GEOLOGICAL SURVEY OF CANADA

OPEN FILE 2545

"Optimum offset" shallow seismic reflection profiles from the Okanagan Valley, British Columbia

S.E. Pullan, J.A. Hunter, R.A. Burns, R.L. Good

1992

Energy, Mines and Resources Canada   Énergie, Mines et Ressources Canada

Canada

"OPTIMUM OFFSET" SHALLOW SEISMIC REFLECTION PROFILES FROM THE OKANAGAN VALLEY, BRITISH COLUMBIA

S.E. Pullan, J.A. Hunter, R.A. Burns, and R.L. Good

SUMMARY

In the summer of 1984, six high resolution "optimum offset" shallow seismic reflection profiles (varying in length from 200 m to 2.9 km) were recorded in the Okanagan Valley, north of Vernon, British Columbia. This survey was a test of the "optimum offset" technique, which was then under development at the Geological Survey of Canada. The site was chosen because it was known from previous work in the area that there was a considerable thickness (up to several hundred metres) of unconsolidated sediments in the valley. The aim of the survey was to test the technique as a means of mapping the structure of the buried bedrock valley and of the overlying sediments. The entire data set is presented in this Open File Report.

INTRODUCTION

Seismic reflection methods have been well established in the oil industry for decades, but until recently, the equipment, field work and data processing required to implement these methods have been prohibitively expensive for engineering, groundwater, geotechnical, or Quaternary mapping applications. Until the 1980's, refraction, rather than reflection methods were used almost exclusively in these fields when subsurface structural information was required. Refraction methods depend on the measurement of only the time of first arrival of seismic energy at a series of source-receiver separations, and so do not require digitization of the seismic wave train or computer processing of the data. Thus, refraction surveys can be carried out with relatively simple and inexpensive equipment, and have been used for several decades to obtain estimates of the depth to bedrock and, where possible, to determine the major lithologic boundaries within the overburden.

Refraction techniques are subject to several limitations, the most critical of which are (i) the basic assumption that velocity increases with depth, (ii) the large source energies and long spread lengths required to obtain refractions from horizons deeper than 20-30 m below surface, and (iii) the difficulty in resolving detailed structure on the target horizon and from within the overburden sequence.

Reflection methods offer several potential advantages over seismic refraction techniques. Energy is reflected back towards the surface from any interface across which there is a change in acoustic impedance (product of density and seismic velocity of the material), whether this change is due to an increase or decrease in velocity (or no change in velocity at all, but a change in density). Also, the amplitude of reflected signal is large in comparison to a refraction event, and this means that smaller, non-destructive sources can be used to obtain reflections from horizons at considerable depth. Finally, reflection techniques have the potential of providing considerable subsurface structural detail, depending on the frequencies of the seismic signals that are recorded.

The first production of "engineering" seismographs with digital, enhancement and filtering capabilities in the late 1970's, and the start of the microcomputing revolution at approximately the same time, allowed the testing and development of seismic reflection methods for engineering, groundwater and other shallow applications. Testing of shallow seismic reflection methods at the Geological Survey of Canada (GSC) began in the early 1980's, when a Nimbus 1210F digital engineering seismograph was mated to an Apple II microcomputer (Hunter et al., 1982a, 1982b).

The original objective of the research at the GSC was to develop a reflection technique that could be implemented by small geophysical contracting companies who could afford a relatively minimal investment in equipment and computing capability. This led to the development of the "optimum offset" shallow seismic reflection technique, which is the simplest form of shallow seismic reflection profiling possible. The technique was originally designed for mapping the overburden-bedrock interface, as the often large velocity contrast at this boundary can give rise to a prominent, easily identifiable reflection event on the seismic record. In many areas, this simple technique has also proved to be an effective means of mapping structure within the overburden (Hunter et al., 1984, 1989; Hunter and Pullan, 1989; Pullan and Hunter, 1990).

During the 1980's, other research groups took a different approach to development of shallow seismic reflection methods. These groups adapted and modified conventional common-depth point (CDP) methods used extensively in the petroleum industry for shallow high resolution applications (Steeples and Knapp, 1982; Steeples et al., 1985; Doornenbal and Helbig, 1983). CDP techniques offer an effective means of enhancing the reflection signal by gathering and stacking a multiplicity of data that come from a particular subsurface location. However, in the early 1980's, the large amounts of data generated in a CDP survey required the use of a mainframe computer to handle the data storage, manipulation, and processing involved in producing a final seismic section. This put the application of CDP methods beyond the scope of most small geophysical companies, and made them too expensive for most engineering or groundwater applications.

The last decade has brought about a revolution in engineering seismographs and in personal computing and data storage capabilities, and has made the application of CDP methods to shallow problems a viable and more cost-effective alternative to the simple optimum offset technique in the present day environment (Somanas et al., 1987; Steeples and Miller, 1990). However, the optimum offset technique remains a useful method, with its own particular strengths and limitations (Pullan et al., 1991). The results of the Okanagan Valley optimum offset shallow seismic reflection survey provide an excellent illustration of the potential of the method.

OKANAGAN VALLEY SURVEY

During the 1980's, the Geological Survey of Canada tested the optimum offset shallow seismic reflection technique in a variety of geological settings across Canada. The tests were aimed primarily at mapping the buried bedrock topography, but also at delineating structure within the overburden materials wherever possible. The Okanagan Valley, or Vernon, survey was a test of this technique in an area of extremely thick overburden. Fulton (1972) described the valley fill as "a complexly mixed and interbedded sequence of fine-grained sand and silt and clay containing highly variable amounts of gravel and till", which he estimated could be as much as 550 m thick in parts of the valley.

A seismic refraction survey carried out in 1966 had attempted to assess the size and shape of the buried valleys, and to determine the stratigraphy of the unconsolidated fill (MacAulay and Hobson, 1972). The survey was successful in defining the gross configuration of the valleys, but was unable to provide any information pertaining to the fill stratigraphy. The Vernon optimum offset survey in 1984 was an attempt to evaluate the usefulness of the shallow seismic reflection technique in mapping the bedrock topography and overburden stratigraphy.

METHOD AND RECORDING PARAMETERS

The optimum offset technique is the simplest form of shallow seismic reflection profiling possible. Each trace of the final section is obtained by recording the output of a single geophone separated from the source by a given offset. The optimum offset is chosen after examination of a number of multichannel records shot at test sites around the survey area. The test records are also used to identify the target reflection and other events on the seismic record (such as possible groundroll and airwave interference), and to determine recording parameters such as filter settings, amplifier gains, and record length. The optimum offset section is then produced trace-by-trace by moving the position of the source and corresponding receiver progressively down the line in equal increments (Figure 1). Multichannel records are required, at least intermittently along the survey line, for velocity analysis. These records are usually recorded at each spread set-up, along with the optimum offset data. More detail on the implementation of this technique in the field can be found in Hunter and Pullan (1989).

Approximately 7.5 km of optimum offset data were recorded on survey lines run along quiet roads north of Vernon in the Okanagan valley in July and August 1984 (Figures 2-4). The surface material was a dry, hard-packed silt, and at the time of the survey, the water table was approximately 5 m below ground surface.

Optimum offsets of 150-225 m were used in order to map the subsurface structure to depths of several hundred metres without interference from groundroll. High frequency geophones (50 Hz, damped to 0.7 times critical damping, single geophone per channel), and geophone spacings of 3 m were used throughout the survey. The data were recorded on a Nimbus 1210F engineering seismograph and stored on cassette tape in the field using a Nimbus

G724S tape recorder. The low frequency components of the seismic signal were reduced by the use of the high frequency geophones and of analog filters on the seismograph.

A variety of seismic sources, including a 16 lb sledge hammer and steel plate, both 12- and 8-gauge "Buffalo" guns (Pullan and MacAulay, 1987), and a 65 kg weight drop, were used in this survey. One objective of this survey was to test the usefulness and limitations of these different sources. The smaller sources (sledge hammer and 12-gauge Buffalo gun) produced sufficient energy to obtain reflection signals from as deep as 400 m below surface, while the larger sources (8-gauge Buffalo gun and weight drop) were necessary to improve the signal-to-noise ratio on reflections from greater depth or in areas where the ambient noise level was high.

In this survey, the shells used with the Buffalo gun sources were detonated well above the water table, which meant that the dramatic improvement in energy level and frequency content that has been observed when the shell is detonated in damp or water-saturated material (Pullan and MacAulay, 1987) was not evident. However, the guns did provide a higher level of seismic energy than the respective weight drop sources, and a noticeable improvement in record quality was obtained when a water tamp was used in the 1 m deep shot holes.

The data were transferred to an Apple II+ microcomputer on a daily basis in the field office, stored on floppy disk, and processed using software developed at the GSC (Norminton and Pullan, 1986). Preliminary sections were produced on an Epson widetrack, dot-matrix printer in the field office, after static corrections, an automatic gain control and gain tapers had been applied to the data. Final sections were produced later on a flatbed plotter, after digital filtering of the data.

RESULTS

Final sections of the six optimum offset shallow seismic reflection profiles collected in the Okanagan Valley in 1984 are presented in Plates 1 through 7. Recording and display parameters are listed explicitly for each line. All profiles are shown here at the same horizontal scale. Minimal interpretation is attempted in this Open File report, which is aimed at presenting the entire suite of data for use in geological studies of the area, or to provide information on the applicability of the optimum offset technique in similar geological settings.

The depth scales shown on the final sections have been calculated using a velocity depth function obtained from an analysis of the multichannel data recorded along with the optimum offset records. These data only provide information on the shallow portion of the velocity depth function (because of the limited moveout on reflections from depth), and indicate that the velocity increases from a near-surface value of 1500 m/s to approximately 1800 m/s at a depth of 400 m. Below this depth, it is assumed that the velocity of overburden materials is constant at a value of 1800 m/s. It should be noted that the depth scale is only meaningful above the bedrock surface.

Vernon - Line 100 (Plate 1)

Plate 1 shows Line 100, a 1.5 km east-west line which was shot across the east side of the valley (Figure 3), and provides an excellent profile of the valley fill. The line passed by an irrigation borehole (B.C. Dept. of Environment, Water Well 118; offset approximately 100 m to the north of its position on Plate 1) that provides some geological control and aids in the stratigraphic interpretation of the seismic section. A simplified borehole log is shown in Plate 1 at the closest approach of the line to the borehole.

The optimum offset section shows an upper unit of flat-lying sediments that reach a maximum thickness of 300 m in the deepest part of the valley. This unit pinches out against gradually against an underlying unconformity (records V-110 to V-123), and then against bedrock as it rises steeply on the east side of the valley (records V-97 to V-108). The borehole log indicates that these flat-lying sediments are fine-grained materials, probably proglacial lacustrine deposits. The high-amplitude reflection that rises towards the surface at the east end of the profile is undoubtably bedrock, as the east end of this line is very close to bedrock outcrop.

The unconformable horizon between a depth of 220 and 320 m corresponds to the top of coarse-grained sands and gravels, within which the aquifers used for irrigation are found. The sands and gravels have been tentatively interpreted as Quaternary in age, but the possibility exists that they may be Tertiary deposits (R.J. Fulton, pers. comm.). Few continuous reflections can be found in these lower units, and bedrock definition below them is poor, probably as a result of the high acoustic impedance contrast at the unconformity, scattering within the coarse-grained units, and low signal level at these depths. The signal-to-noise ratio throughout the entire record deteriorates at the western end of the profile (records V-129 to V-138), as the line approached Highway 97A and high ambient noise levels were encountered.

Vernon - Line 200 (Plate 2)

Plate 2 shows Line 200, a short 250 m southeast-northwest profile shot across the highway from Line 100 (Figure 2). The objective of this line was to obtain a continuation of the profile of valley fill obtained in Line 100. However, at this site bedrock is relatively shallow, and in fact, with an offset of 150 m, the bedrock refraction is the first arrival on several of the records (V-204 to V-206). The data are presented here, but the offset was too large to obtain any useful reflection data. A profile recorded with a smaller offset (<100 m) may have been more successful in mapping the buried bedrock topography and in obtaining information on the overburden stratigraphy.

Vernon - Line 300 (Plate 3)

Plate 3 shows Line 300, a 2.9 km north-south line that runs north from the east end of Line 100 (Figure 3). As the Okanagan valley strikes approximately NNE-SSW in this area, Line 300 reveals a section of the valley fill deposits that cuts through the east side of the valley at a high angle. A very sketchy log from an observation well drilled close to the north end of the line is available to provide limited stratigraphic control for the seismic section. The log does not correlate well with the seismic section, but it does suggest that the lowermost reflections observed between V-300 and V-341 are related to gravel horizons within the overburden, and not to a reflection from the bedrock surface. The hammer source used for this profile does not appear to have produced enough energy to see even a hint of a reflection from bedrock beneath these gravel units.

An interpretation of the seismic profile can be made based on the limited information from the borehole and on a comparison of the seismic signatures observed on Line 100 and 300. The south end of Line 300 is characterized by a large amplitude reflection, interpreted to be the bedrock surface, that dips to the north from a depth of approximately 30 m below surface at record V-379 to 230 m below surface at record V-346. Above this reflection is the unit of flat-lying, fine-grained sediments, also evident on Line 100, interpreted to be proglacial, lacustrine deposits.

North of record V-346, the bedrock definition is drastically reduced, where it is presumably overlain by coarser-grained material. The well-defined, flat-lying nature of the upper 200 m of sediment that is evident on Line 100 and on the south end of Line 300, changes somewhat north of record V-339 (V-339 to V-304). It is possible that this change in character is caused by a local influx of coarser, poorly sorted material. There is no definition of the bedrock surface in this area, as implied by the borehole log inserted between records V-307 and V-308.

At the extreme north end of the profile (records V-304 to V-300), the character of the records again resembles the sequence seen on Line 100; a unit of flat-lying, coherent reflections from surface to a depth of approximately 260 m, underlain by a wedge of coarser-grained material above a reflection that could possibly be interpreted to be the bedrock surface, dipping from 260 m below surface to a depth of approximately 350 m at the north end of the seismic line.

Vernon - Line 400 (Plate 4)

Plate 4 shows Line 400, a short 200 m north-south profile shot in the middle of the valley between the town of Armstrong and Otter Lake (Figure 4). The line passed by an irrigation borehole (B.C. Dept. of Environment, Water Well 117) that provides some stratigraphic control. The well was offset approximately 100 m to the east of the centre of the line, and was drilled on the top of a hill, from an elevation of approximately 23 m above the ground surface on which the seismic profile was shot. The elevation difference has been corrected for in the representation of the drill log on Plate 4.

The borehole log indicates a predominantly fine-grained sequence of sediments with relatively small amounts of sand and gravel above bedrock at a depth of 560 m below surface. The correlation of lithologic units as determined from the drill log with the seismic section is not good, but this is attributed to the offset of the borehole from the seismic line, and to the probability that this offset is updip of the valley fill material.

Based on the lithology from the drill log and the interpretation of other seismic lines in the area, it is felt that the reflection package at a time of 350 ms is related to the upper sand unit. This unit may be characterized by substantial variations in thickness, as the seismic profile seems to indicate some lensing in the north-south direction (see south end of profile). The high-amplitude reflection package at approximately 475 ms, is interpreted to be the top of the sand and gravel unit, based on the reflection character. The bedrock (or shale/bedrock package) is interpreted to be the reflection energy observed at a two-way travel time of approximately 650 ms. These units are all indicated to be higher in the section on the drill log than on the seismic section, which implies either that the velocities assumed in the upper part of the section are too high for an accurate determination of the depth scale, and/or that the stratigraphy has a component of dip to the west in this area.

Vernon - Line 500 (Plates 5 & 6)

Plates 5 and 6 show Line 500, a 680 m southeast-northwest profile obtained immediately north of the north end of Okanagan Lake (Figure 4). One second of data was recorded along this survey line because reflection energy from two-way travel times as great as 850 ms was observed. A 65 kg weight drop was used as the energy source for this profile.

Plate 5 shows the recorded data before the application of a digital filter. This is to clearly show the low frequency, high-amplitude energy at 900-1000 ms, which is ground roll interference (noise). It also shows the low-frequency package of energy on the east end of the profile at a time of 700-800 ms, which has an apparent dip to the east. Much of this energy is removed when the data has been digitally filtered (Plate 6), and it is suspected that this event may be shear wave interference. However, this interpretation remains speculative at this time.

Without borehole control along this seismic line, an interpretation of the subsurface stratigraphy is difficult. A bedrock knoll outcrops not far from the east end of the line, and this leads to the interpretation of the high-amplitude reflection package which dips to the west from 475 ms at the east end of the profile as bedrock. The overlying sediment sequence exhibits a smaller component of dip to the west, and this continues along the entire section. Definition on the bedrock (?) surface deteriorates in the western half of the profile. It is not known whether this is because of the depth of the horizon (estimated to be greater than 500 m in this area), or to loss of energy and scattering in overlying coarse-grained units, or to a misinterpretation of this event as the bedrock surface. At the west end of the profile, a high-frequency event which dips to the east is observed (see records V-509 to V-512 at 850-900 ms). This event may possibly be related to the bedrock surface (?). There may in fact be considerable relief on the bedrock surface in this area, which could contribute to the difficulty in tying the subsurface stratigraphy across this section.

Vernon - Line 700 (Plate 7)

Plate 7 shows Line 700 (for some reason no Line 600 was ever recorded), a 2 km northeast-southwest profile located east of Line 300 and north of Line 100 (Figure 3). There is no borehole control on this line, so any interpretation of the data relies on a comparison of the seismic signatures with Lines 100 and 300.

The upper unit observed along the entire length of Line 700 is composed of flat-lying, coherent reflections, and is interpreted to be the fine-grained, lacustrine deposits seen in the borehole on Line 100. Below this unit is an unconformity that is approximately 270 m below surface at the south end of the profile (record V-754), rises to minimum depth of 130 m at record V-717, and dips slightly again at the north end of the seismic line. This reflection presumably corresponds to the top of coarser-grained material. The reflections from within this unit tend to be relatively incoherent and erratic. A deeper large-amplitude reflection can be seen intermittently along the profile (e.g. at a depth of approximately 400 m on records V-742 to V-749; at a depth of approximately 325 m on records V-734 to V-739; at a depth of approximately 230 m on records V-724 to V-725). This reflection could possibly represent the bedrock surface, or it could be caused by another sequence of coarse-grained or compacted sediments.

CONCLUSIONS

The objective of the Okanagan Valley survey was test the potential of the optimum offset shallow seismic reflection technique as a means of mapping bedrock topography and overburden stratigraphy in an area where the unconsolidated sediments where known to be up to several hundred metres thick. The survey was extremely successful in this regard, and clearly demonstrated the potential of shallow reflection methods over refraction techniques for mapping detailed subsurface structure. It is thought that the fine-grained sediments on surface, though they were not water-saturated, contributed to this being an excellent site for shallow seismic reflection surveys. The suite of data presented in this Open File report is unique in that it represents the deepest subsurface penetration we have yet achieved with the simple technique and equipment used here. In particular, Lines 300 and 700, which show reflections from depths of up to 400 m, were recorded using only a 16 lb sledge hammer and steel plate as the seismic source.

The optimum offset profiles showed excellent definition of the bedrock surface and overlying stratigraphy where the overburden was composed of fine-grained sediments. However, the definition of the bedrock surface deteriorated dramatically when thick sequences of coarse-grained material were encountered in the overburden. This could be due to the loss of seismic energy due to the large acoustic impedance contrast at the surface of the coarse-grained unit, to scattering of energy within the unit itself, or to a small acoustic impedance contrast at the interface between (Tertiary?) gravels and the underlying bedrock. Larger sources (to improve the signal-to noise ratio) or common depth point (CDP) processing could possibly improve the delineation of the bedrock surface on the shallow seismic reflection profiles.

ACKNOWLEDGMENTS

The Okanagan Valley was originally suggested as a site for testing the optimum offset reflection technique by H.A. MacAulay, who also was instrumental in designing and building the 8-gauge Buffalo gun and weight drop sources used during this survey. The field work was carried out with the help of two very able summer students, John Scaife and Jon Braithwaite, who worked diligently through an extremely hot July and August, 1984.

REFERENCES

Doornenbal, J.C., and Helbig, K., 1983,
High-resolution reflection seismics on a tidal flat in the Dutch Delta - acquisition, processing and interpretation; First Break, **1 (5)**, p. 9-20.

Fulton, R.J., 1972,
Bedrock topography of the North Okanagan Valley and stratigraphy of the unconsolidated valley fill: Part B: Stratigraphy of unconsolidated fill and Quaternary development of North Okanagan Valley; Geological Survey of Canada, Paper 72-8, Part B, p.9-17.

Hunter, J.A., Burns, R.A., Good, R.L., MacAulay, H.A., and Gagne, R.M., 1982a,
Optimum field techniques for bedrock reflection mapping with the multichannel engineering seismograph; in Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 125-129.

Hunter, J.A., Burns, R.A., Gagne, R.M., Good, R.L., and MacAulay, H.A., 1982b,
Mating the digital engineering seismograph with the small computer - Some useful techniques; in Current Research, Part B, Geological Survey of Canada, Paper 82-1B, p. 131-138.

Hunter, J.A., Pullan, S.E., Burns, R.A., Gagne, R.M., and Good, R.L., 1984,
Shallow seismic reflection mapping of the overburden-bedrock interface with the engineering seismograph - Some simple techniques; Geophysics, **49**, p. 1381-1385.

Hunter, J.A., and Pullan, S.E., 1989,
The optimum offset shallow seismic reflection technique; in Proc., 2nd Symposium of the Application of Geophysics to Engineering and Environmental Problems, (SAGEEP '89), Golden, CO, March 13-16, 1989, p. 143-174.

Hunter, J.A., Pullan, S.E., Burns, R.A., Gagne, R.M., and Good, R.L., 1989,
Applications of a shallow seismic reflection method to groundwater and engineering studies; in Proc., Exploration '87, Third Decennial International Conference of Geophysical and Geochemical Exploration for Minerals and Groundwater, G.D. Garland (ed.), Ontario Geological Survey, Special Volume 3, p. 704-715.

MacAulay, H.A., and Hobson, G.D., 1972,
Bedrock topography of the North Okanagan Valley and stratigraphy of the unconsolidated valley fill: Part A: A seismic refraction survey of the North Okanagan and South Shuswap Valleys; Geological Survey of Canada, Paper 72-8, Part A, p. 1-8.

Norminton, E.J., and Pullan, S.E., 1986,
Seismic reflection software for engineering seismographs; Geological Survey of Canada, Open File 1277, 120 pp.

Pullan, S.E., and Hunter, J.A., 1990,
Delineation of buried bedrock valleys using the optimum offset shallow seismic reflection technique; in Geotechnical and Environmental Geophysics, v. III, Geotechnical, S.H. Ward (ed.), Society of Exploration Geophysicists, Tulsa, OK, p. 75-87.

Pullan, S.E., and MacAulay, H.A., 1987,
An in-hole shotgun source for engineering seismic surveys; Geophysics, **52**, p. 985-996.

Pullan, S.E., Miller, R.D., Hunter, J.A., and Steeples, D.W., 1991,
Shallow seismic reflection surveys - CDP or "optimum offset"?; in Expanded Abstracts, 61st Annual International Meeting of the Society of Exploration Geophysicists, p. 576-579.

Somanas, D., Bennett, B., and Chung, Y., 1987,
In-field seismic CDP processing with a microcomputer; The Leading Edge, **6**, no.7, p. 24-26, 48.

Steeples, D.W., and Knapp, R.W., 1982,
Reflections from 25 feet or less; in Expanded Abstracts, 52nd Annual International Meeting of the Society of Exploration Geophysicists, p. 469-471.

Steeples, D.W., Knapp, R.W., and Miller, R.D., 1985,
Field efficient shallow CDP surveys; in Expanded Abstracts, 55th Annual International Meeting of the Society of Exploration Geophysicists, p. 150-152.

Steeples, D.W., and Miller, R.D., 1990,
Seismic reflection methods applied to engineering, environmental, and groundwater problems; in Geotechnical and Environmental Geophysics, v. I, Tutorial, S.H. Ward (ed.), Society of Exploration Geophysicists, Tulsa, OK, p. 1-30.

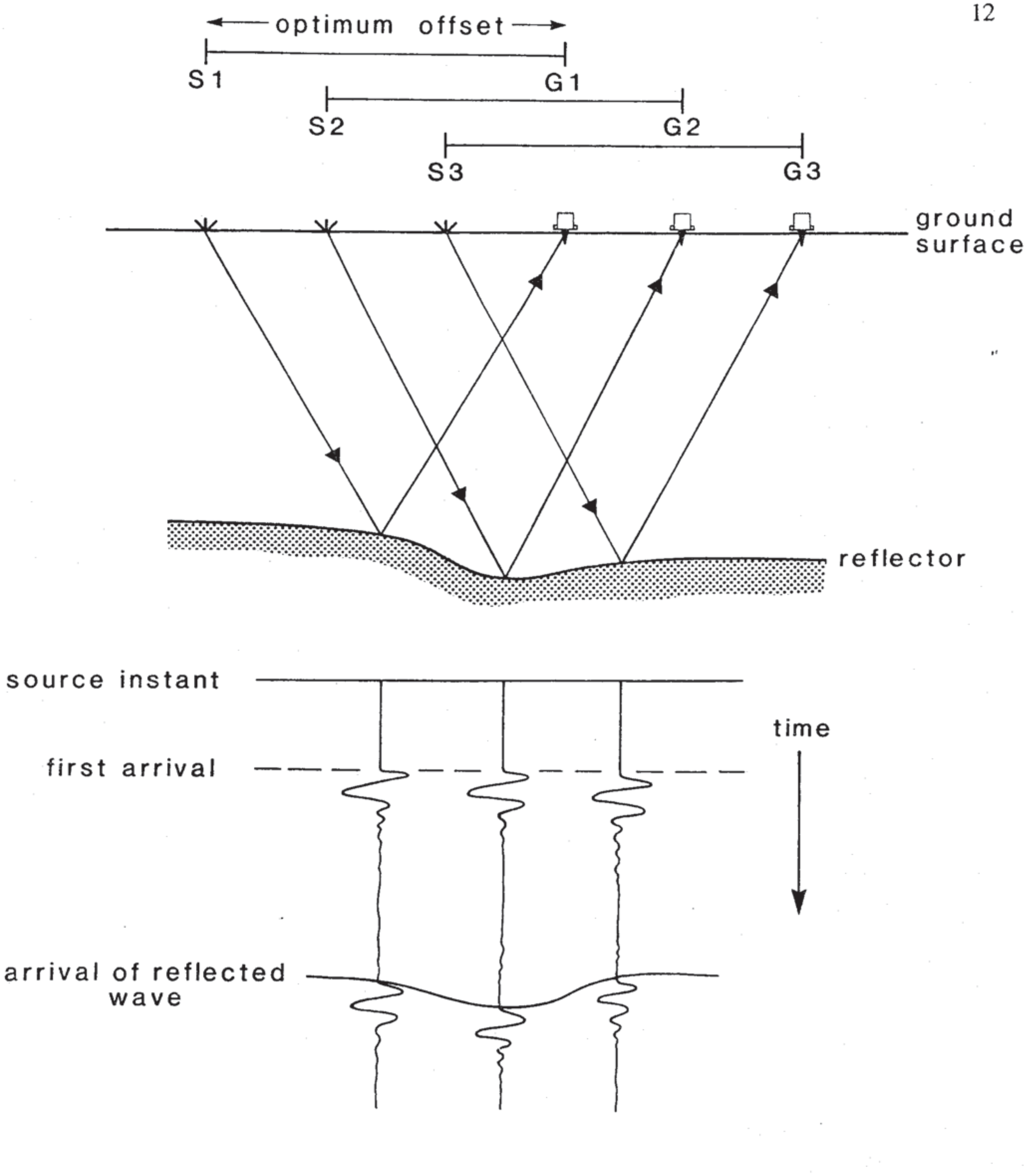

Figure 1. A schematic representation of the optimum offset technique. The traces which make up the schematic section shown at the bottom of the figure were obtained by shooting first from source position 1 (S1) and recording the output from geophone 1 (G1), then from S2 to G2, and finally from S3 to G3.

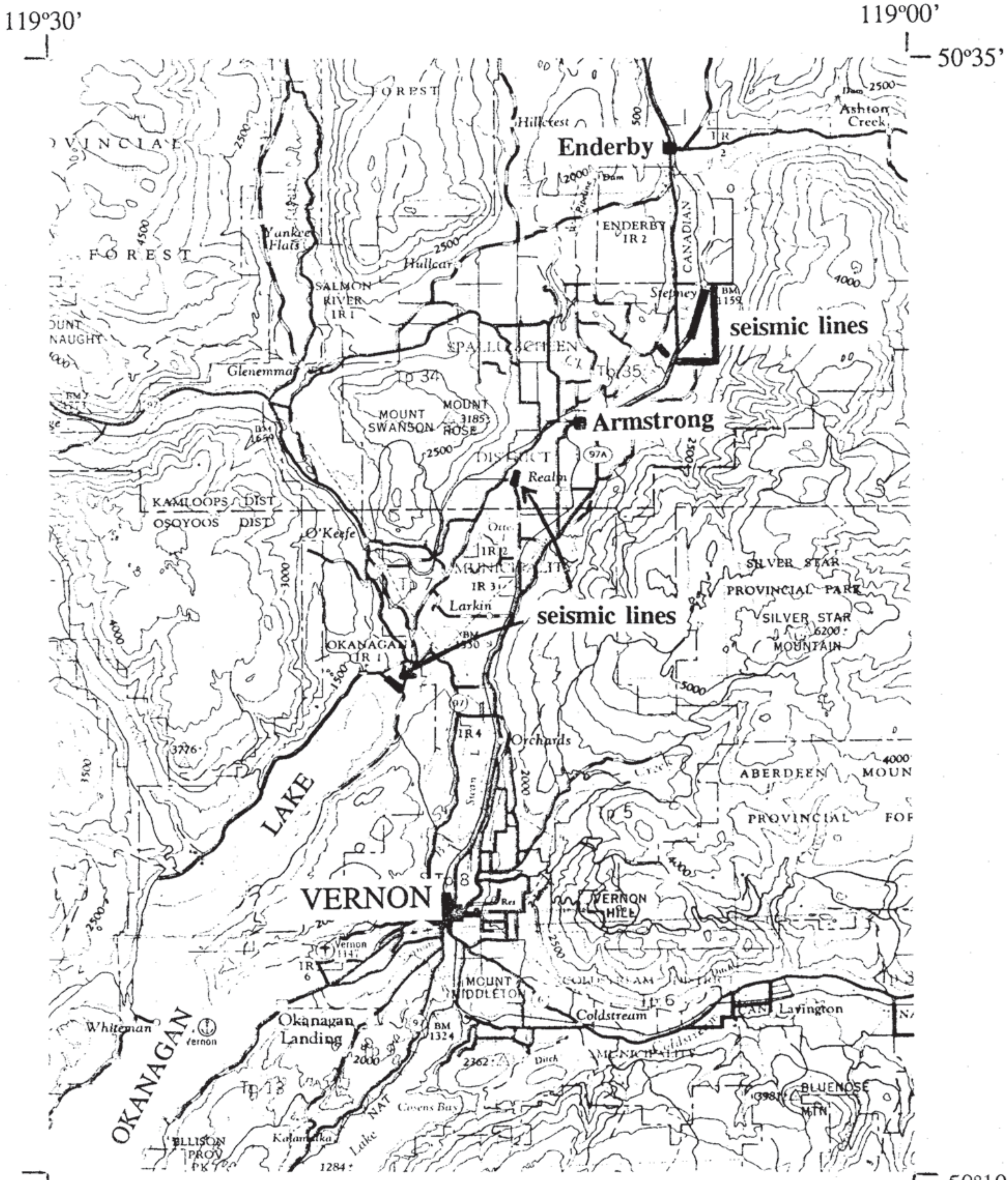

Figure 2. Map of the Vernon survey area, showing locations of the six seismic profiles obtained in 1984 (from 1:250,000 Topographic Map "Vernon, British Columbia", 82L).

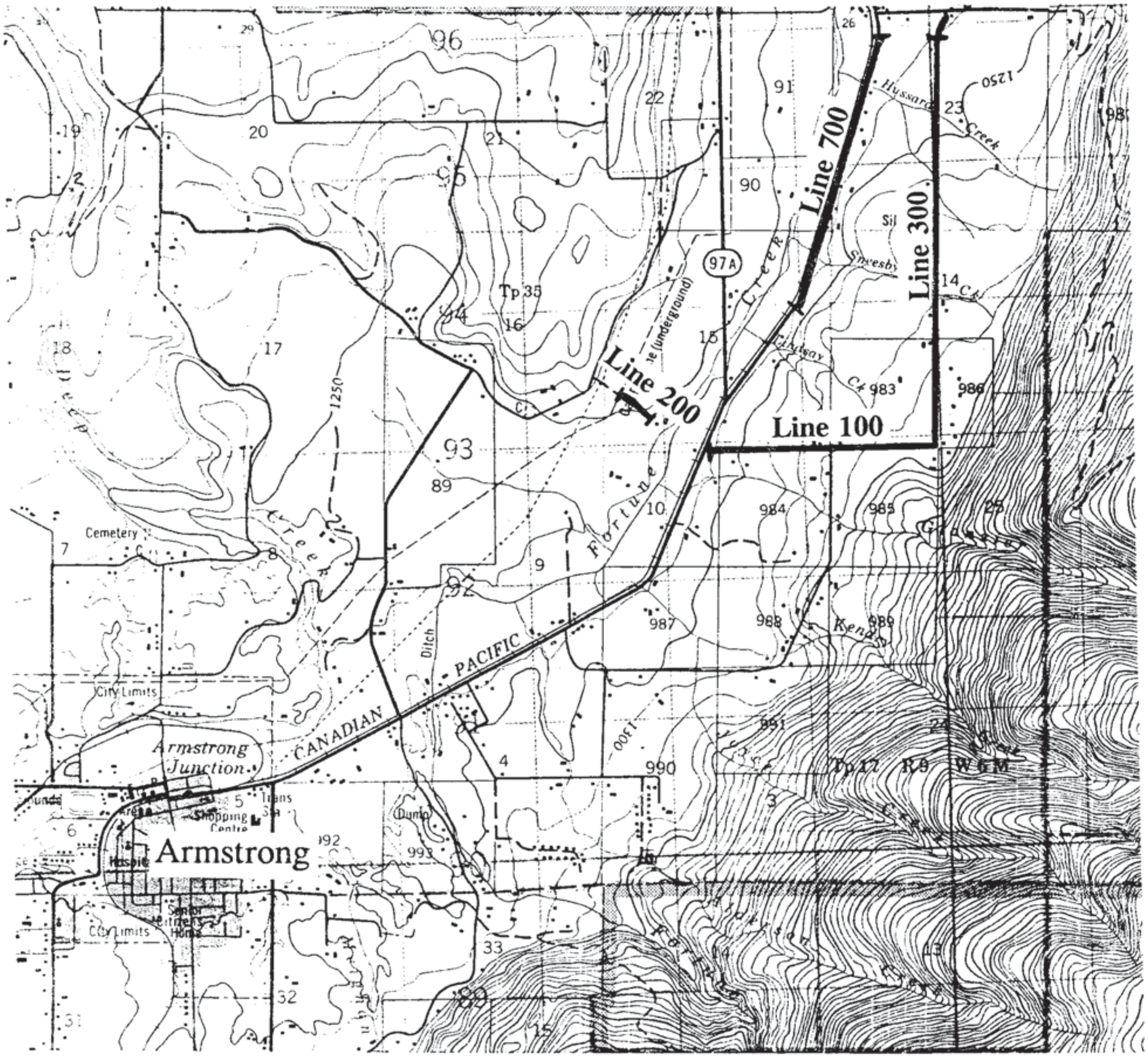

Figure 3. Map showing locations of seismic lines 100, 200, 300 and 700, north of Armstrong (from 1:50,000 Topographic Map "Vernon, British Columbia", 82L/6).

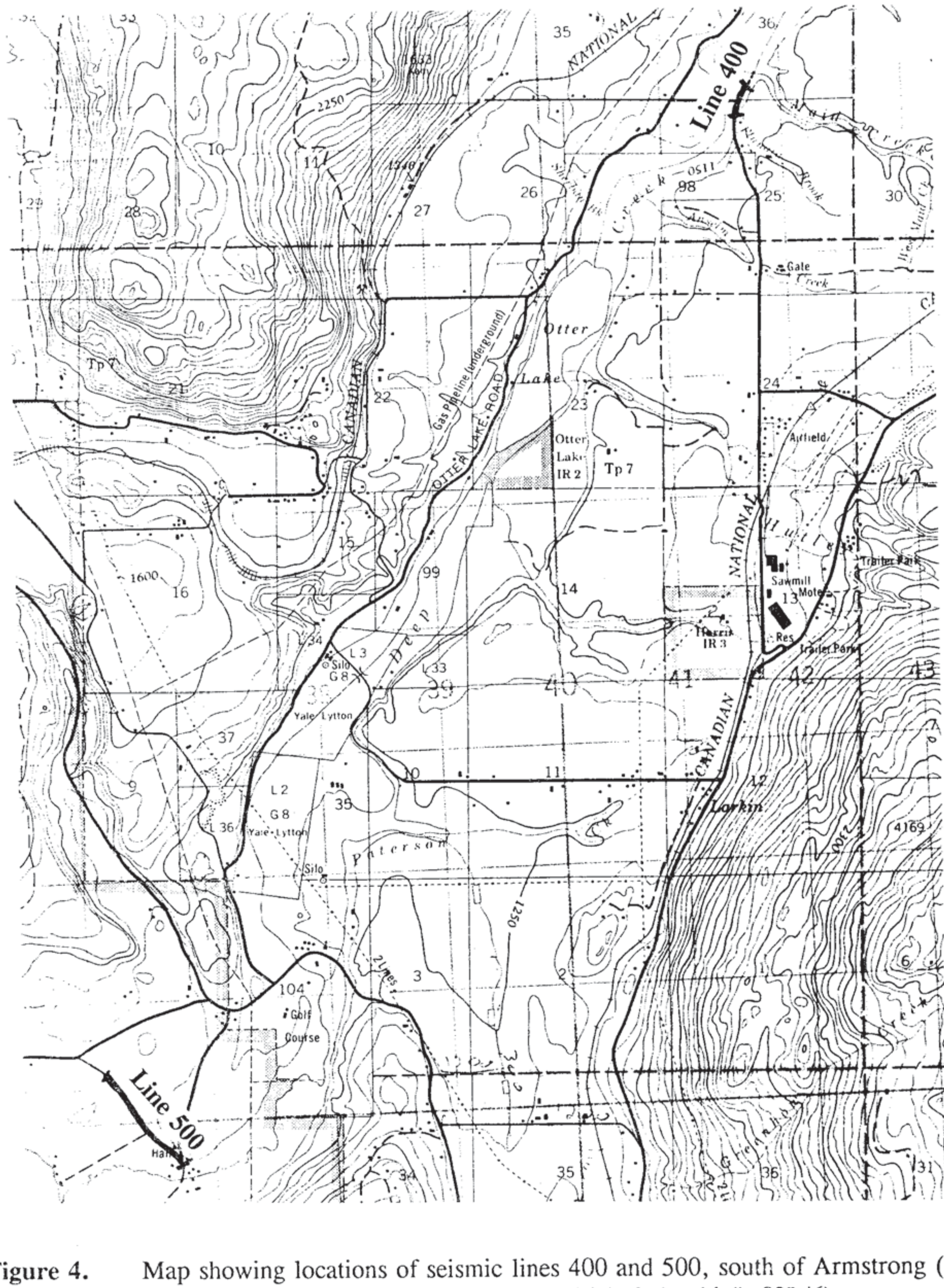

Figure 4. Map showing locations of seismic lines 400 and 500, south of Armstrong (from 1:50,000 Topographic Map "Vernon, British Columbia", 82L/6).

VERNON, B.C. - LINE 100 (PLATE 1)

Common Offset Seismic Reflection Data

Recorded July, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	12-gauge "Buffalo gun" (average 2 stacks)
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	150 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 90 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	500 milliseconds
Samples per Trace:	1024
Sample Rate:	0.5 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	Bandpass Filter 80-300 Hz (-3 db points, 18 db rolloffs)
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	Variable (to reduce amplitudes below bedrock arrival)
Static Corrections:	Alignment of First Arrivals

VERNON, B.C. - LINE 200 (PLATE 2)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	12-gauge "Buffalo gun" (average 2 stacks)
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	150 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 90 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	500 milliseconds
Samples per Trace:	1024
Sample Rate:	0.5 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	N/A
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	Variable (to reduce amplitudes below bedrock arrival)
Static Corrections:	Alignment of Overburden Refraction Arrival

VERNON, B.C. - LINE 300 (PLATE 3)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	16 lb sledge hammer and steel plate (average 2 stacks)
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	150 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 100 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	500 milliseconds
Samples per Trace:	1024
Sample Rate:	0.5 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	Bandpass Filter 80-300 Hz (-3 db points, 18 db rolloffs)
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	Variable (to reduce amplitudes below bedrock arrival)
Static Corrections:	Alignment of First Arrivals

VERNON, B.C. - LINE 400 (PLATE 4)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	8-gauge "Buffalo gun" (average 3 stacks)
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	198 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 80 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	1000 milliseconds (1 s)
Samples per Trace:	1024
Sample Rate:	1 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	Bandpass Filter 80-320 Hz (-3 db points, 18 db rolloffs)
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	N/A
Static Corrections:	Alignment of First Arrivals

VERNON, B.C. - LINE 500 (PLATE 5)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	65 kg weight drop (from height of 3 m) and steel plate
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	225 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 100 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	1000 milliseconds (1 s)
Samples per Trace:	1024
Sample Rate:	1 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	N/A
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	N/A
Static Corrections:	Alignment of First Arrivals

VERNON, B.C. - LINE 500 (PLATE 6)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	65 kg weight drop (from height of 3 m) and steel plate
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	225 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 100 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	1000 milliseconds (1 s)
Samples per Trace:	1024
Sample Rate:	1 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	Bandpass Filter 40-160 Hz (-3 db points, 18 db rolloffs)
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	N/A
Static Corrections:	Alignment of First Arrivals

VERNON, B.C. - LINE 700 (PLATE 7)

Common Offset Seismic Reflection Data

Recorded August, 1984

RECORDING PARAMETERS

Recording Instrument(s):	Nimbus 1210F engineering seismograph (12 channel), Nimbus G724S digital tape recorder (Fixed gain - 8 bit A/D)
Source:	16 lb sledge hammer and steel plate (1-4 stacks)
Receiver:	Mark Products geophone (50 Hz), single geophone/channel
Source-Receiver Offset:	150 m
Shot/Geophone Spacing:	3 m
Analog Filters:	Bandpass Filter centred at 100 Hz ("Inverse Notch" with 6 db rolloffs) Notch Filter - 60 Hz
Recording Timescale:	500 milliseconds
Samples per Trace:	1024
Sample Rate:	0.5 millisecond

DISPLAY PARAMETERS

Computer/Plotter:	Apple II+/Tektronix 4663 Flatbed
Digital Filter:	Bandpass Filter 80-300 Hz (-3 db points, 18 db rolloffs)
Automatic Gain Control:	200 sample window, gain factor = 15
Gain Tapers:	Variable (to reduce amplitudes below bedrock arrival)
Static Corrections:	Alignment of First Arrivals