GEOLOGICAL SURVEY OF CANADA

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Ground penetrating radar investigations of wood chip covered slopes along the Norman Wells pipeline (Northwest Territories): 1991

Brian Moorman

1994

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GROUND PENETRATING RADAR INVESTIGATIONS OF WOOD CHIP COVERED SLOPES ALONG THE NORMAN WELLS PIPELINE: 1991

by

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FOREWORD

This report documents work undertaken as part of the federal government's Permafrost and Terrain Research and Monitoring Program along the 869 km Norman Wells to Zama oil pipeline. The 324 mm diameter, shallow burial (1 m) pipeline, traverses the discontinuous permafrost zone of northwestern Canada and began operation in April 1985. A joint monitoring program with Interprovincial Pipe Line Inc. was established following the signing of an Environmental Agreement between the pipeline company and the Department of Indian and Northern Affairs (INAC). The Geological Survey of Canada of the Department of Natural Resources is a principal participant in this program.

A major component of the research involves the detailed quantification of changes in the ground thermal regime, geomorphic and subsurface conditions at a series of instrumented sites and wood chip insulated slopes along the pipeline route. This project was developed in cooperation with the Terrain Sciences Division of the Geological Survey in order to examine and quantify the effects of pipeline construction, operation and maintenance in thaw sensitive terrain.

Many components of this research are contracted out. The work undertaken in this consultant's report describes but one aspect of these site investigations. Interpretations contained herein are often limited to the specific database under analysis and thus may not represent an integrated or comprehensive analysis of all site observations. The opinions and views expressed by the authors are their own and do not necessarily reflect those of the Geological Survey of Canada or Indian and Northern Affairs Canada.

Funding for the research and analyses reported herein was provided by INAC through their Northern Affairs Program and the Northern Oil and Gas Action Plan (NOGAP), and by the Geological Survey of Canada through the Panel on Energy Research and Development (PERD) program.

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Introduction

Slope stability is one of the major concerns in pipeline design in the North. In permafrost regions, minor warming of the ground can cause thawing of the permafrost and produce a dramatic decrease in soil strength. In 1984 and 1985 the Norman Wells buried pipeline was constructed from Norman Wells, N.W.T at the southern edge of the zone of continuous permafrost to Zama, Alberta in the zone of scattered sporadic permafrost (MacInnes et al., 1989). Much of the permafrost along the pipeline has mean annual temperatures within a few degrees of 0 °C and is thus considered thermally unstable. For this reason an insulating blanket of wood chips was placed on the ground surface where the pipeline traversed thaw sensitive sloping ground. In total there are 56 wood chip covered slopes along the pipeline. As this procedure is relatively new, considerable effort has gone into monitoring the effectiveness of the wood chips.

As part of the "Environmental Agreement" for the Norman Wells pipeline, the Departments of Indian and Northern Affairs (INAC) and Energy, Mines and Resources (EMR), the National Research Council of Canada (NRC) and Agriculture Canada have established a co-operative Permafrost and Terrain Research and Monitoring (PTRM) program. Background information on the development and monitoring of the pipeline can be found in various Department of Indian and Northern Affairs, and Geological Survey of Canada publications (Burgess, 1988; Burgess and Naufal, 1990; MacInnes et al., 1989a; 1989b; Pilon et al., 1989).

One of the objectives of the PTRM program is to determine and quantify the impacts of the pipeline on the permafrost and terrain. Since the construction of the pipeline, thaw bulbs have developed on the Right Of Way (ROW) and around the pipe, due to clearing of vegetation, and the warm (greater than 0 °C, on average annually) pipe temperature. This has raised concerns over the stability of several wood chip insulated slopes. These concerns have prompted further investigations to be done in addition to the existing monitoring program.

From August 22 to 27, 1991, Ground Penetrating Radar (GPR) surveys were carried out by Dr. Alan Judge of the Geological Survey of Canada (GSC) and myself, at four of the wood chip covered slopes along the Norman Wells pipeline. The purpose was to investigate the development of the thaw bulbs and observe the general subsurface condition of the slopes. Although most of the slopes surveyed already had temperature cables installed, GPR was used to gain continuous three dimensional information on the lithologic and thermal structure of the slopes. This was accomplished by using the GPR to extrapolate out from the location of the bore holes from which lithologic and thermal information is available.

This project was initiated in the summer of 1989 and continued in 1990 (Moorman, 1991). Promising results from the 1989 and 1990 surveys, prompted the 1991 GPR program. When possible, the results from the 1991 surveys are compared to those of the previous surveys. As this is an assessment research program, different equipment and survey configurations were used to determine the usefulness of the method and the optimal procedures to be used.

The four slopes surveyed in 1991 were Great Bear—Slope 29b (km 79), Ochre River—Slope 82 (km 286), Unnamed—Slope 109 (km 352), and Mackenzie River—Slope 142 (km 529) as shown in Figure 1. All the slopes are on the south side of their respective stream or river and thus, down slope direction is "pipeline" north, opposite to the direction of oil flow. It should be noted that throughout this report, compass directions will relate to pipeline north. As the pipeline bends at several locations, this does not always relate to true north.

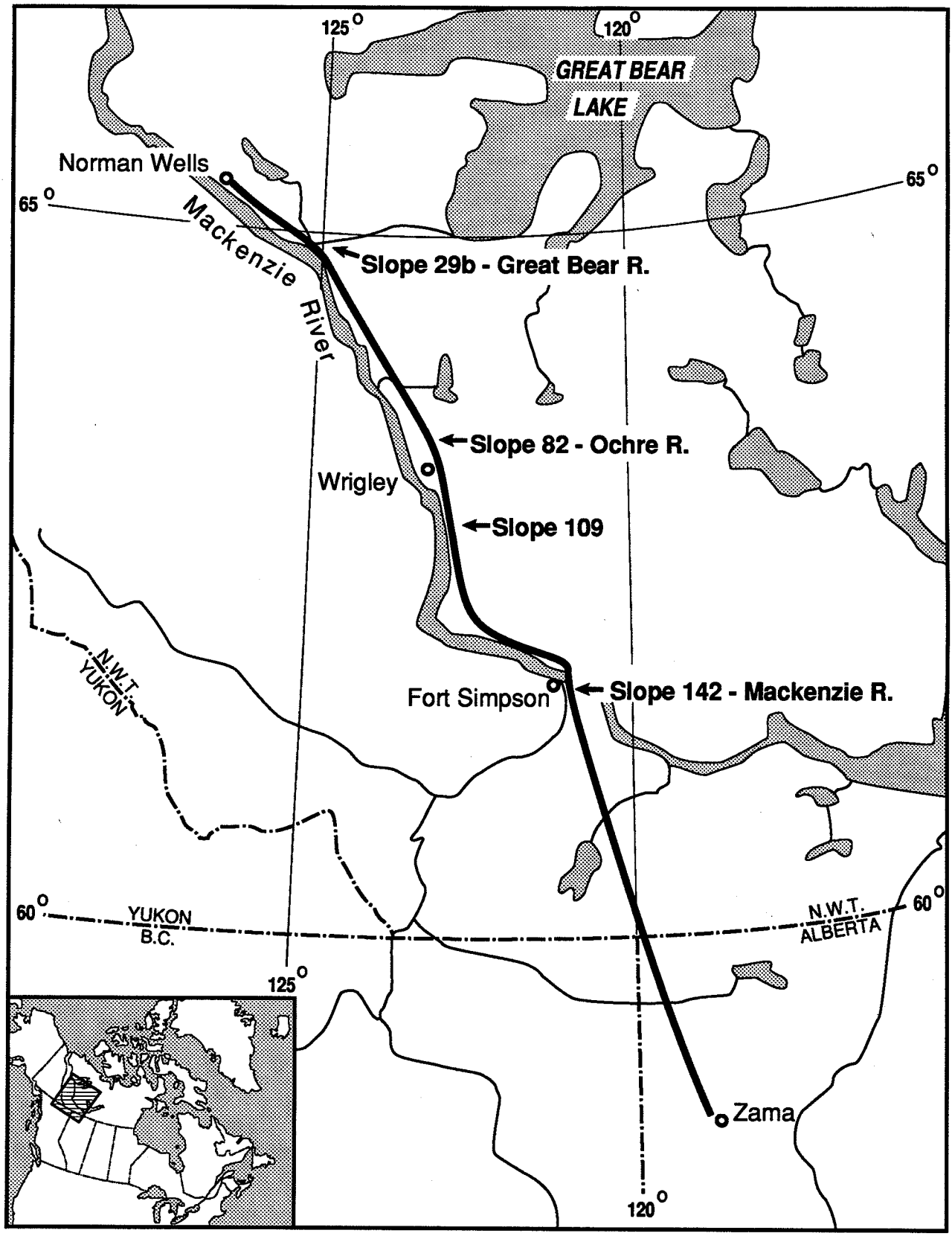

Figure 1. Location of the woodchip covered slopes where GPR surveys were conducted in 1991.

Methodology

For this project the pulseEKKO IV ground penetrating radar system was used to collect all of the GPR the data. A 400 V transmitter was used for all of the profiles. Antennas with two different centre frequencies were tested. The 100 MHz antennas were used when deeper penetration was desired, and 200 MHz antennas were used for greater resolution. For a discussion of the comparisons between resolution and depth of penetration see (Moorman, 1990). The GPR profiles were plotted using the pulseEKKO software and a Hewlett Packard Paintjet printer. The data resides at the GSC with Dr. Alan Judge.

The distance between stations, or the step, for the profiles was either 50 cm or 1 m. At Slope 109 (Cross profile 2) a comparison was done between profiles with 50 cm steps and 1 m steps to investigate the effects of station frequency on horizontal resolution.

The long profiles were run in the down slope direction and the cross profiles were always run from west to east. At the Ochre River slope, Slope 109, and Mackenzie River slope the long profiles were run roughly down the centre of the travel side of the ROW (i.e. offset from the pipe by approximately 8 m). At the Great Bear slope the long profiles were run over top of the pipe so the structure directly above the pipe could be mapped. The cross profiles usually started and finished at the edges of the cleared ROW. The exception to this is at the Great Bear slope where some of the profiles at the base of the slope extended into the forest on either side of the ROW.

From the spatial information recorded during surveying, site plan maps were drawn up for each slope. As a result of time constraints, precision surveying could not be carried out. As a result, distances in the down slope direction (north — south) have an approximate uncertainty of 0.5 m. The cross slope precision is generally 0.5 m but varies, up to 2.5 m. The only major consequence of coarse precision is a certain amount of uncertainty associated with the location of the sides of the wood chip cover. Relative to the ends of the GPR profiles, the edges of the wood chip cover are always mapped to the nearest metre, but their absolute spatial position may be less precise.

The down slope topographic profile for three of the slopes can also be found on the site plans. These were constructed using data from Abney level surveys conducted down the centre of the ROW. The GPR profiles were not corrected for topography because the vertical exaggeration would have to be decreased to the point that near surface detail would be lost. Additionally, all of the reflections of interest are parallel or near parallel to the surface and the pipe, and topographic correction would not aid interpretation.

The temperature profiles shown for each of the slopes were created from data collected for the PTRM program and supplied by Margo Burgess of the Geological Survey of Canada.

Table 1. Profile names and file numbers for the 1991 GPR slope surveys along the Norman Wells pipeline.

Slope	Name	File Number	Frequency	Comments
Great Bear (Slope 29b)	Long profile 1	41	200 MHz	
	Long profile 2	40	200 MHz	
	Cross profile 1	36	200 MHz	up slope from wood chips
	Cross profile 2	35	200 MHz	
	Cross profile 3	34	200 MHz	
	Cross profile 4	33	200 MHz	
	Cross profile 5	32	200 MHz	
	Cross profile 6	31	200 MHz	
	Cross profile 7	30	200 MHz	
	Cross profile 8	29	200 MHz	
	Cross profile 9	28	200 MHz	down slope from wood chips
	Cross profile 10	37	200 MHz	down slope from wood chips
	Cross profile 11	38	200 MHz	down slope from wood chips
	Cross profile 12	39	200 MHz	down slope from wood chips
Ochre River (Slope 82)	Long profile 1	24	200 MHz	
	Cross profile 1	27	200 MHz	
	Cross profile 2	26	200 MHz	
	Cross profile 3	25	200 MHz	
Slope 109	Long profile 1	20	200 MHz	
		17	100 MHz	
	Cross profile 1	23	200 MHz	
	Cross profile 2	18	100 MHz	
		19	100 MHz	50 cm steps
	Cross profile 3	22	200 MHz	
	Cross profile 4	21	200 MHz	
Mackenzie River (Slope 142)	Long profile 1	1	100 MHz	
	Cross profile 1	4	100 MHz	
	Cross profile 2	3	100 MHz	
	Cross profile 3	2	100 MHz	

Results

All of the GPR profiles and interpretations from the woodchip slopes studied in 1991 are shown in Appendices A-D. Each appendix contains a site plan for the slope, graphs of relevant ground temperature information and the GPR profiles in the same order as displayed in Table 1. Appendix E contains the data sheets for all of the profiles. These data sheets contain the information regarding the parameters used during data collection, as well as the processing and plot layout parameters for each of the GPR profiles.

The GPR profiles were interpreted using radar stratigraphic principles which have been adapted from seismic stratigraphy theory (Moorman, 1990). The profiles were interpreted by using a three step procedure. First, a subsurface model for some point along the profile was developed using the known thermal and lithologic structure (as determined from stratigraphic and

thermal logs). Next, the measured or estimated velocity structure was used to predict the location and strength of reflections. Finally, GPR ray path tracing was applied to the model, and predicted signal return times were compared to the returns observed on the GPR profile. Using this method subsurface lithologic and thermal (frozen/unfrozen) interfaces could be identified and their depth estimated. The returns were then correlated along the profile to laterally map the variations in depth of the interfaces.

Ghost returns (i.e. returns that are not produced by the geologic structure of interest) such as multiples, side-sweep reflections, and surface reflections, were identified and taken into consideration during interpretation. Due to the frequency used, multiple reflections are abundant in many of the profiles. They can be identified by 1) consistent repetitions, 2) gradual decrease in signal strength later in the time window, and 3) an angle of dip that doubles with each order of multiple.

In order to simplify the interpreted profiles, only the ground surface and the important interfaces are plotted. The returns interpreted to be ghosts or reflections that do not represent important geologic structure have been omitted. The ground surface is indicated by the first return, the direct air wave, which arrives at the receiver almost instantaneously (after 1.7 ns when the antenna spacing is 50 cm) after the pulse is generated. The second return is usually the direct ground wave. This is the energy that travels directly from the transmitter to the receiver through the near surface "skin" of the ground. Variations in the travel time of the direct ground wave indicate spatial variations in the near surface propagation velocity of the ground. This is usually caused by changes in lithology or moisture content. It is not plotted on the interpretation profiles as it does not provide direct information on the subsurface structure.

The depth scale plotted on each profile (except Great Bear long profile 1 interpretation) was produced by the pulseEKKO plotting software which uses a simple single layer model. This model assumes that the velocity is known and remains constant along the entire length of the profile and to the depth of interest. Although these assumptions are usually incorrect, this method can be used to produce reasonable results in most cases. In some instances when the velocity structure varies dramatically with depth or along the profile, the reliability of the depth scale greatly decreases. Figure 2 schematically demonstrates how increased subsurface complexity increases the distortion of the depth scale on the GPR profile. In different scenarios the calculated depth scale can be very accurate or dramatically overestimate or underestimate the depths of reflectors. Inaccurate depth scales can be identified and corrected using the subsurface verification from core logs and temperature cables.

At some locations (eg. Mackenzie River—Slope 142) little verification on the nature of the subsurface was available. In these cases the depth of possible interfaces may be interpreted but if the materials on either side of the interface could not be confirmed the interpreted profile was not labelled.

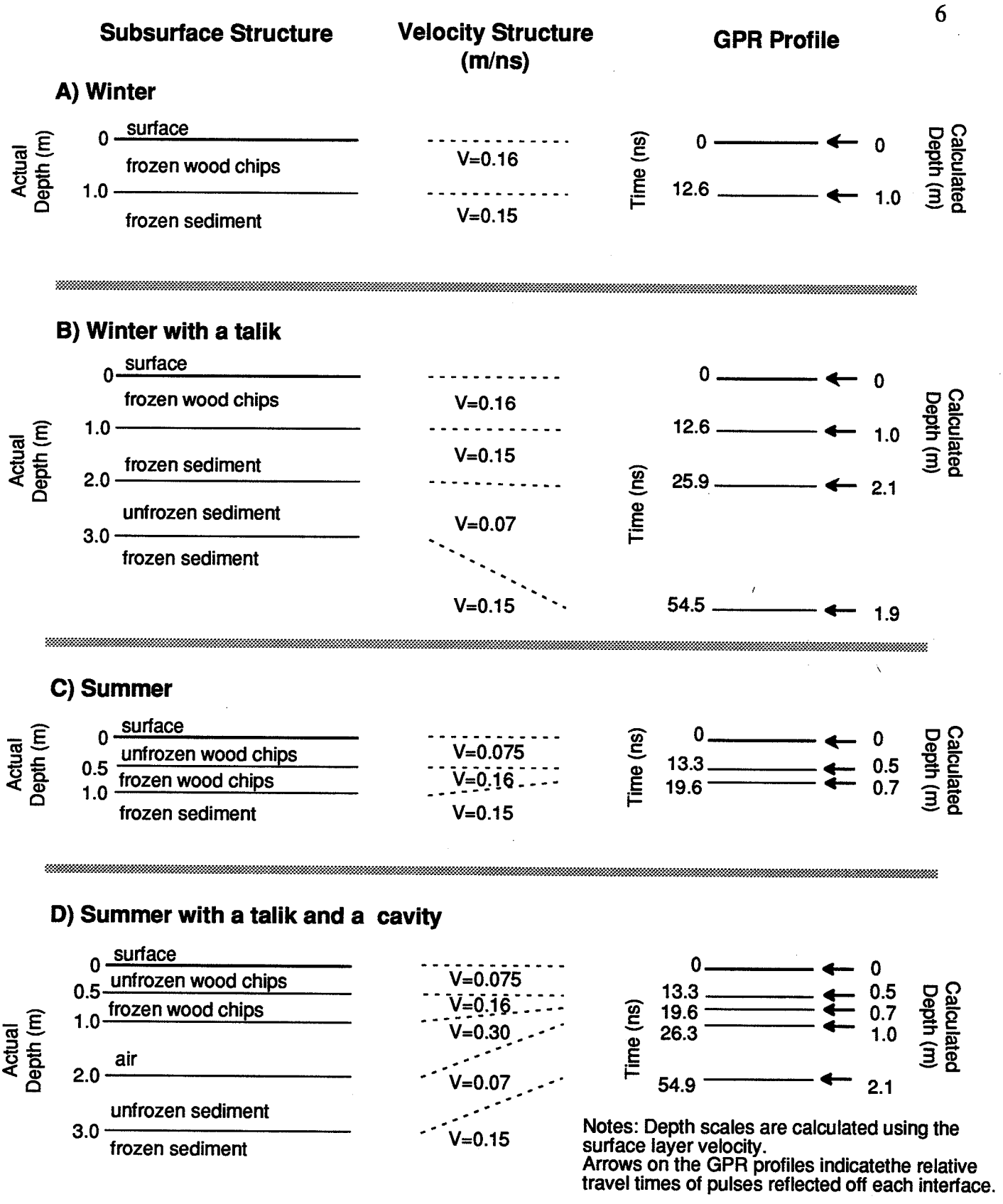

Figure 2. *Schematic representation of the effects of complex subsurface structure on the appearance of the GPR profile. When the velocity of a layer differs significantly from surface velocity the relative separation of returns change dramatically.*

Great Bear River

Two long profiles were run along the Great Bear slope. The first was run over top of the pipe near the middle of the slope to try to delineate the length of a cavity that was discovered during active layer probing. The second long profile was run over the pipe at the base of the slope, starting on the wood chips and proceeding about 60 m beyond the bottom edge of the wood chips. This profile was run to examine the thickness of cover currently over the pipe. Cross profiles were run every 20 m down the slope starting at the upper thermal fence (84-3b) and continuing to beyond the end of the lower long profile. The relative location of the profiles is shown on the site plan.

On long profile 1 the velocity structure is very complex with depth, and changes considerably along the profile. For most of the profile the subsurface structure resembles that of example "D" in Figure 2. Because of this complexity, the surface velocity used as a estimate for the depth scale construction on the GPR profile proved inadequate, producing errors in the depth of interfaces of up to 100% at a depth of 2 m. On the interpreted profile a more precise depth scale was constructed using a single layer model with the average velocity of the top 2 m (determined by verification of the depths of reflectors by active layer probing and a small excavation which perforated the cavity). This depth scale is accurate to within the resolution limits of the GPR in the top 4 m of the subsurface. However, it should be noted that because the cavity does not extend the entire length of the profile and lateral velocity variations could not be incorporated into the velocity structure model, the depth scale can only provide an estimate of the depths from which reflections occur. The depth of interfaces on this interpretation will be most accurate in the sections with the cavity and least accurate where the cavity is not present.

Depth scale uncertainty aside, long profile 1 does provide considerable information on the depth of thaw and extent and shape of the cavity above the pipe. The depth of thaw appears to be the first reflection (the third return). Its depth varies very little over the length of the profile.

The start of the cavity is indicated about 15 m along the profile where an extra pulse appears between the third and fourth returns. The cavity appears to extend down to the 80 m position. Between the 60 m and 65 m positions the return from the base of the profile rises up and the cavity appears to pinch out.

The return at about 33 ns is likely from the base of the cavity, as the interface between air and unfrozen saturated mud produces a strong reflection. The return at about 40 ns could possibly indicate the base of the thaw or it may be a reflection from the base of the pipe. Below this depth the record is dominated by multiple reflections. Returns from interfaces much below this point are likely to be weak due to the large proportion of the energy already reflected to the surface and the adsorptive properties of unfrozen mud. For this reason later returns tend to be masked by the multiples.

Long profile 2 was surveyed to assess whether the depth of the pipe and any lithologic variations below the pipe could be could mapped. At the base of the Great Bear slope (29b) there has been considerable thermokarst activity since the construction of the pipeline. As the ice melted out of the soil above the pipe, the relative pipe depth has decreased. The original lithology at the thermal fence 84-3a consisted of 30 cm of organic silt at the surface, below which there was approximately 1 m of ice and silt, then below that, silt to a depth of about 2.5 m in the vicinity of the pipe. Below 2.5 m clayey silt was encountered. The pipe was originally buried 1 m below the

surface. The current depth of the pipe was measured with a blunt ended probe along the long profile 2 line. As displayed in Figure 3, the depth to the pipe has decreased considerably, indicating that the backfill covering the pipe has decreased in thickness between 70 and 90%.

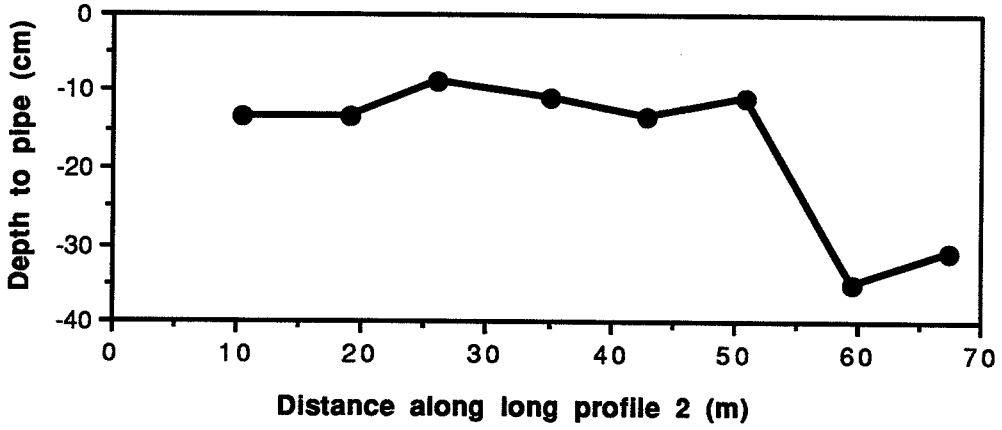

Figure 3. *Depth to the top of the pipe below the surface at the base Great Bear Slope 29b as measured by Dr. Stanislav Grechishev.*

The pipe is presently too shallow to be delineated with GPR, at the frequency used. On long profile 2, the only real reflection that could be detected amongst the multiples was at a depth of 2 m. If the majority of the ice and silt horizon has disappeared due to thawing (as suggested by the measured depth of the pipe) then the interface between the silt and the clayey silt would now be at 2 m depth. The temperature cables at thermal fence 84-3a indicate that the depth of thaw is also about 2 m. Thus the reflection observed in the GPR long profile 2 was probably produced by the interface between unfrozen silt above and frozen clayey silt below.

The cross profiles run at the top and bottom of the slope (where wood chips were not present) clearly show the character of the thaw bulb below the pipe. The depth of thaw is interpreted to vary from less than 1 m off the ROW to over 2 m near the pipe on cross profiles 1, 9, 10, 11, and 12 . The depth of thaw on the cross profiles at the base of the slope correlates with the interpreted thaw depth on long profile 2 and the thermal data from the temperature cables at fence 84-3a. These profiles indicate that the thaw front has not reached the base of the silt unit near the edge of the ROW. At the top of the slope the depth of thaw appears to be underestimated. On cross profile 1, just north of thermal fence 84-3b, it is indicated that the ground is thawed to a depth of 1.8 m, however, the data from the temperature cables indicate that the thaw depth is between 3.0 m and 3.5 m below the surface. This discrepancy is probably the result of the velocity that was used to calculate the depth scale being lower than the true propagation velocity at this location. The sediments at the top of this slope are drained sand and thus are likely to have a higher velocity than the saturated silts and clays down slope. A propagation velocity of 0.12 m/ns was used to calculate a correct depth scale on the interpreted profile.

Cross profiles 2 - 8 were run across the wood chips. In most of these profiles the base of wood chips can be observed, as the transition from wood chips to sediment provides a good

reflector. The depth of thaw on the wood chip covered slope varies between 58 cm and 70 cm (see Figure 4). It is always within the wood chips, And thus is not observed on the GPR profiles as a result of the the shallow depth and the resolution (as dictated by the frequency of the antennas used) of the GPR system.

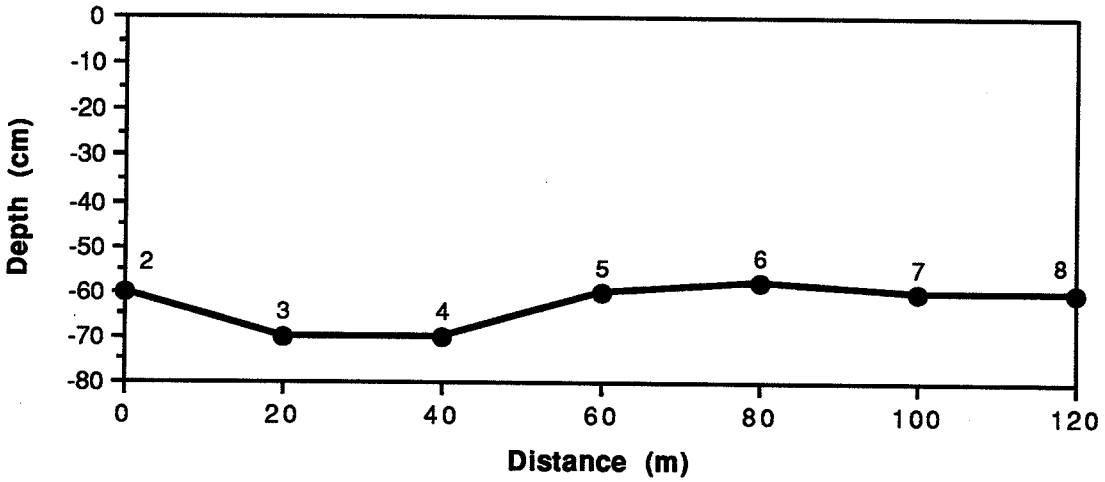

Figure 4. *Depth of thaw on the Great Bear woodchip slope 29b in the centre of the ROW measured by Dr. Stanislav Grechishev. Measurements were taken at the centre point of cross profiles. Numbers indicate cross profile number.*

The reflections observed in profiles 2 - 8 suggest the presence of the cavity or pipe but the size or exact location difficult to discern as the cavity size is close to the resolution of the GPR system in the configuration used.

Four of the cross profiles surveyed in 1991 can be compared to the cross profiles surveyed previous years. Neither of the long profiles are comparable because the previous years profiles were run down the centre of the travel side of the ROW, not over the pipe.

Cross profile 1 (36) was located in roughly the same location as GB100UC from the 1989 surveys (Moorman, 1991). In 1989 the survey was conducted at 100 MHz and thus there is greater depth of penetration but the depth resolution is slightly decreased. The 100 MHz survey does not suffer from strong multiple reflections and has a depth of penetration of 5 m compared to 2 m in the 1991 survey. The multiple reflections observed on the 1991 surveys are likely not a function of the frequency, but a result of the state of thaw in the ground.

Cross profile 3 (34), run across the top portion of the wood chips, crossed approximately in the same location as profile GB200UC, from 1990. Upon comparison with the 1991 survey there are indications that the subsurface cavity may have begun to form prior to August 1990. The cavity is considerably more obvious in the 1991 survey, but minor anomalous reflections do occur in the same location on the 1990 survey.

The 1990 lower cross profile GB200LC crossed the wood chip slope in the vicinity of the 1991 cross profiles 7 (30) and 8 (29). In 1990, surveys were run with a 1 m separation between traces. As a result, it is more difficult to correlate interfaces between traces on the older profiles, and thus interpretation is difficult without local subsurface verification. On the 1991 profiles the anomaly over the pipe is far more easily delineated than on the 1990 profiles.

The bottom profile in the 1989 surveys, GB100LC, crossed the ROW near where the 1991 cross profile 12 (39) was surveyed. The 100 MHz frequency used in the earlier profiles makes interpretation more difficult, but it is evident that the depth of thaw interface has moved. There is no indication that the thaw bulb has penetrated down significantly between 1989 and 1991, but its width does appear to have increased by about 10 m. In 1991 the deep portion of the thaw bulb extends from about the 10 m to the 50 m position along the profile, while in 1989 it appears to extend from the 10 m to the 40 m position along the profile. In both surveys, the depth of thaw extends down to the interface between the silt and the clayey silt near the centre of the ROW. The signal loss will dramatically increase within unfrozen clayey silt, thus little penetration into this layer is expected when it begins to thaw.

Ochre River

At the Ochre River slope one long profile and three cross profiles were surveyed. The long profile was run down the centre of the travel side of the ROW. The three cross profiles were run near the top, middle and bottom of the wood chip cover, as shown in the site plan.

On the long profile the base of the wood chips is interpreted to be at a depth of about 1.2 m. This agrees well with estimates (determined from the original thickness and the estimated settlement) (Hanna, 1990). The depth of thaw (within the wood chips) could be mapped along many portions of the profile. The lower portions of the profiles are dominated by multiple reflections such that returns from below the base of the wood chips are masked.

The profiles surveyed in 1990 were done with 50 MHz antennas and 2 m antenna separation (Moorman, 1991). The depth of thaw is not visible at all within the wood chips in the 1990 long profile, however, the base of the wood chips and deeper structures are discernable. On the 1990 long profile a strong return from about 1 m below the base of the wood chips indicates a dramatic dielectric interface. This may be the a frozen/unfrozen interface, or it may represent the interface between clay and ice rich clay as formed by a previous thaw. On the 1991 long profile, some deeper structure is apparent (such as the chaotic zone below the base of the wood chips about 102 m from the start of the profile), however its character is masked by multiple reflections and without subsurface verification it is impossible to determine its origin. As there are numerous metallic ventilation conduits buried or partially buried in the slope the source of returns from later times are undeterminable.

On the cross profiles, the depth of thaw and the base of the wood chips is interpreted. On cross profile 1 strong returns from between 3 m and 4 m depth suggest the presence of deeper structure as well.

The 50 MHz profiles from 1990 provide good indications of the structure to a depth of up to 8 m, but only profiles done with 200 MHz antennas (such as long profile 1 from 1991) can clearly delineate the near surface features such as the geometry of the seasonal thaw front.

Slope 109

Two long GPR profiles were run down the centre of the travel side of the ROW on slope 109 (one 100 MHz profile with a 1 m step, and one 200 MHz profile with a 0.5 m step). Cross profiles were done at four locations along this slope. The cross profiles were concentrated around a depression in the surface of the wood chips as shown in the site plan.

The base of the wood chips is clearly interpretable on all of the profiles, however other interfaces are not as distinct. On the long profiles there is considerable variation in the travel time (from 15 ns to 30 ns) for the return interpreted to represent the base of the wood chips. This corresponds with 0.5 m to over 1 m depth using a propagation velocity of 0.075 m/ns. This velocity was estimated using data from other wood chip slopes, however, precise velocity determinations were not done at this location. As only 0.4 m of wood chips were spread on the slope at the time of construction, this estimated velocity may be a little too high, or post-construction modifications have resulted in a change in the wood chip thickness. The later possibility is supported by the irregular thickness indicated on the GPR long profiles. Considerable differential settlement is evident on the current surface of the slope and past attempts to smooth the surface could have resulted in the chips having an irregular thickness.

In the 1990 50 MHz GPR profile, the depth of thaw varies between 2 m and 3.2 m below the surface (Moorman, 1991). This interface is not indicated on the 1991 profiles due to the high attenuation of 200 MHz and 100 MHz energy and the strength of the multiple reflections. The multiples on the 100 MHz profile are not as strong as on the 200 MHz profile, but there still is no extra structure discernable .

The geometry of the wood chips is shown on all of the cross profiles surveyed in 1991. On cross profiles 2a and 2b the advantages of more closely spaced traces can be observed. With the trace spacing at 1 m the base of the wood chips is clearly displayed, but the returns from the pipeline are limited in their lateral extent. On cross profile 2b the use of 50 cm steps increases the number of coherent returns from the pipe enough to identify the hyperbolic form, allowing the location of the pipe to be easily determined.

Both cross profile 3 and 4 were run across a surface depression in the wood chips (see site plan). Due to the strength of the multiple returns on the GPR profiles, any subsurface cause of this depression in not indicated.

Mackenzie River

One long profile and three cross profiles were surveyed at the Mackenzie River slope. Lithologic information was not available for this slope so interpreted interfaces could not be identified as specific lithologic contacts. The temperature profiles from three locations on the slope indicate dramatic variability in the depth to frozen soil (see temperature profiles). At the upper cables (HT 145, T 10) the zero degree isotherm is interpolated to be at a depth of 1.2 m. The entire 9 m of the middle cable (91-7) was in unfrozen soil. The lower cables (HT 144, T 22) indicate a complex thermal structure. Using the data from the near surface cable (HT 144) the depth of thaw can be extrapolated to about 1.4 m below the surface. Data from the deep cable (T 22) indicates the

thawing front is at a depth of about 4.2 m. The thaw bulb depths are indicated on the interpreted profile with "v"'s for each thermistor cable.

The character of the returns arriving at 150 ns suggests that there may be some energy being reflected from deeper interfaces. Because the thaw depth interface is not present later than 50 ns it is suggested that the interface may be too gradual to produce a strong reflection in this region. The dipping portion of the third return at the 100 m position could represent the edge of the thick portion of the thaw bulb. More detailed interpretation is limited by a lack of subsurface verification for the GPR data.

The travel time of the direct ground wave varied across the ROW on all three cross profiles. The increase in travel time near the pipe is the result of lower propagation velocities, and thus probably the wood chips are wetter near the pipe trench.

Conclusions and Recommendations

Ground penetrating radar can be used successfully for geotechnical analysis where the lithology and permafrost conditions need to be measured in a non-destructive manner. Ground penetrating radar provides two dimensional pseudo-sections of the subsurface indicating changes in lithology, ice content, and frozen/unfrozen interfaces. The GPR profiles can be used to delineate the shape of units, and with the aid of subsurface verification, the depth of interfaces can be determined to within 30 cm. Velocity soundings provide an estimate of the propagation velocity of the near surface material but the precise depths of lithologic and thermal interfaces need to be measured using cores and temperature cables for conclusive mapping of the subsurface.

Most of the 1991 surveys were conducted with 200 MHz antennas in order to examine fine detail in the near surface. These antennas provided a resolution in the order of 30 cm with interpretable reflections coming from interfaces at a maximum depth of 2 to 3 m. The majority of the interference that masked the weaker and deeper reflections resulted from near surface multiple reflections. In the 1989 and 1990 surveys, the maximum depth of penetration of the 200 MHz, 100 MHz and 50 MHz surveys was 5-6 m, 6-8 m and, 9-10 m respectively. However, there was an approximate resolution of only 0.5 m for the 100 MHz surveys, and 1 m for the 50 MHz surveys. Multiple reflections were not observed in the 1989 or 1990 surveys.

Several specific conclusions can be made about how the GPR was able delineate the subsurface structure of the wood chip slopes:

1) The geometry and down slope extent of the cavity at the Great Bear slope was mapped. Precise measurements were complicated by the complex subsurface structure but the GPR determined interface depths were corrected with subsurface probing. This test showed that GPR can be used to efficiently determine the magnitude of subsurface problems and further research should be conducted on developing the techniques used for cavity detection.

2) It was possible to map the geometry of thaw bulbs when the depth of thaw was greater than 1 m below the surface, but less than the depth of penetration of the GPR. The depth of penetration varied depending on the texture of the soil. The deepest penetration can be observed in well drained sands such as at the top of the Great Bear slope, while the depth of penetration is limited to as little as 2 m in areas of wet clays. On many of the 1991 profiles the depth to

which interpretable data was available was greatly limited by strong multiple reflections. As strength of multiples is dependant on the thermal structure of the subsurface and the frequency used, it is suggested that winter surveying be attempted and further experimentation using alternate frequency antennas be conducted when required.

3) Temporal changes in the thaw bulb were determined by comparing data sets collected in the three consecutive summers of surveying. The greatest changes were observed at the base of the Great Bear slope where an ice rich layer had completely thawed resulting in considerable surface subsidence and a decrease in the mineral soil cover over the pipeline. Further GPR research should be conducted to determine rates of thaw bulb expansion and to measure ongoing change.

4) The base of the wood chips could be mapped at most slopes with only minor subsurface verification. Changes in the water content of the chip layer could easily be detected from the differences in the travel time of the direct ground wave. The feasibility of using GPR to monitor wood chip settlement and water movement within the wood chips should be investigated.

This study has demonstrated how in certain settings GPR can be used to provide three dimensional information on subsurface conditions (including depth of thaw, shape of cavities, thickness of wood chips, and variations in soil or wood chip moisture content). The usefulness of GPR to monitor change was identified by comparing surveys done in different years. This includes charting the growth of thaw bulbs and the resulting alteration to the topography and thickness of lithologic units. In order to provide this information, subsurface verification is essential, especially when there is considerable variability in the lithologic or thermal structure of the ground.

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Appendix A

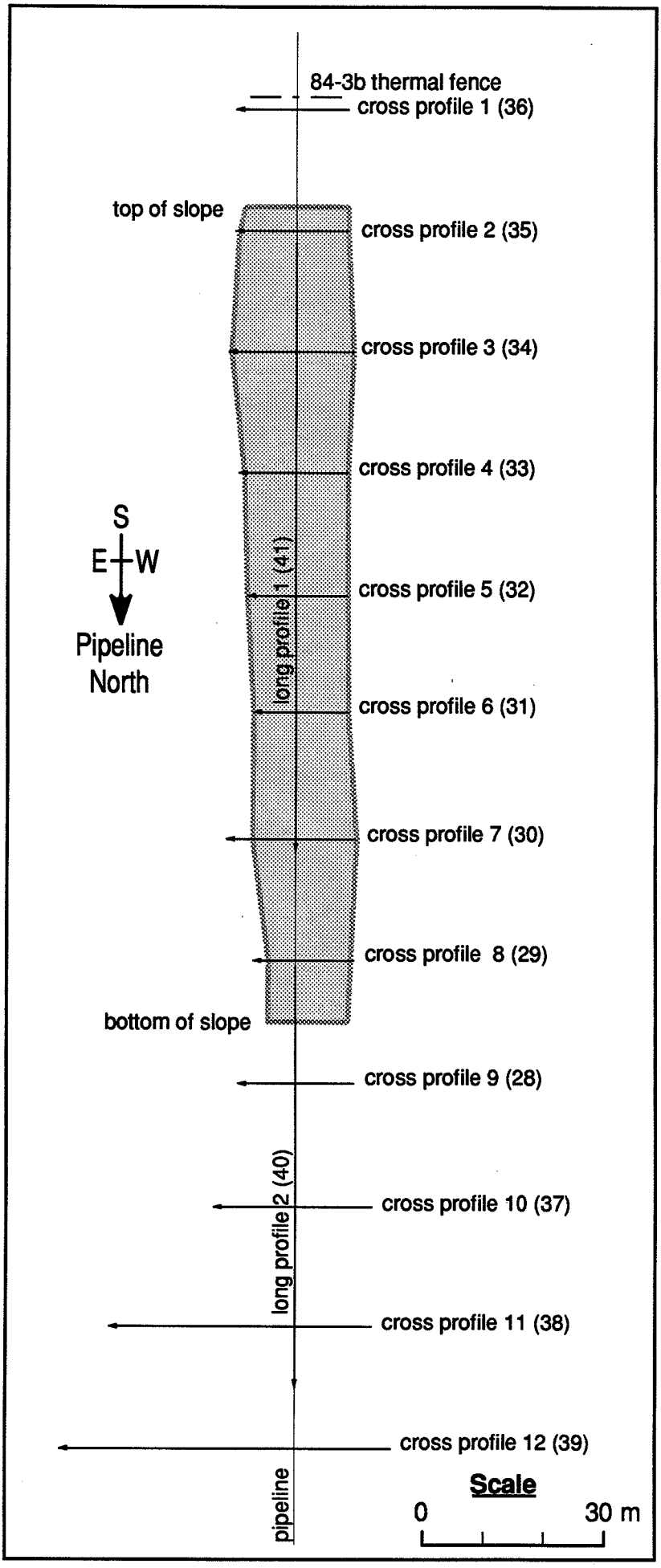
Data:

Great Rear River

Slope 29b

(km 79)

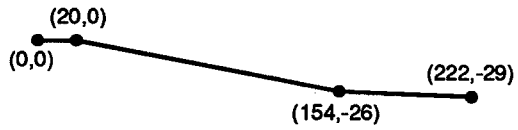
Great Bear
Slope 29b Site Plan

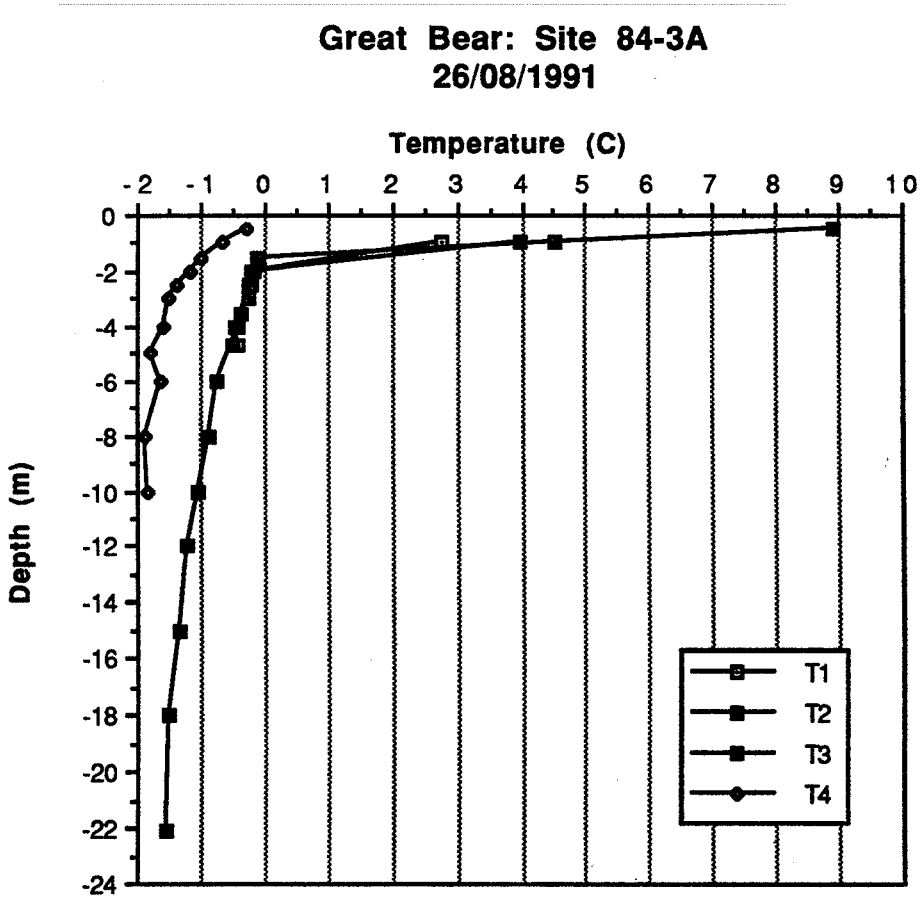


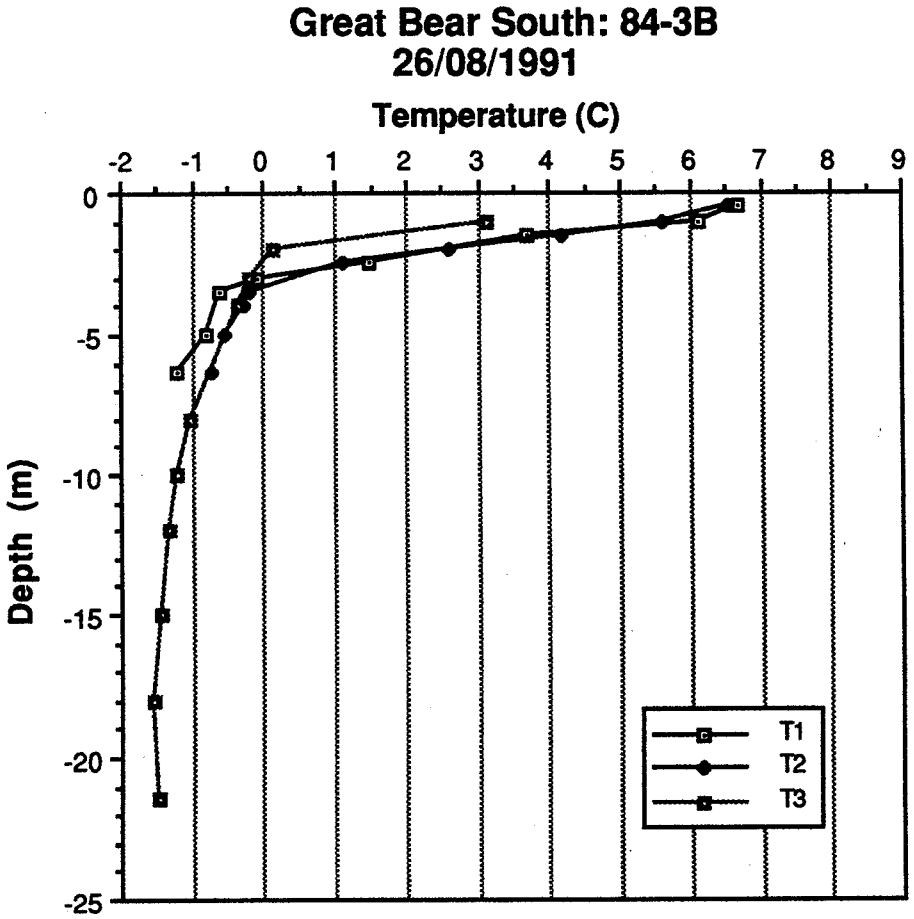
Legend

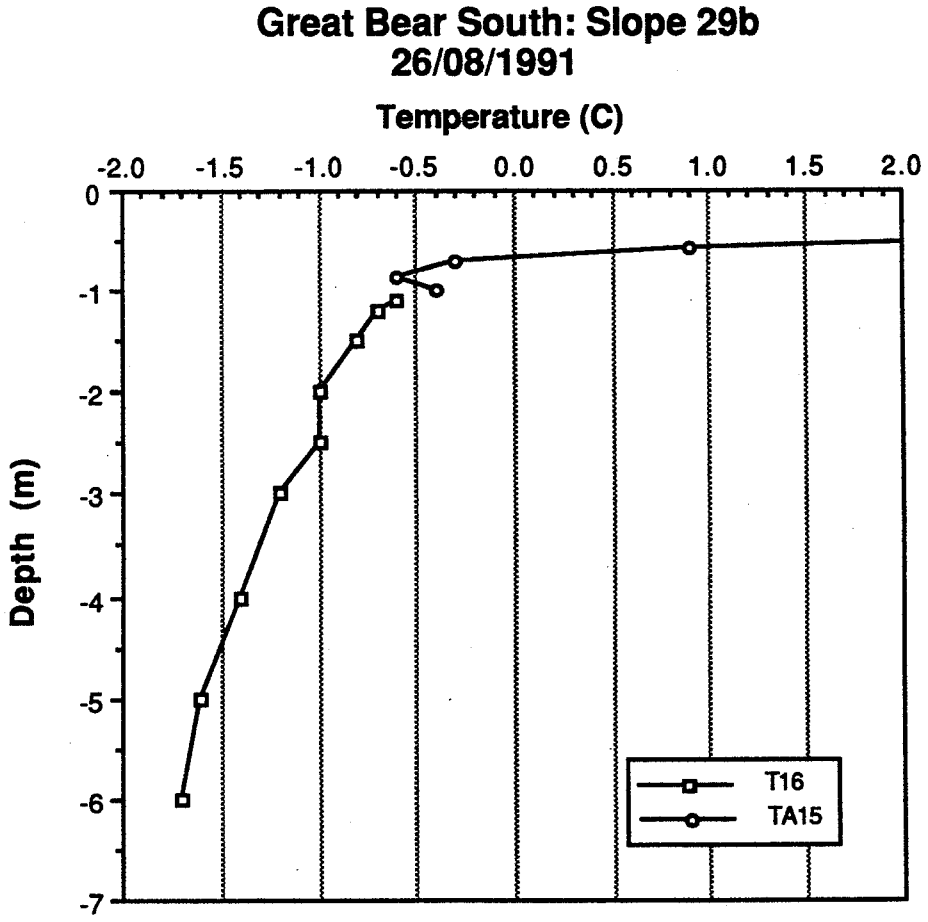
- GPR profile (arrow indicates direction)
- (##) GPR file number
- woodchip cover

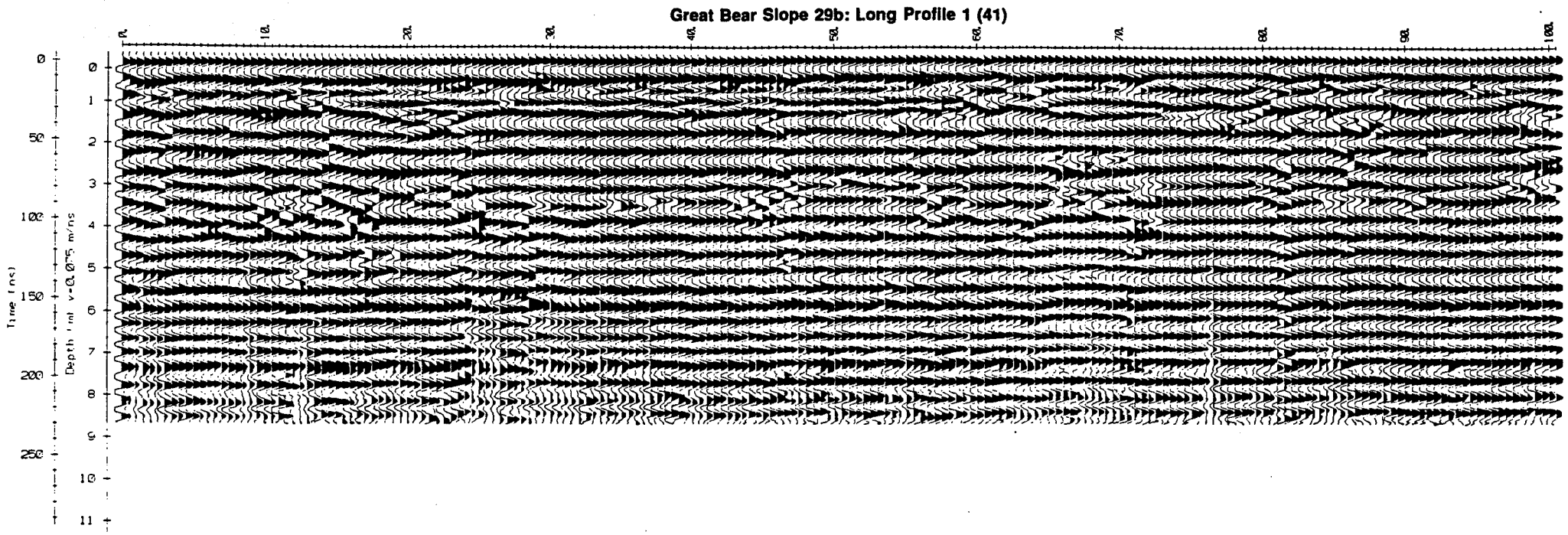
Down Slope Profile
(metres)

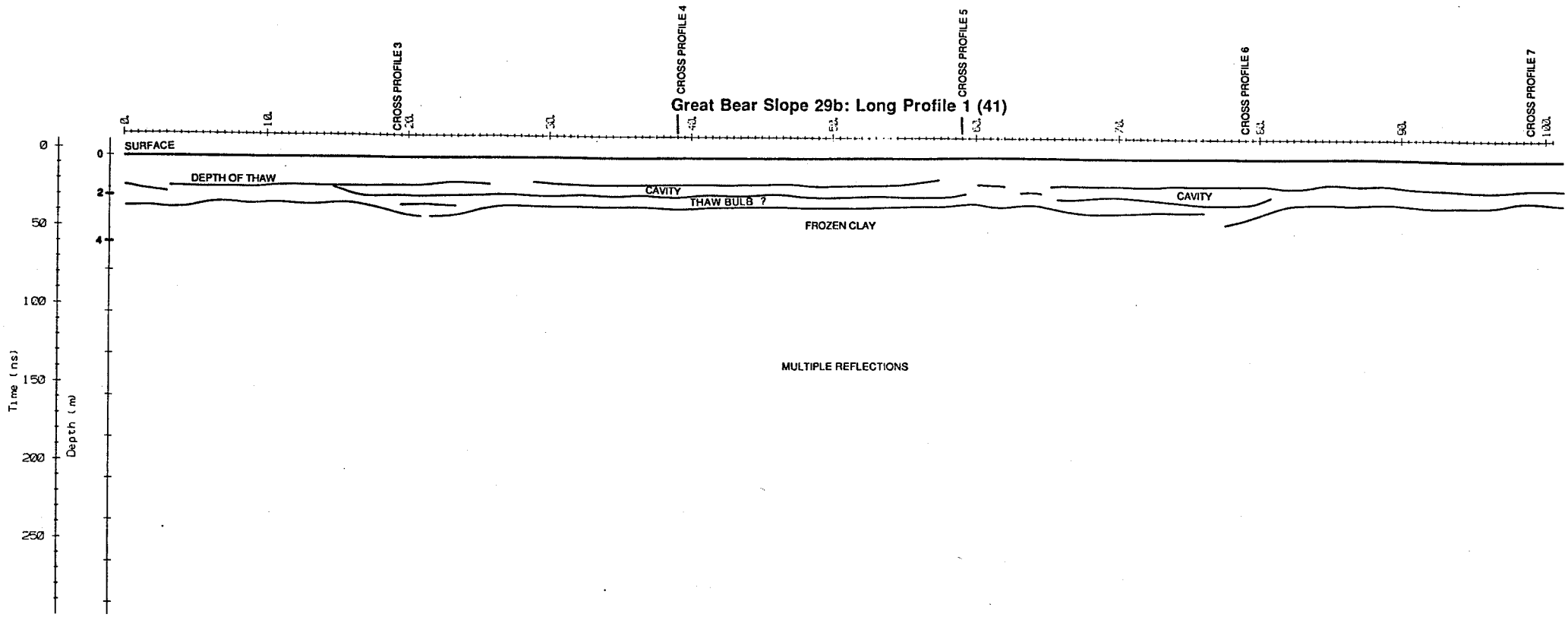


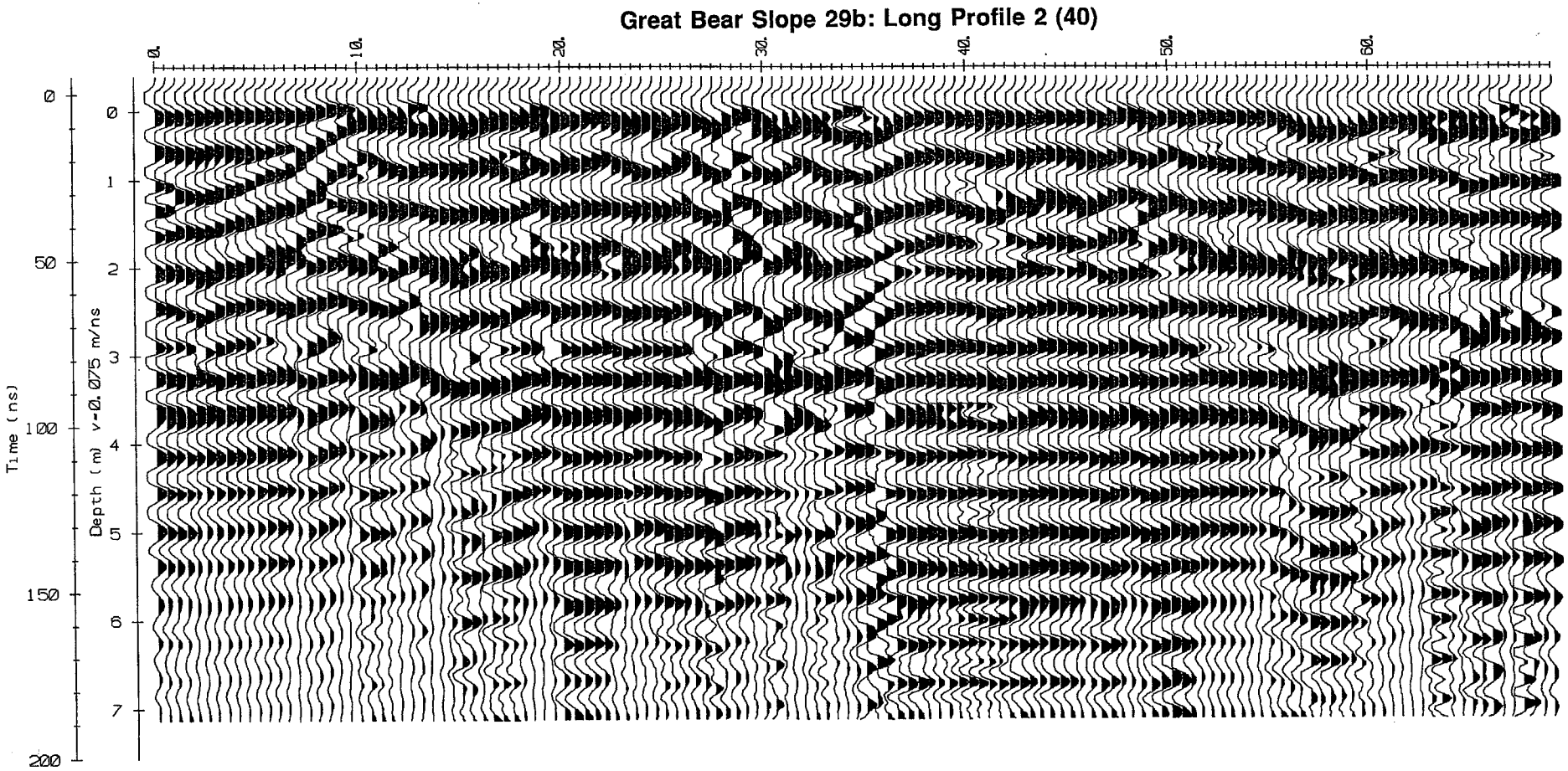

Great Bear: Site 84-3A
26/08/1991
Temperature (C)
-2 -1 0 1 2 3 4 5 6 7 8 9 10
Depth (m)
0 -2 -4 -6 -8 -10 -12 -14 -16 -18 -20 -22 -24
T1
T2
T3
T4

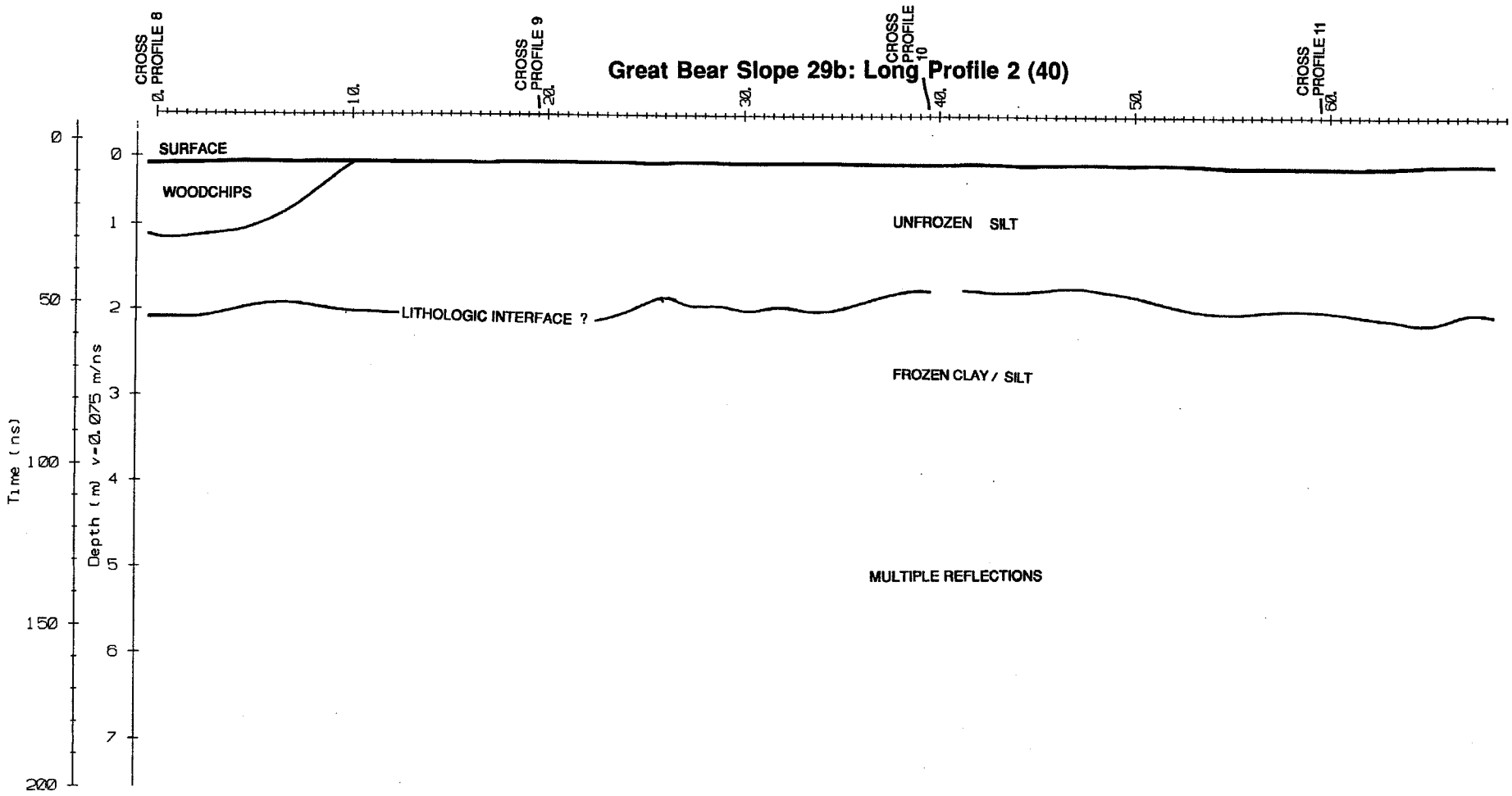

Great Bear South: 84-3B
26/08/1991
Temperature (C)
-2
-1
0
1
2
3
4
5
6
7
8
9
0
-5
-10
-15
-20
-25
Depth (m)
T1
T2
T3


Great Bear South: Slope 29b
26/08/1991
Temperature (C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
0
-1
-2
-3
-4
-5
-6
-7
Depth (m)
T16
TA15

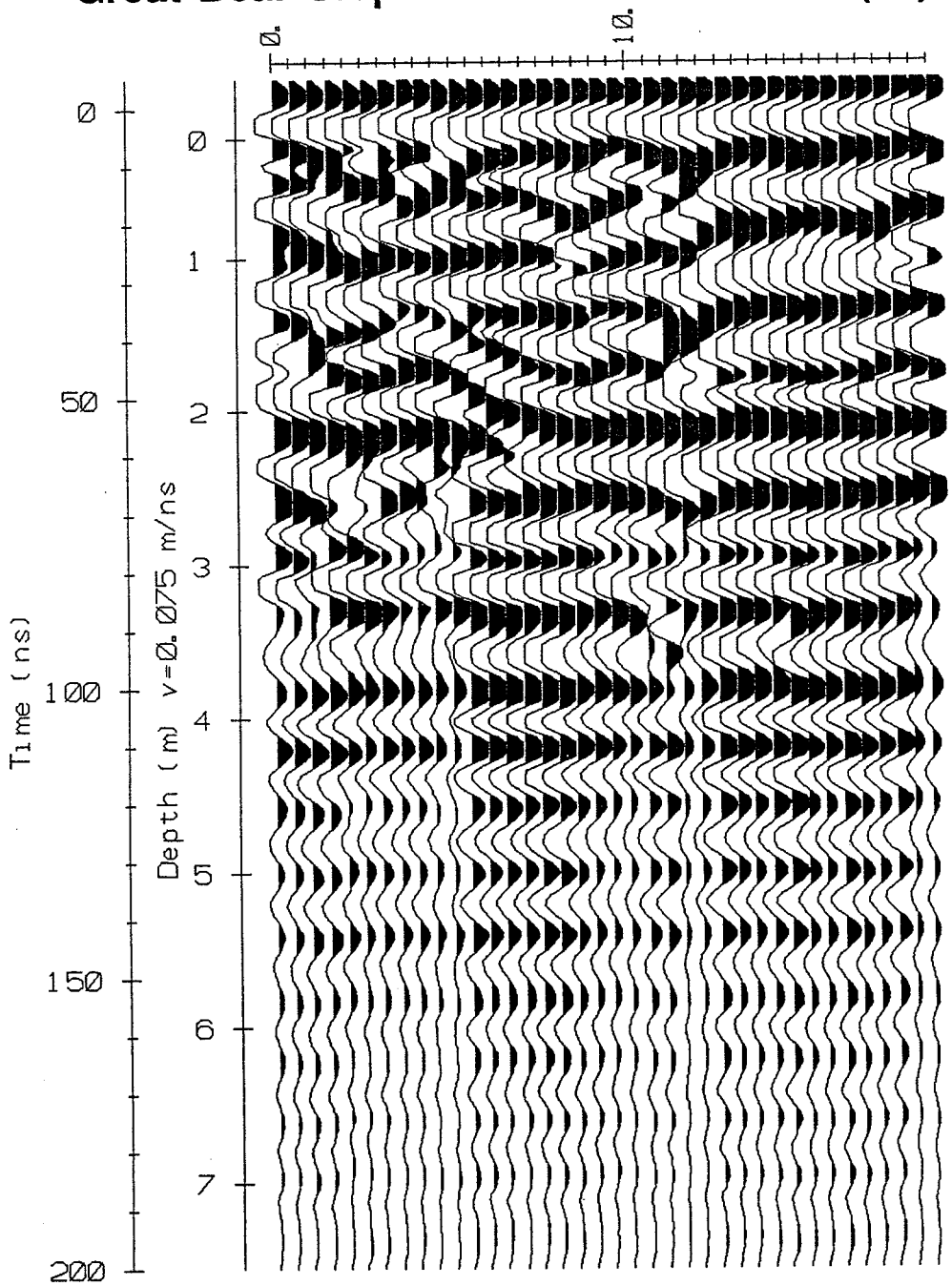

Great Bear Slope 29b: Long Profile 1 (41)
0
10
20
30
40
50
60
70
80
90
100
Time (ns)
0
50
100
150
200
250
Depth (m) v=0.075 m/ns
0
1
2
3
4
5
6
7
8
9
10
11


Great Bear Slope 29b: Long Profile 1 (41)
CROSS PROFILE 3
CROSS PROFILE 4
CROSS PROFILE 5
CROSS PROFILE 6
CROSS PROFILE 7
SURFACE
DEPTH OF THAW
CAVITY
THAW BULB ?
CAVITY
FROZEN CLAY
MULTIPLE REFLECTIONS
Time (ns)
Depth (m)

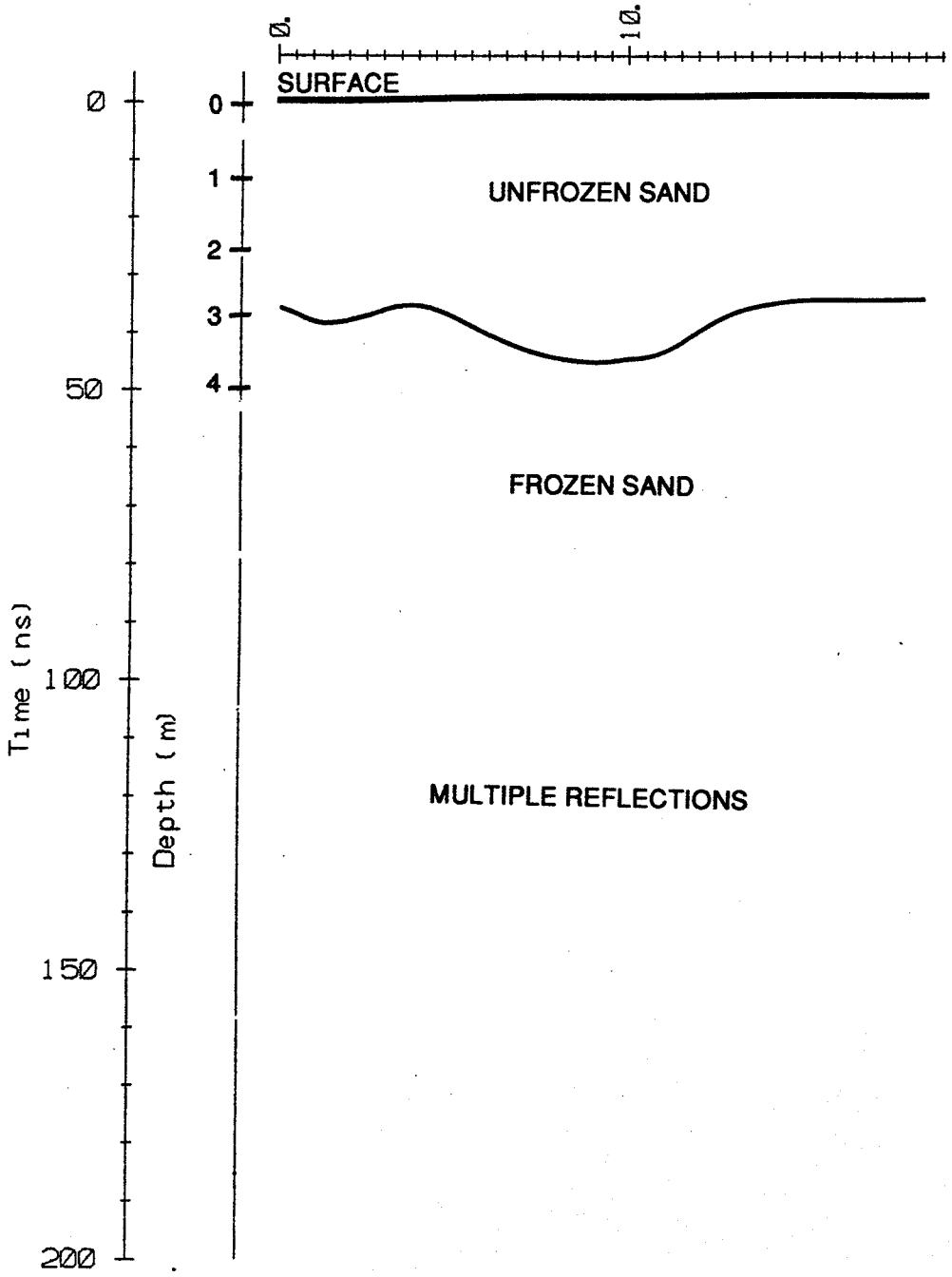

Great Bear Slope 29b: Long Profile 2 (40)
0.
10.
20.
30.
40.
50.
60.
0
50
100
150
200
Time (ns)
0
1
2
3
4
5
6
7
Depth (m) v=0.075 m/ns


Great Bear Slope 29b: Long Profile 2 (40)
CROSS PROFILE 8
CROSS PROFILE 9
CROSS PROFILE 10
CROSS PROFILE 11
0.
10.
20.
30.
40.
50.
60.
SURFACE
WOODCHIPS
UNFROZEN SILT
LITHOLOGIC INTERFACE ?
FROZEN CLAY / SILT
MULTIPLE REFLECTIONS
Time (ns)
Depth (m) v=0.075 m/ns
0
50
100
150
200
1
2
3
4
5
6
7

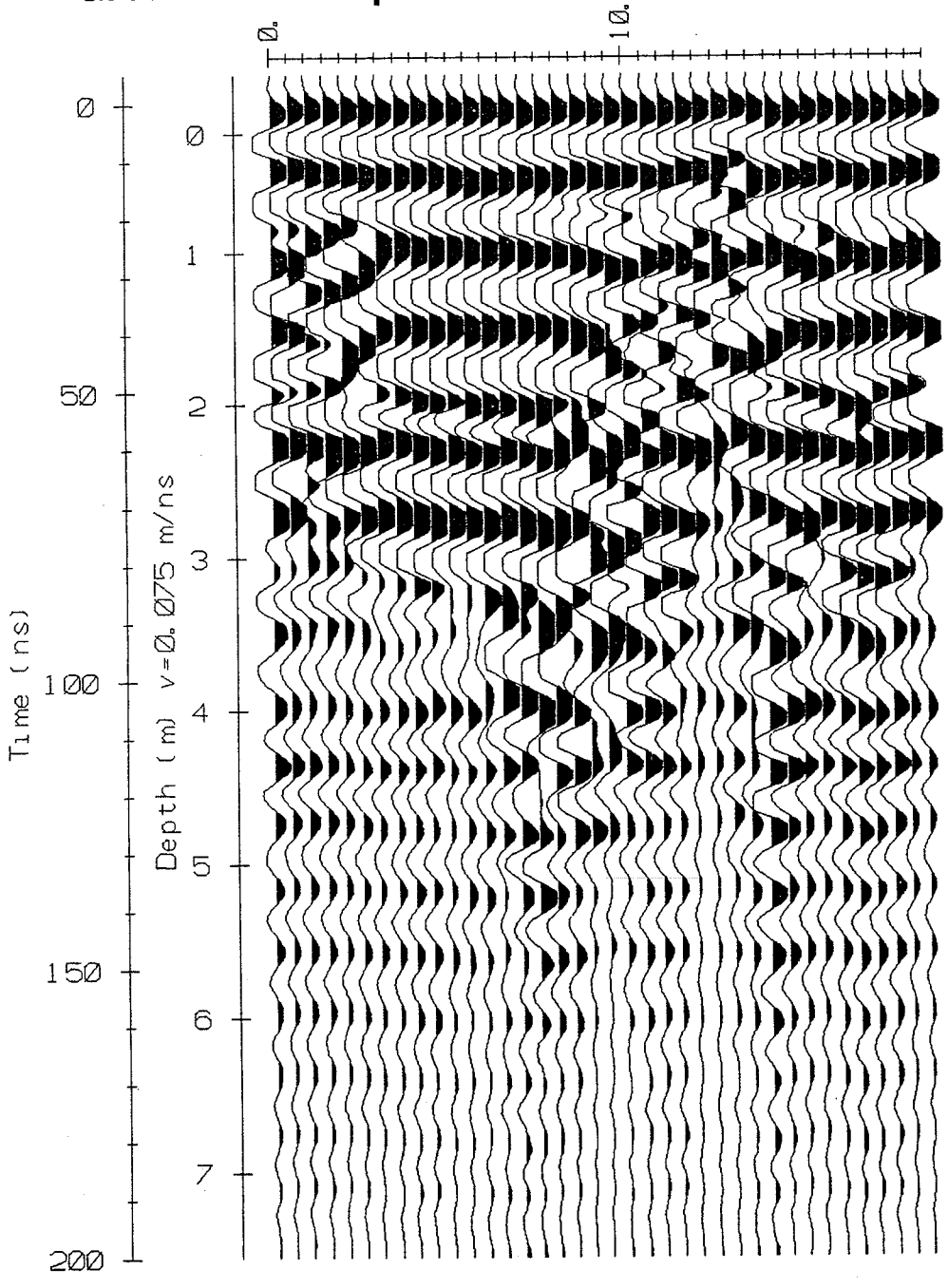
Great Bear Slope 29b: Cross Profile 1 (36)



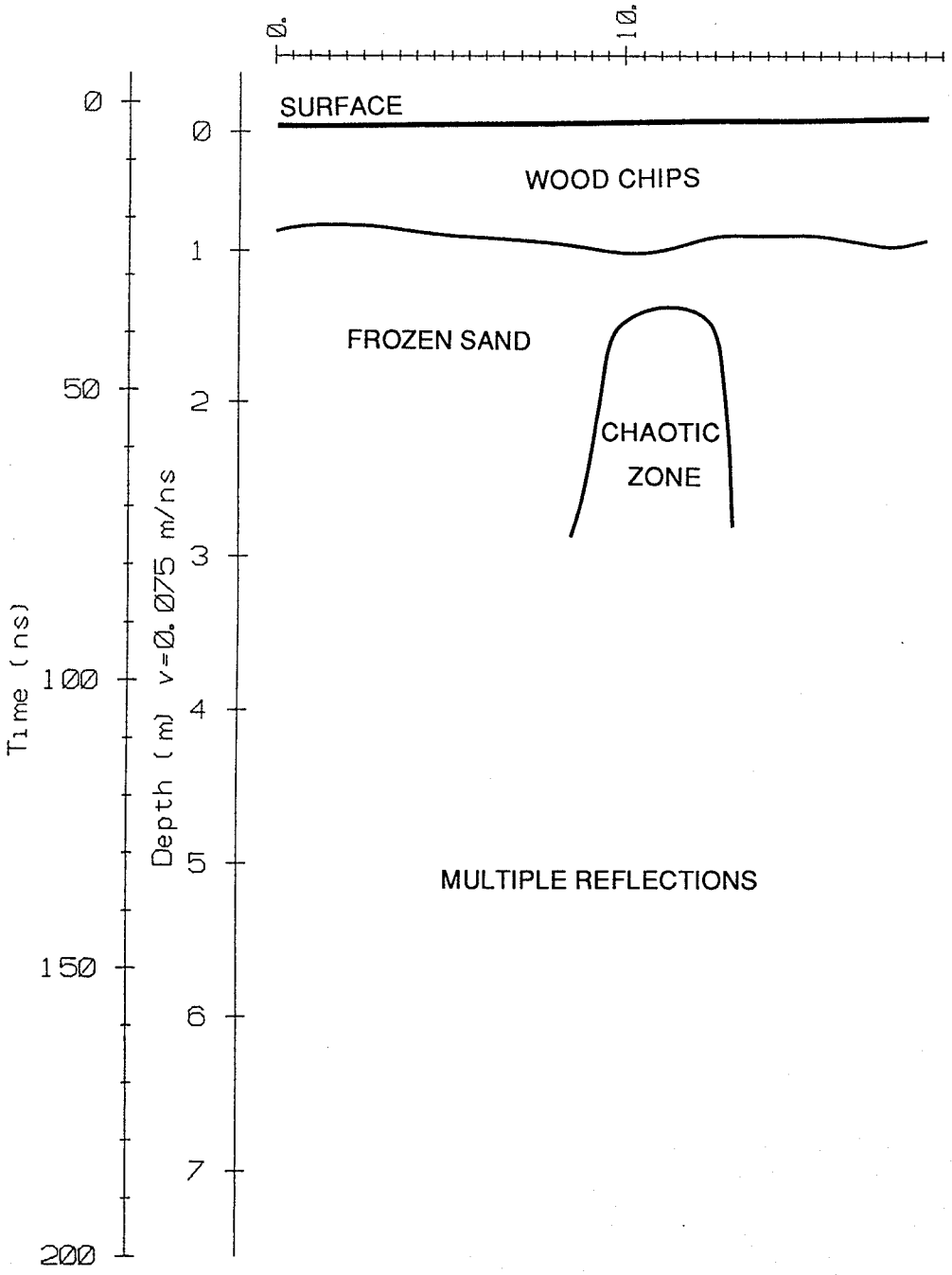
Great Bear Slope 29b: Cross Profile 1 (36)



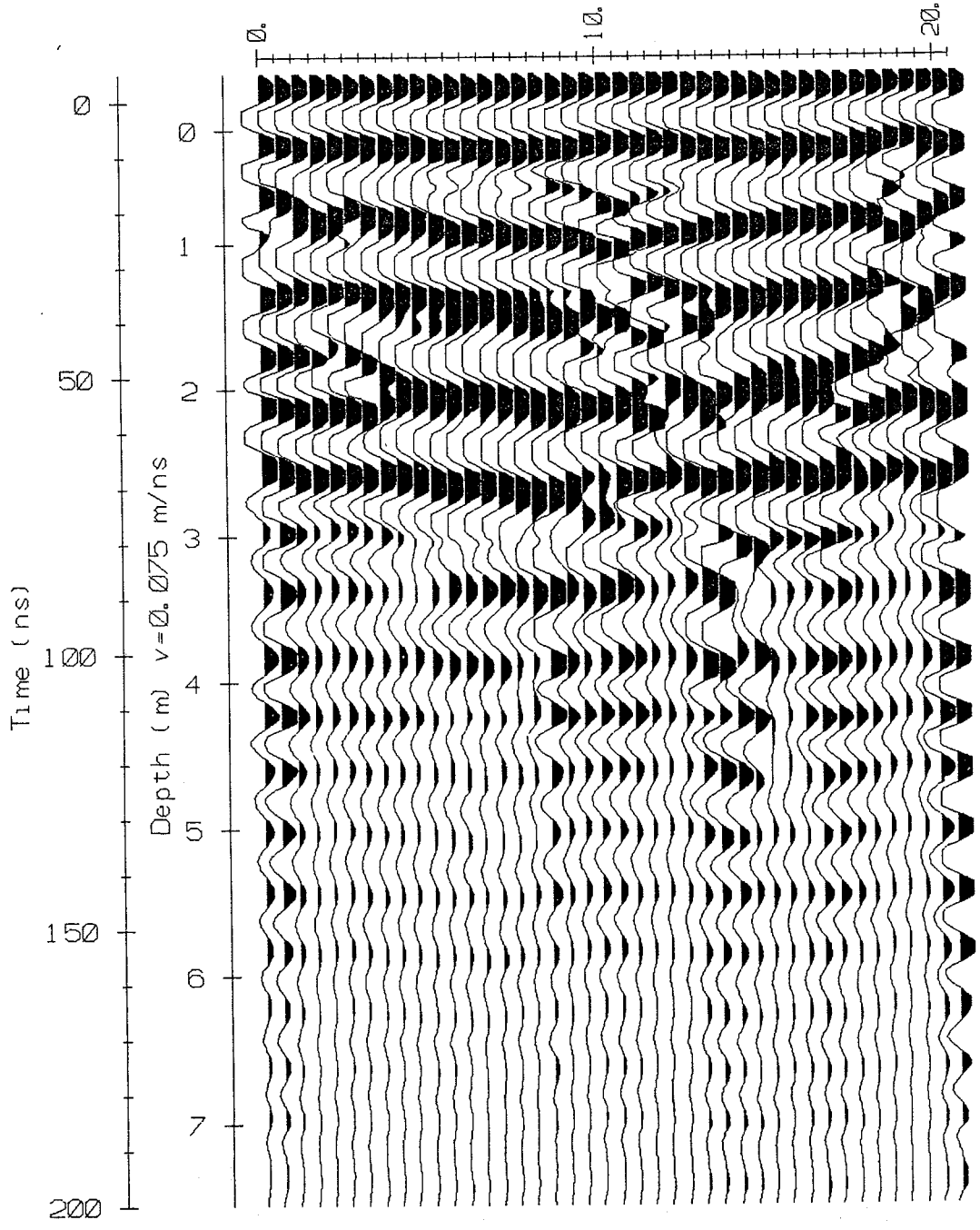
Great Bear Slope 29b: Cross Profile 2 (35)



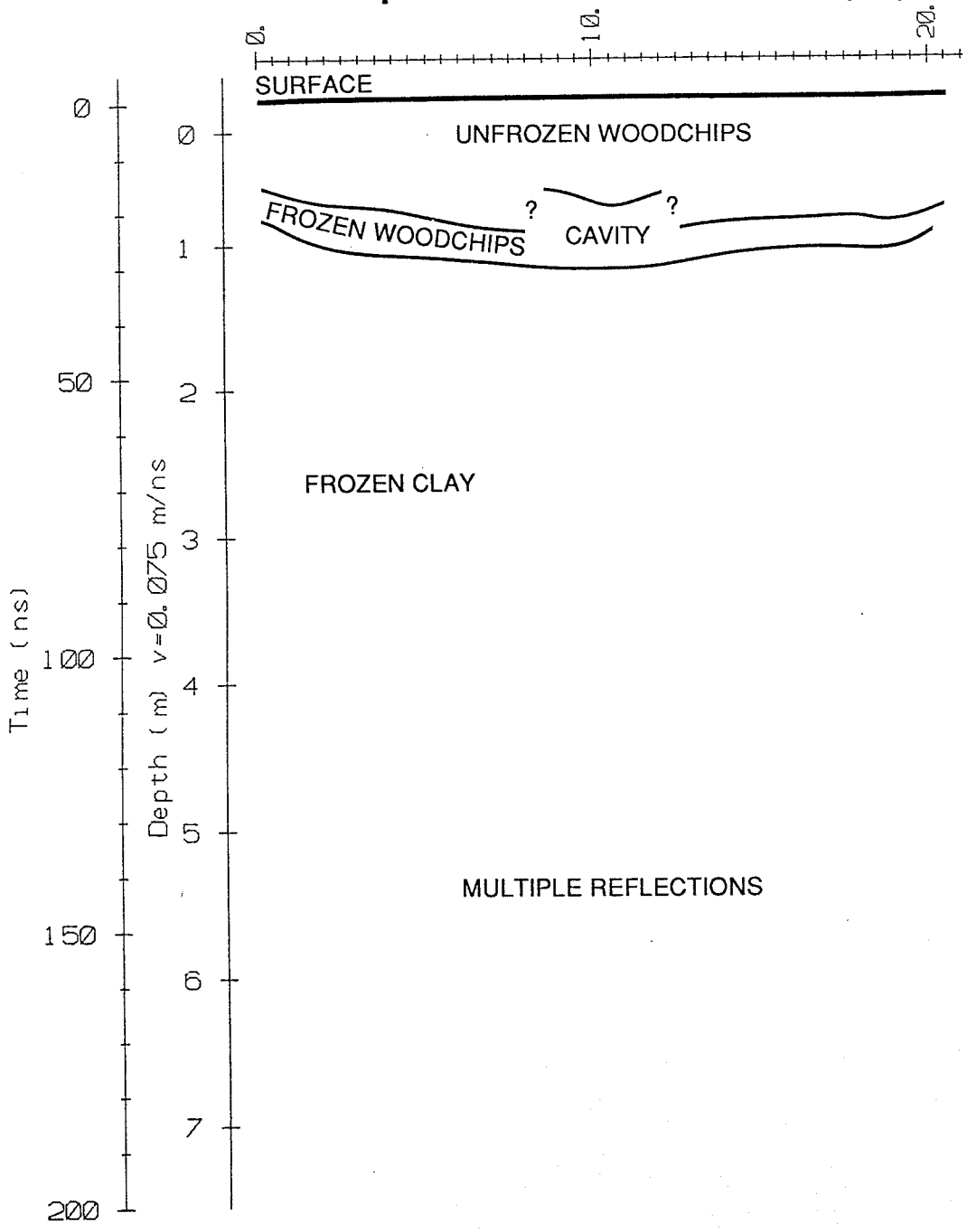
Great Bear Slope 29b: Cross Profile 2 (35)



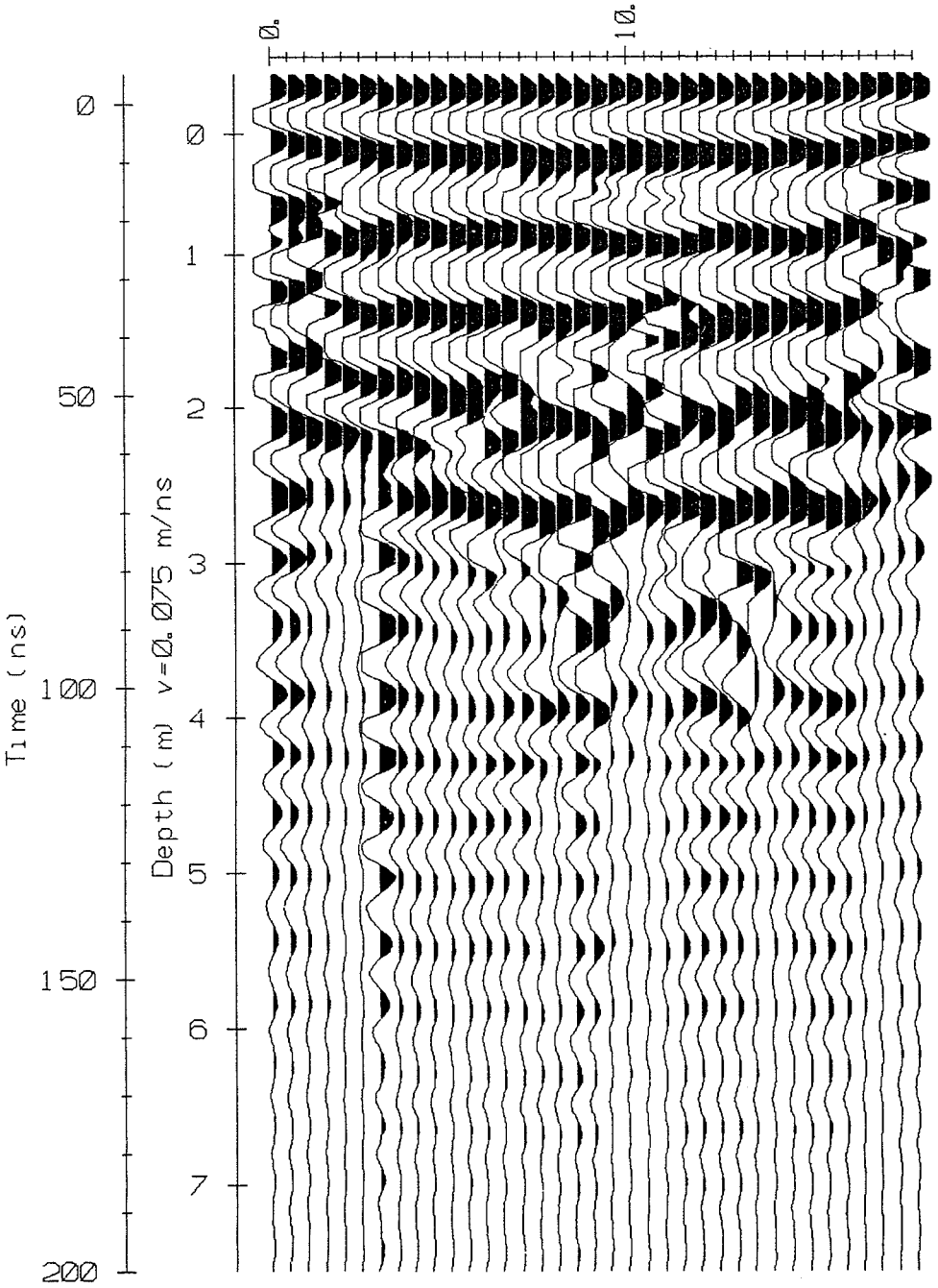
Great Bear Slope 29b: Cross Profile 3 (34)



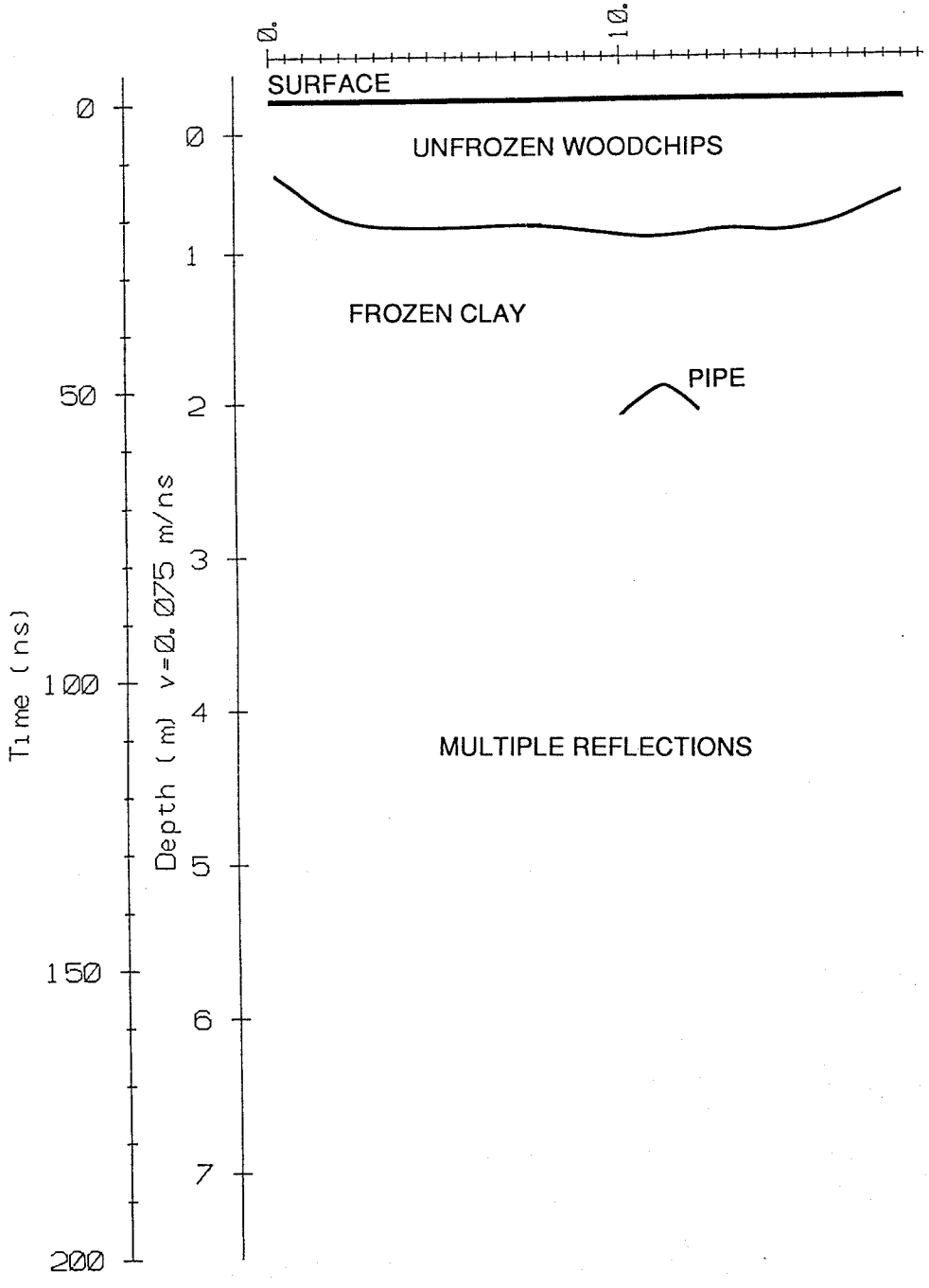
Great Bear Slope 29b: Cross Profile 3 (34)



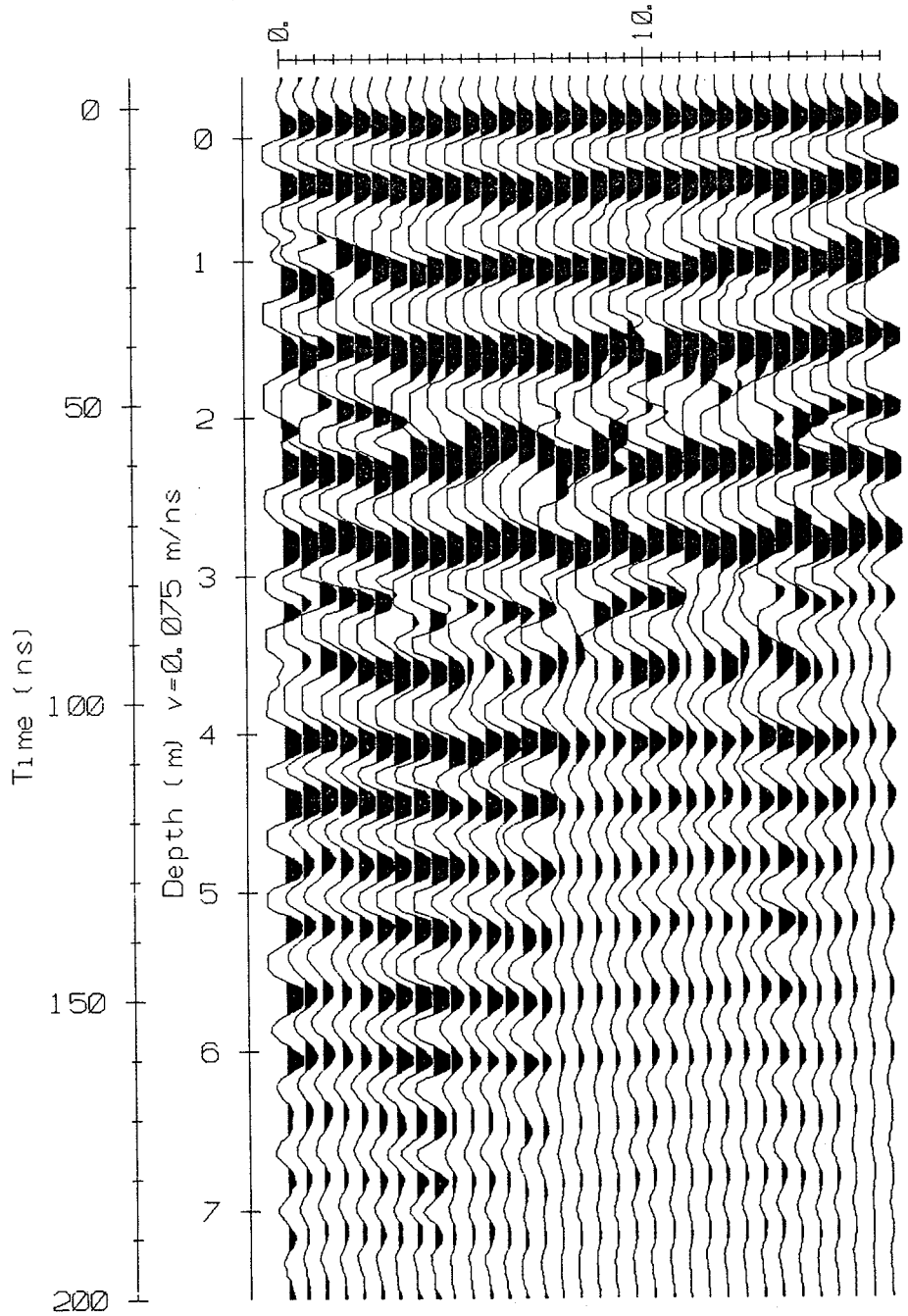
Great Bear Slope 29b: Cross Profile 4 (33)



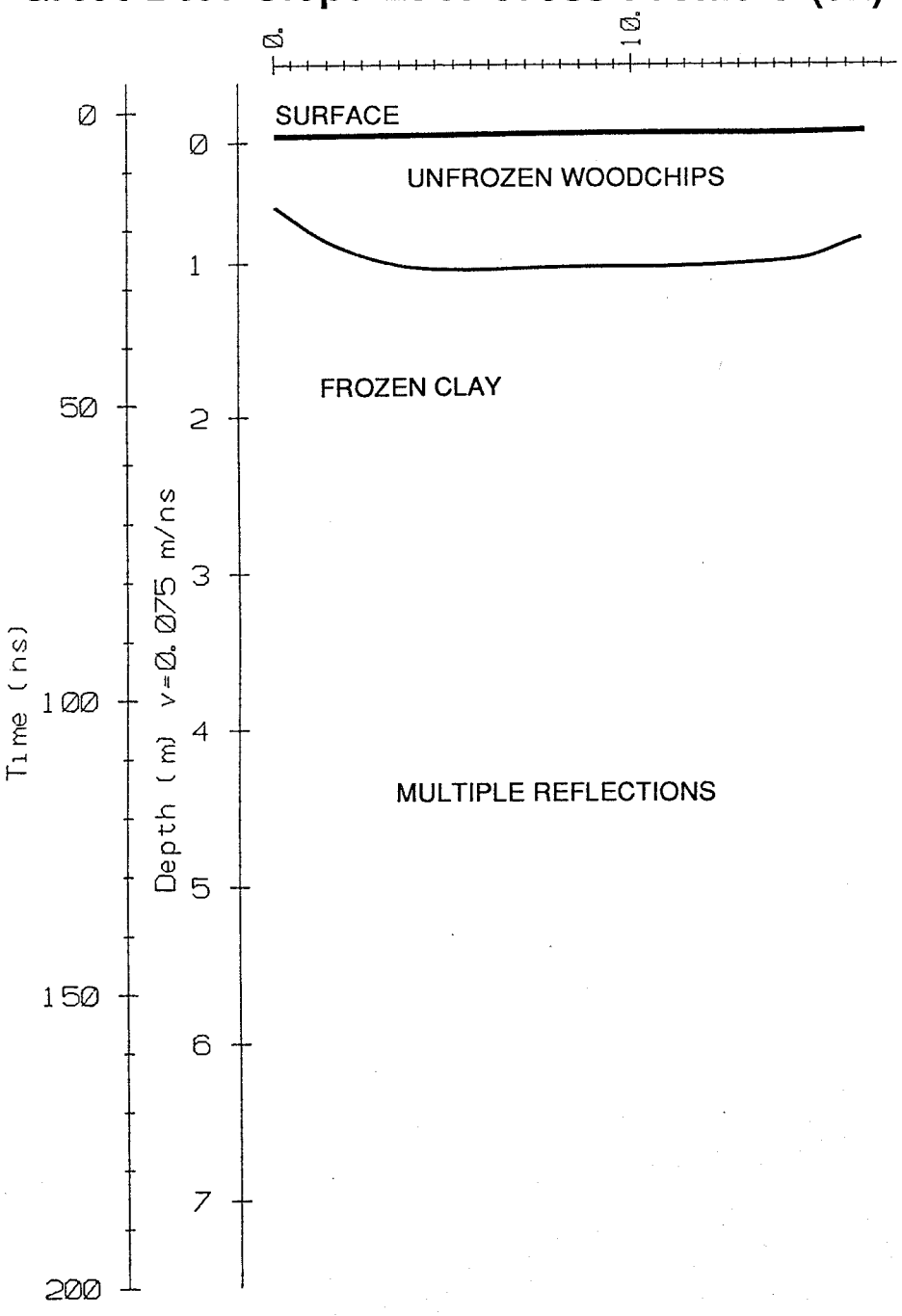
Great Bear Slope 29b: Cross Profile 4 (33)



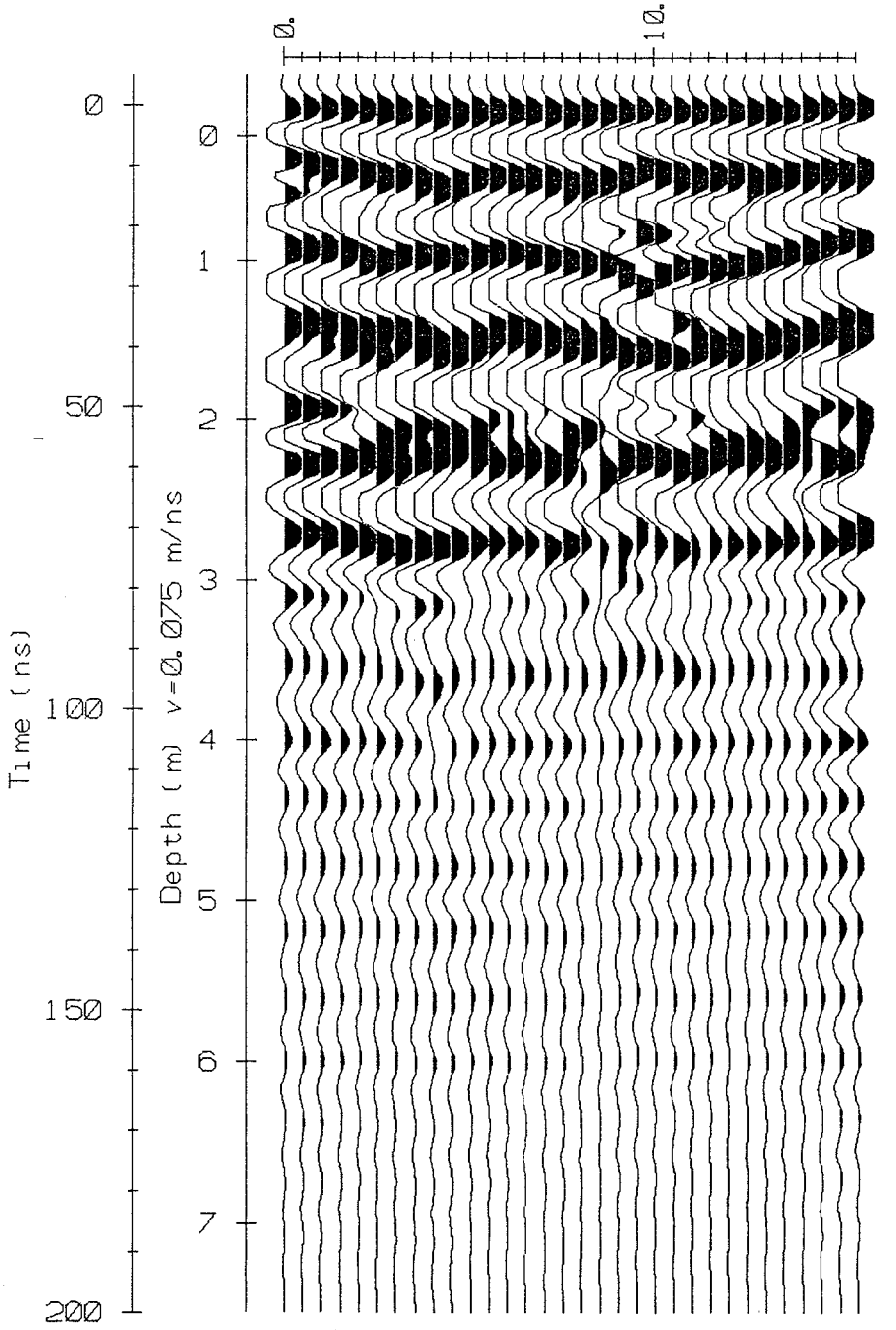
Great Bear Slope 29b: Cross Profile 5 (32)



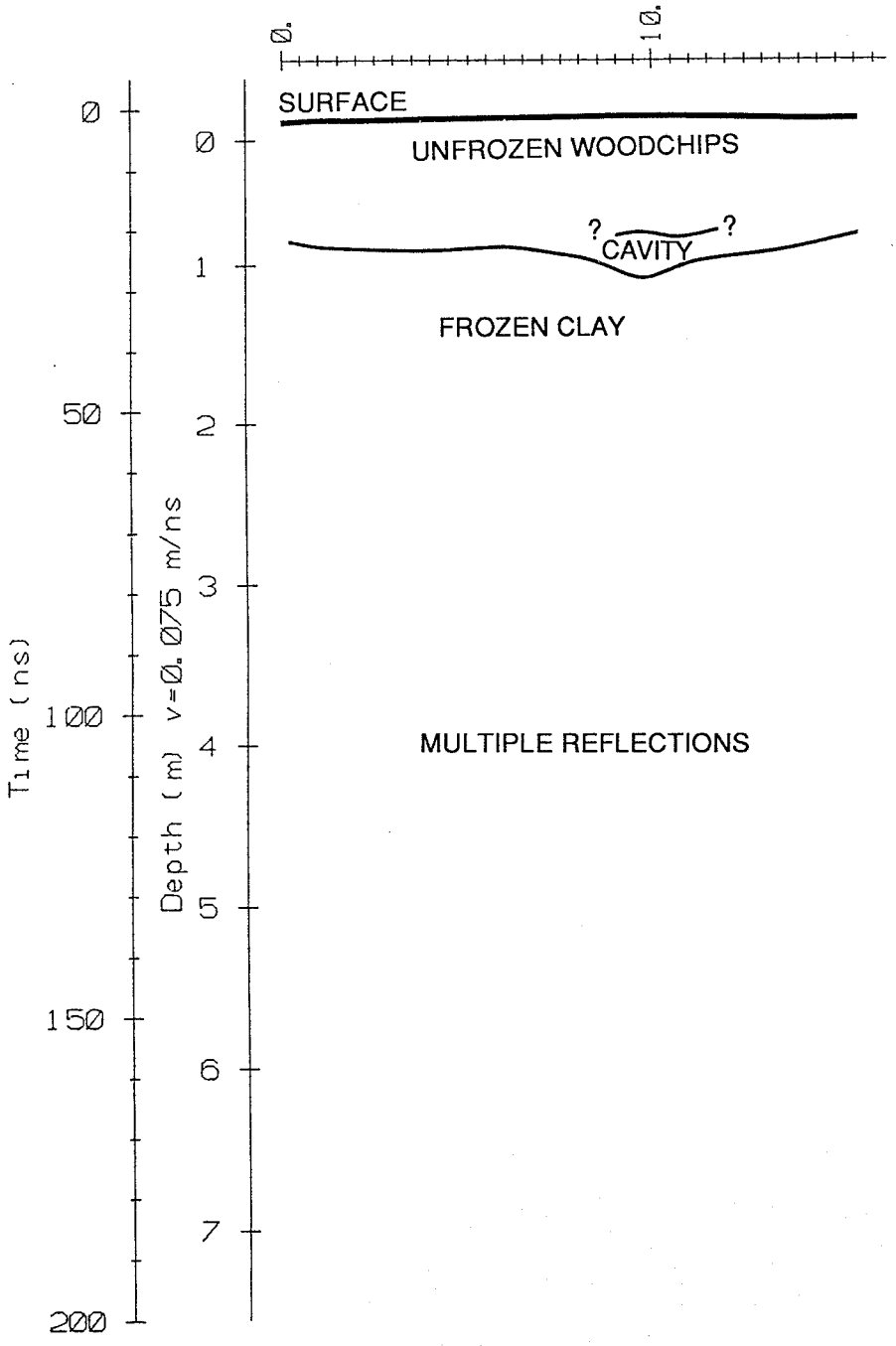
Great Bear Slope 29b: Cross Profile 5 (32)



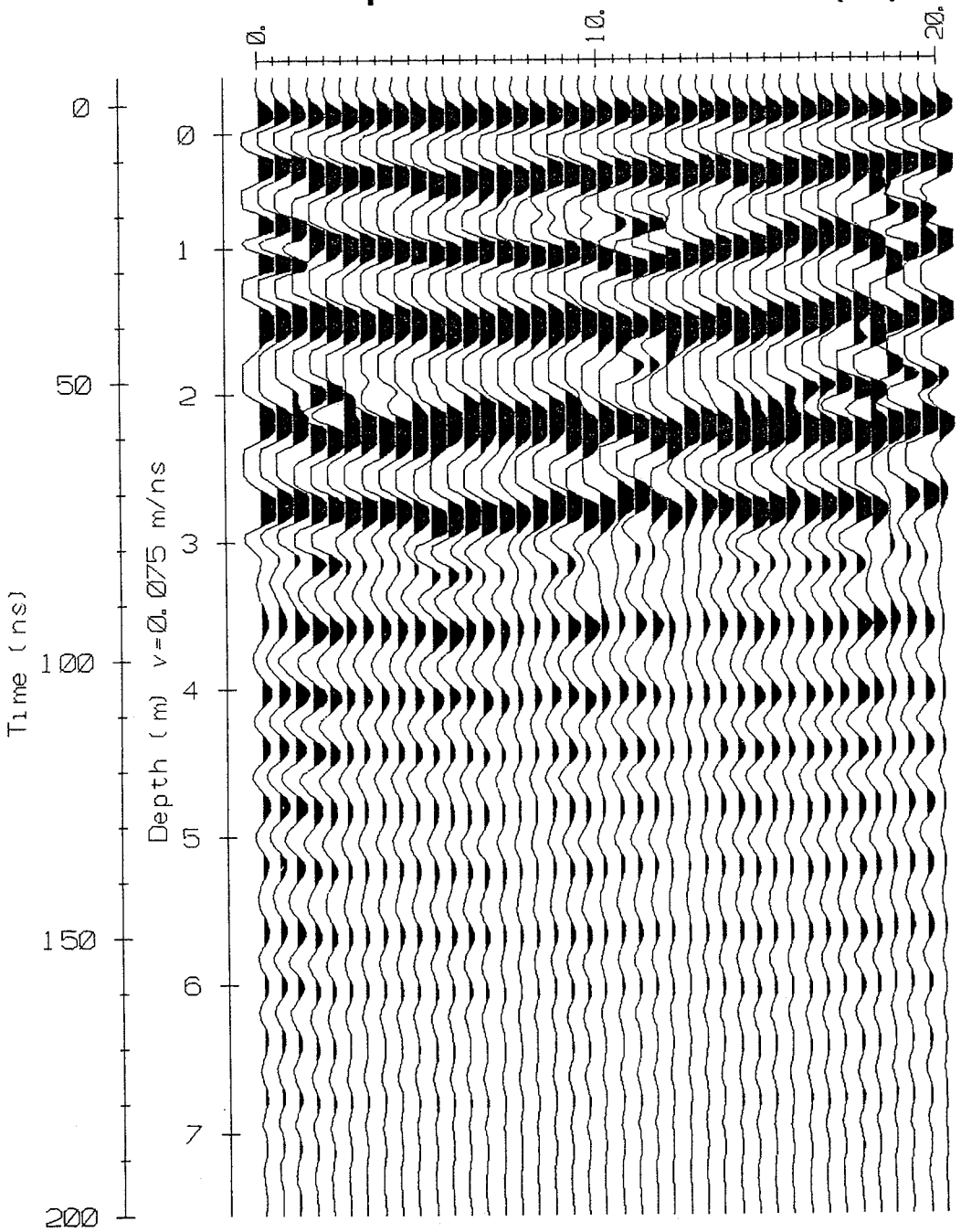
Great Bear Slope 29b: Cross Profile 6 (31)



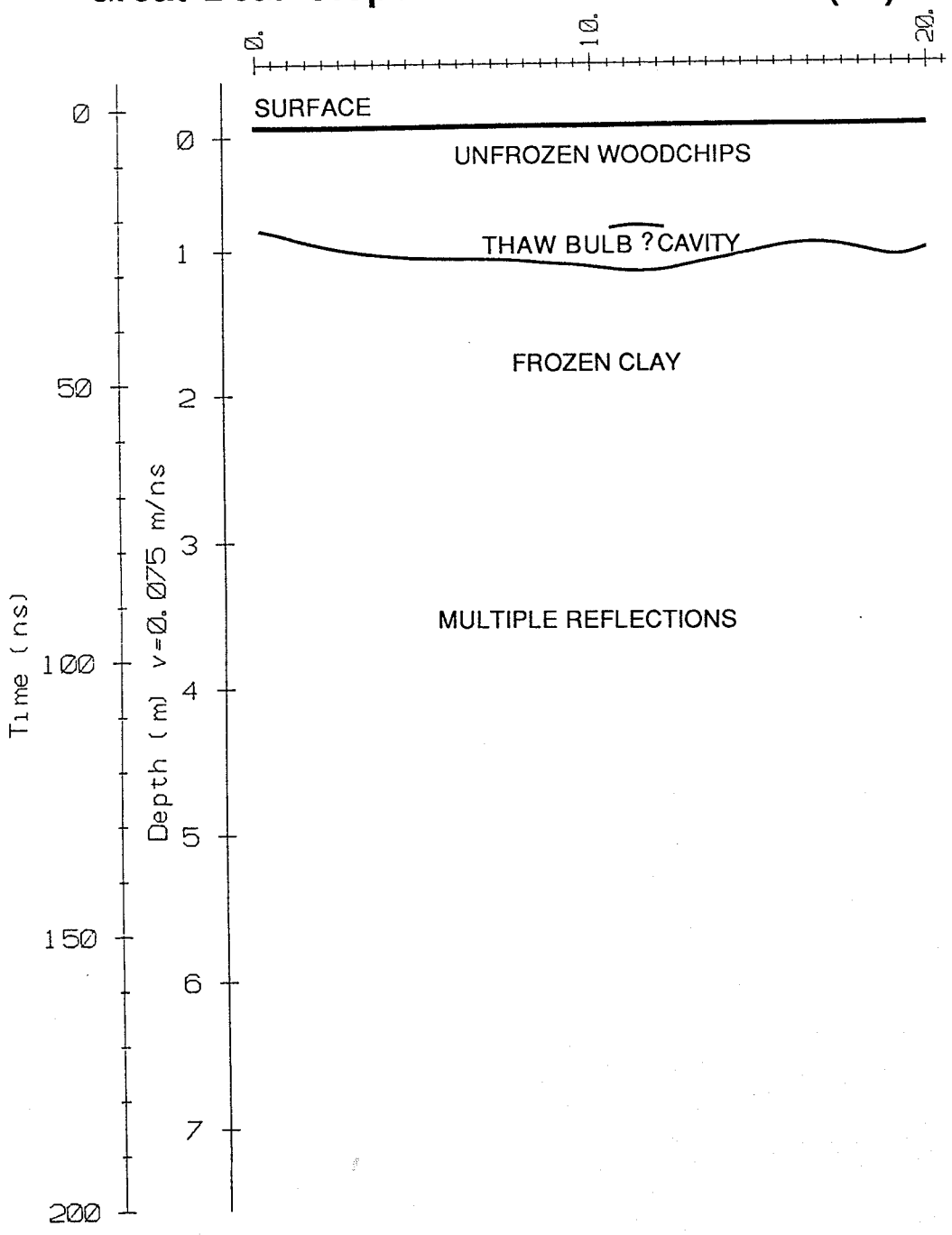
Great Bear Slope 29b: Cross Profile 6 (31)



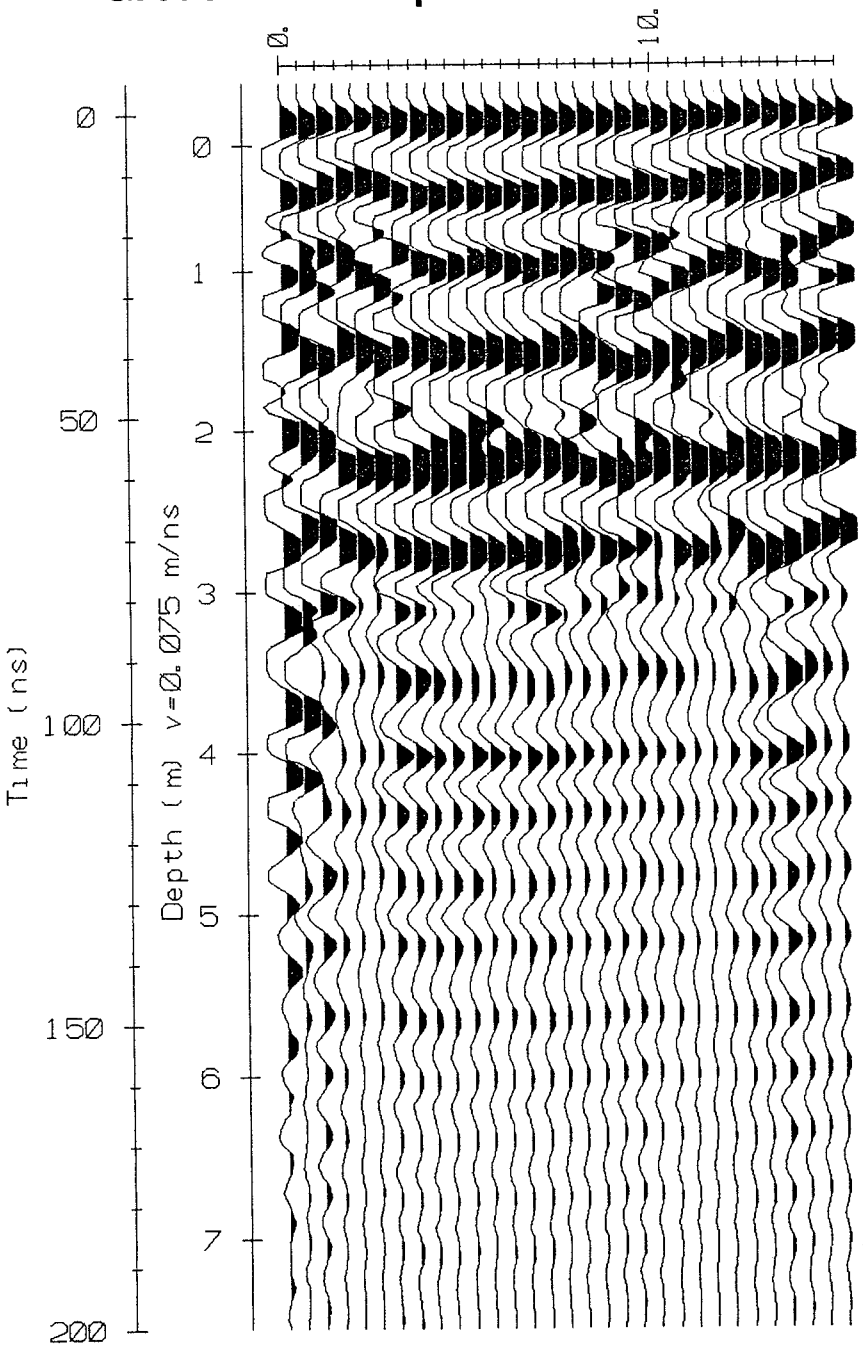
Great Bear Slope 29b: Cross Profile 7 (30)



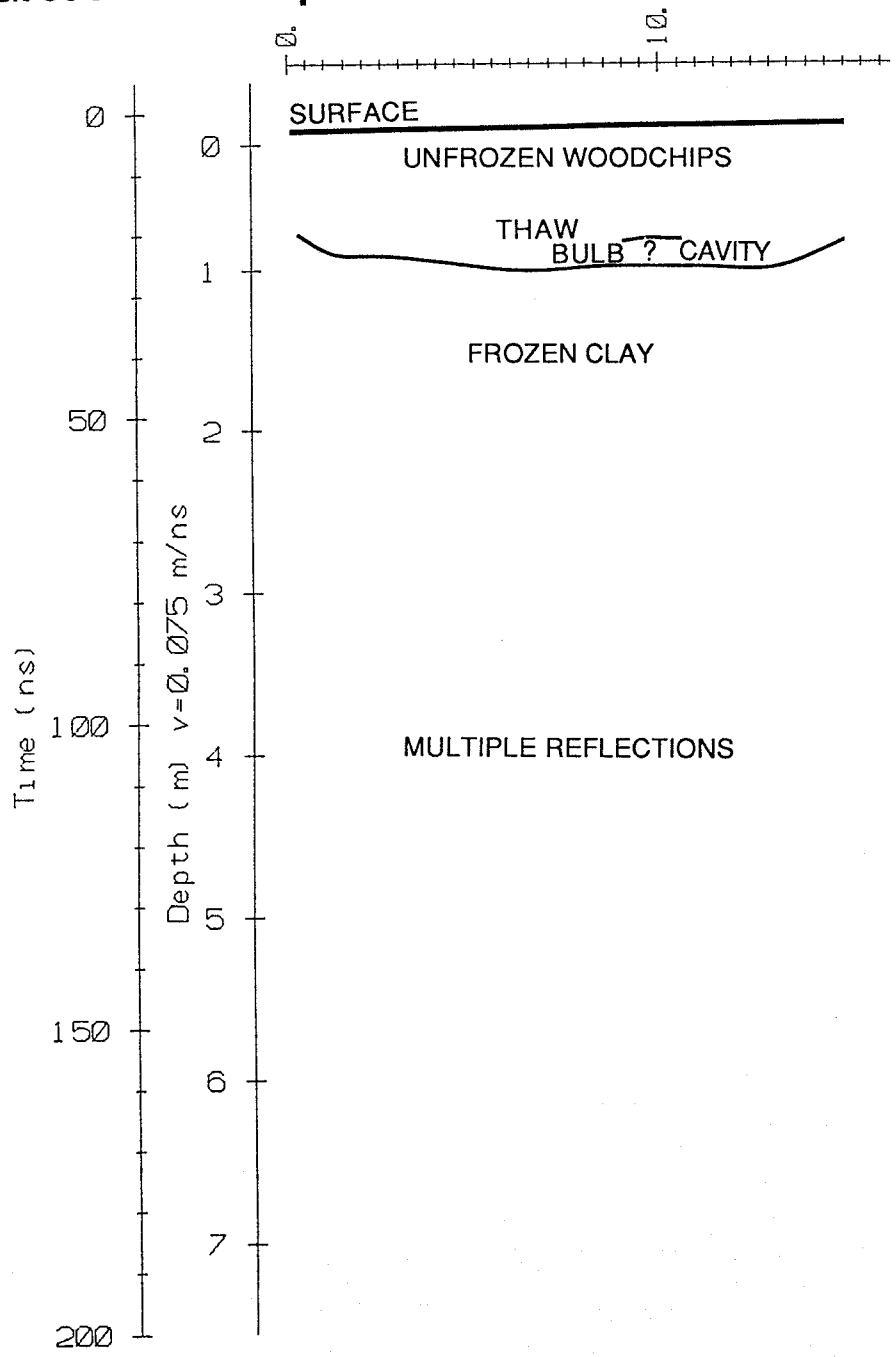
Great Bear Slope 29b: Cross Profile 7 (30)



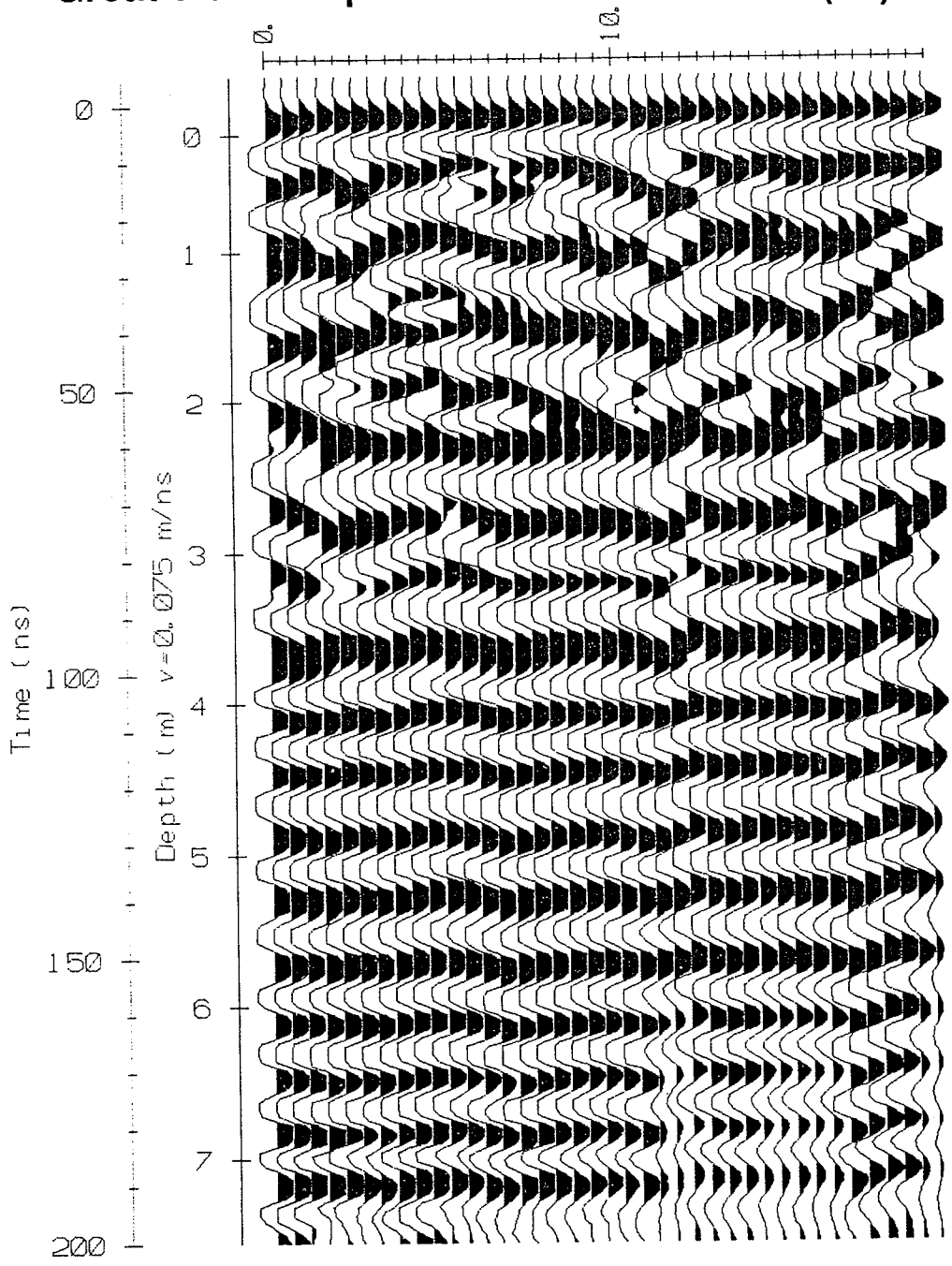
Great Bear Slope 29b: Cross Profile 8 (29)



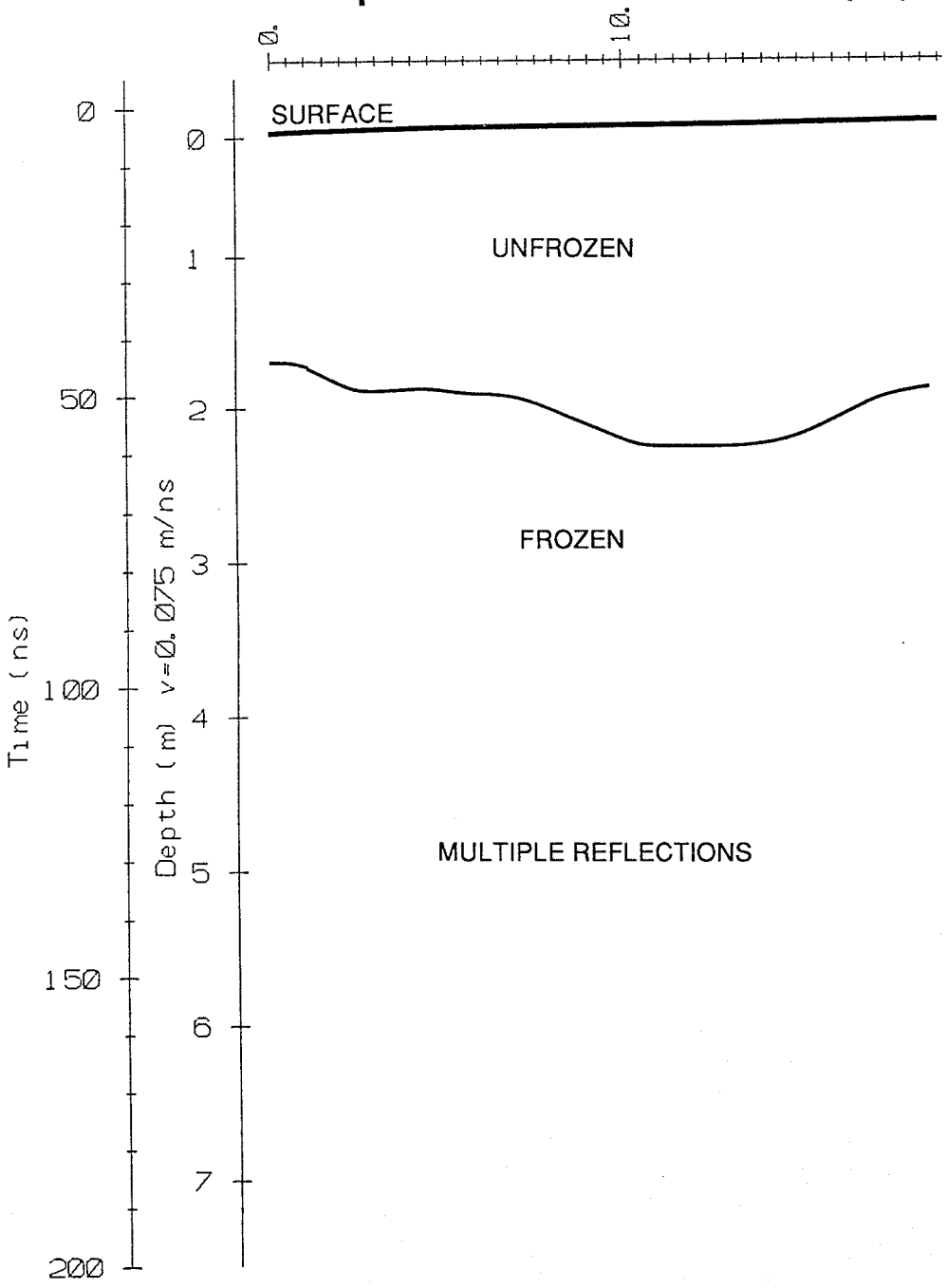
Great Bear Slope 29b: Cross Profile 8 (29)

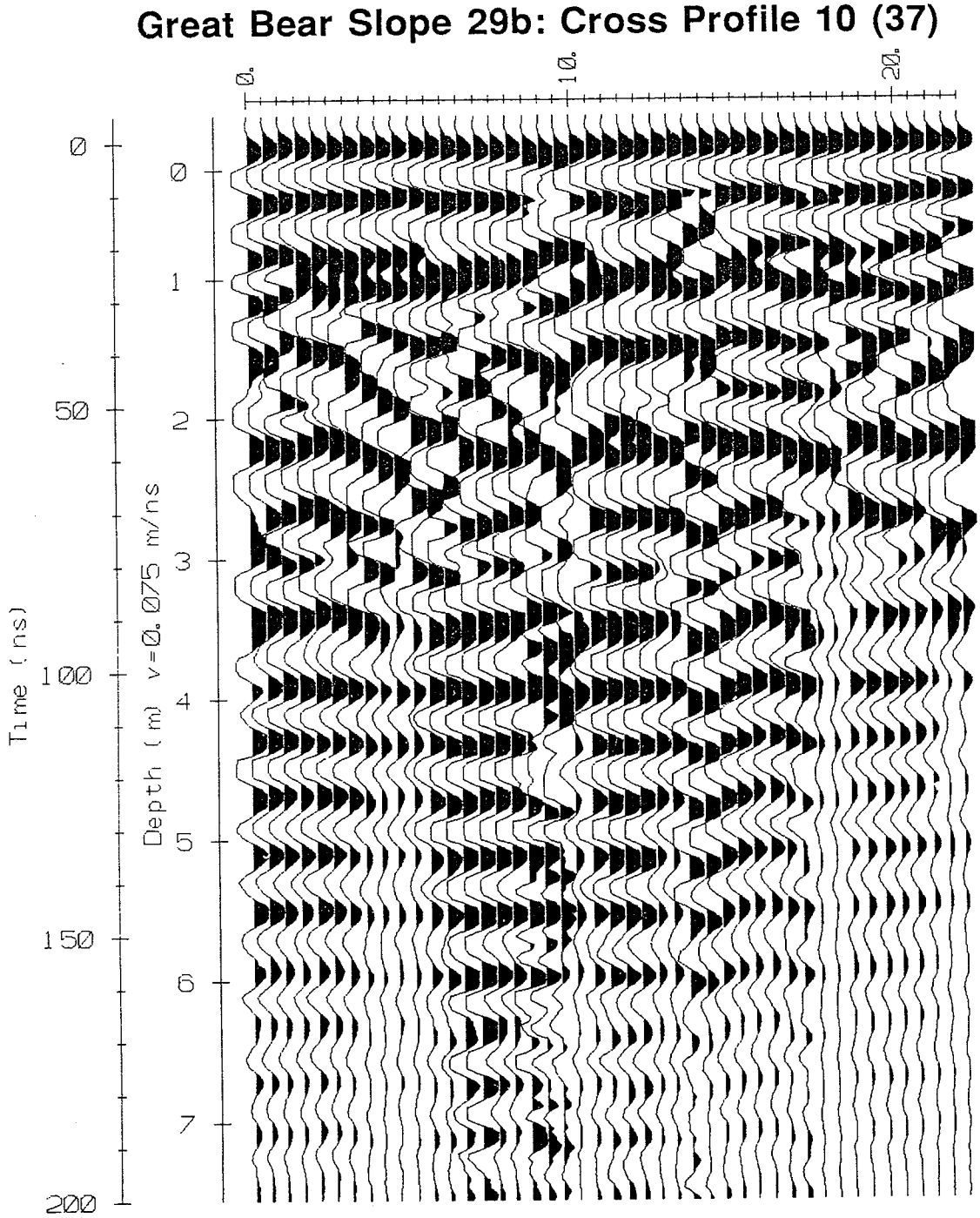


Great Bear Slope 29b: Cross Profile 9 (28)

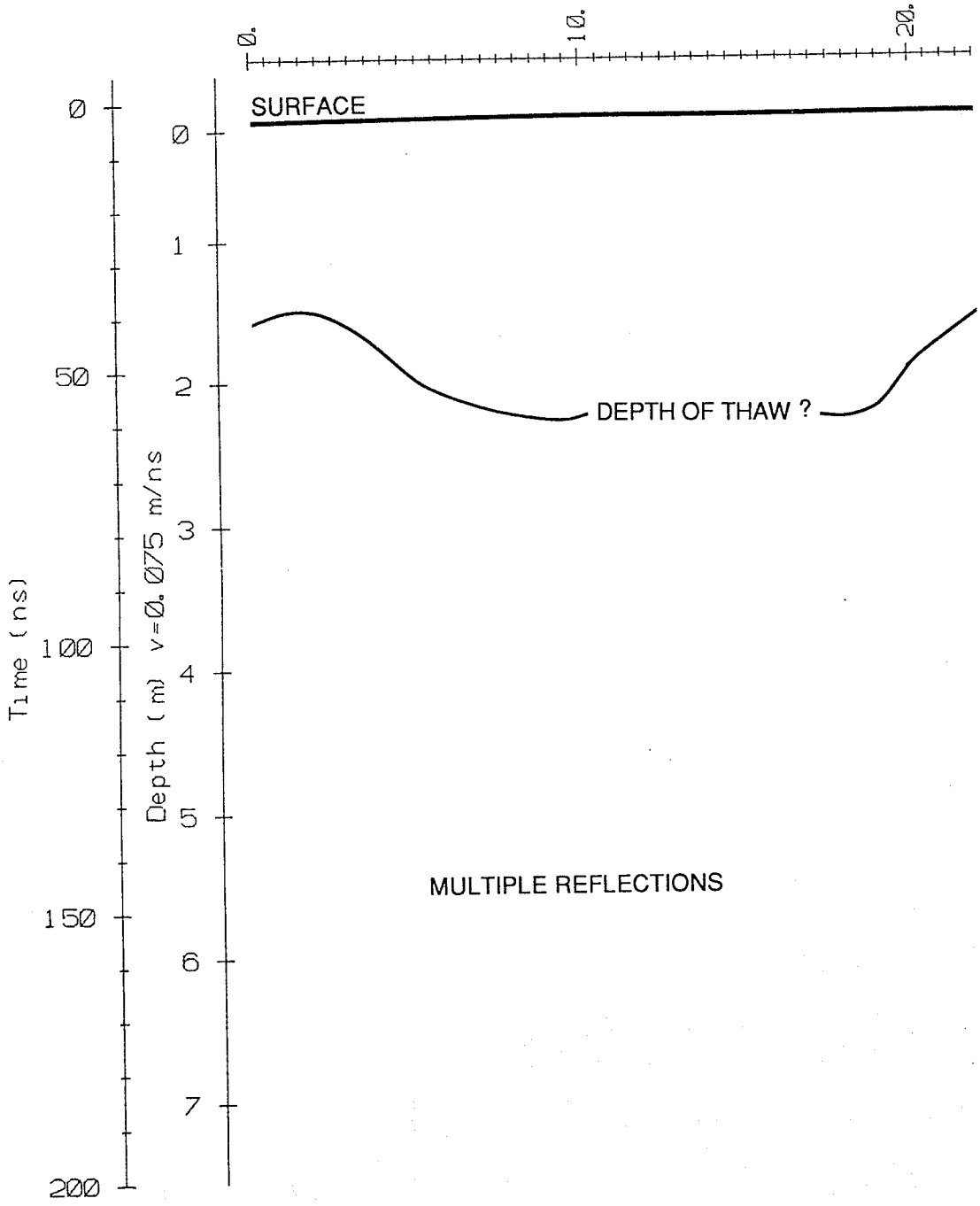


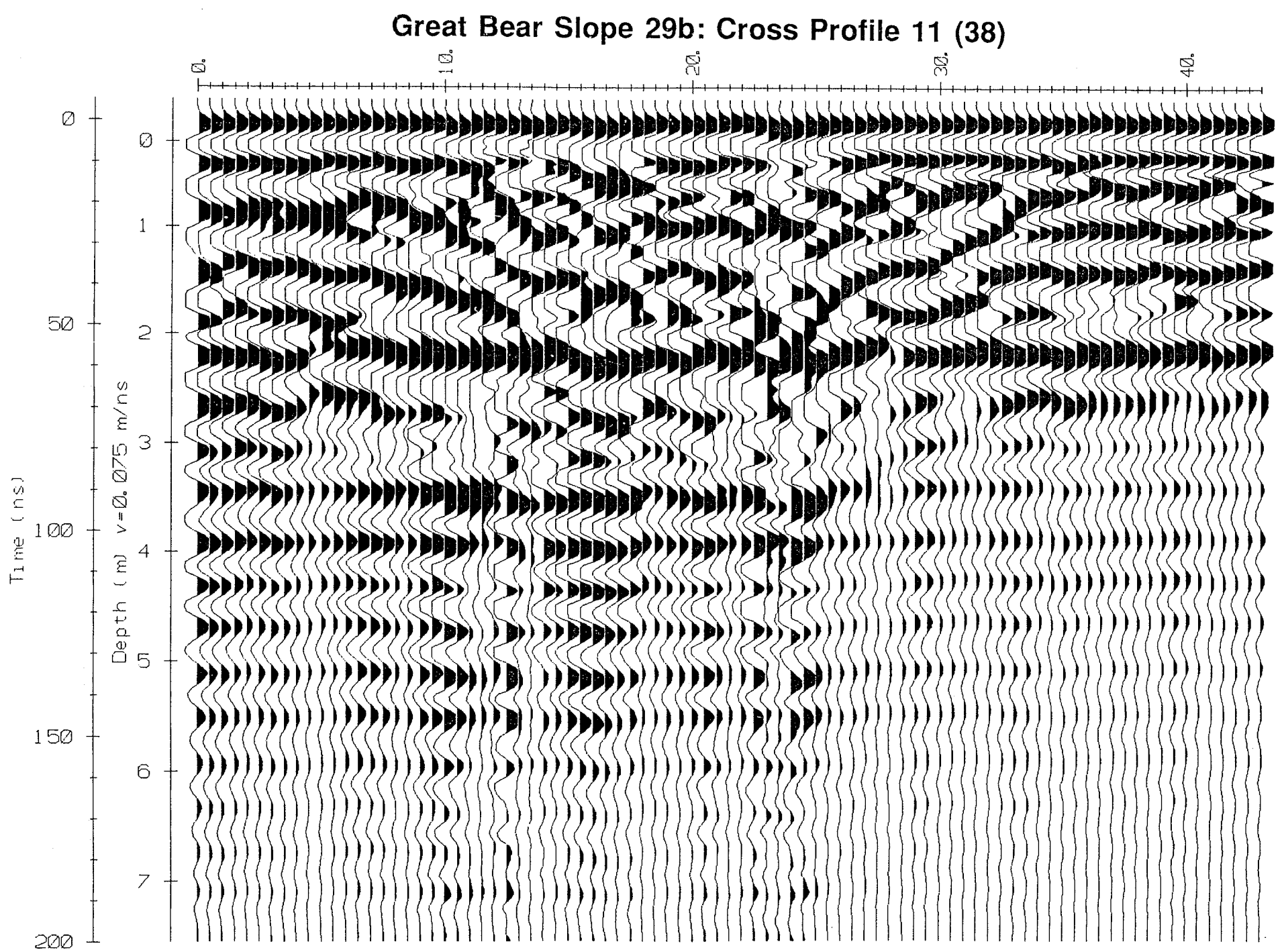
Great Bear Slope 29b: Cross Profile 9 (28)



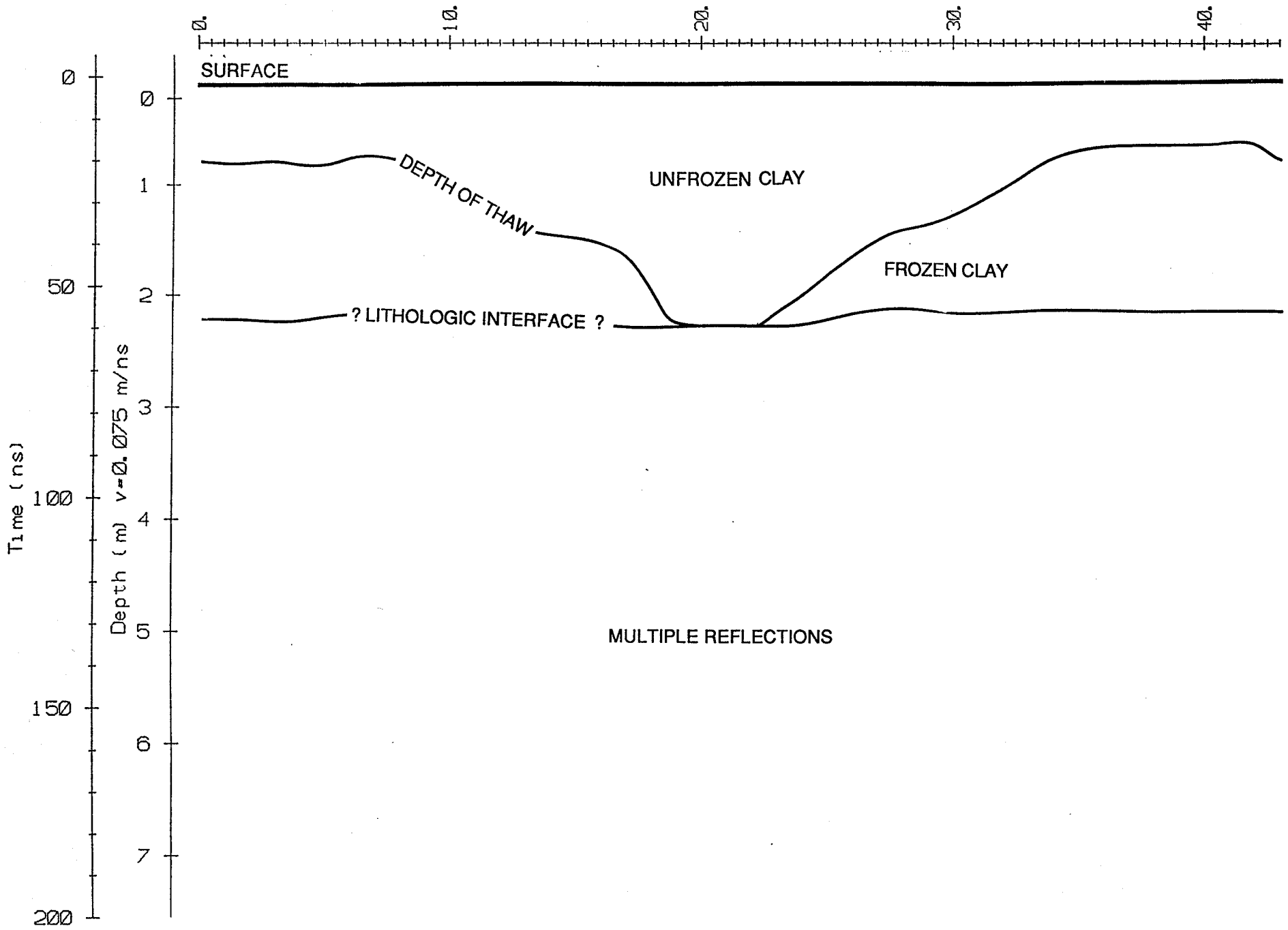

Great Bear Slope 29b: Cross Profile 10 (37)
0.
10.
20.
0
50
100
150
200
Time (ns)
0
1
2
3
4
5
6
7
Depth (m) v=0.075 m/ns

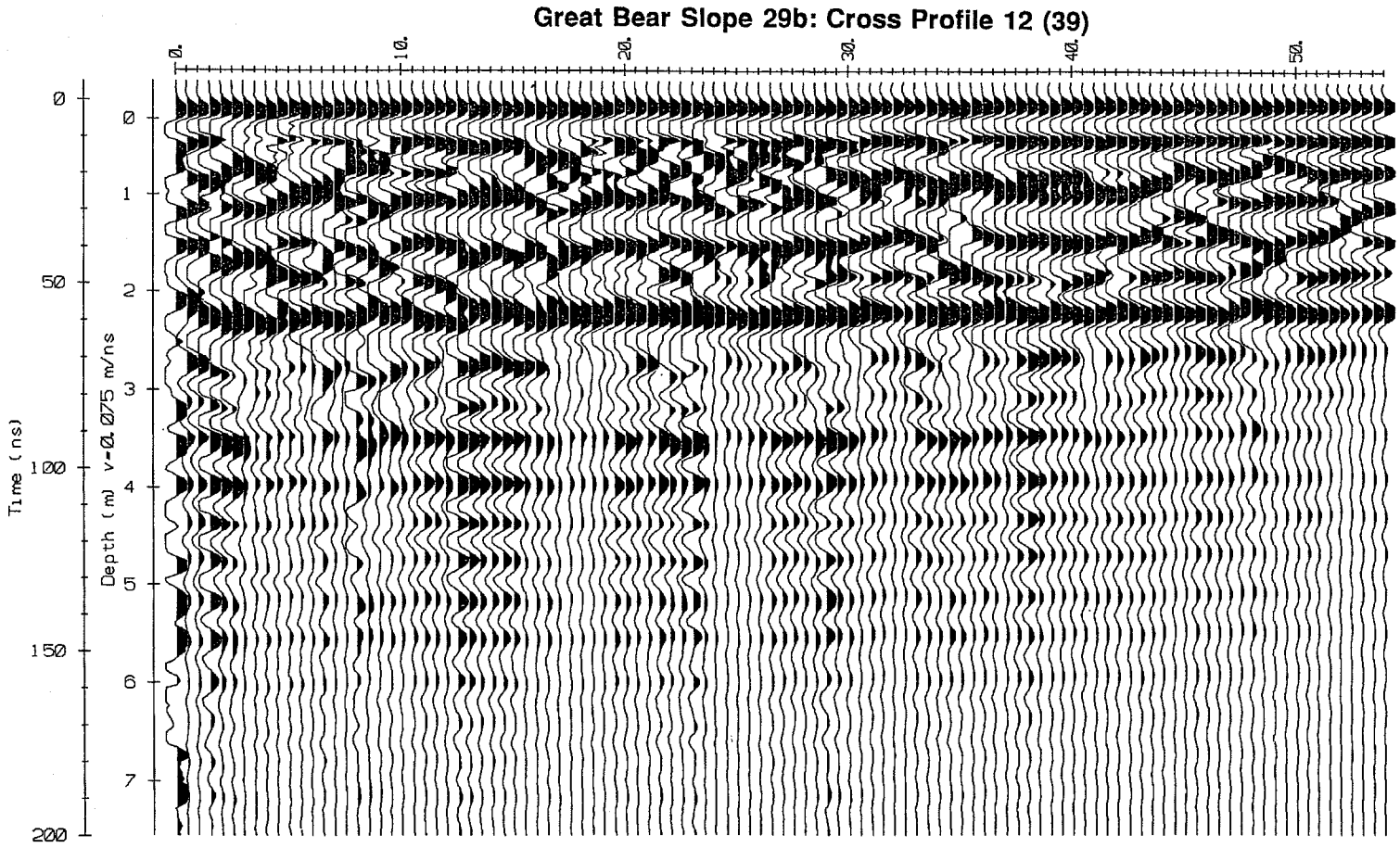
Great Bear Slope 29b: Cross Profile 10 (37)

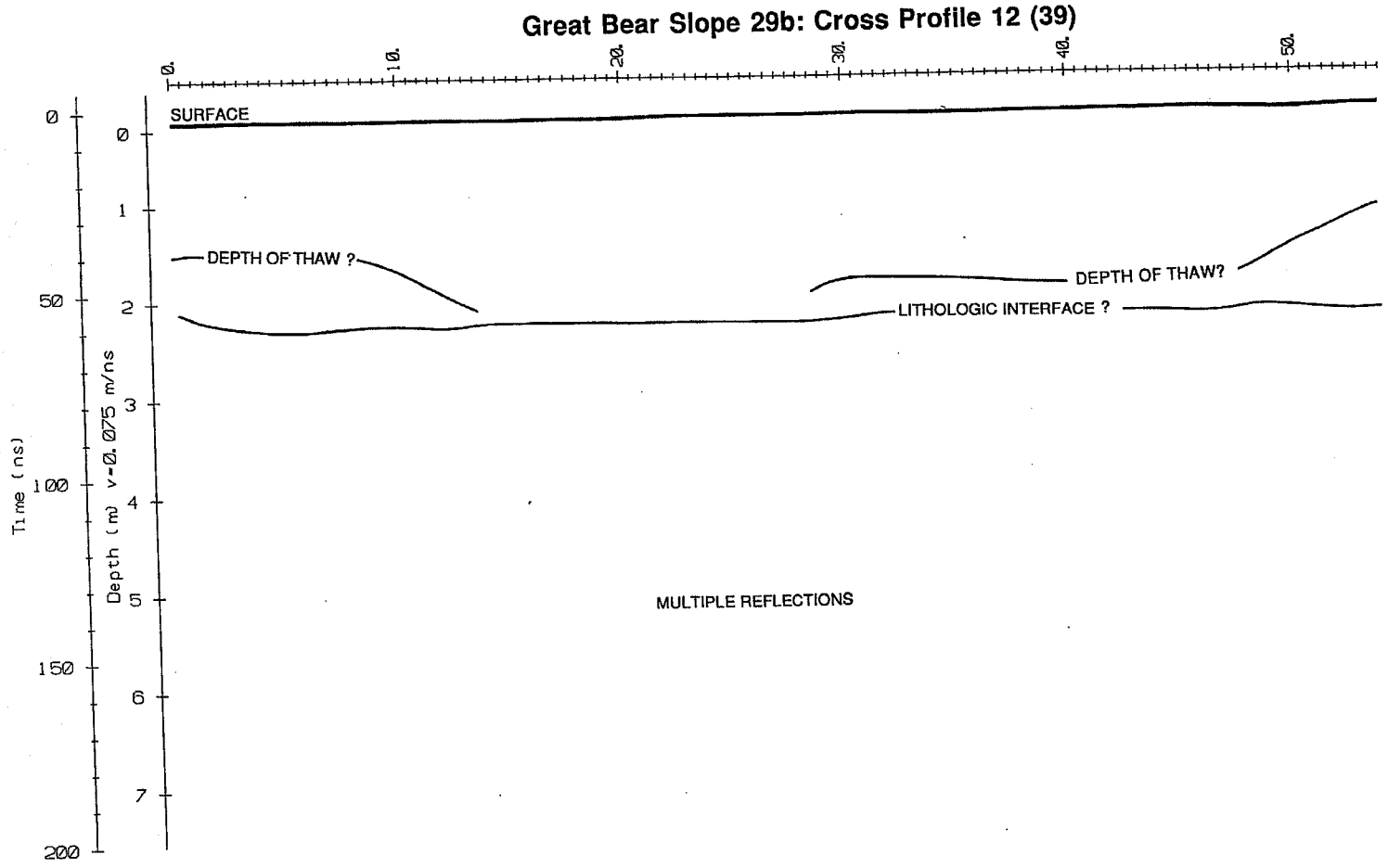



Great Bear Slope 29b: Cross Profile 11 (38)
0.
10.
20.
30.
40.
0
50
100
150
200
Time (ns)
0
1
2
3
4
5
6
7
Depth (m) v=0.075 m/ns

Great Bear Slope 29b: Cross Profile 11 (38)




Great Bear Slope 29b: Cross Profile 12 (39)
0.
10.
20.
30.
40.
50.
0
50
100
150
200
Time (ns)
0
1
2
3
4
5
6
7
Depth (m) v=0.075 m/ns


Great Bear Slope 29b: Cross Profile 12 (39)
0.
10.
20.
30.
40.
50.
SURFACE
DEPTH OF THAW ?
DEPTH OF THAW?
LITHOLOGIC INTERFACE ?
MULTIPLE REFLECTIONS
Time (ns)
Depth (m) v=0.075 m/ns
0
50
100
150
200
1
2
3
4
5
6
7

Appendix B

Data:

Ochre River

Slope 82

(km 286)

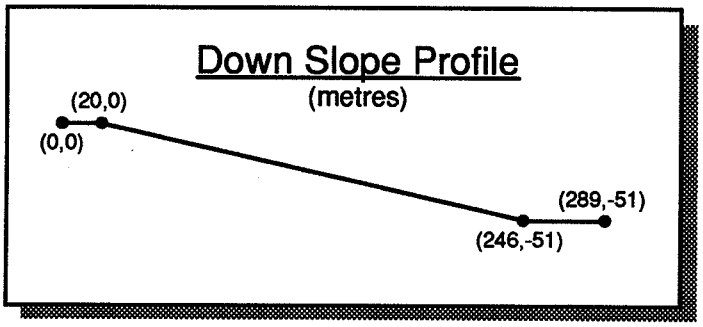
Ochre River
Slope 82 Site Plan

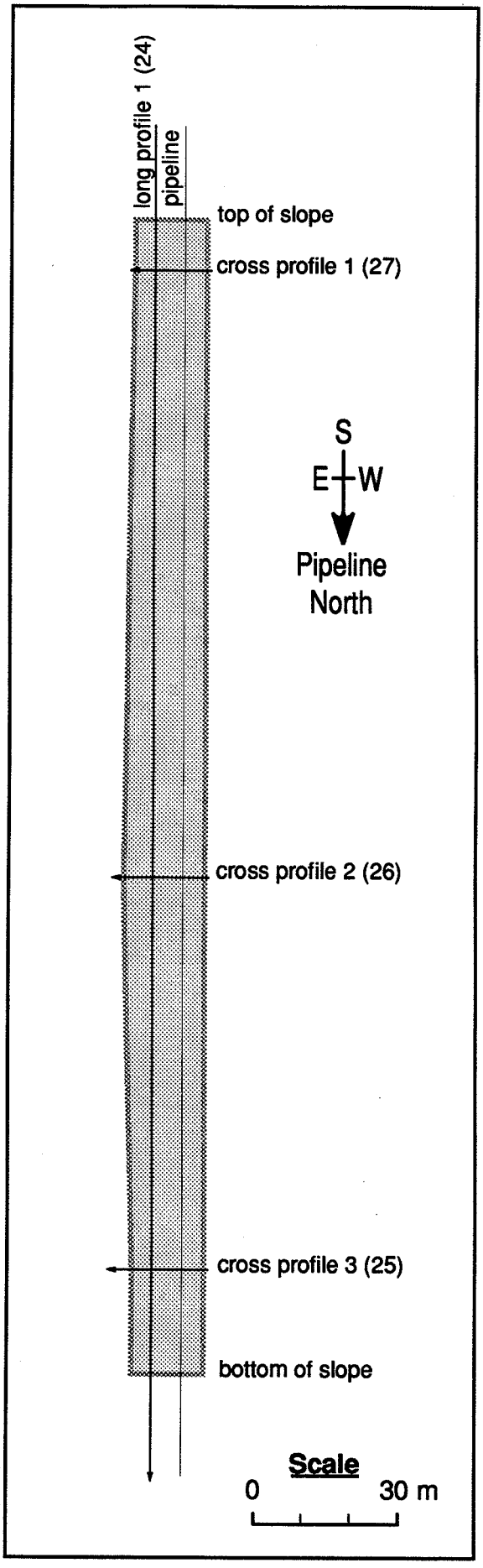
Legend

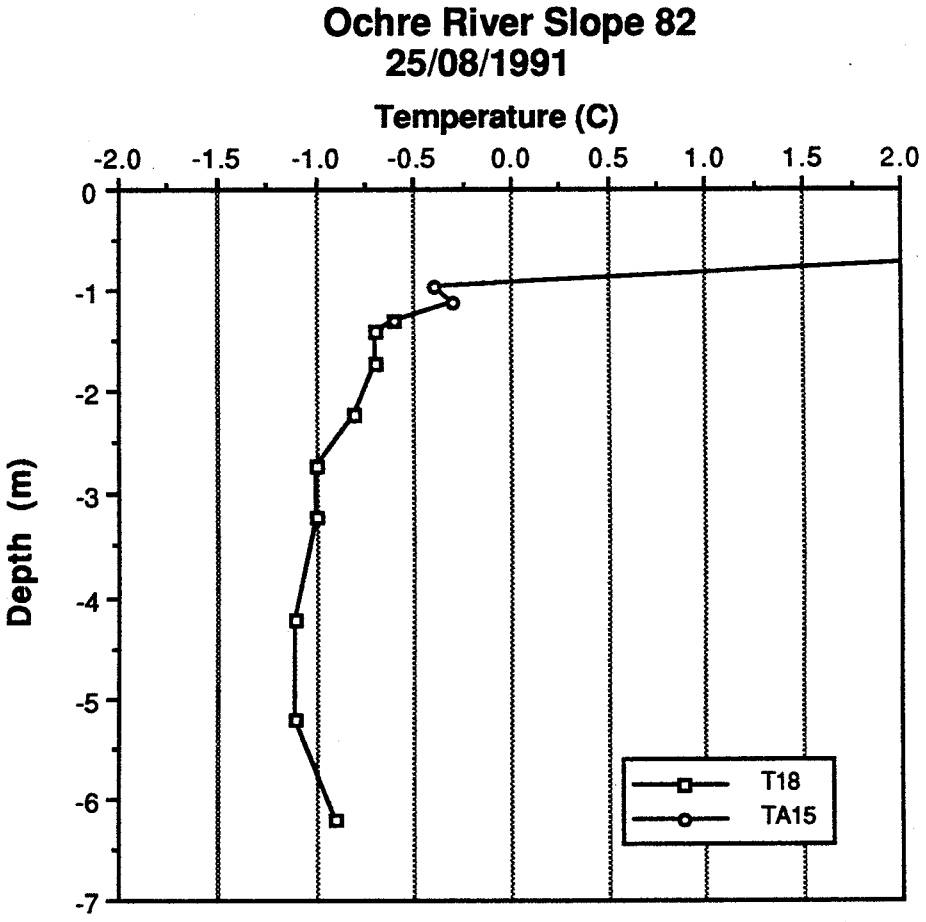
GPR profile
(arrow indicates direction)

(##) GPR file number

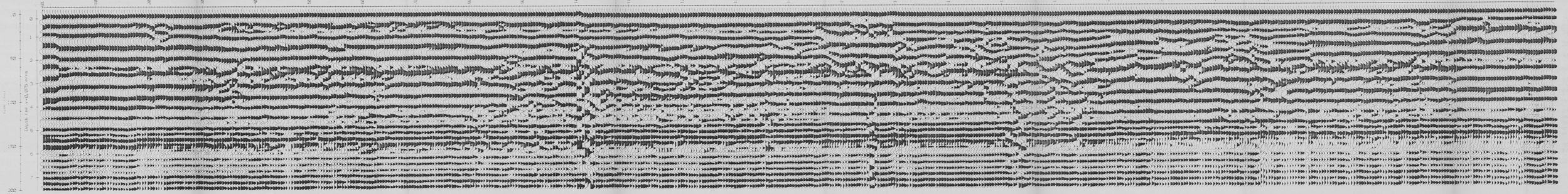
woodchip cover



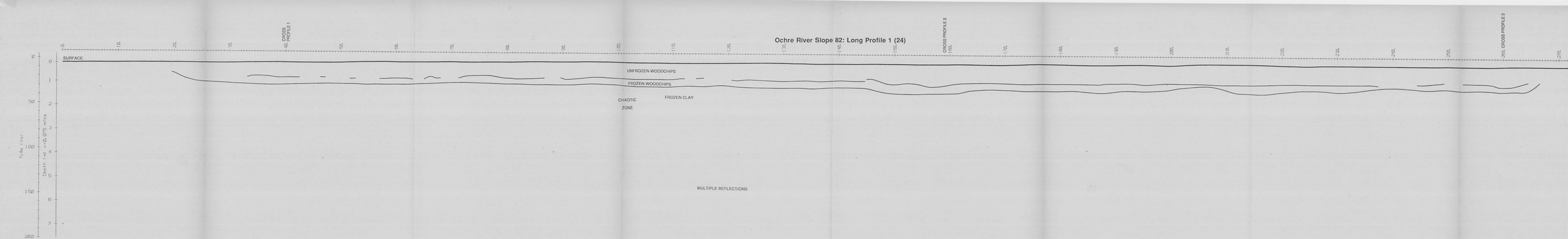



Ochre River Slope 82
25/08/1991
Temperature (C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
0
-1
-2
-3
-4
-5
-6
-7
Depth (m)
T18
TA15

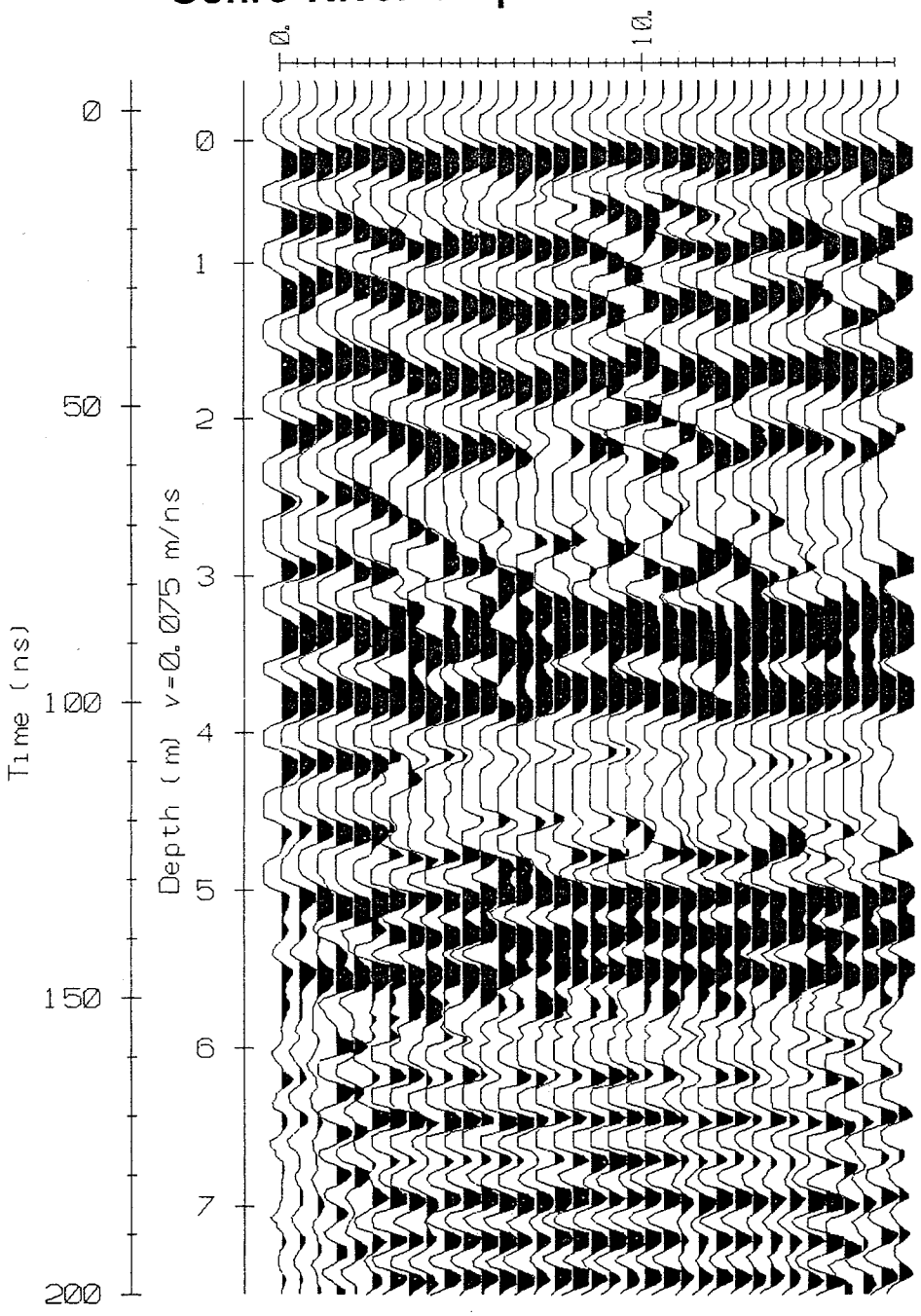
Ochre River Slope 82: Long Profile 1 (24)



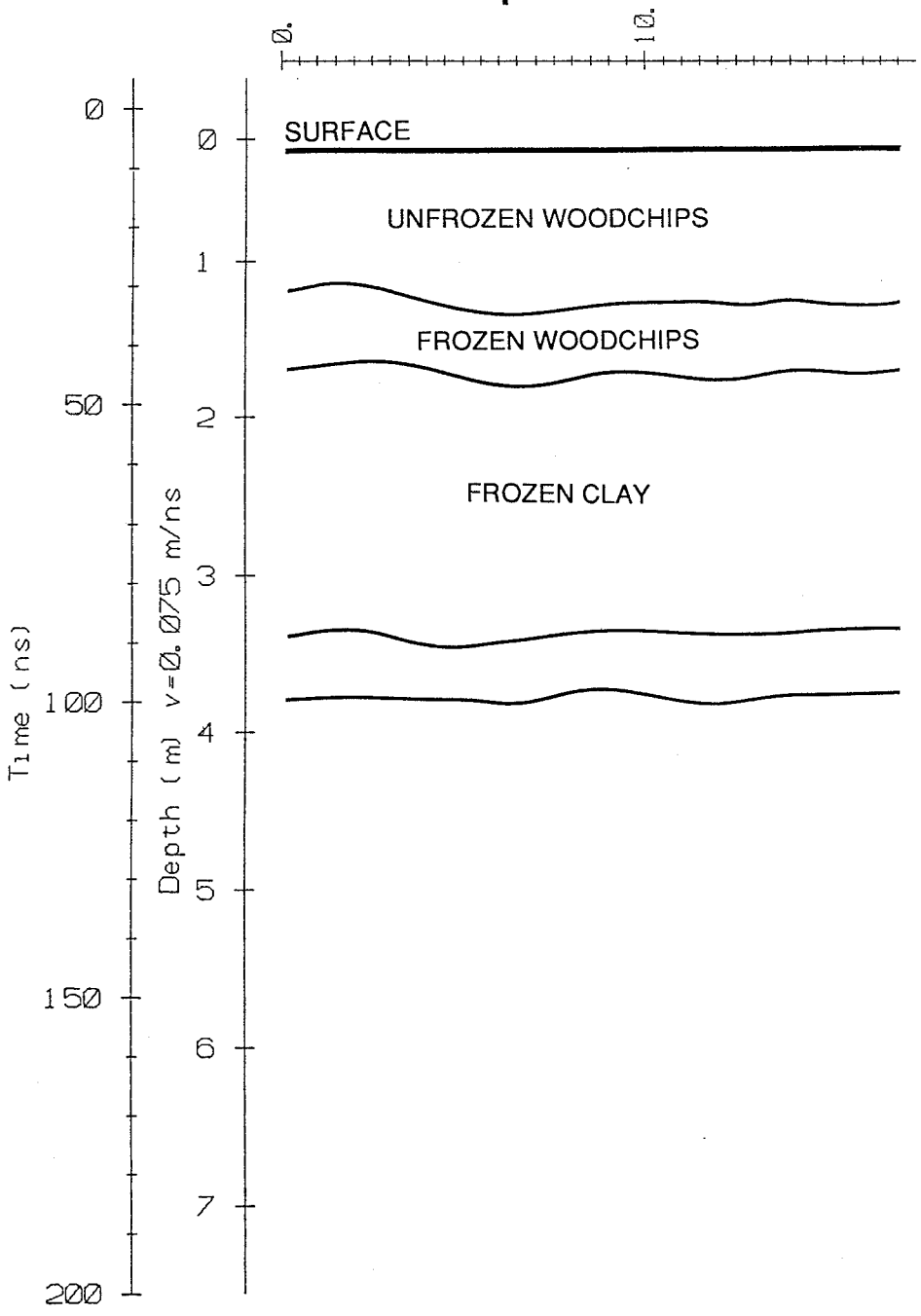
Ochre River Slope 82: Long Profile 1 (24)



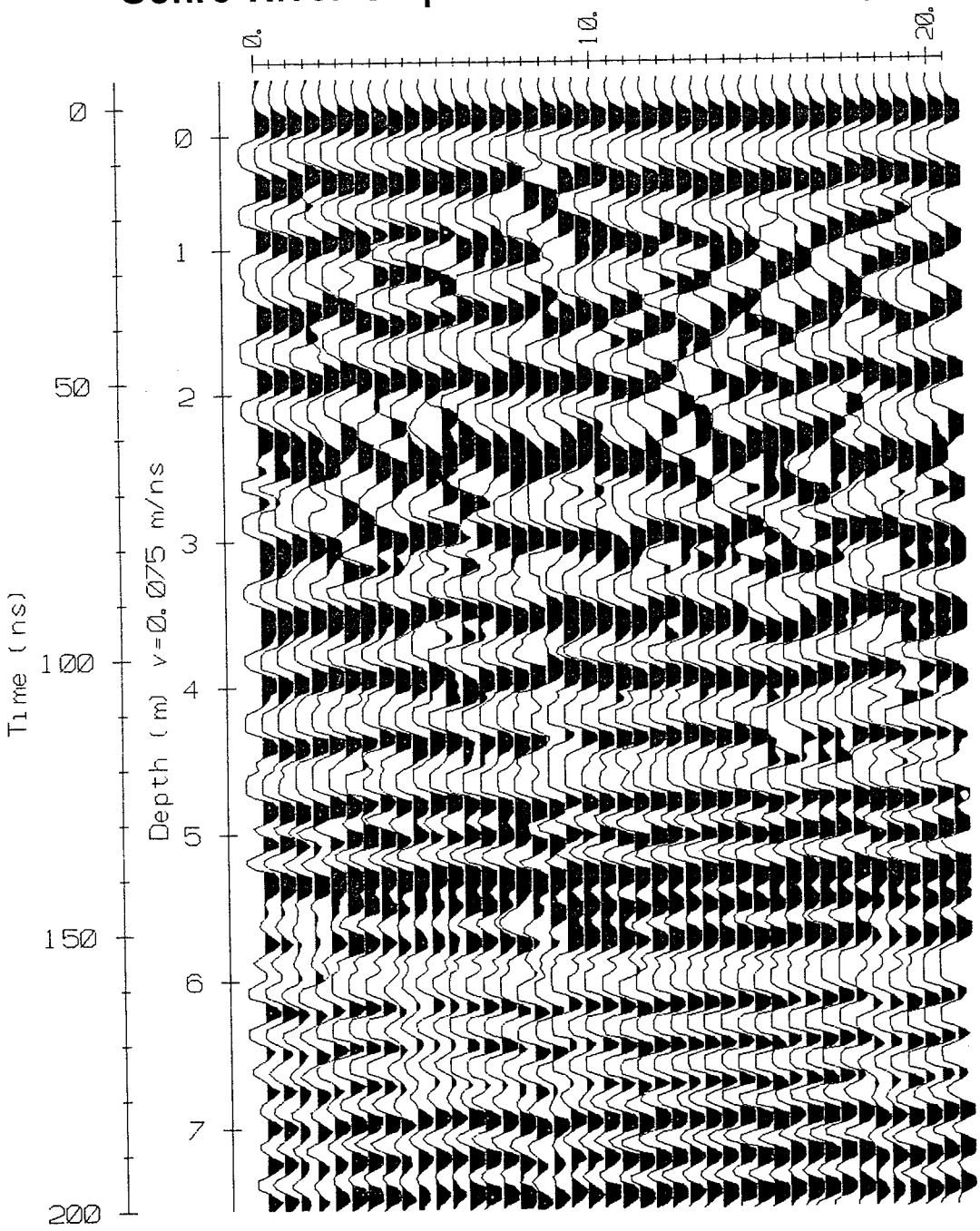
Ochre River Slope 82: Cross Profile 1 (27)



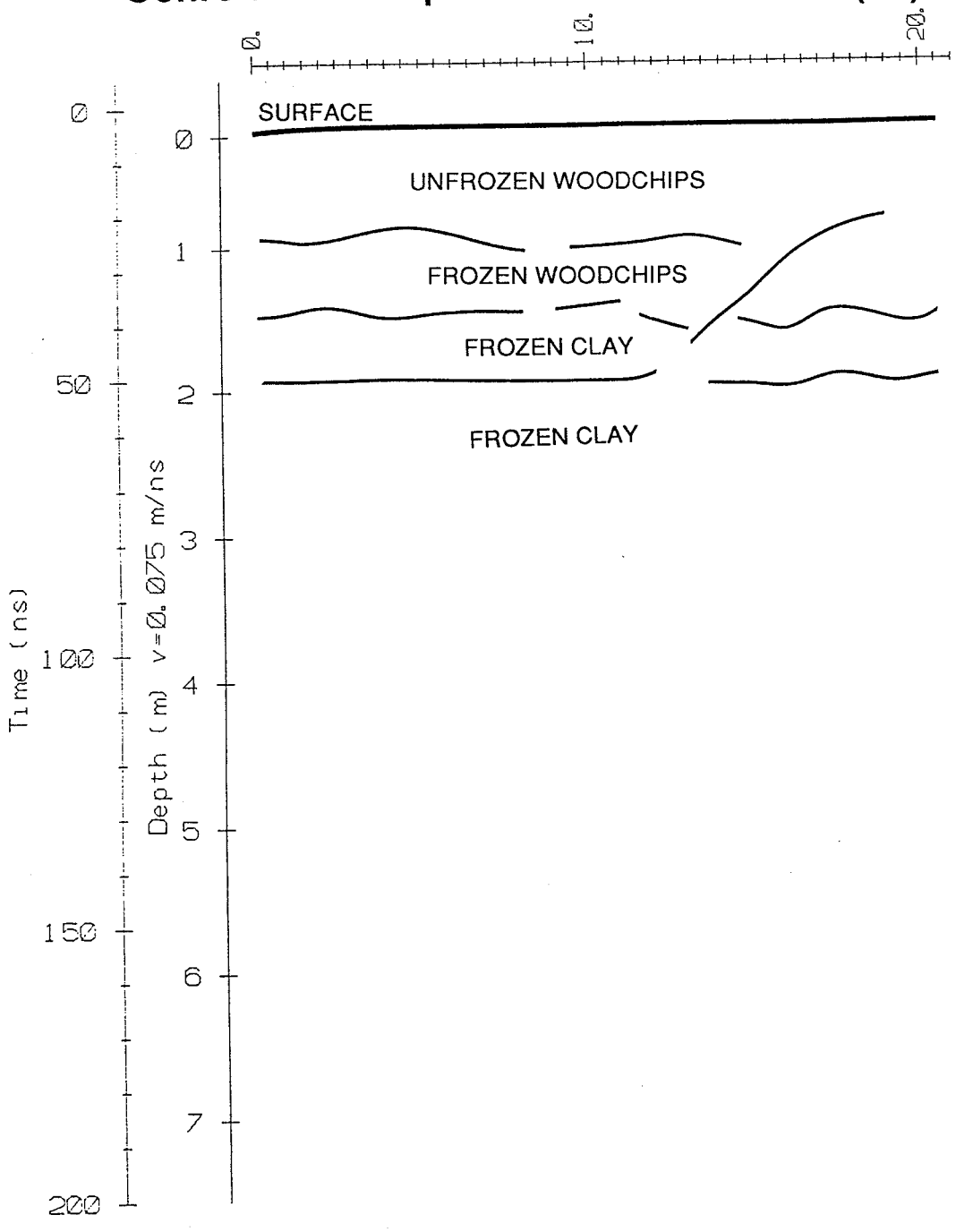
Ochre River Slope 82: Cross Profile 1 (27)



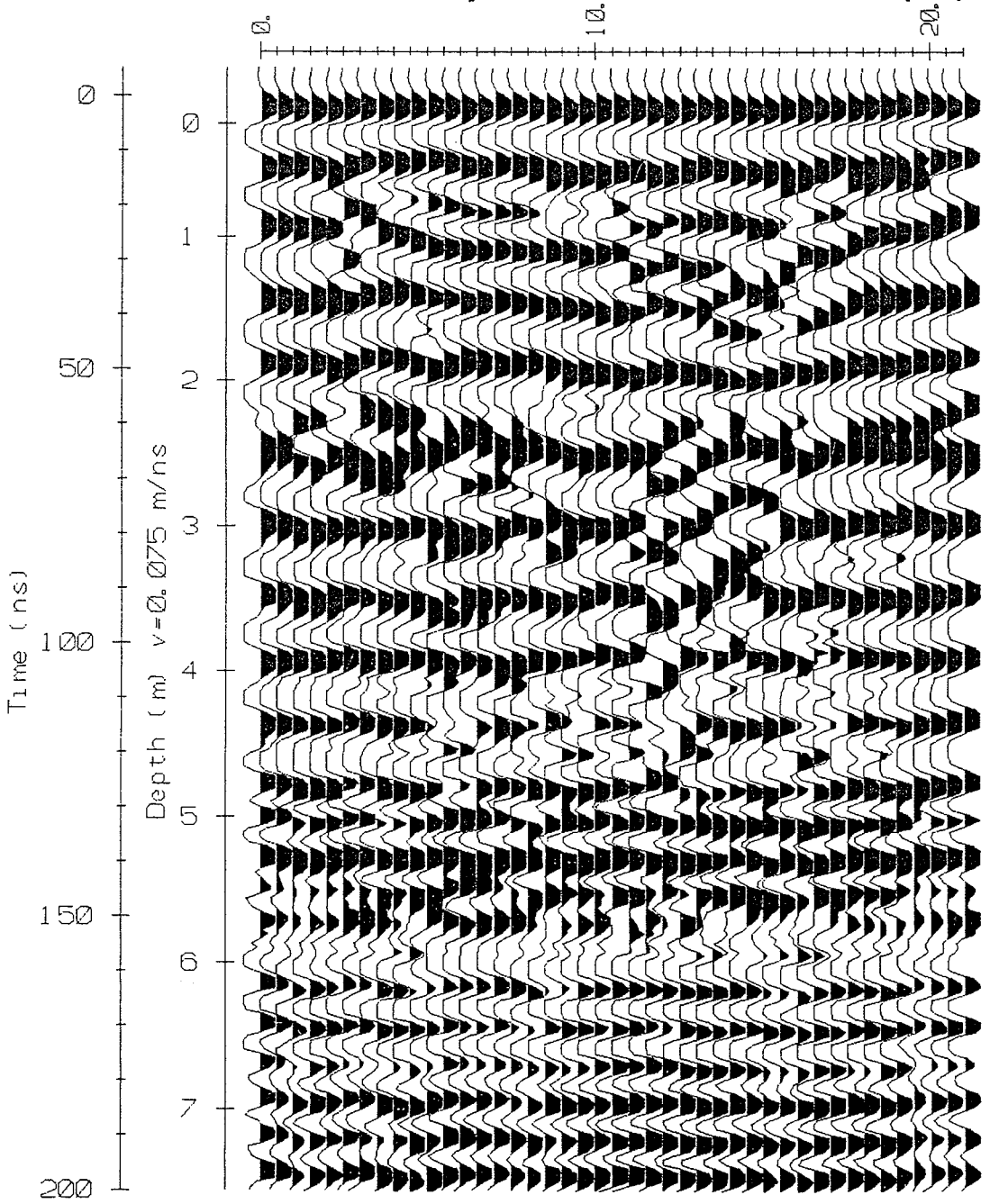
Ochre River Slope 82: Cross Profile 2 (26)



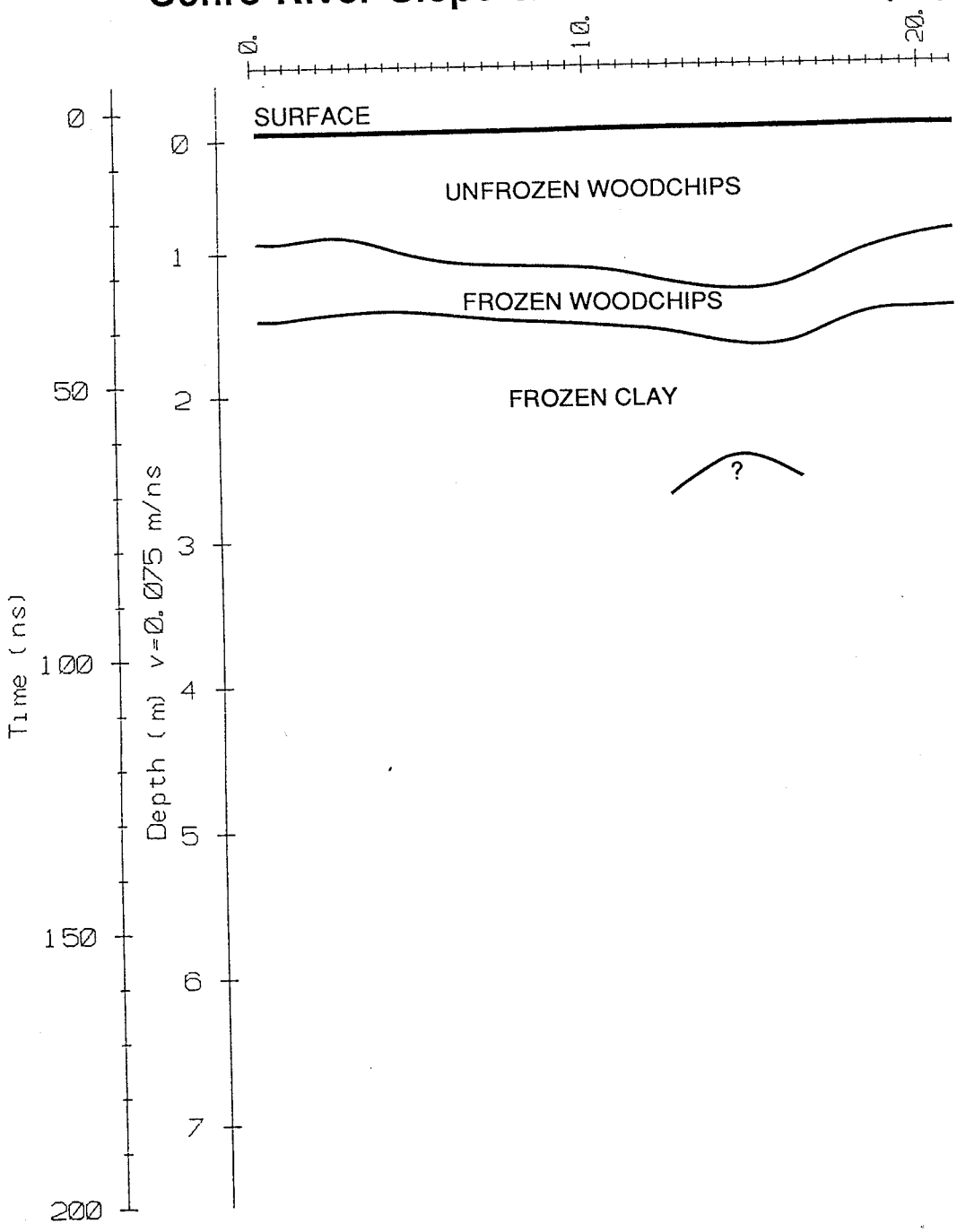
Ochre River Slope 82: Cross Profile 2 (26)



Ochre River Slope 82: Cross Profile 3 (25)



Ochre River Slope 82: Cross Profile 3 (25)



Appendix C

Data:

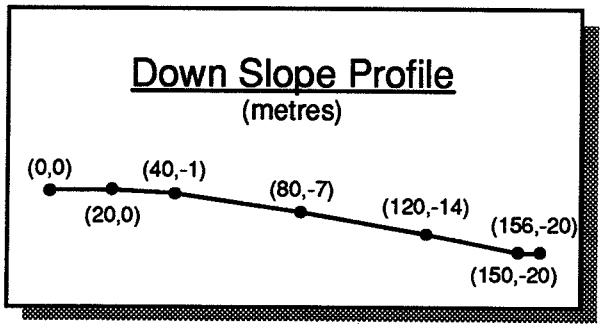
Slope 109

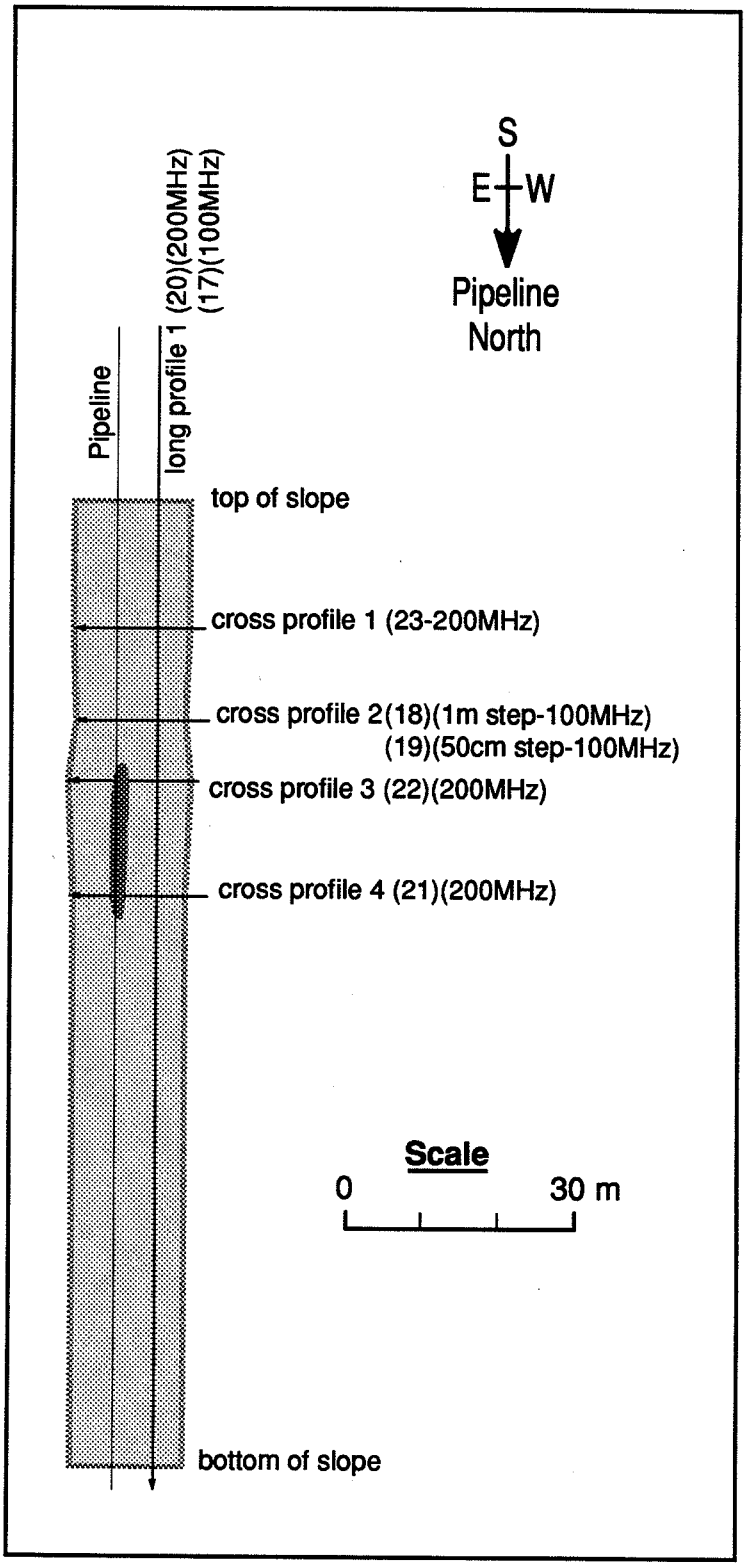
(km 352)

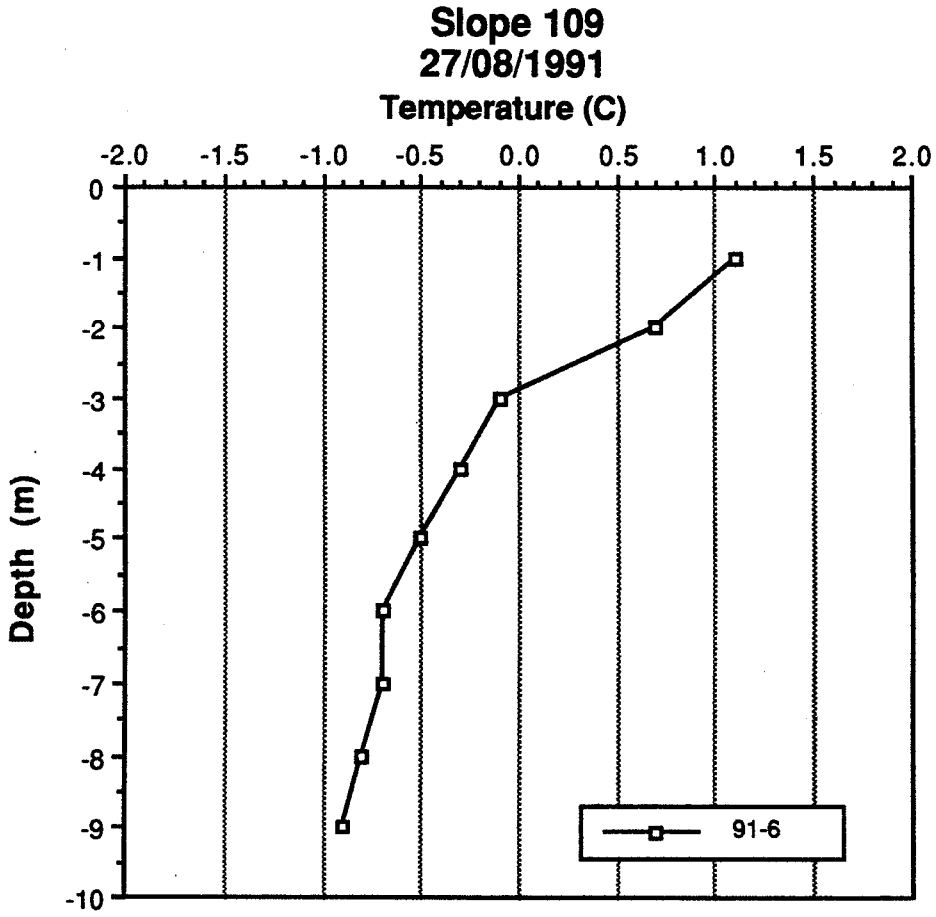
Slope 109
Site Plan

Legend

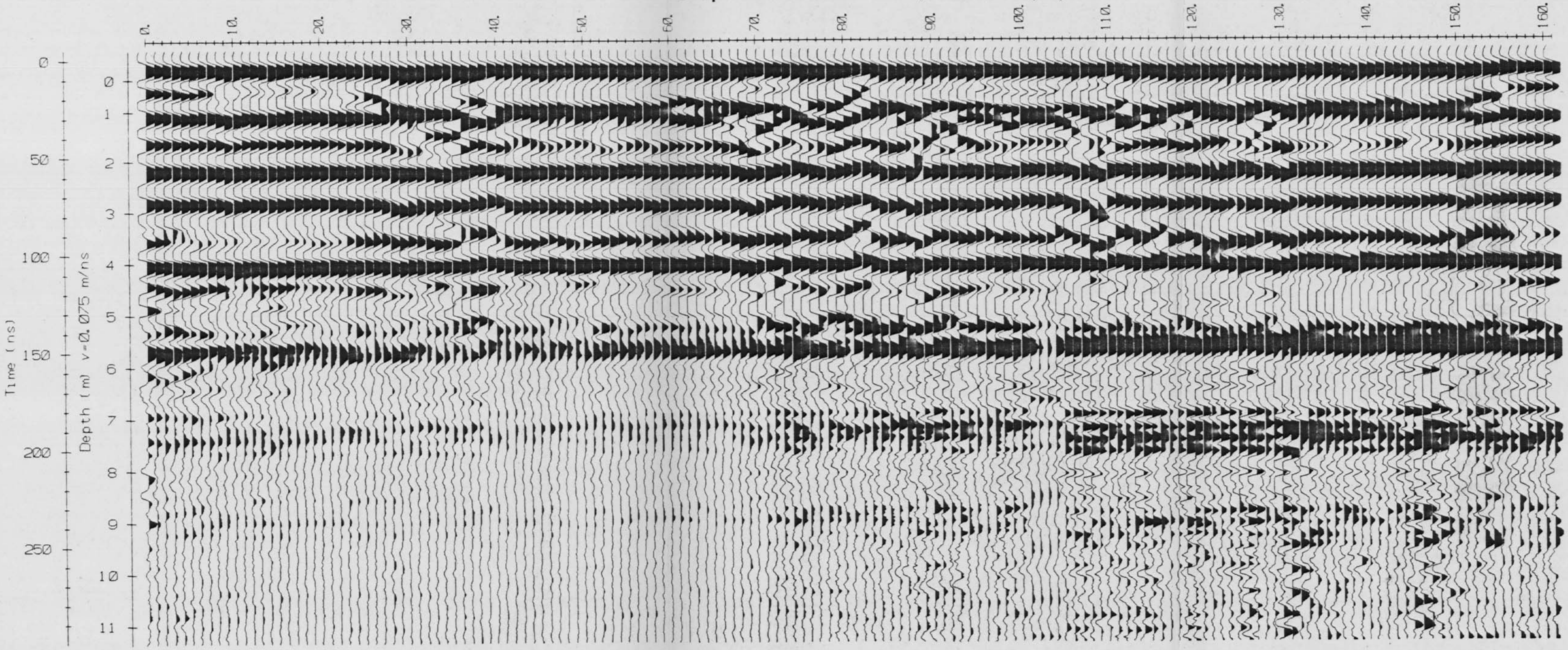
- GPR profile (arrow indicates direction)
- (##) GPR file number
- woodchip cover
- depression

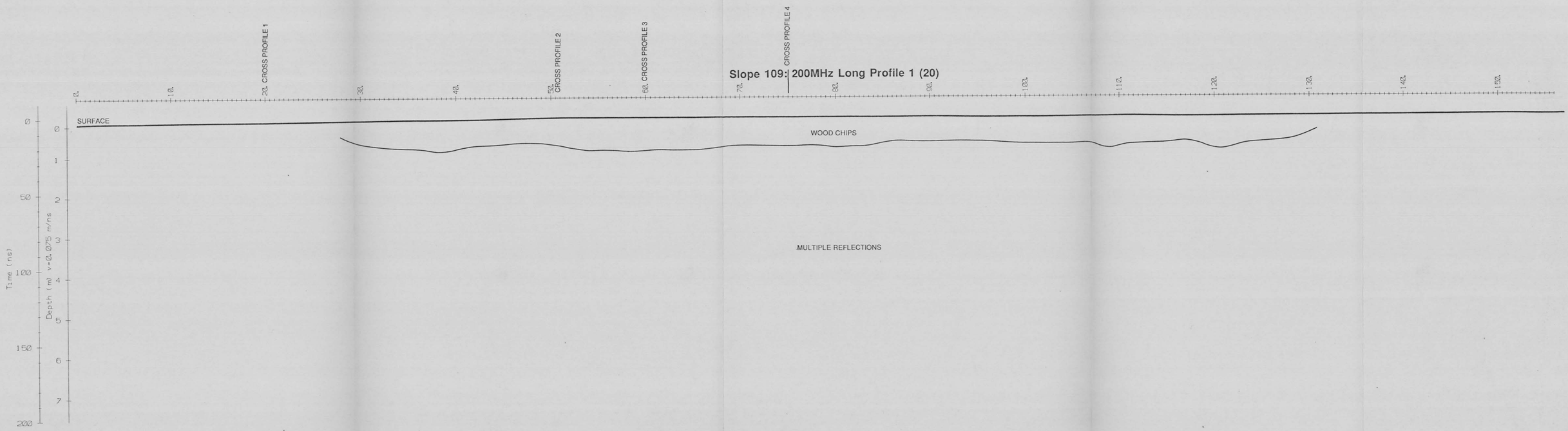




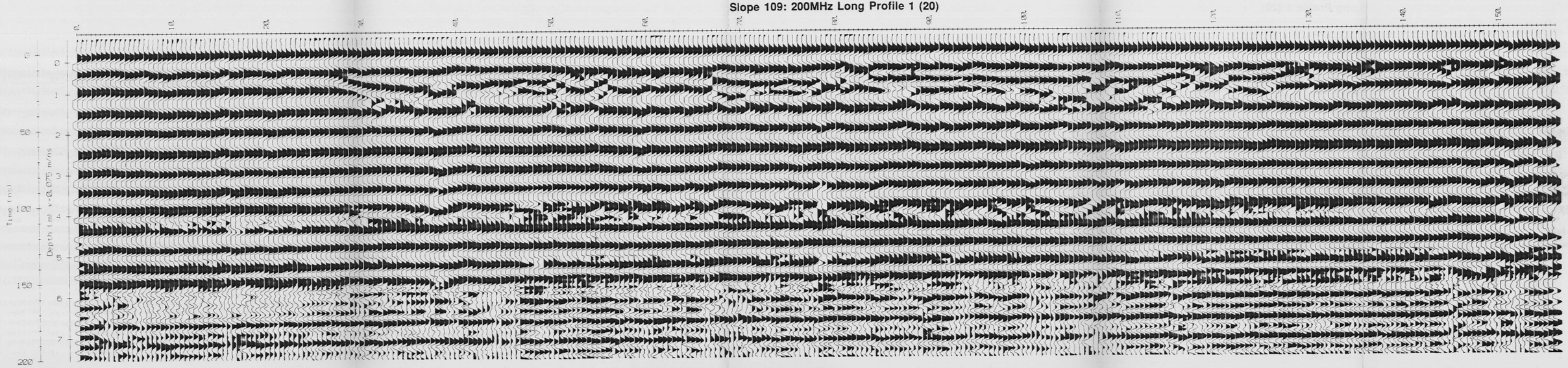

Slope 109
27/08/1991
Temperature (C)
-2.0
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
2.0
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
Depth (m)
91-6

Slope 109: 100MHz Long Profile 1 (17)

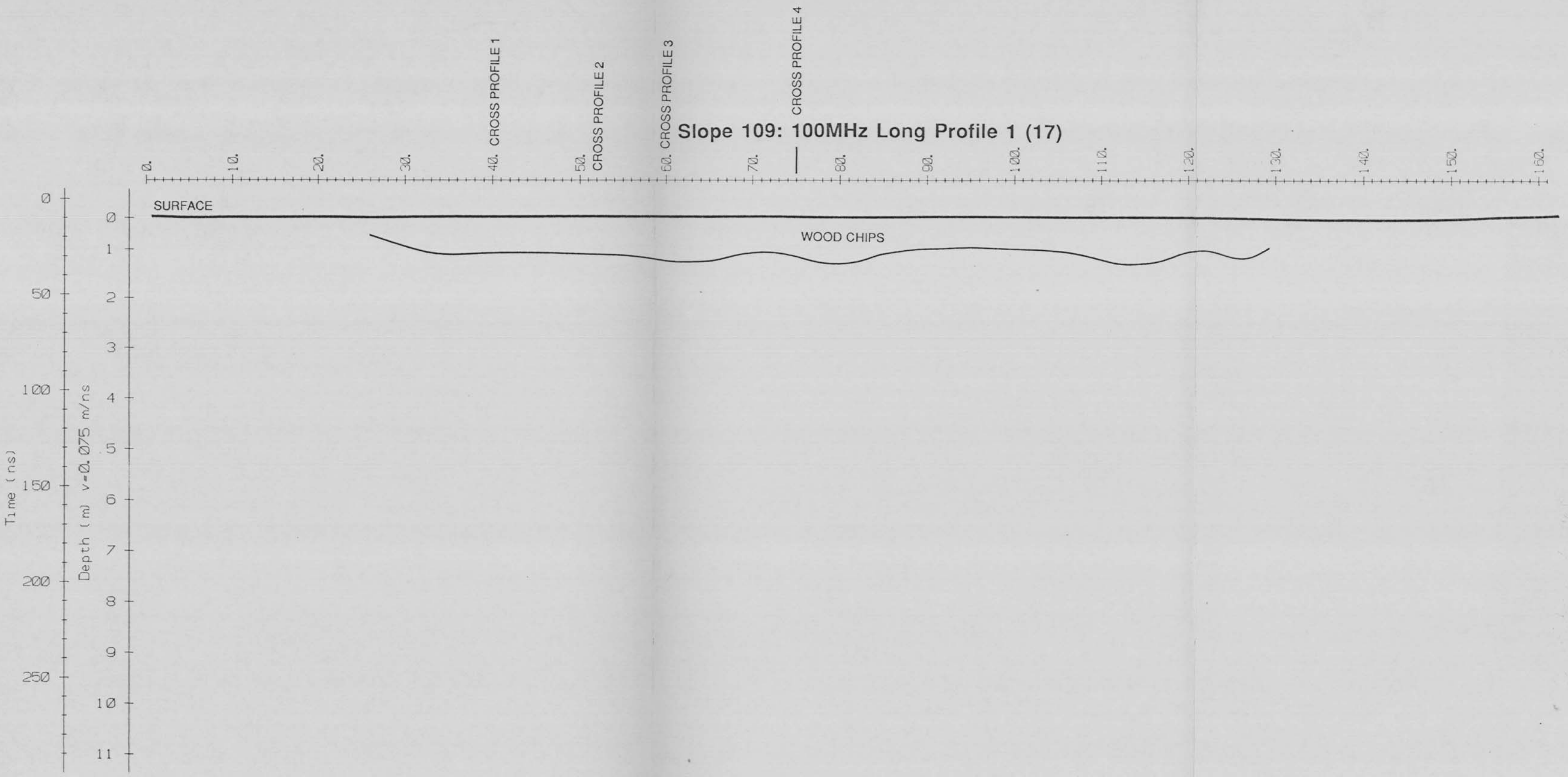



Slope 109: 200MHz Long Profile 1 (20)
0.
10.
20. CROSS PROFILE 1
30.
40.
50. CROSS PROFILE 2
60. CROSS PROFILE 3
70.
80. CROSS PROFILE 4
90.
100.
110.
120.
130.
140.
150.
SURFACE
WOOD CHIPS
MULTIPLE REFLECTIONS
Time (ns)
0
50
100
150
200
Depth (m) v=0.075 m/ns
0
1
2
3
4
5
6
7

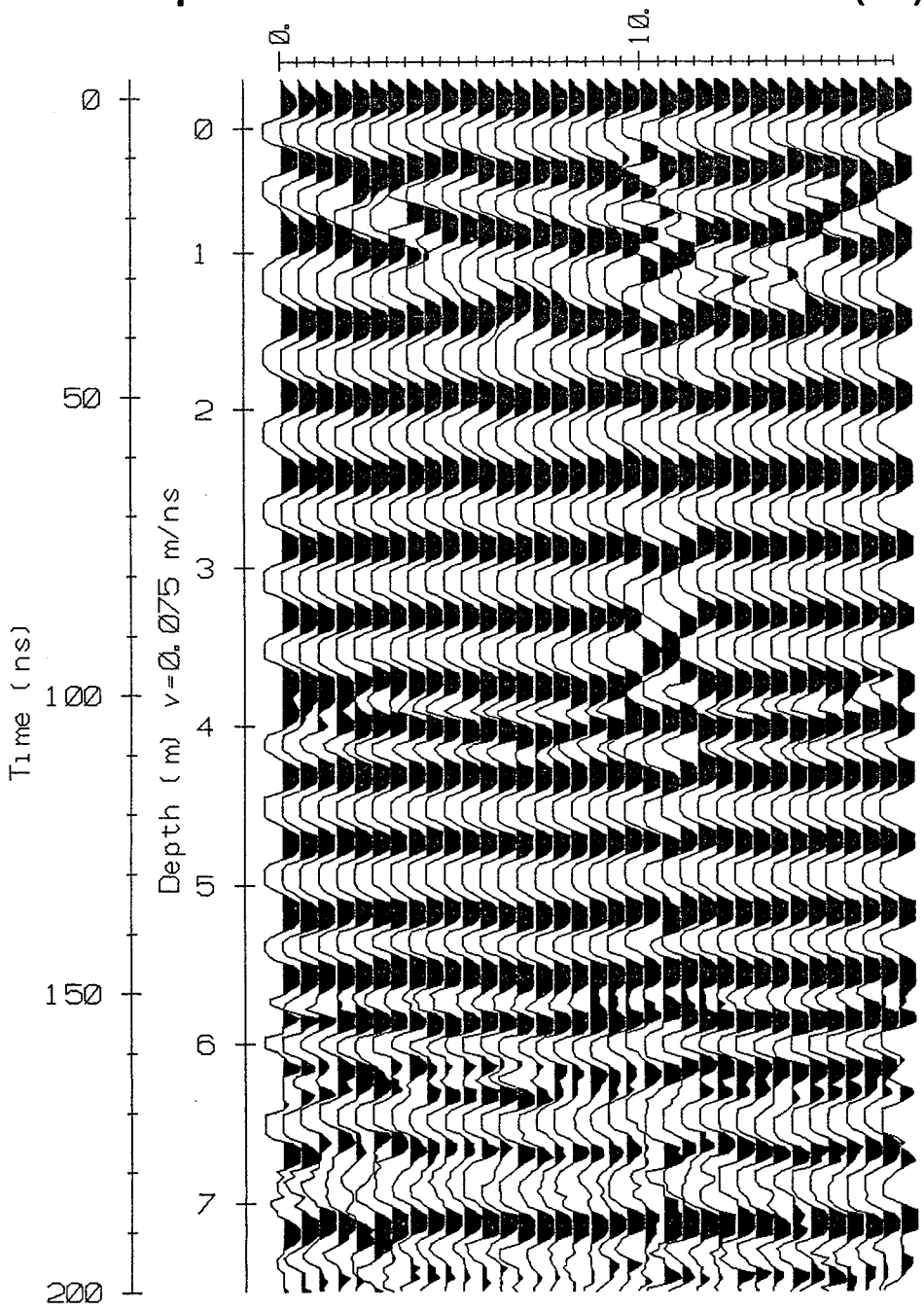
Slope 109: 200MHz Long Profile 1 (20)



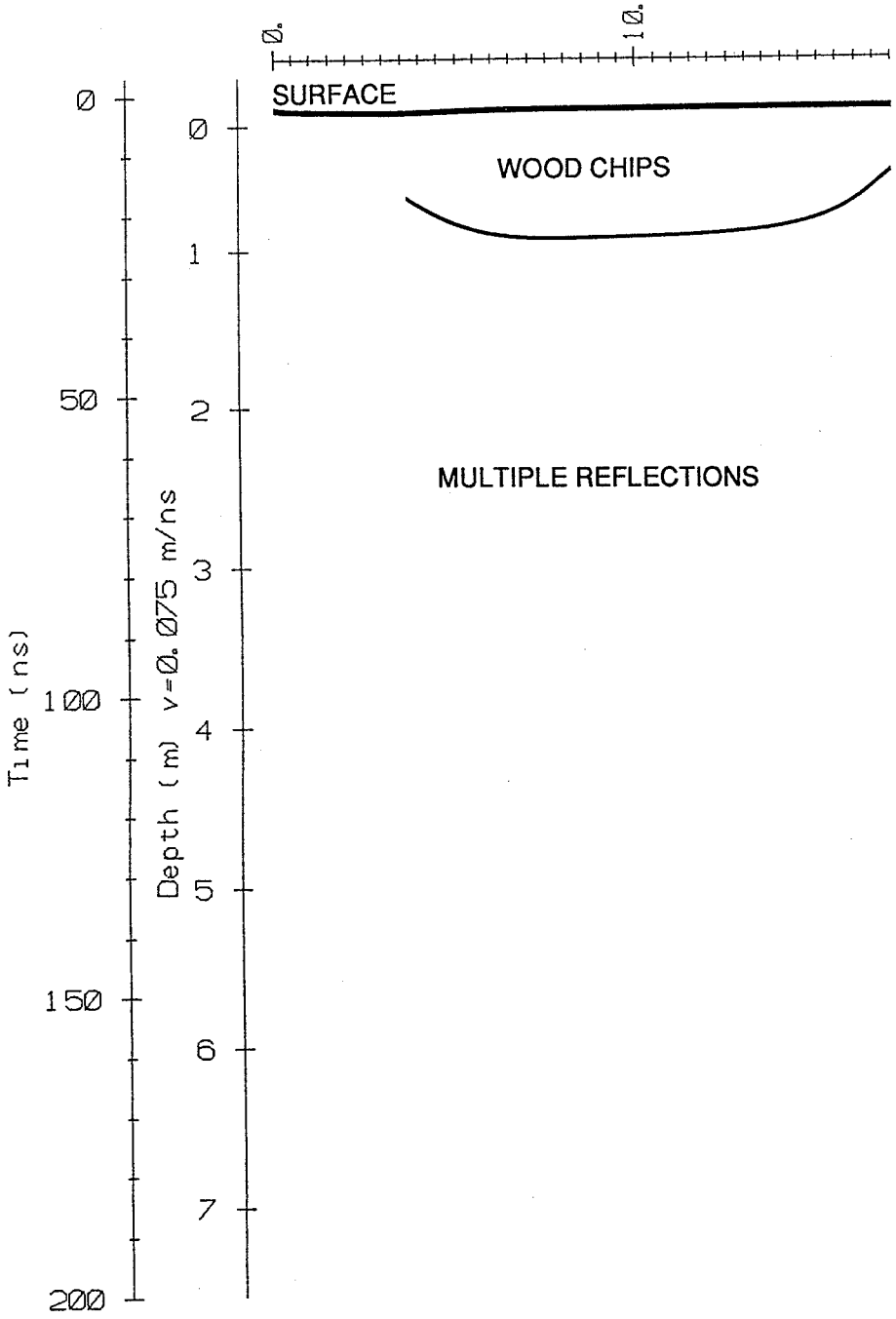
Slope 109: 100MHz Long Profile 1 (17)



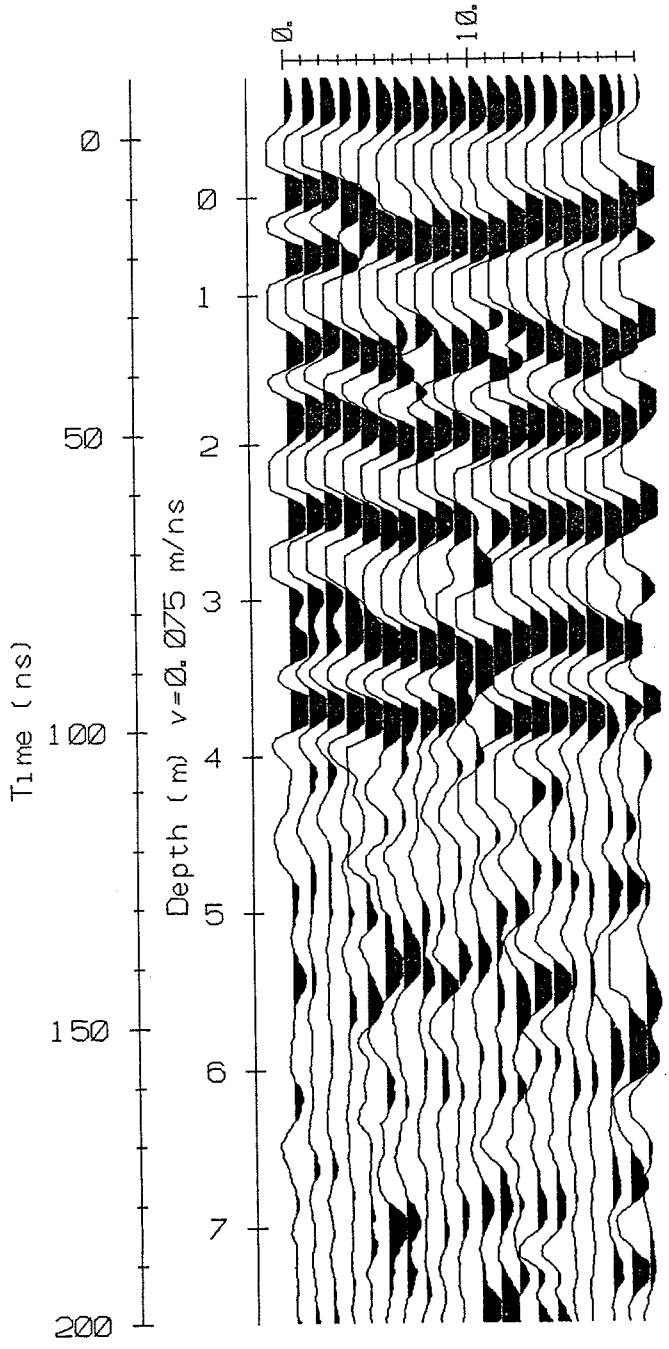
Slope 109: 200MHz Cross Profile 1 (23)



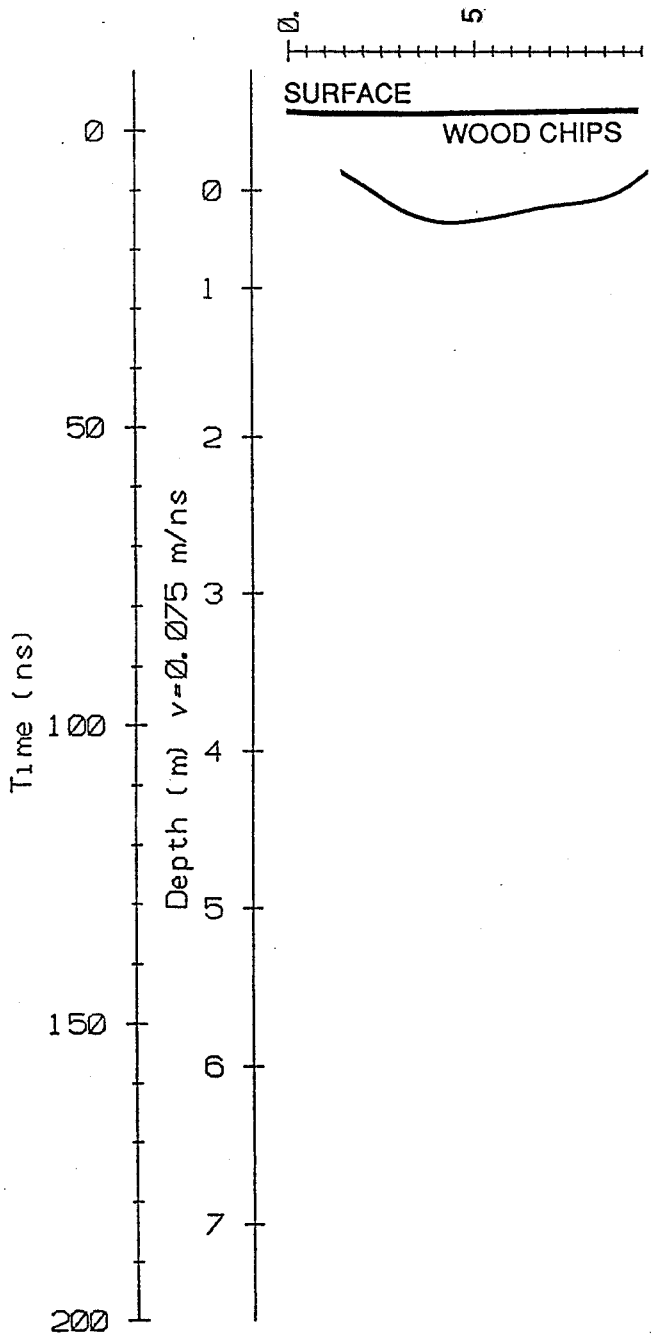
Slope 109: 200MHz Cross Profile 1 (23)



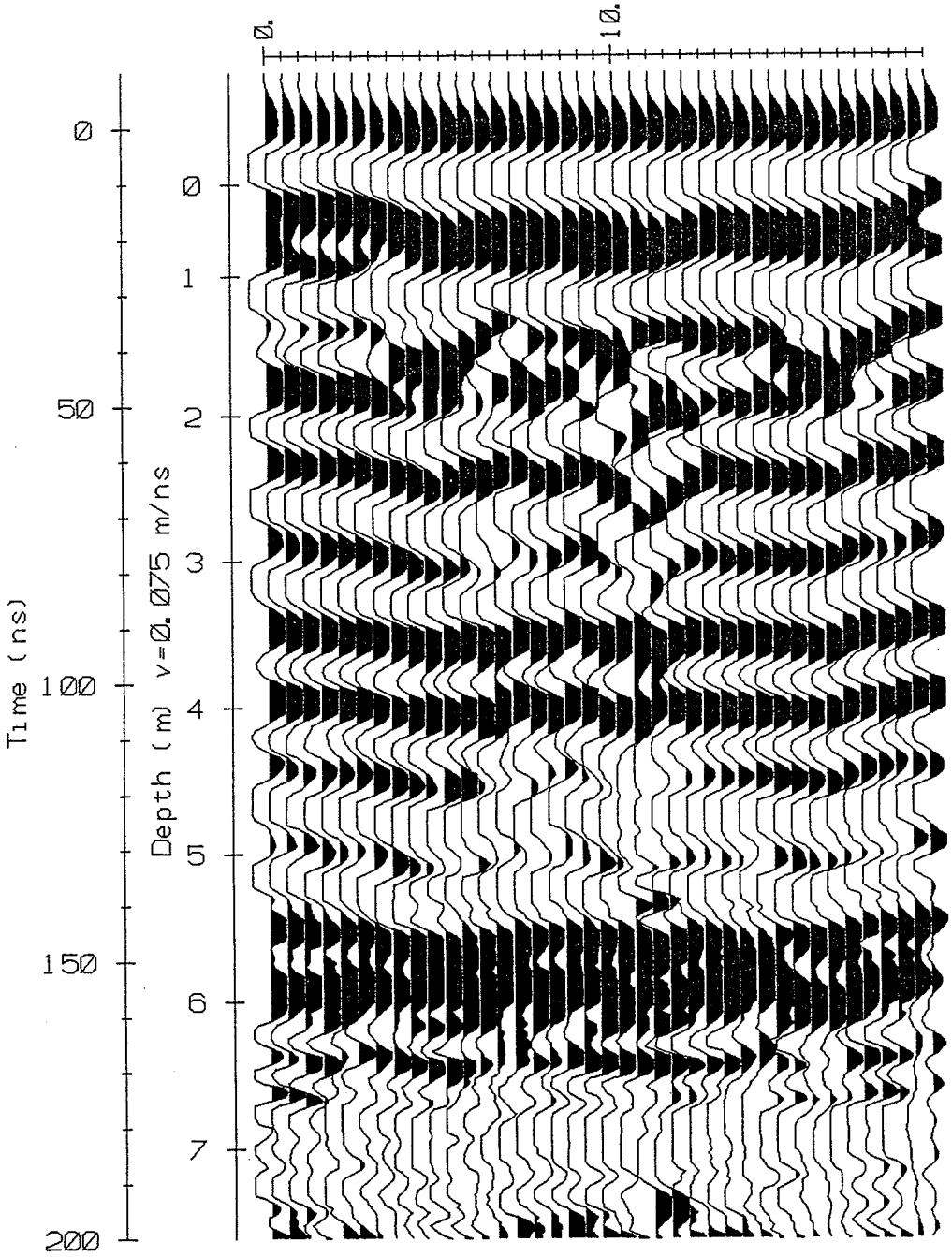
Slope 109: 100MHz Cross Profile 2a (18) 1m steps



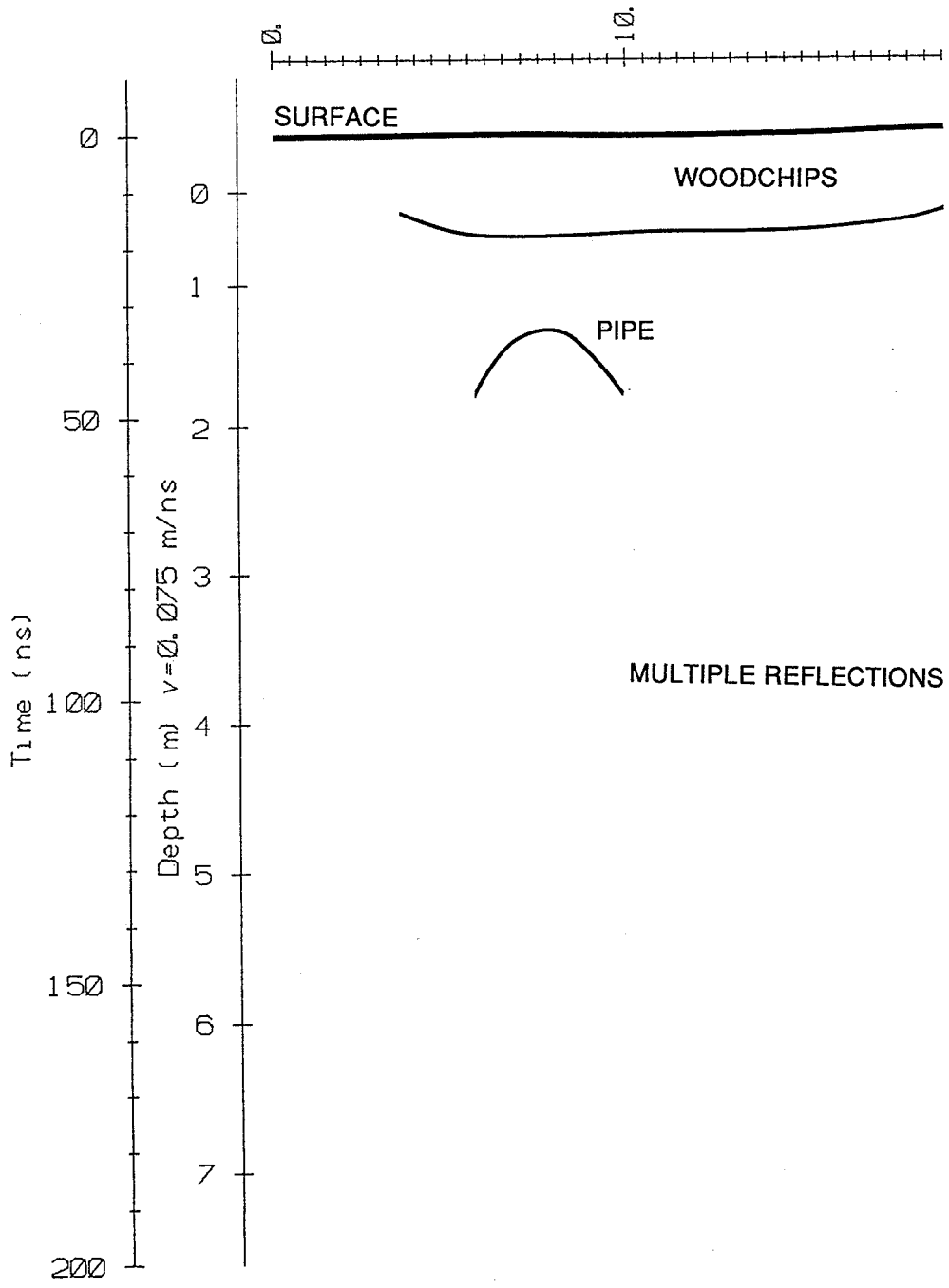
Slope 109: 100MHz Cross Profile 2a (18) 1m steps



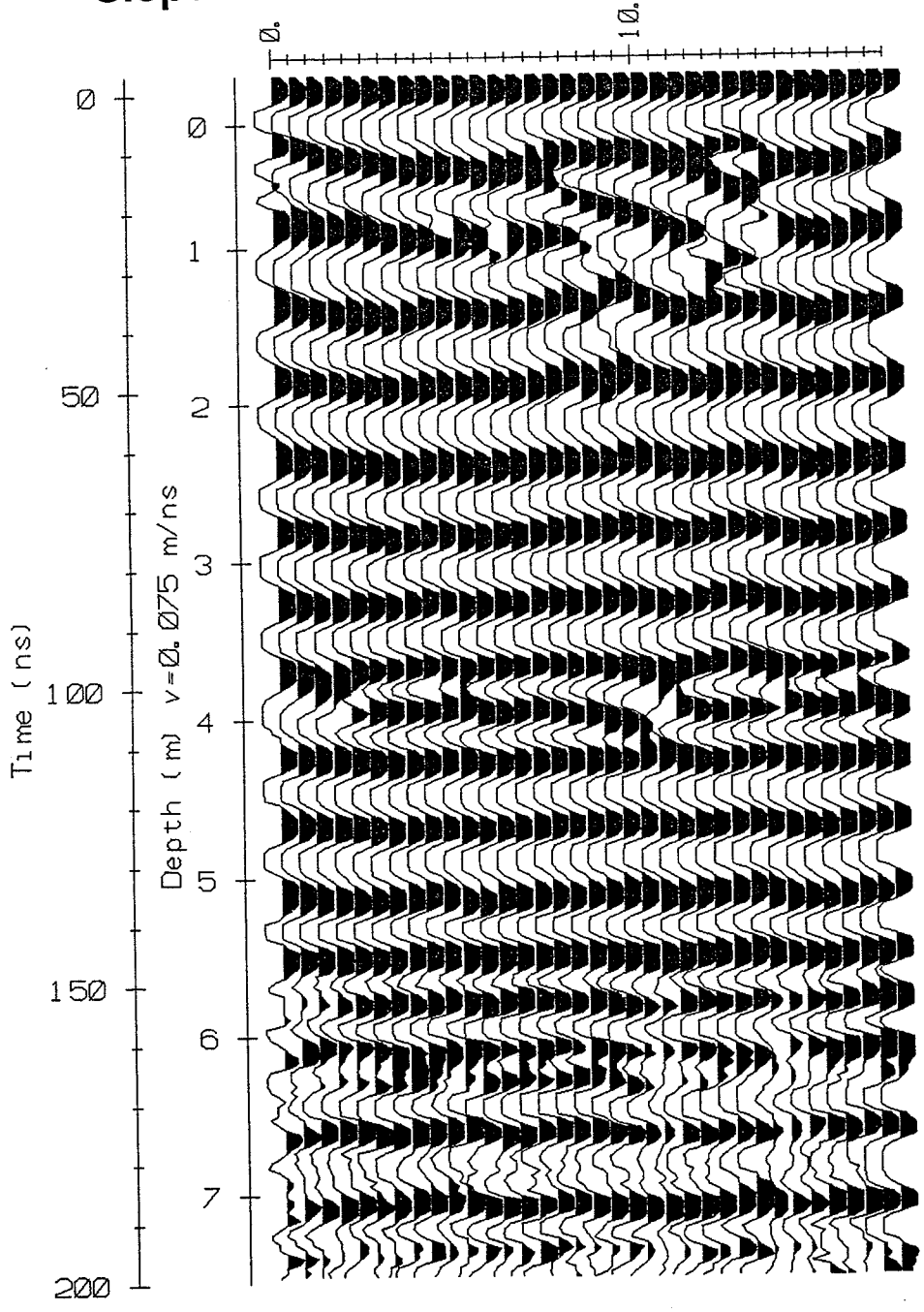
Slope 109: 100MHz Cross Profile 2b (19) 50cm steps



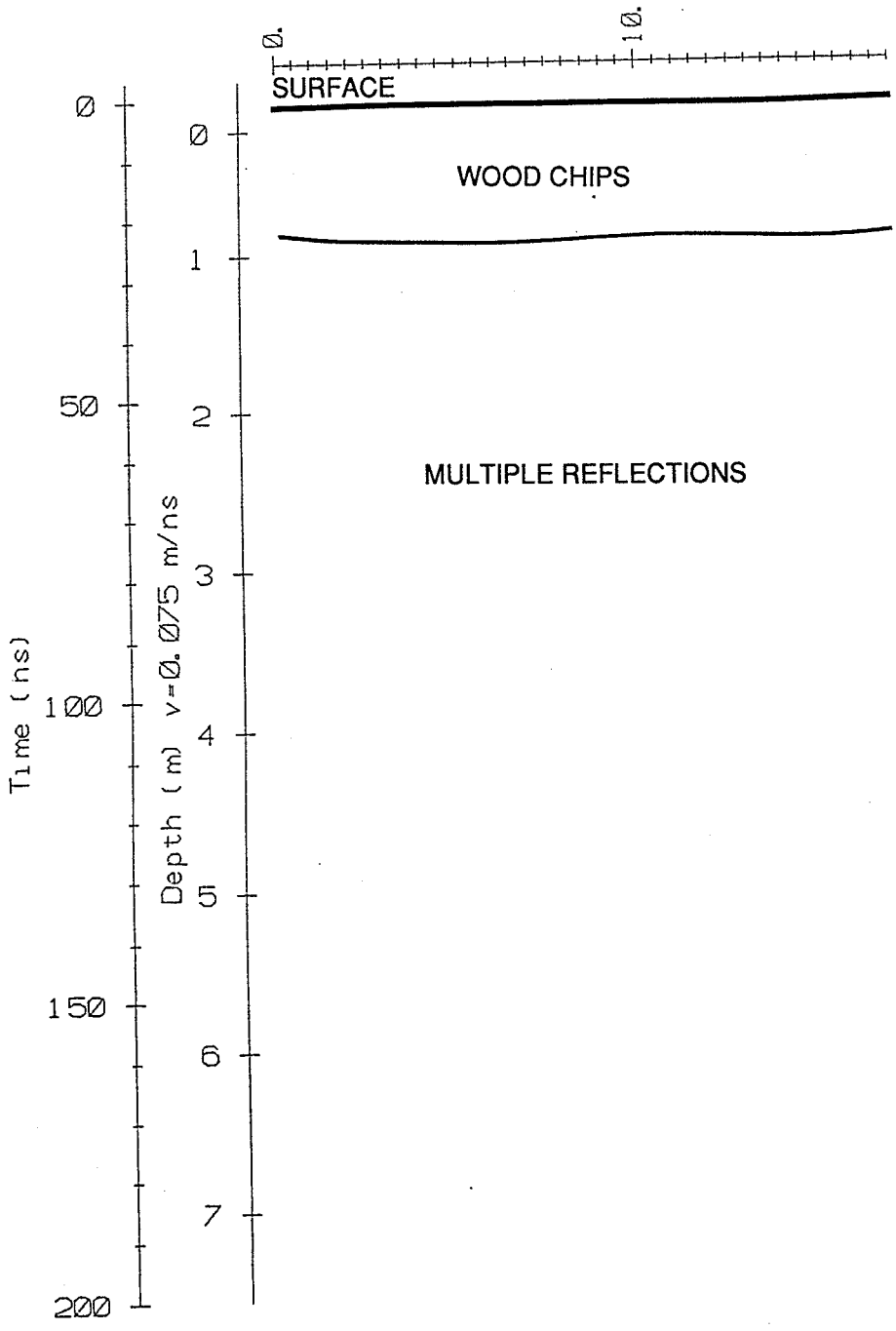
Slope 109: 100MHz Cross Profile 2b (19) 50cm steps



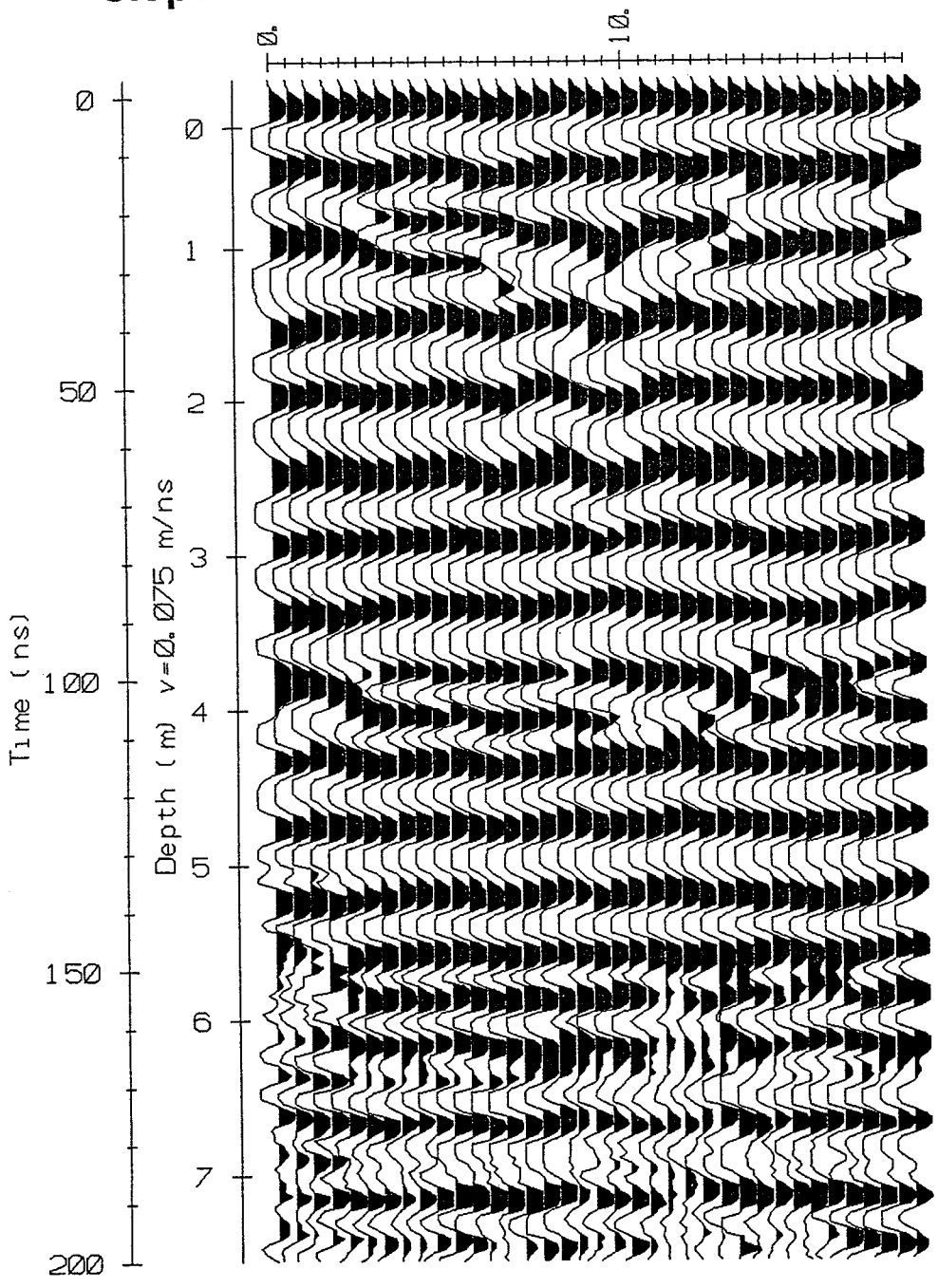
Slope 109: 200MHz Cross Profile 3 (22)



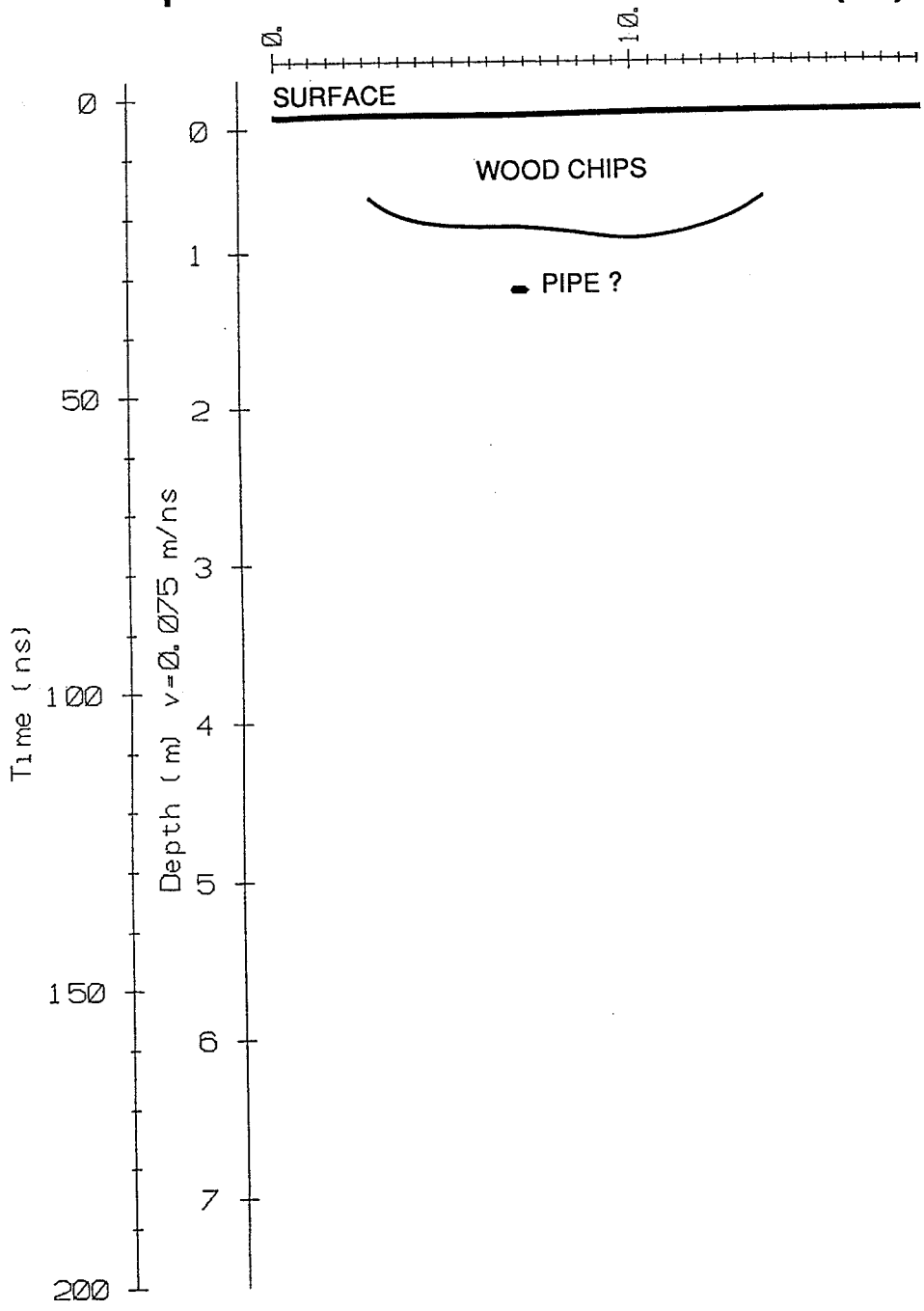
Slope 109: 200MHz Cross Profile 3 (22)



Slope 109: 200MHz Cross Profile 4 (21)



Slope 109: 200MHz Cross Profile 4 (21)



Appendix D

Data:

Mackenzie River

Slope 142

(km 529)

Mackenzie River
Slope 142 Site Plan

Legend

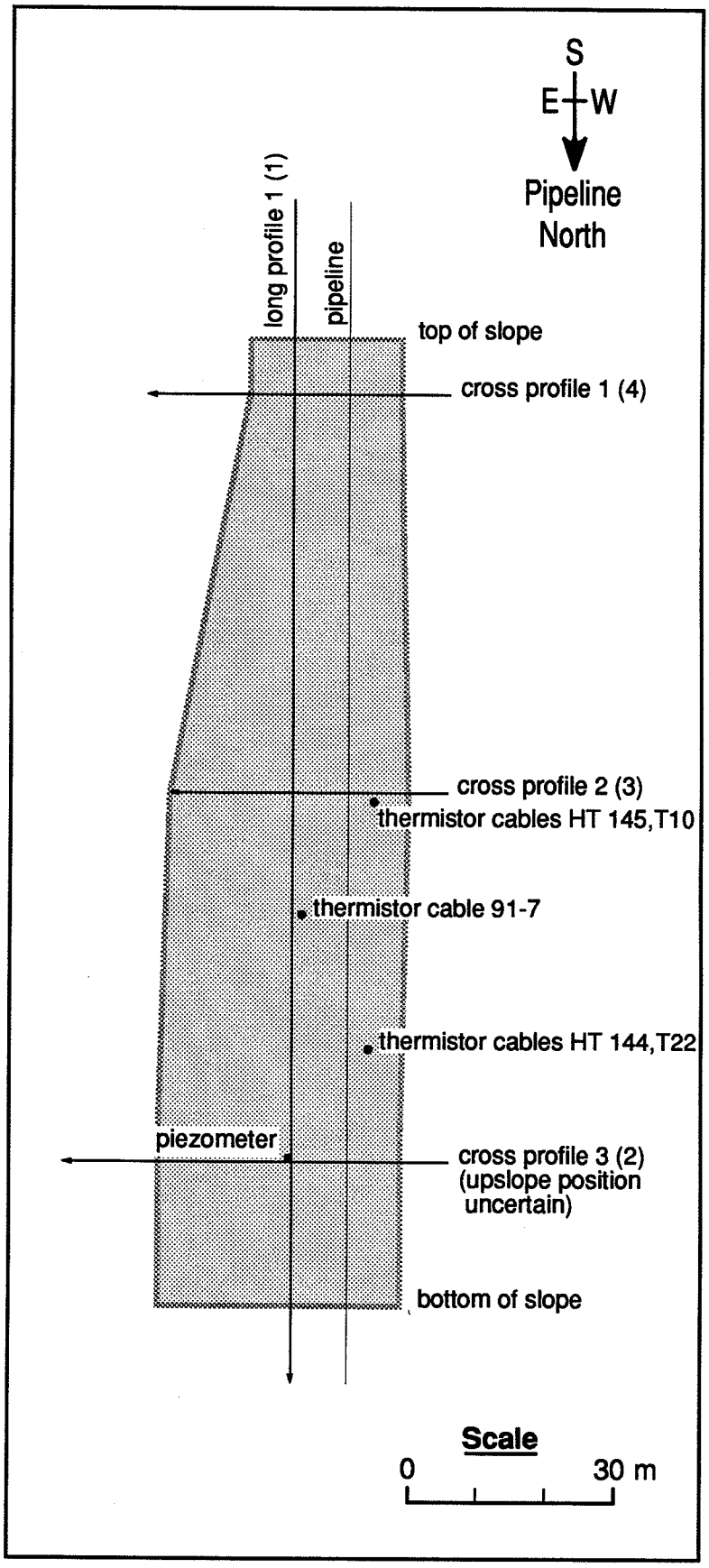
GPR profile
(arrow indicates direction)

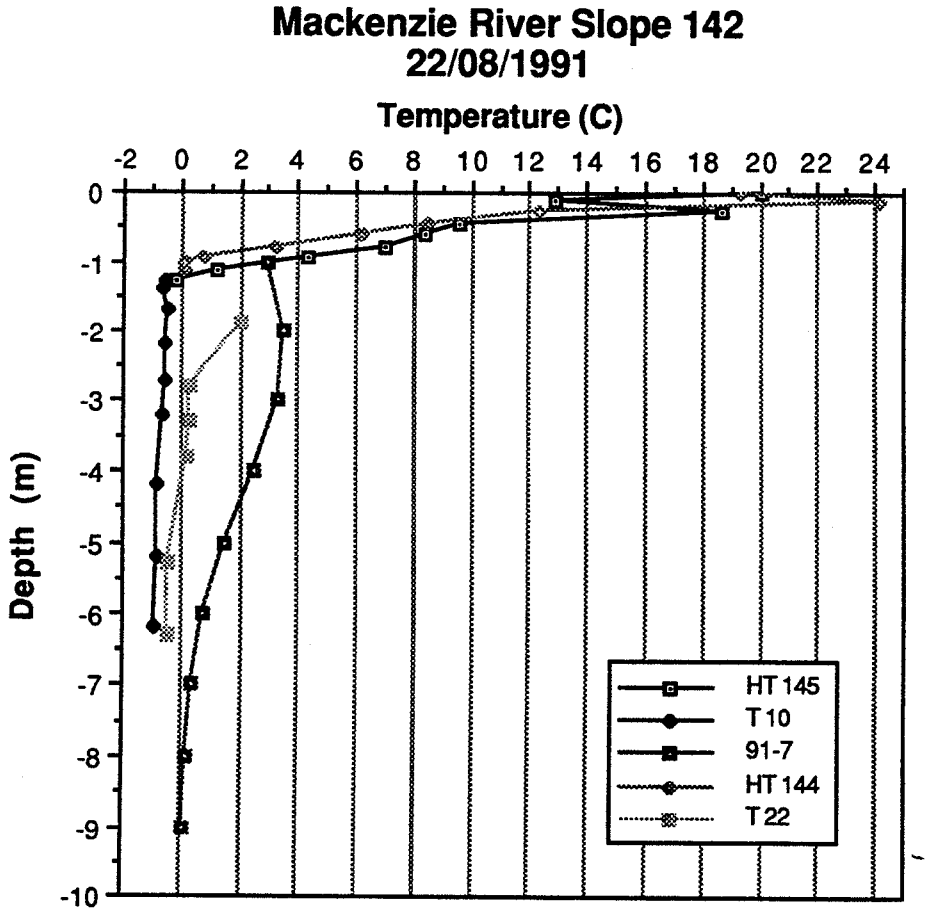
(##) GPR file number

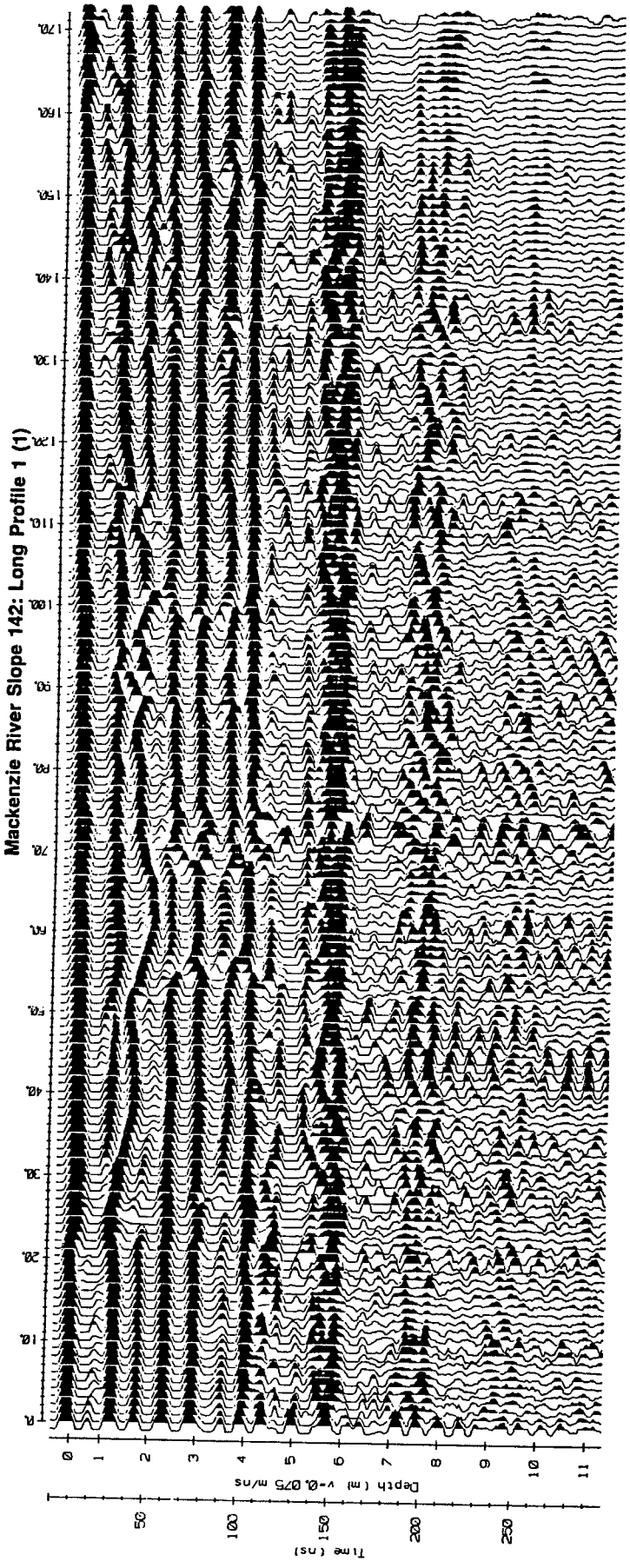
woodchip cover

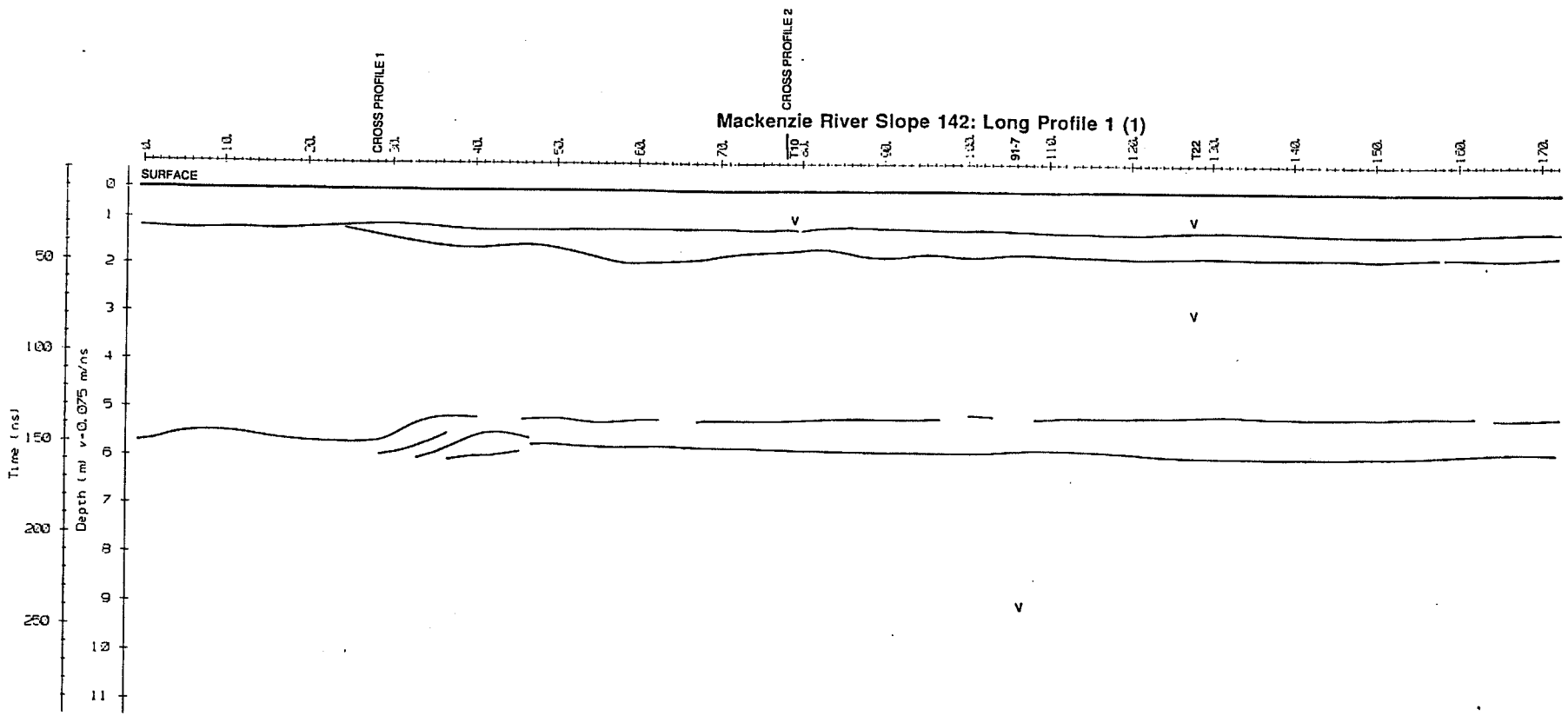
Down Slope Profile

data not available

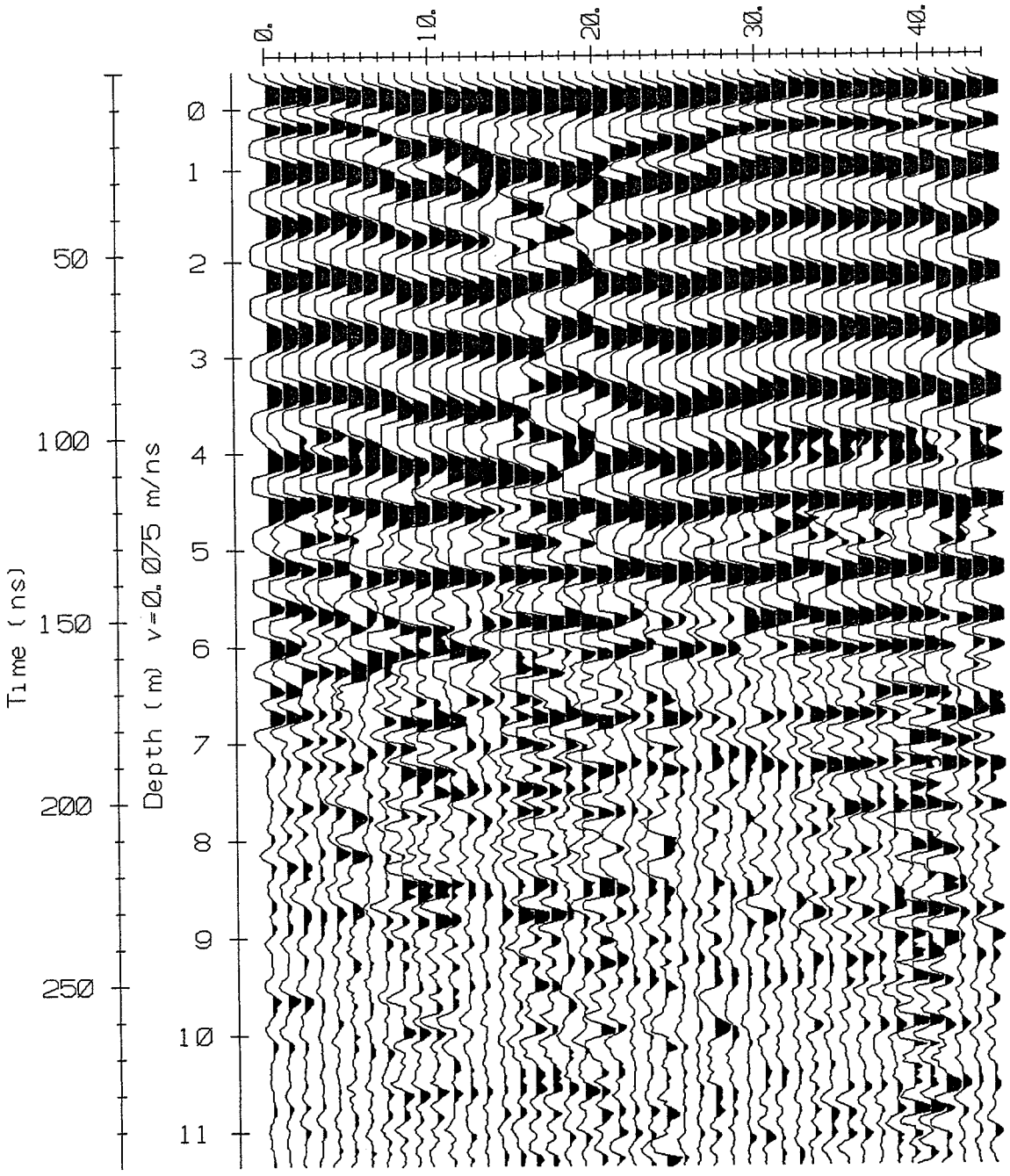



Mackenzie River Slope 142
22/08/1991
Temperature (C)
-2 0 2 4 6 8 10 12 14 16 18 20 22 24
0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10
Depth (m)
HT145
T10
91-7
HT144
T22

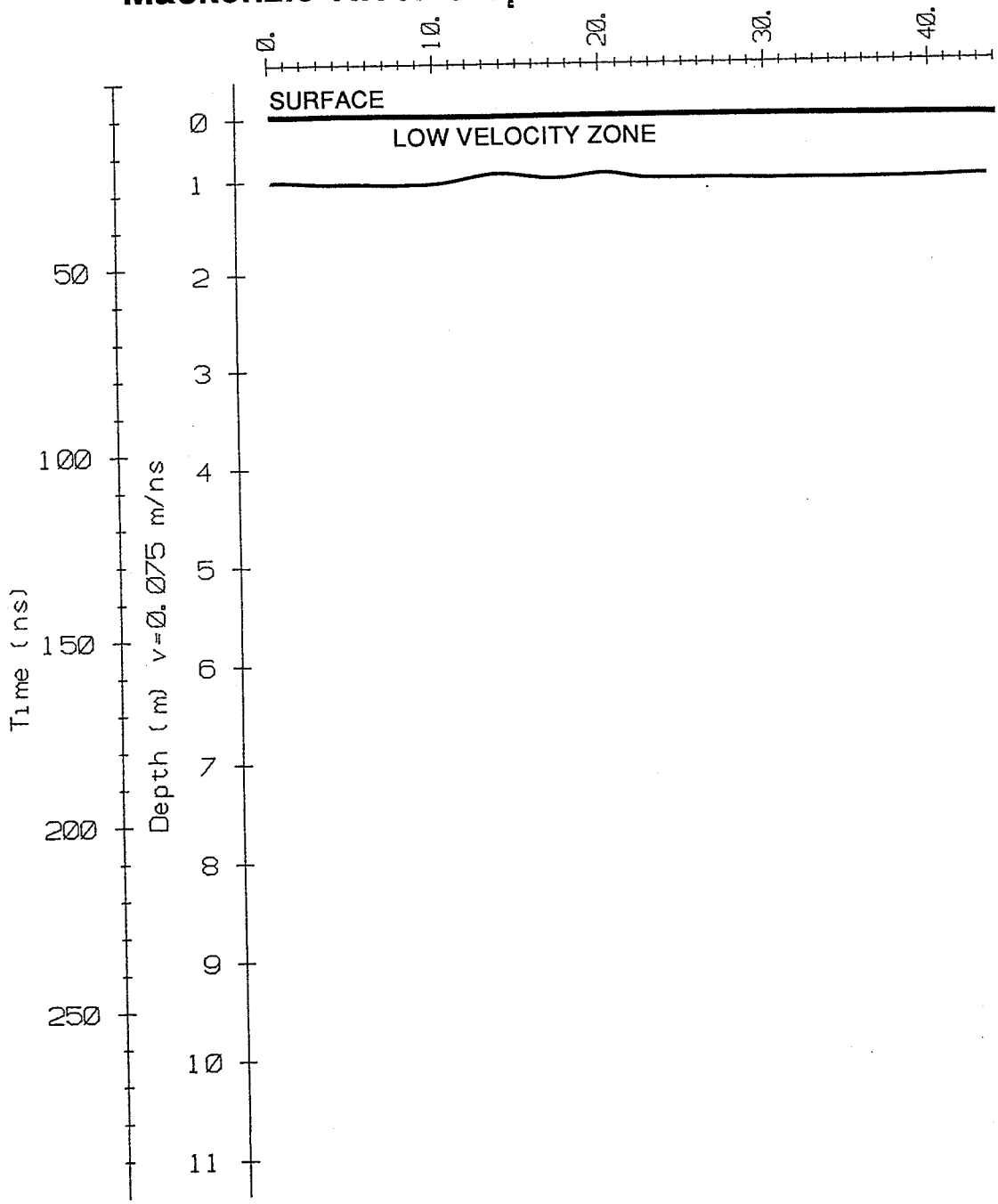

Mackenzie River Slope 142: Long Profile 1 (1)
Depth (m) v=0.075 m/ns
Time (ns)


Mackenzie River Slope 142: Long Profile 1 (1)
CROSS PROFILE 1
CROSS PROFILE 2
SURFACE
Time (ns)
Depth (m) v=0.075 m/ns
0
50
100
150
200
250
1
2
3
4
5
6
7
8
9
10
11

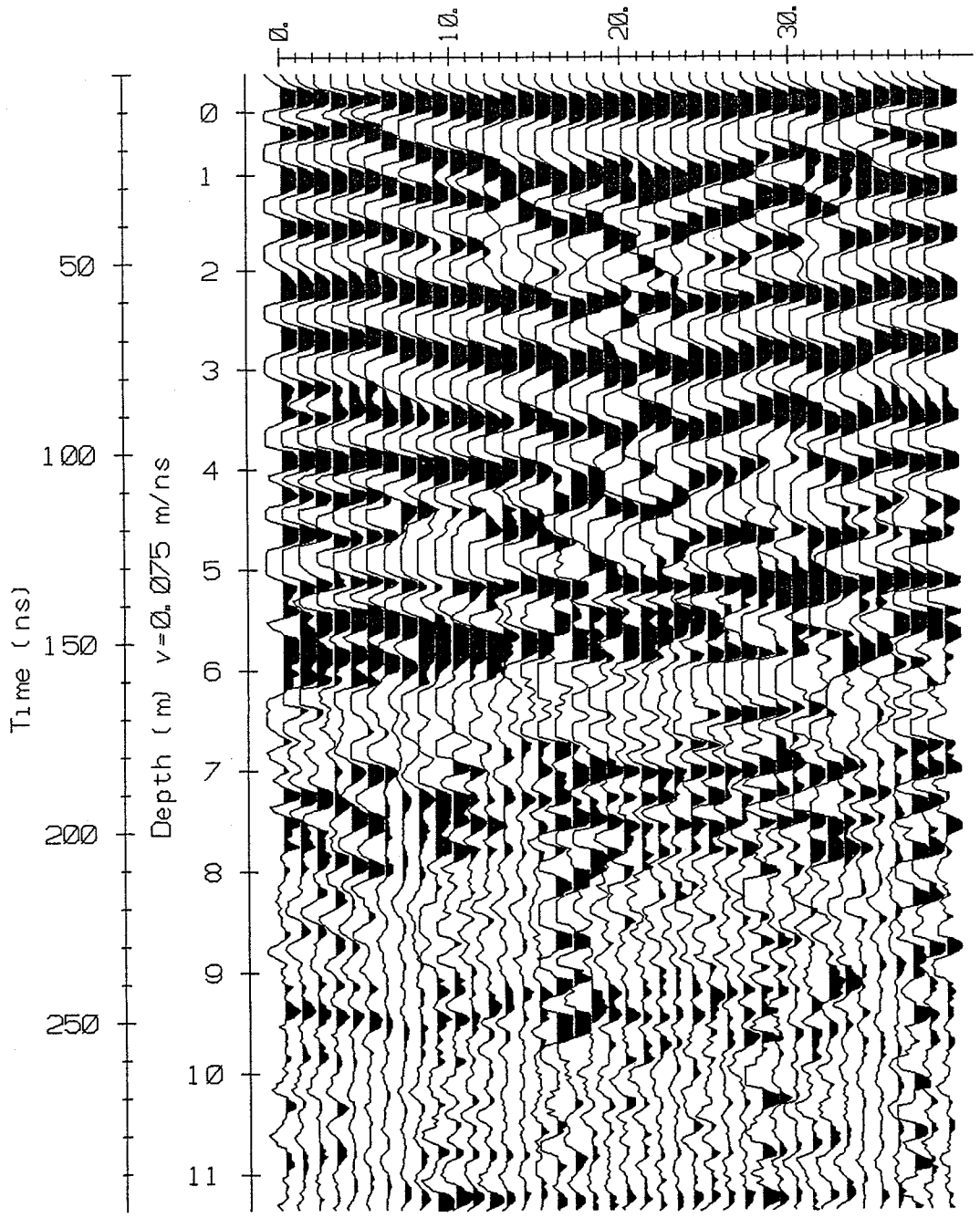
Mackenzie River Slope 142: Cross Profile 1 (4)



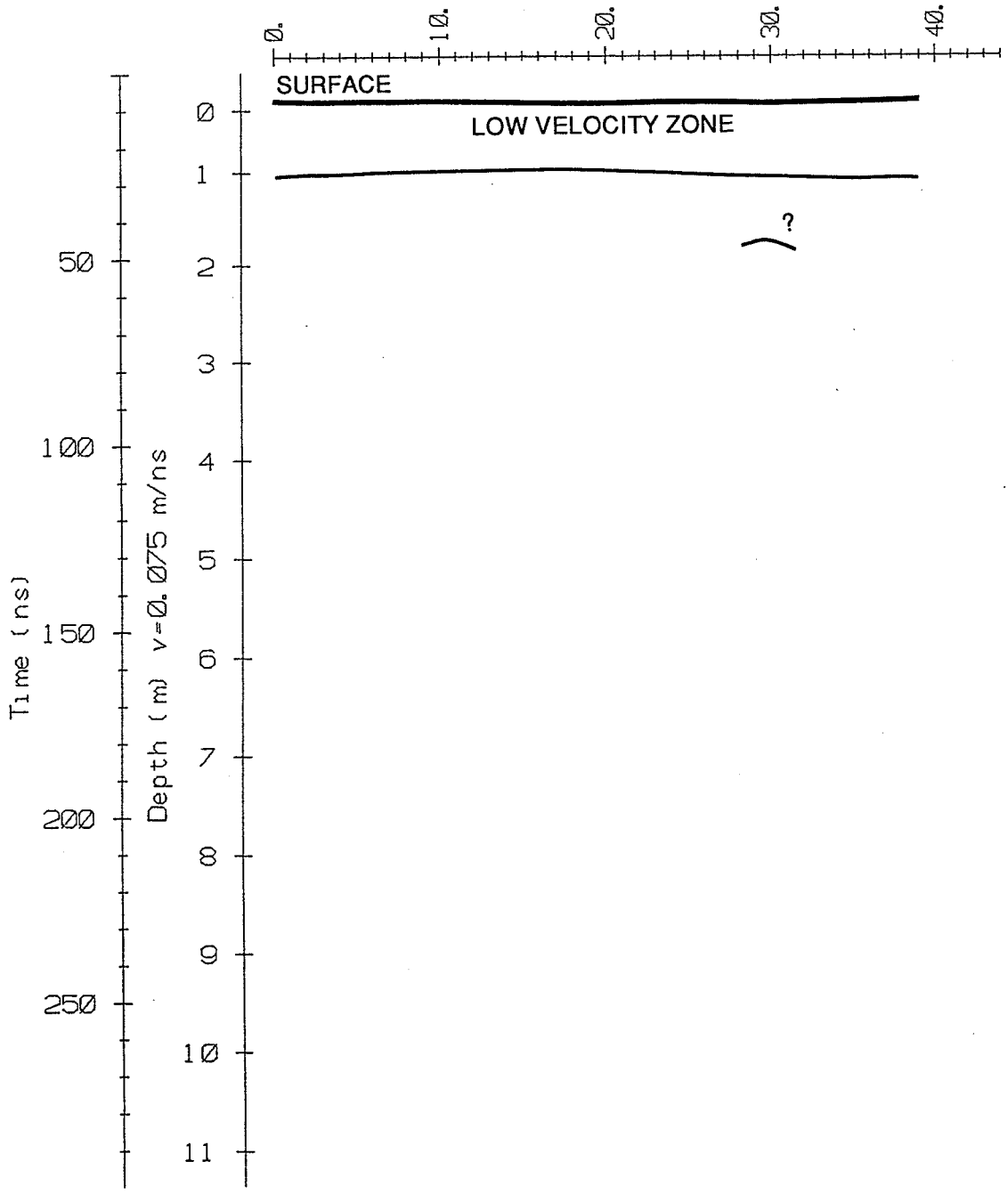
Mackenzie River Slope 142: Cross Profile 1 (4)



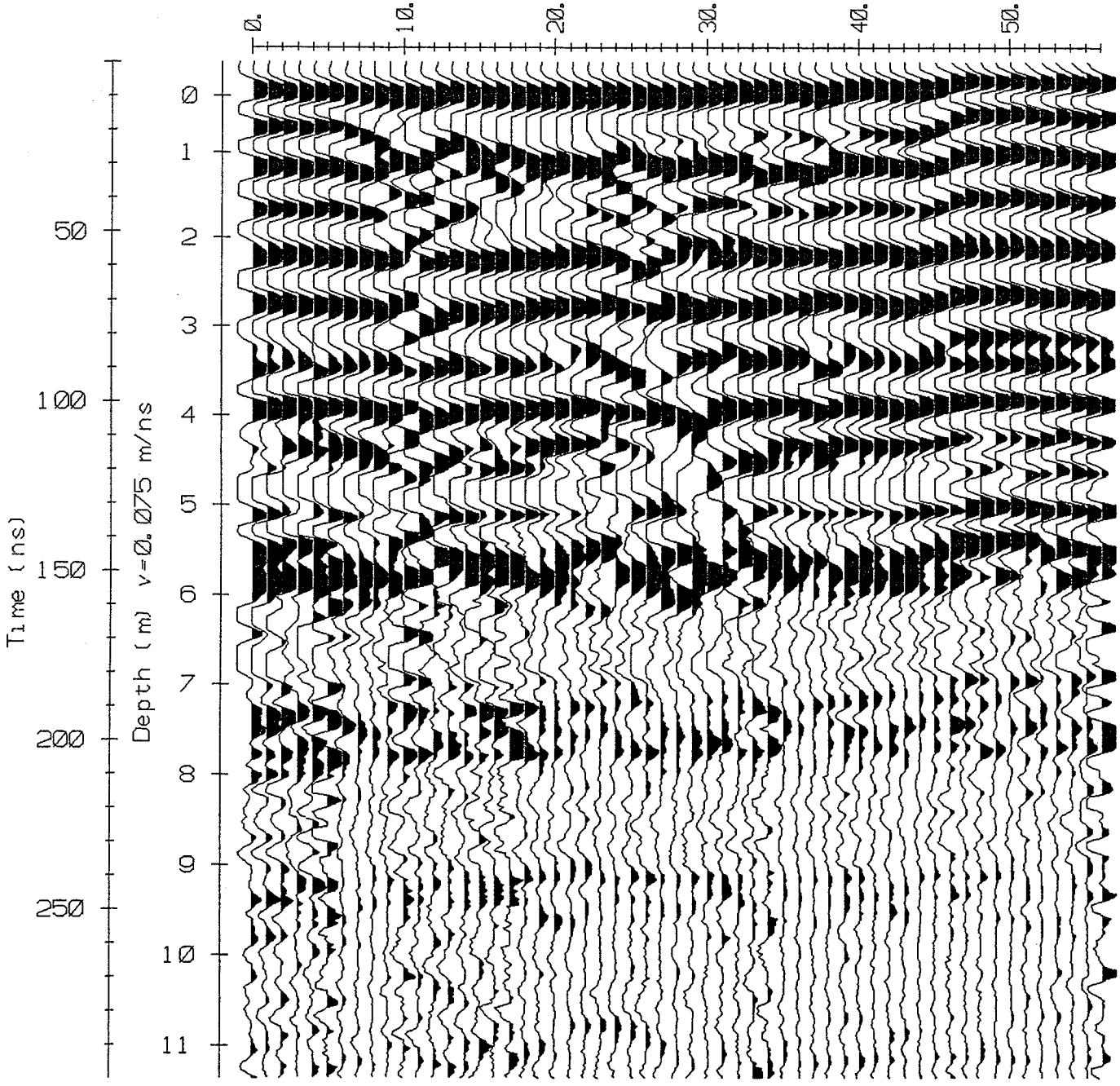
Mackenzie River Slope 142: Cross Profile 2 (3)



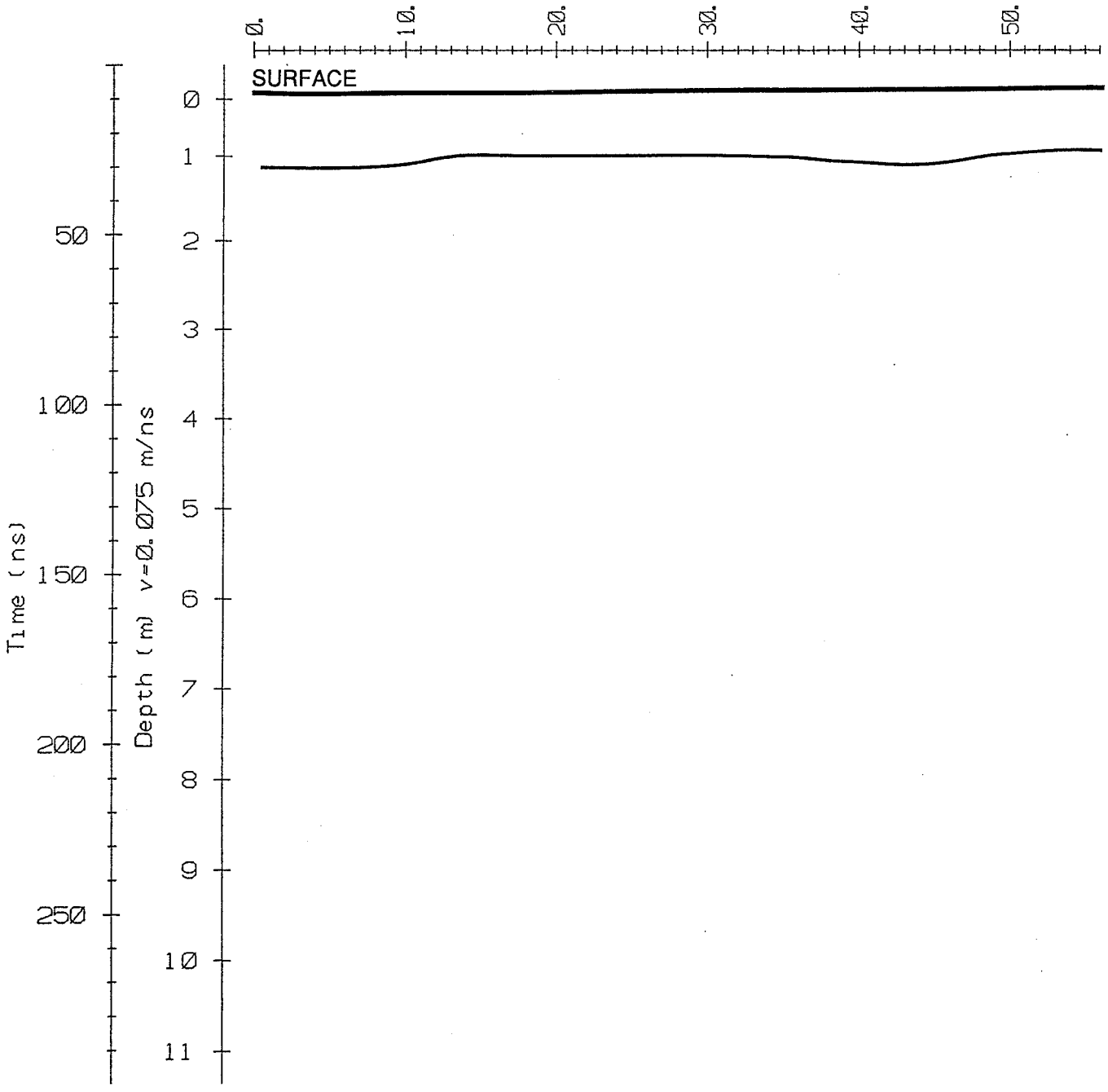
Mackenzie River Slope 142: Cross Profile 2 (3)



Mackenzie River Slope 142: Cross Profile 3 (2)



Mackenzie River Slope 142: Cross Profile 3 (2)



Appendix E

GPR Data Sheets

```
AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\41.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        ALONG PIPE, 25m DOWN FROM TOP OF CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 202
ÅH        NUMBER OF PTS/TRC   = 312
ÅH        TIMEZERO AT POINT   = 25
ÅH        TOTAL TIME WINDOW   = 250
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 100.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 8 points
ÅH        Selection   : Time = -5 to 300  ns
ÅH                      Trace = 1 to 202
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\40.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        ALONG TOP OF PIPE, STARTING 9.5m UP FROM BASE OF CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 139
ÅH        NUMBER OF PTS/TRC   = 250
ÅH        TIMEZERO AT POINT   = 14
ÅH        TOTAL TIME WINDOW   = 200
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 69.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 8 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 139
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
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ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\36.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 9: 150m UP FROM BASE OF CHIPS AT 84-3B FENCE
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 38
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 24
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 18.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 38
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\35.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 8: 130m UP FROM BASE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 38
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 19
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 18.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
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ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
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ÅH     PLOT LAYOUT PARAMETERS:
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ÅH        Data File  = e:\pipeli91\34.hd
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ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 7: 110m UP FROM THE BASE OF THE WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 42
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 24
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 20.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 42
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ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
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ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH
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ÅH     DATA FILE #1 PARAMETERS:
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ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 6: 90m UP FROM BASE OF WOOD CHIP SLOPE
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 37
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 24
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 18.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 37
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
```

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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\32.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 5: 70m UP FROM BASE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 34
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 19
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 16.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 34
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
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ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\31.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 4: 50m UP FROM BOTTOM EDGE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 32
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 23
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 15.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 20 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 32
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
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ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\30.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 3: 40m UP FROM BASE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 41
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 22
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 20.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 20 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 41
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
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ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\29.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 2: 10m ABOVE THE BASE OF THE WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 31
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 24
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 15.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 20 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 31
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\28.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 1: 10m BELOW BASE OF SLOPE
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 39
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 26
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 19.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 20 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 39
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\37.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 10: 30m DOWN FROM BASE OF CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 45
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 20
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 22.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 45
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
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ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\38.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 11: 50m DOWN FROM BASE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 87
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 19
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 43.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 87
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\39.hd
ÅH        1
ÅH        GREAT BEAR RIVER SOUTH SIDE
ÅH        CROSS 12: 70m DOWN FROM BASE OF WOOD CHIPS
ÅH        26/08/91
ÅH        NUMBER OF TRACES    = 109
ÅH        NUMBER OF PTS/TRC   = 375
ÅH        TIMEZERO AT POINT   = 17
ÅH        TOTAL TIME WINDOW   = 300
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 54.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 15 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 109
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\24.hd
ÅH        1
ÅH        OCHRE RIVER
ÅH        ALONG ROW STARTING 20m UP FROM TOP OF SLOPE
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 569
ÅH        NUMBER OF PTS/TRC   = 437
ÅH        TIMEZERO AT POINT   = 63
ÅH        TOTAL TIME WINDOW   = 350
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 284.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 8 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 569
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\27.hd
ÅH        1
ÅH        OCHRE RIVER
ÅH        CROSS 3: TOP OF SLOPE, 11m DOWN FROM TOP OF CHIPS
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 35
ÅH        NUMBER OF PTS/TRC   = 437
ÅH        TIMEZERO AT POINT   = 63
ÅH        TOTAL TIME WINDOW   = 350
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 17.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 50 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 35
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\26.hd
ÅH        1
ÅH        OCHRE RIVER
ÅH        CROSS 2: mid slope 158 ALONG LONG PROFILE
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 42
ÅH        NUMBER OF PTS/TRC   = 437
ÅH        TIMEZERO AT POINT   = 63
ÅH        TOTAL TIME WINDOW   = 350
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 20.5000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 50 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 42
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\25.hd
ÅH        1
ÅH        OCHRE RIVER
ÅH        CROSS 1: 20m UP FROM BOTTOM EDGE OF CHIPS
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 43
ÅH        NUMBER OF PTS/TRC   = 437
ÅH        TIMEZERO AT POINT   = 63
ÅH        TOTAL TIME WINDOW   = 350
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 21.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.200  of full window
ÅH          Region    : 1 to 50 points
ÅH        Selection   : Time = -5 to 200  ns
ÅH                      Trace = 1 to 43
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\20.hd
ÅH        1
ÅH        SLOPE 109
ÅH        ALONG ROW ATARTING 20m UP FROM TOP OF SLOPE
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 313
ÅH        NUMBER OF PTS/TRC   = 437
ÅH        TIMEZERO AT POINT   = 63
ÅH        TOTAL TIME WINDOW   = 350
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 156.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.400  of full window
ÅH          Region    : 1 to 25 points
ÅH        Selection   : Time = -10 to 200  ns
ÅH                      Trace = 1 to 313
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
ÅH
ÅH
ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = b:\17.hd
ÅH        1
ÅH        SLOPE 109
ÅH        ALONG ROW STARTING 20m UP FROM TOP OF SLOPE
ÅH        24/08/91
ÅH        NUMBER OF TRACES    = 162
ÅH        NUMBER OF PTS/TRC   = 625
ÅH        TIMEZERO AT POINT   = 62
ÅH        TOTAL TIME WINDOW   = 500
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 161.0000
ÅH        STEP SIZE USED      = 1.0000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 100.00
ÅH        ANTENNA SEPARATION  = 1.0000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.500  of full window
ÅH          Region    : 1 to 50 points
ÅH        Selection   : Time = -5 to 300  ns
ÅH                      Trace = 1 to 162
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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AÅHÅH
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ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\23.hd
ÅH        1
ÅH        SLOPE 109
ÅH        cross 3: TOP CROSS PROFILE, 40m ALONG LONG PROFILE
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 35
ÅH        NUMBER OF PTS/TRC   = 312
ÅH        TIMEZERO AT POINT   = 62
ÅH        TOTAL TIME WINDOW   = 250
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 17.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.400  of full window
ÅH          Region    : 1 to 25 points
ÅH        Selection   : Time = -3 to 200  ns
ÅH                      Trace = 1 to 35
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\18.hd
ÅH        1
ÅH        SLOPE 109
ÅH        CROSS 1: 33m FROM TOP 1m ABOVE LOWER HARDY PIEZOMETER TUBE
ÅH        24/08/91
ÅH        NUMBER OF TRACES    = 20
ÅH        NUMBER OF PTS/TRC   = 625
ÅH        TIMEZERO AT POINT   = 73
ÅH        TOTAL TIME WINDOW   = 500
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 19.0000
ÅH        STEP SIZE USED      = 1.0000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 100.00
ÅH        ANTENNA SEPARATION  = 1.0000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.400  of full window
ÅH          Region    : 1 to 25 points
ÅH        Selection   : Time = -10 to 200  ns
ÅH                      Trace = 1 to 20
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\19.hd
ÅH        1
ÅH        SLOPE 109
ÅH        CROSS 1: 33m FROM TOP 1m ABOVE LOWER HARDY PIEZOMETER TUBE
ÅH        24/08/91
ÅH        NUMBER OF TRACES    = 39
ÅH        NUMBER OF PTS/TRC   = 625
ÅH        TIMEZERO AT POINT   = 61
ÅH        TOTAL TIME WINDOW   = 500
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 19.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 100.00
ÅH        ANTENNA SEPARATION  = 1.0000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.400  of full window
ÅH          Region    : 1 to 25 points
ÅH        Selection   : Time = -10 to 200  ns
ÅH                      Trace = 1 to 39
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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ÅH     PulseEKKO IV Data Sheet
ÅH
ÅH     DATA FILE #1 PARAMETERS:
ÅH        Data File  = e:\pipeli91\22.hd
ÅH        1
ÅH        SLOPE 109
ÅH        CROSS 2: MIDDLE CROSS LINE, 60m ALONG LONG PROFILE
ÅH        25/08/91
ÅH        NUMBER OF TRACES    = 35
ÅH        NUMBER OF PTS/TRC   = 312
ÅH        TIMEZERO AT POINT   = 64
ÅH        TOTAL TIME WINDOW   = 250
ÅH        STARTING POSITION   = 0.0000
ÅH        FINAL POSITION      = 17.0000
ÅH        STEP SIZE USED      = 0.5000
ÅH        POSITION UNITS      = metres
ÅH        NOMINAL FREQUENCY   = 200.00
ÅH        ANTENNA SEPARATION  = 0.5000
ÅH        PULSER VOLTAGE (V)  = 400
ÅH        NUMBER OF STACKS    = 64
ÅH        SURVEY MODE         = Reflection
ÅH
ÅH     PROCESSING SELECTED:
ÅH        Trace Stacking     : 2
ÅH        Points Stacking    : 7
ÅH        Trace Differencing: N
ÅH        Gain Type   : AGC
ÅH          Window    : 1.000  pulse widths
ÅH          Amount    : 0.400  of full window
ÅH          Region    : 1 to 25 points
ÅH        Selection   : Time = -3 to 200  ns
ÅH                      Trace = 1 to 35
ÅH
ÅH     PLOT LAYOUT PARAMETERS:
ÅH        Trace Spacing      : 0.096"
ÅH        Trace Width        : 0.192"
ÅH        Trace Position     : 0.500" to 7.000"
ÅH        Left/Right Margin  : 0.000" / 0.000"
ÅH        Border Size        : 0.500"
ÅH        Page Length/Width  : 11.000" / 8.500"
ÅH        Printer Name       : HP PaintJet 180 dpi
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PulseEKKO IV Data Sheet

DATA FILE #1 PARAMETERS:
   Data File  = e:\pipeli91\21.hd
   1
   SLOPE 109
   CROSS 1: LOWER CROSS LINE, 75m ALONG LONG PROFILE
   25/08/91
   NUMBER OF TRACES    = 37
   NUMBER OF PTS/TRC   = 312
   TIMEZERO AT POINT   = 62
   TOTAL TIME WINDOW   = 250
   STARTING POSITION   = 0.0000
   FINAL POSITION      = 18.0000
   STEP SIZE USED      = 0.5000
   POSITION UNITS      = metres
   NOMINAL FREQUENCY   = 200.00
   ANTENNA SEPARATION  = 0.5000
   PULSER VOLTAGE (V)  = 400
   NUMBER OF STACKS    = 64
   SURVEY MODE         = Reflection

PROCESSING SELECTED:
   Trace Stacking     : 2
   Points Stacking    : 7
   Trace Differencing: N
   Gain Type   : AGC
     Window    : 1.000  pulse widths
     Amount    : 0.400  of full window
     Region    : 1 to 25 points
   Selection   : Time = -3 to 200  ns
                 Trace = 1 to 37

PLOT LAYOUT PARAMETERS:
   Trace Spacing      : 0.096"
   Trace Width        : 0.192"
   Trace Position     : 0.500" to 7.000"
   Left/Right Margin  : 0.000" / 0.000"
   Border Size        : 0.500"
   Page Length/Width  : 11.000" / 8.500"
   Printer Name       : HP PaintJet 180 dpi
```

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PulseEKKO IV Data Sheet

DATA FILE #1 PARAMETERS:
   Data File  = e:\pipeli91\1.hd
   1

   RUNNING DOWN SLOPE
   22/08/91
   NUMBER OF TRACES    = 173
   NUMBER OF PTS/TRC   = 625
   TIMEZERO AT POINT   = 57
   TOTAL TIME WINDOW   = 500
   STARTING POSITION   = 0.0000
   FINAL POSITION      = 172.0000
   STEP SIZE USED      = 1.0000
   POSITION UNITS      = metres
   NOMINAL FREQUENCY   = 100.00
   ANTENNA SEPARATION  = 1.0000
   PULSER VOLTAGE (V)  = 400
   NUMBER OF STACKS    = 64
   SURVEY MODE         = Reflection

PROCESSING SELECTED:
   Trace Stacking     : 2
   Points Stacking    : 7
   Trace Differencing: N
   Gain Type   : AGC
     Window    : 1.000  pulse widths
     Amount    : 0.400  of full window
     Region    : 1 to 30 points
   Selection   : Time = 0 to 300  ns
                 Trace = 1 to 173

PLOT LAYOUT PARAMETERS:
   Trace Spacing      : 0.096"
   Trace Width        : 0.192"
   Trace Position     : 0.500" to 7.000"
   Left/Right Margin  : 0.000" / 0.000"
   Border Size        : 0.500"
   Page Length/Width  : 11.000" / 8.500"
   Printer Name       : HP PaintJet 180 dpi
```

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PulseEKKO IV Data Sheet

DATA FILE #1 PARAMETERS:
   Data File  = e:\pipeli91\2.hd
   1

   CROSS 1: BOTTOM
   22/08/91
   NUMBER OF TRACES    = 57
   NUMBER OF PTS/TRC   = 625
   TIMEZERO AT POINT   = 54
   TOTAL TIME WINDOW   = 500
   STARTING POSITION   = 0.0000
   FINAL POSITION      = 56.0000
   STEP SIZE USED      = 1.0000
   POSITION UNITS      = metres
   NOMINAL FREQUENCY   = 100.00
   ANTENNA SEPARATION  = 1.0000
   PULSER VOLTAGE (V)  = 400
   NUMBER OF STACKS    = 64
   SURVEY MODE         = Reflection

PROCESSING SELECTED:
   Trace Stacking     : 2
   Points Stacking    : 7
   Trace Differencing: N
   Gain Type   : AGC
     Window    : 1.000  pulse widths
     Amount    : 0.400  of full window
     Region    : 1 to 30 points
   Selection   : Time = 0 to 300  ns
                 Trace = 1 to 57

PLOT LAYOUT PARAMETERS:
   Trace Spacing      : 0.096"
   Trace Width        : 0.192"
   Trace Position     : 0.500" to 7.000"
   Left/Right Margin  : 0.000" / 0.000"
   Border Size        : 0.500"
   Page Length/Width  : 11.000" / 8.500"
   Printer Name       : HP PaintJet 180 dpi
```

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PulseEKKO IV Data Sheet

DATA FILE #1 PARAMETERS:
   Data File  = e:\pipeli91\3.hd
   1

   CROSS 2: MIDDLE WEST TO EAST (ALWAYS)
   22/08/91
   NUMBER OF TRACES    = 41
   NUMBER OF PTS/TRC   = 625
   TIMEZERO AT POINT   = 52
   TOTAL TIME WINDOW   = 500
   STARTING POSITION   = 0.0000
   FINAL POSITION      = 40.0000
   STEP SIZE USED      = 1.0000
   POSITION UNITS      = metres
   NOMINAL FREQUENCY   = 100.00
   ANTENNA SEPARATION  = 1.0000
   PULSER VOLTAGE (V)  = 400
   NUMBER OF STACKS    = 64
   SURVEY MODE         = Reflection

PROCESSING SELECTED:
   Trace Stacking     : 2
   Points Stacking    : 7
   Trace Differencing: N
   Gain Type   : AGC
     Window    : 1.000  pulse widths
     Amount    : 0.400  of full window
     Region    : 1 to 30 points
   Selection   : Time = 0 to 300  ns
                 Trace = 1 to 41

PLOT LAYOUT PARAMETERS:
   Trace Spacing      : 0.096"
   Trace Width        : 0.192"
   Trace Position     : 0.500" to 7.000"
   Left/Right Margin  : 0.000" / 0.000"
   Border Size        : 0.500"
   Page Length/Width  : 11.000" / 8.500"
   Printer Name       : HP PaintJet 180 dpi
```

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PulseEKKO IV Data Sheet

DATA FILE #1 PARAMETERS:
   Data File  = e:\pipeli91\4.hd
   1

   CROSS 3: TOP CROSS
   22/08/91
   NUMBER OF TRACES    = 45
   NUMBER OF PTS/TRC   = 625
   TIMEZERO AT POINT   = 105
   TOTAL TIME WINDOW   = 500
   STARTING POSITION   = 0.0000
   FINAL POSITION      = 44.0000
   STEP SIZE USED      = 1.0000
   POSITION UNITS      = metres
   NOMINAL FREQUENCY   = 100.00
   ANTENNA SEPARATION  = 1.0000
   PULSER VOLTAGE (V)  = 400
   NUMBER OF STACKS    = 64
   SURVEY MODE         = Reflection

PROCESSING SELECTED:
   Trace Stacking     : 2
   Points Stacking    : 7
   Trace Differencing: N
   Gain Type   : AGC
     Window    : 1.000  pulse widths
     Amount    : 0.200  of full window
     Region    : 1 to 30 points
   Selection   : Time = 0 to 300  ns
                 Trace = 1 to 45

PLOT LAYOUT PARAMETERS:
   Trace Spacing      : 0.096"
   Trace Width        : 0.192"
   Trace Position     : 0.500" to 7.000"
   Left/Right Margin  : 0.000" / 0.000"
   Border Size        : 0.500"
   Page Length/Width  : 11.000" / 8.500"
   Printer Name       : HP PaintJet 180 dpi
```