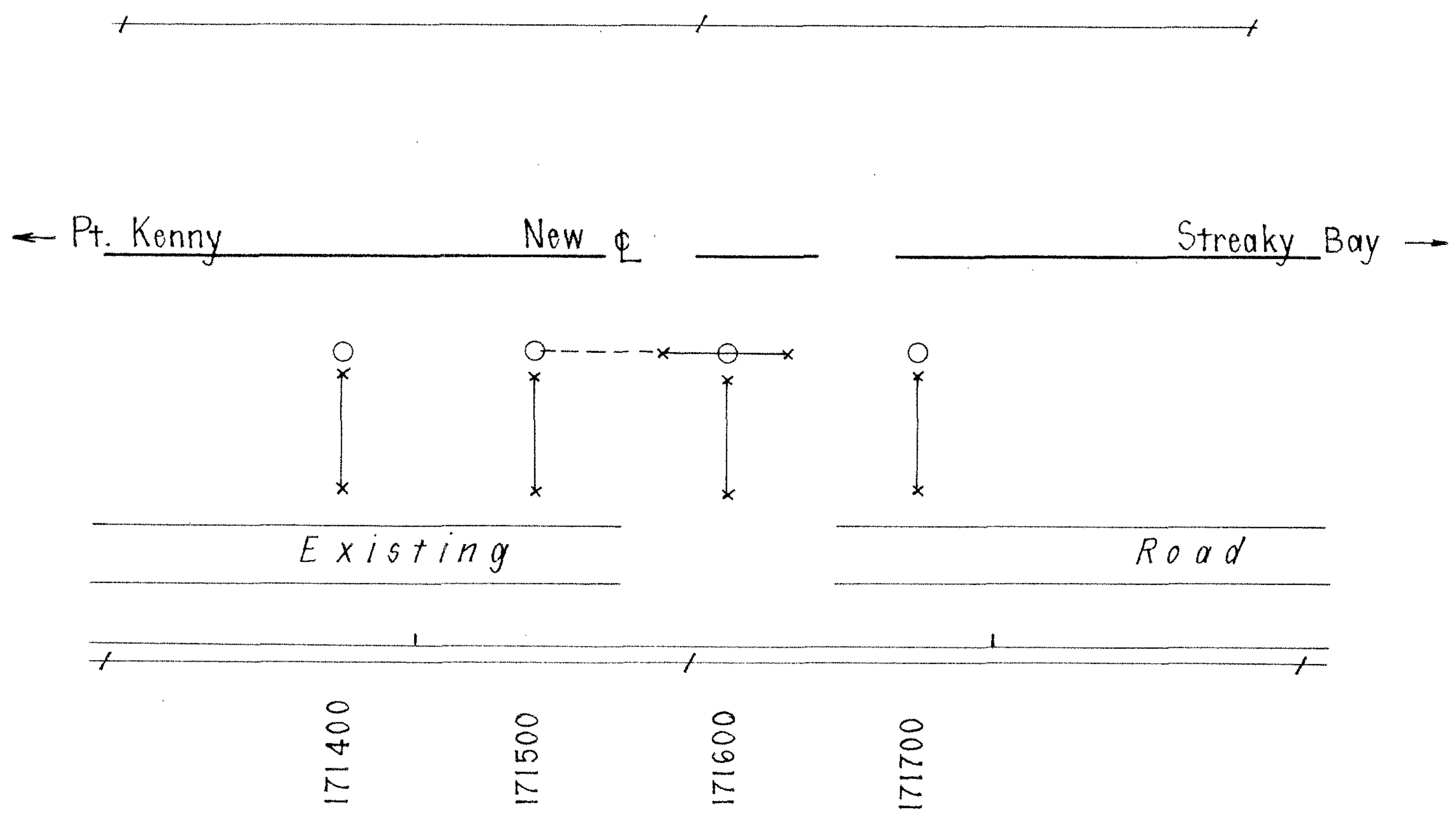
DEPARTMENT OF MINES — SOUTH AUSTRALIA			
FLINDERS HIGHWAY SEISMIC SURVEY PT. KENNY – STREAKY BAY SECTION CUTTING AT CHAINAGE 179500			
EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST	Compiled R. NELSON	Scale:
			Date: 30 Aug. 1974
		Drn. B.D.W.	Drg. No. 74-710 Dgh + l
Director of Mines		Ckd.	

CUTTING AT CHAINAGE 171600



LONGITUDINAL SECTION





Where stated, velocities are derived from west – east oriented spreads, unless prefixed by the symbol "⊥", which implies a north – south orientation.
"Max." and "Min." refer to the maximum and minimum velocities respectively recorded along the length (60 ft) of a particular spread (after applying reciprocal analysis).

LEGEND

×———× Spread using geophones at 5' intervals

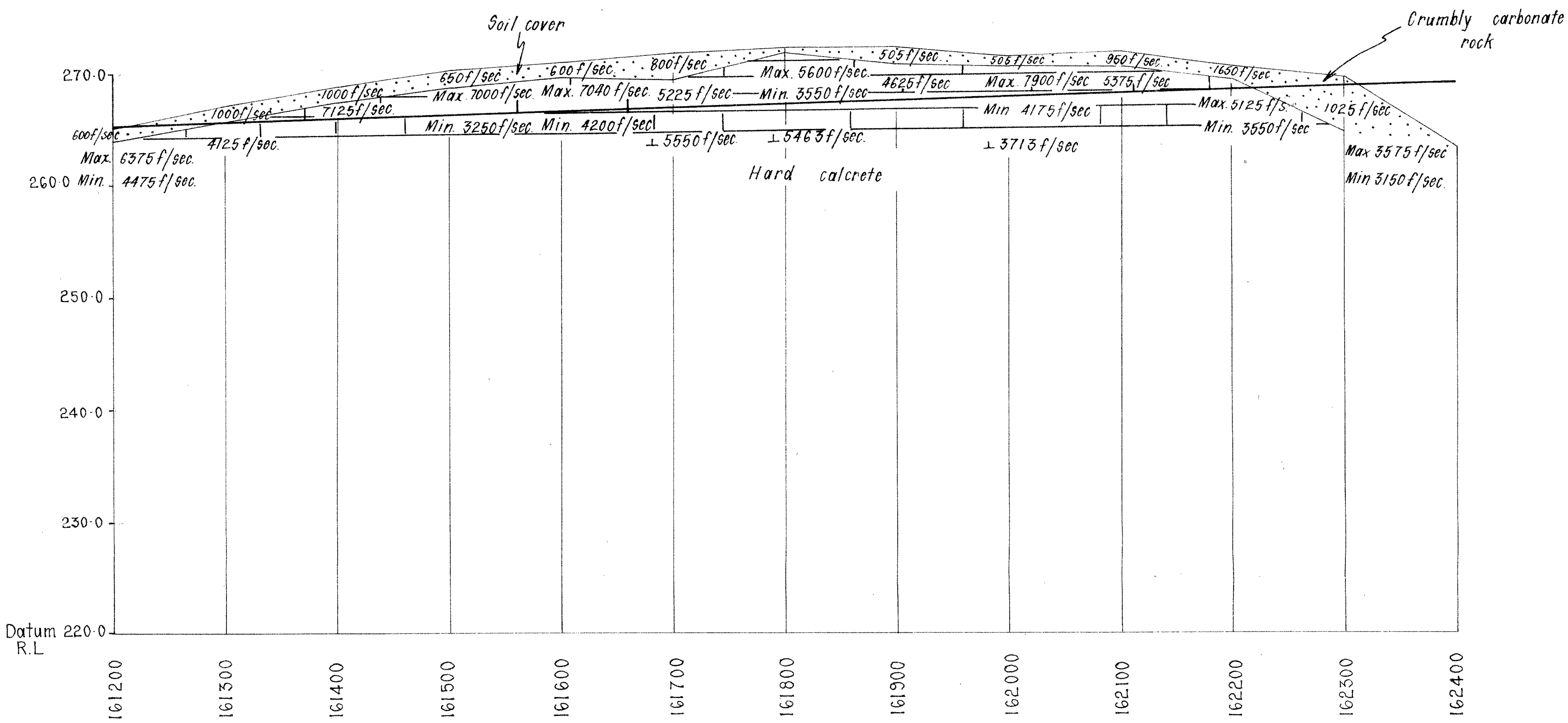
– – – – Hammer seismic spread

DEPARTMENT OF MINES — SOUTH AUSTRALIA

FLINDERS HIGHWAY SEISMIC SURVEY
PT. KENNY – STREAKY BAY SECTION
CUTTING AT CHAINAGE 171600

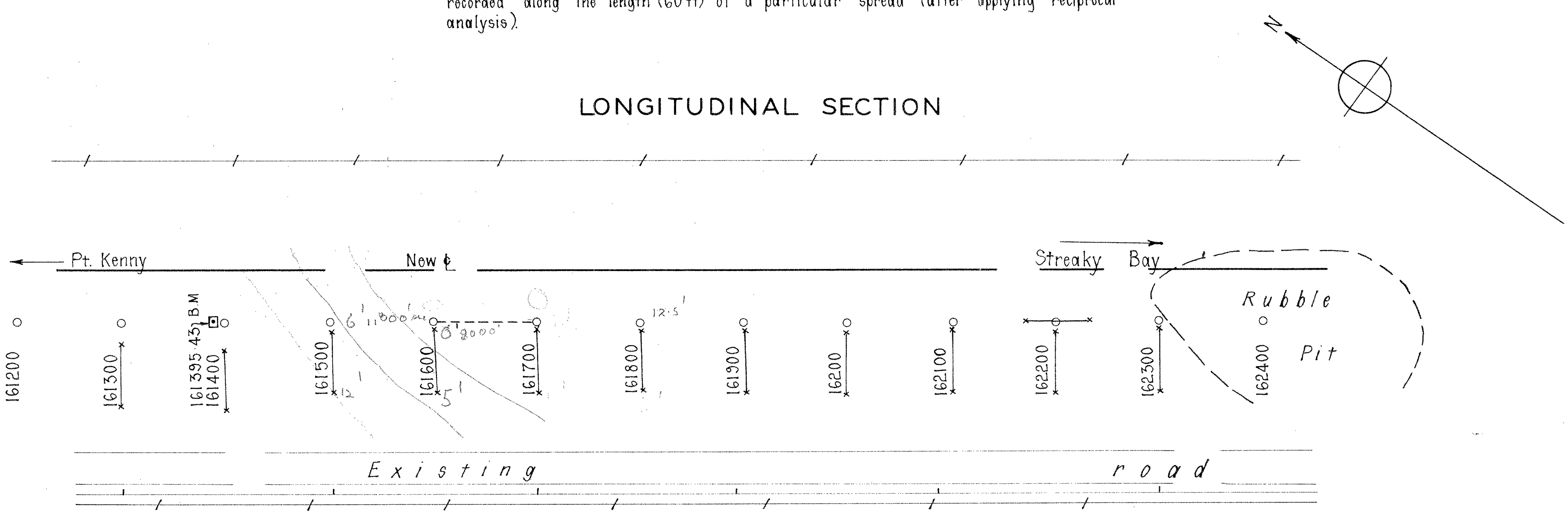
EXPLORATION GEOPHYSICS SECTION	R. NELSON	Drn. R.N.	SCALE:
	GEOPHYSICIST	Tcd. B.D.W	74-709
		Ckd.	Dgh + ℓ
Director of Mines		Exd.	DATE: 30 Aug. 1974

CUTTING AT CHAINAGE 161800



Where stated, velocities are derived from west-east oriented spreads, Unless prefixed by the symbol "⊥", which implies a north-south orientation. Max. and Min. refer to the maximum and minimum velocities respectively recorded along the length (60 ft) of a particular spread (after applying reciprocal analysis).

LONGITUDINAL SECTION



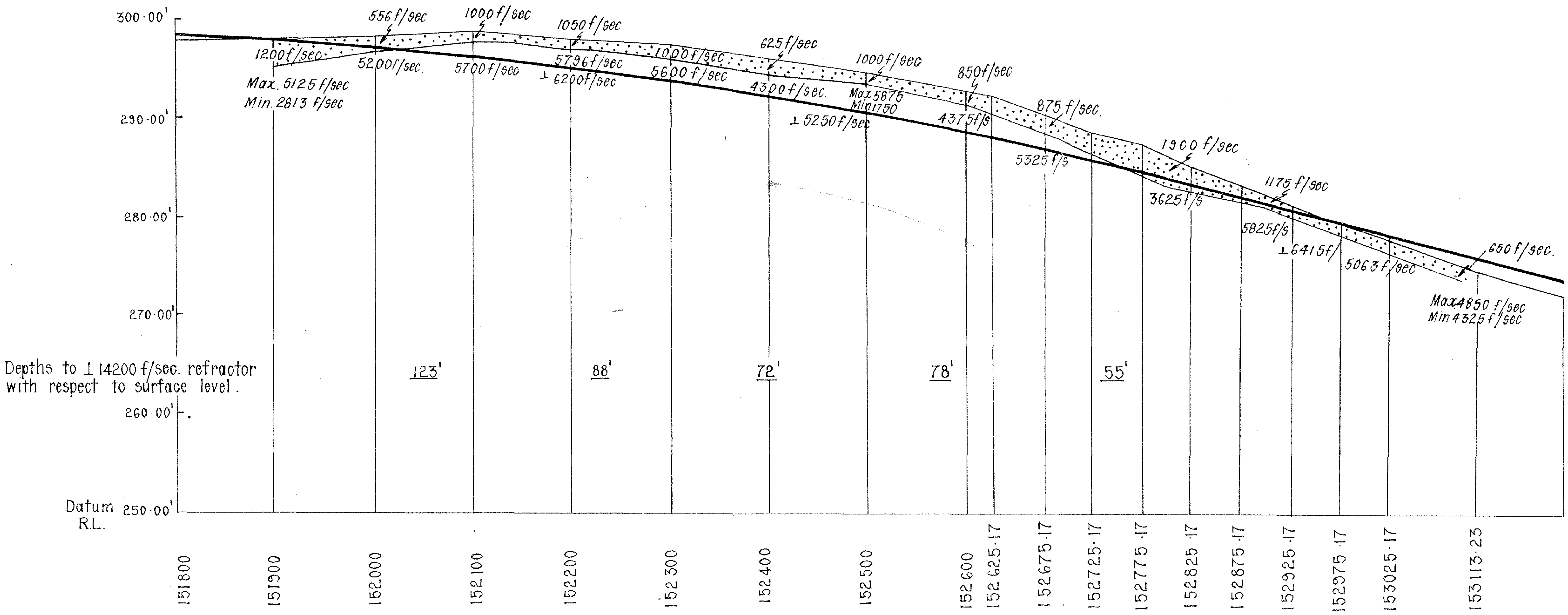
LEGEND

- Spreads using geophones at 5' intervals
- Spreads using geophones at 30' intervals.
- Hammer seismic spread

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
FLINDERS HIGHWAY SEISMIC SURVEY PT. KENNY – STREAKY BAY SECTION CUTTING AT CHAINAGE 161800			
EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST	Compiled R. NELSON	Scale: 1 : 1200
			Date: 30 Aug. 1974
Director of Mines		Drn. B.D.W.	Drg. No. 74-708 Dgh + l
		Ckd.	

200-4.70 A2432

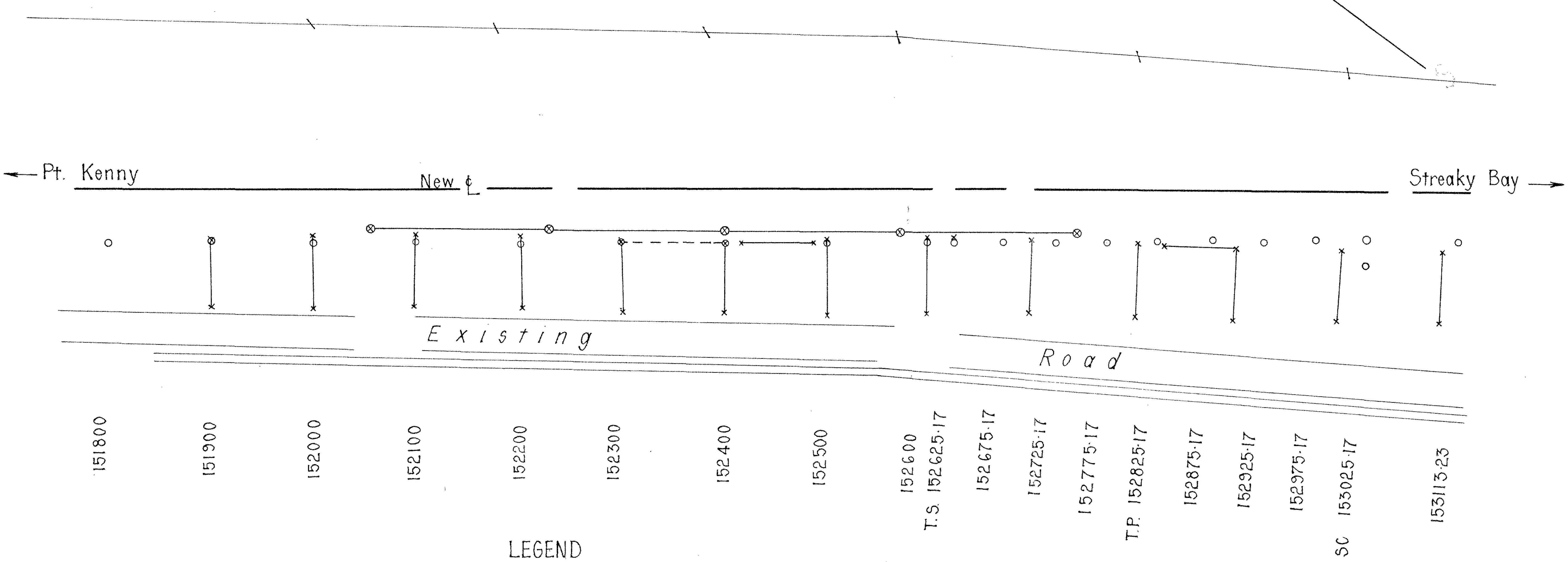
CUTTING AT CHAINAGE 152 500



Where stated, velocities are derived from west–east oriented spreads, unless prefixed by the symbol "⊥", which implies a north – south orientation. Max. and Min. refer to the maximum and minimum velocities respectively recorded along the length (60 ft) of a particular spread (after applying reciprocal analysis)

N

LONGITUDINAL SECTION



LEGEND

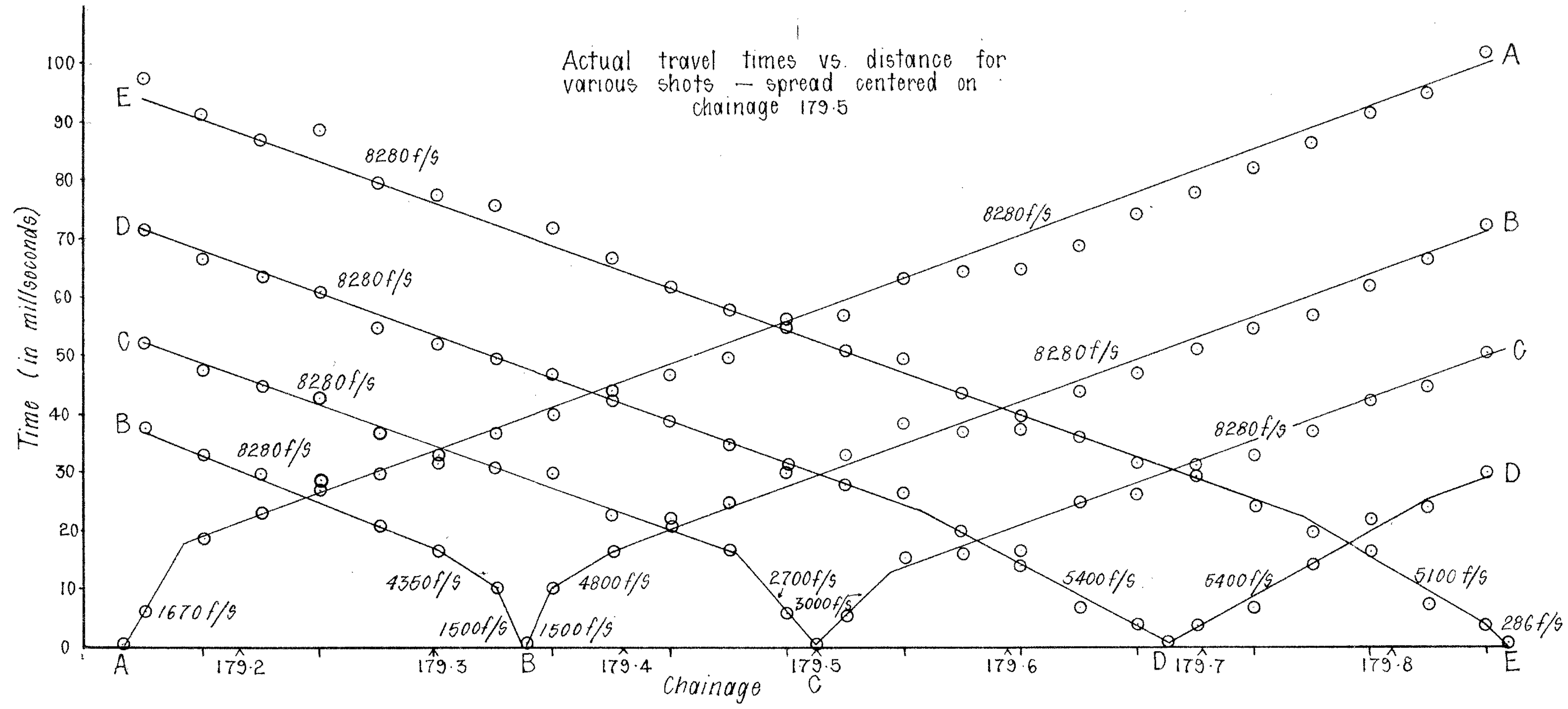
×———× Spreads using geophones at 5' intervals.

⊗———⊗———⊗ Spreads using geophones at 30' intervals.

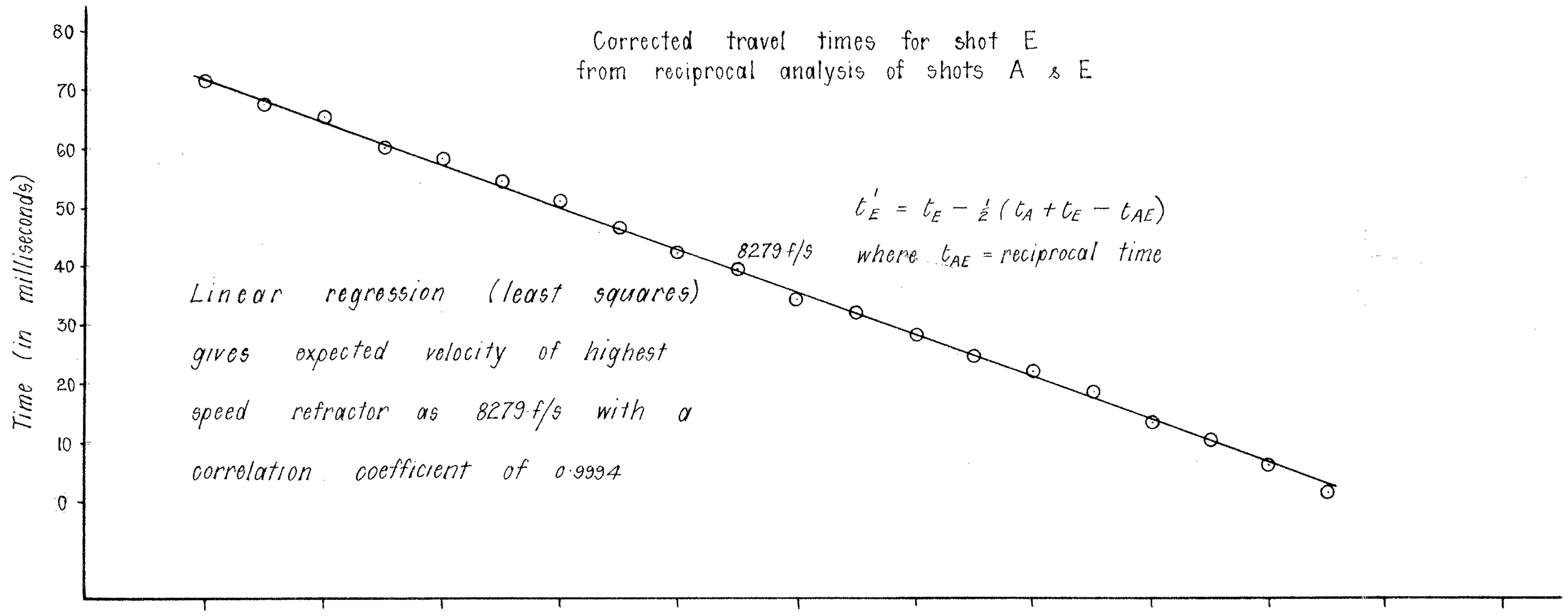
– – – – – – – Hammer seismic spread

DEPARTMENT OF MINES — SOUTH AUSTRALIA			
FLINDERS HIGHWAY SEISMIC SURVEY PT. KENNY – STREAKY BAY SECTION CUTTING AT CHAINAGE 152 500			
EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST	Compiled R. NELSON	Scale: 1 : 1200 Date: 30 Aug 1974
Director of Mines		Drn. B.D.W Ckd.	Drg. No. 74-707 Dgh + ℓ

200—1.70 A2432

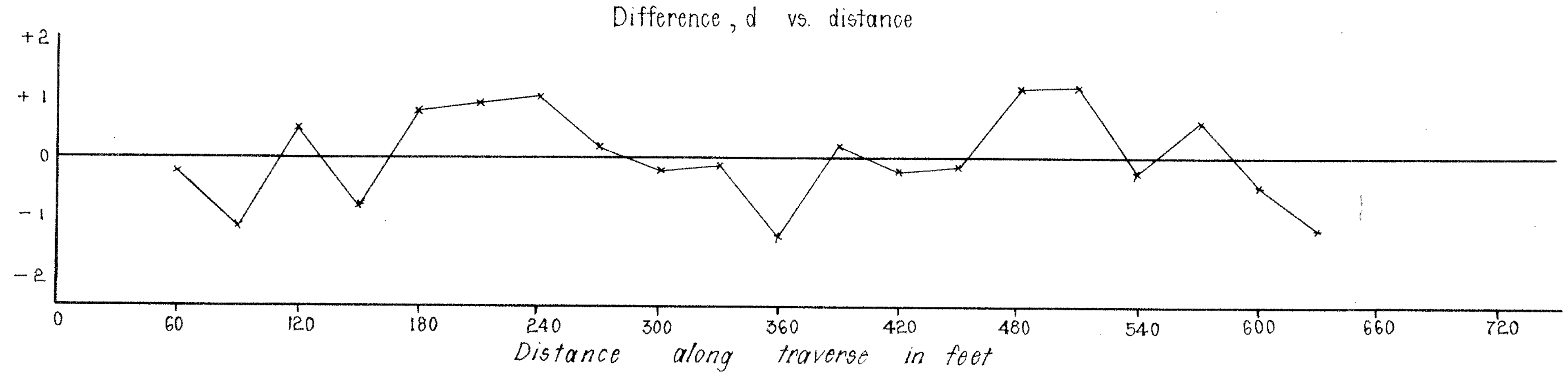


Geophone spacing = 30 feet



87·8	83·3	81·3	76·3	74·3	70·8	67·3	62·8	58·8	55·3	50·5	48·3	44·3	40·8	38·5	34·8	29·8	27·0	22·3	18·0	$t E'$ (measured)
88·0	84·4	80·8	77·1	78·5	69·9	66·3	62·6	59·0	55·4	51·8	48·1	44·5	40·9	37·3	33·6	30·0	26·4	22·8	19·2	$t E'$ (expected from regression)
−0·2	−1·1	+0·5	−0·8	+0·8	+0·9	+1·0	+0·2	−0·2	−0·1	−1·3	+0·2	−0·2	−0·1	+1·2	+1·2	−0·2	+0·6	−0·5	−1·2	Difference, d
6	3	14	4	16	17	18	13	7	10	1	12	8	11	20	19	9	15	5	2	Rank
−	−	+	−	+	+	+	+	−	−	−	+	−	−	+	+	−	+	−	−	Dichotomy

Difference, d vs. distance

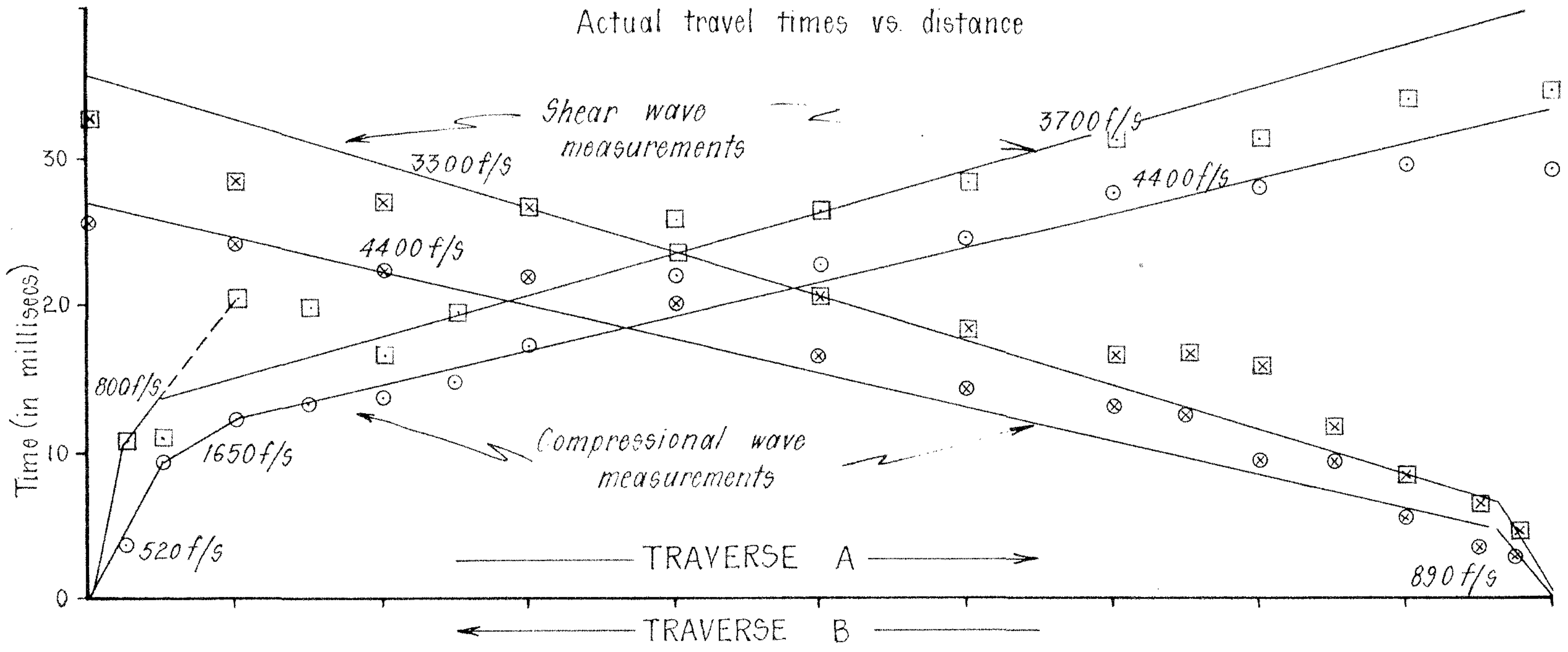


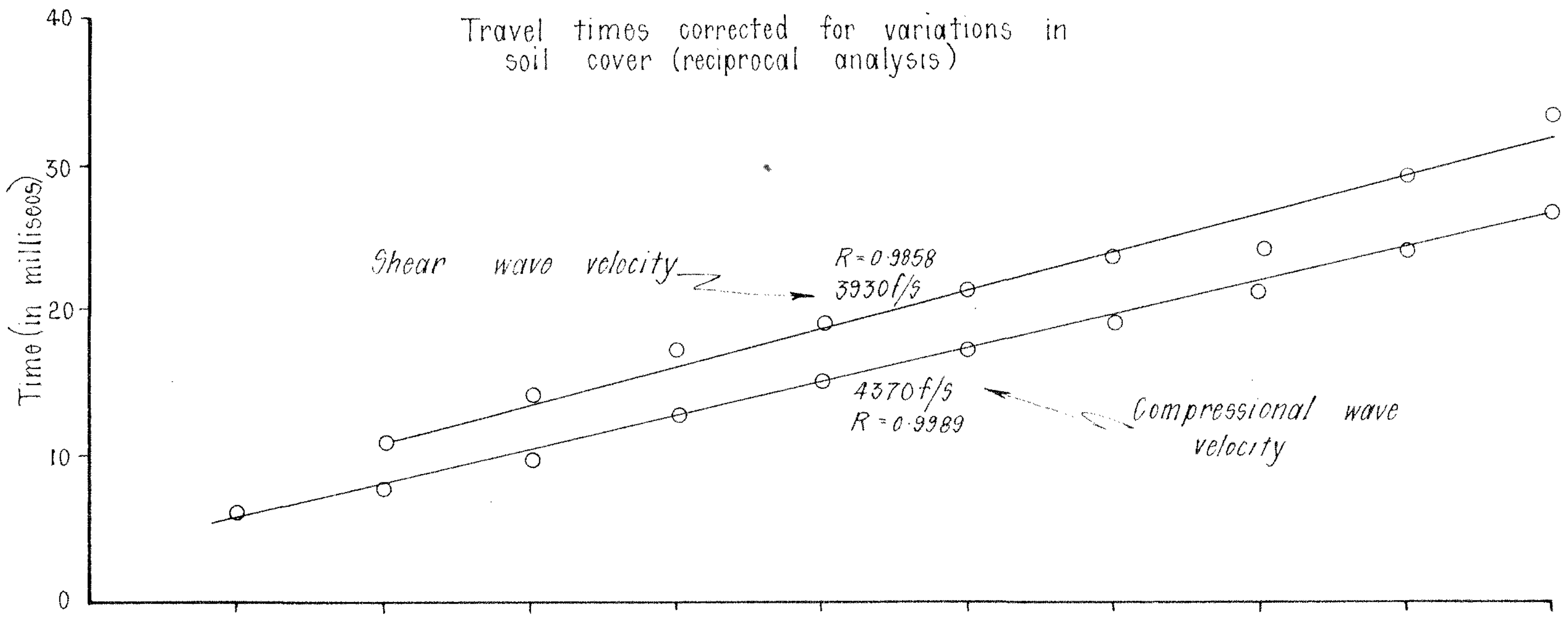
DEPARTMENT OF MINES — SOUTH AUSTRALIA

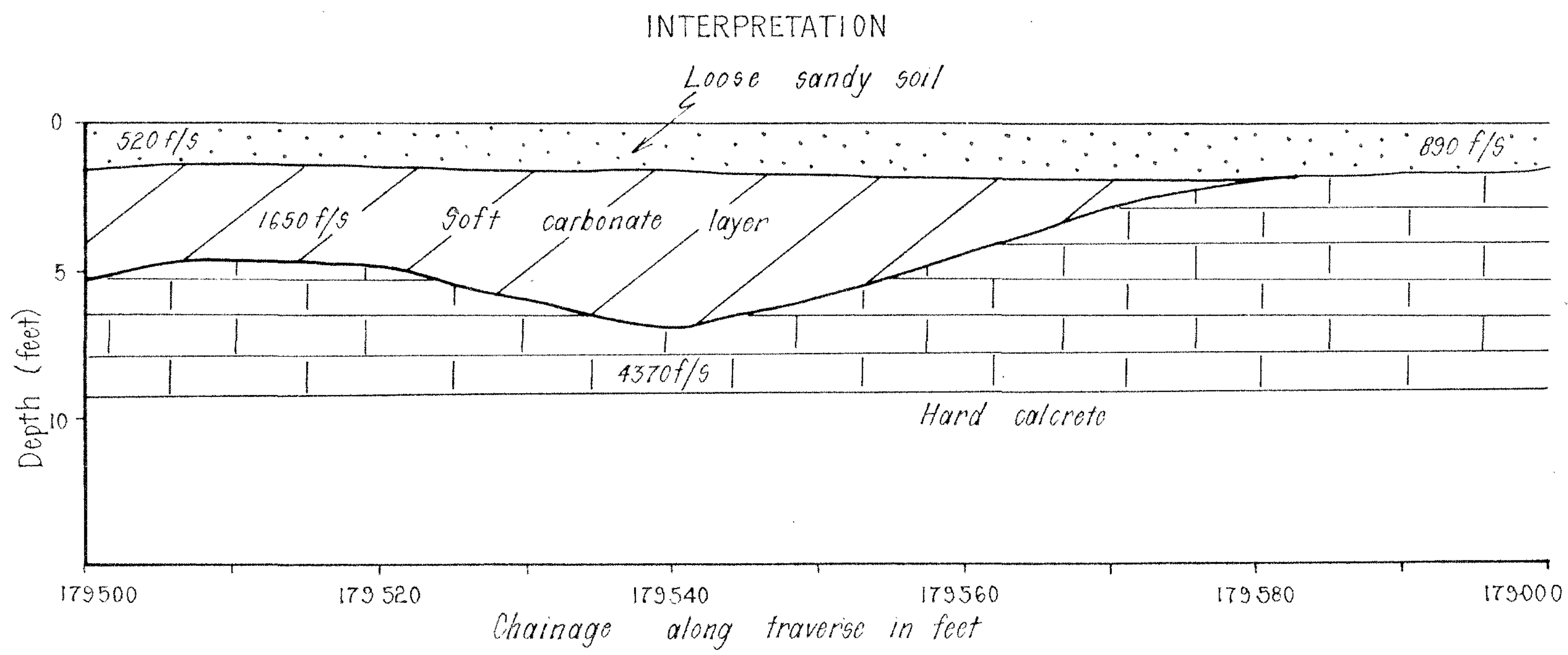
FLINDERS HIGHWAY–TALIA TO STREAKY BAY
SEISMIC SURVEY 1974
CUTTING AT CHAINAGE 179 500

EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST	**Compiled** R. NELSON	**Scale:**
			Date: 30 Aug 1974
		Drn. B.D.W.	**Drg. No.** 74-706 Dgh+l
Director of Mines		**Ckd.**	

200—4.70 A2432







NOTATION

⊙ Compressional wave travel times for traverse A

⊡ Shear " " " " " "

⊗ Compressional " " " " " B

⊠ Shear " " " " " "

R = correlation coefficient for velocity regression

DEPARTMENT OF MINES — SOUTH AUSTRALIA

FLINDERS HIGHWAY – TALIA TO STREAKY BAY

SEISMIC SURVEY 1974

CUTTING AT CHAINAGE 179300

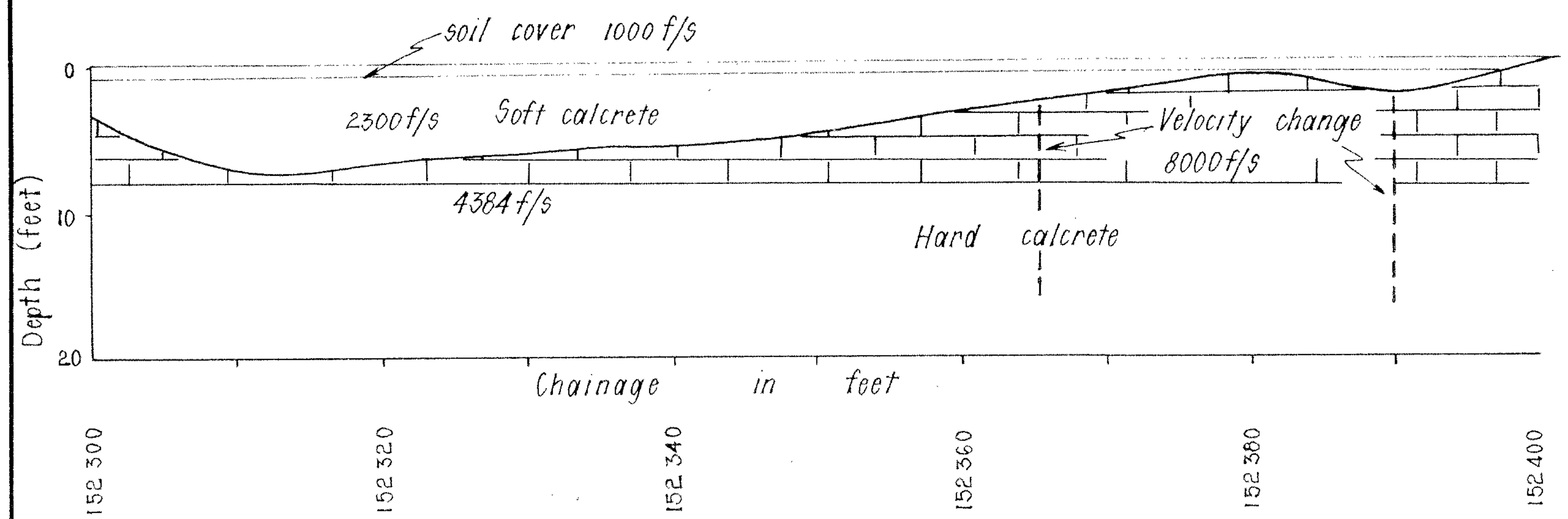
EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST.	Drn. R.N	SCALE:
		Tcd. B.DW	74-705 Dgh + ℓ
		Ckd.	
Director of Mines		Exd.	DATE: 30 Aug 1974

NOTATION

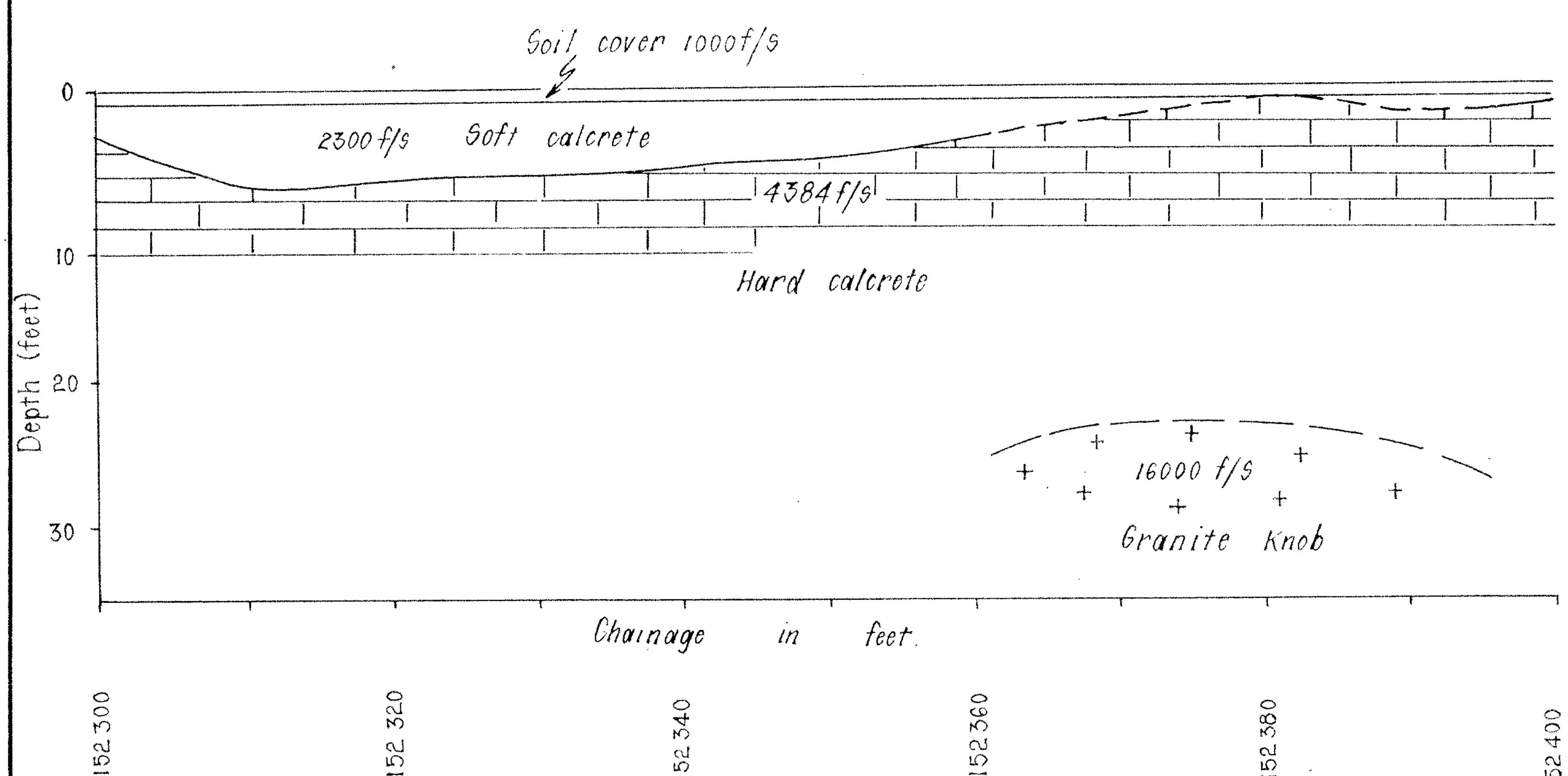
- ○ Compressional wave travel times for traverse A
- □ Shear wave " " " " "
- ⊗ Compressional wave " " " " B
- ⊠ Shear wave " " " " "

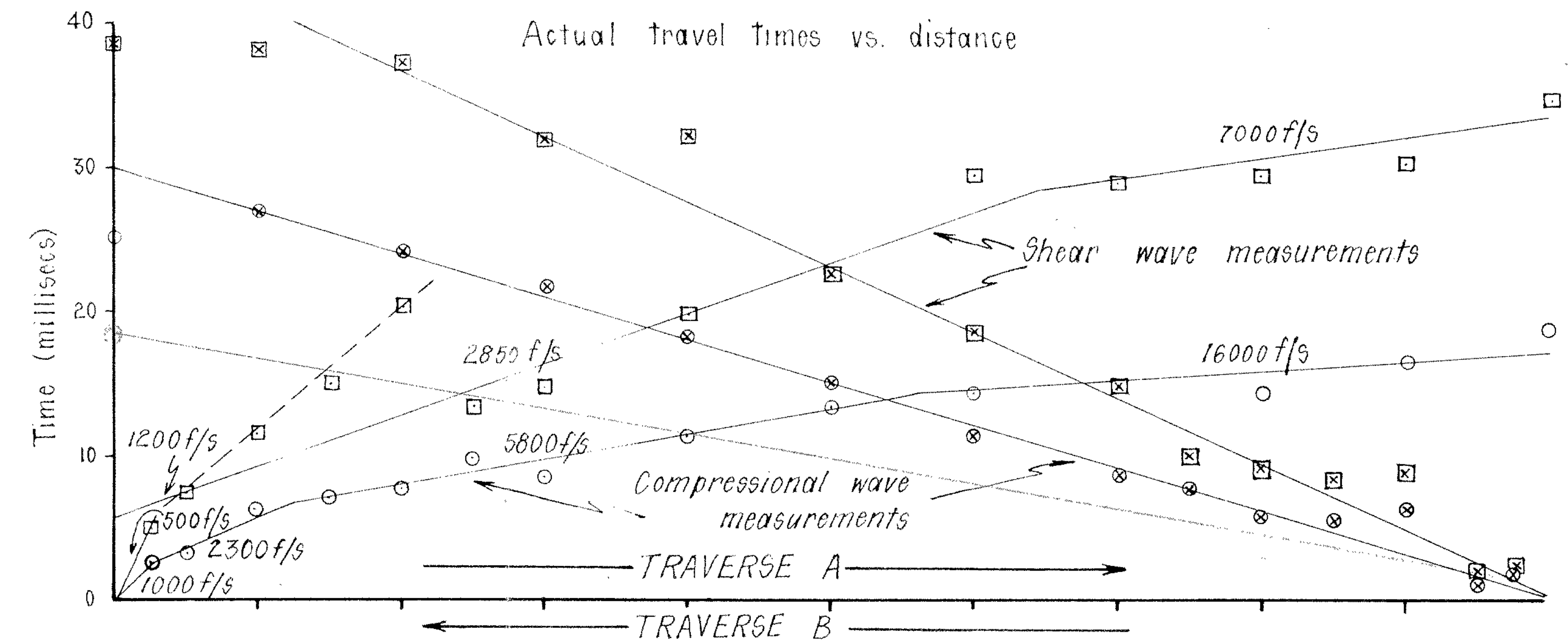
R = correlation coefficient for velocity regression

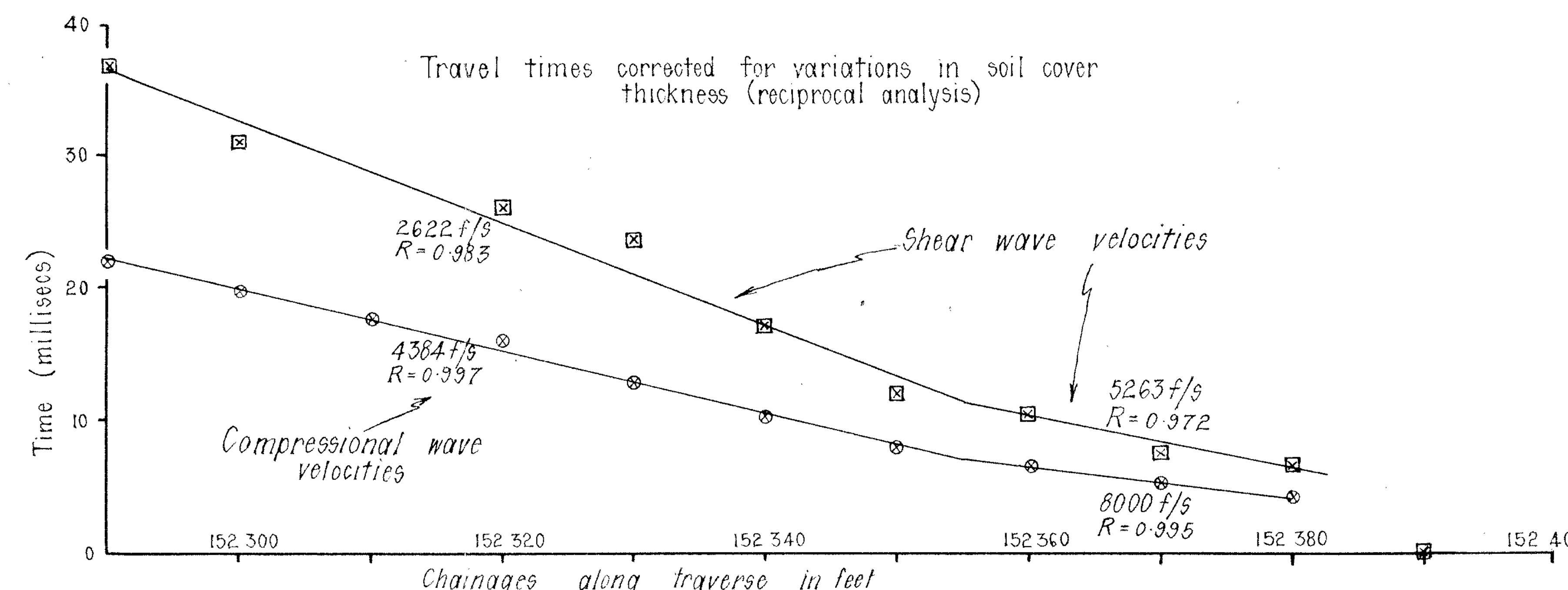
INTERPRETATION I



INTERPRETATION II







DEPARTMENT OF MINES — SOUTH AUSTRALIA			
FLINDERS HIGHWAY – TALIA TO STREAKY BAY SEISMIC SURVEY 1974 CUTTING AT CHAINAGE 152 500			
EXPLORATION GEOPHYSICS SECTION	R. NELSON GEOPHYSICIST	Drn. RN Tcd. BDW Ckd. B.D.W. Exd.	SCALE: 74-702 Dgh + l DATE: 30 Aug 1974
Director of Mines			