Dempster Lateral Gas Pipeline Project

Permafrost Delineation

Geophysical Survey

PREPARED FOR

Foothills Pipe Lines (Yukon) Ltd.

Calgary, Alberta

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
• GEOTECHNICAL DIVISION

ALASKA HIGHWAY GAS PIPE LINE PROJECT

(DEMPSTER LATERAL)

GEOPHYSICAL SURVEY

PREPARED FOR

FOOTHILLS PIPE LINES (YUKON) LTD.

PREPARED BY

HARDY ASSOCIATES (1978) LTD.

CALGARY ALBERTA

DECEMBER 1978

PROJECT NO. K4321

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE OF CONTENTS

1.0 SUMMARY

Electrical resistivity and seismic refraction surveys were performed along the Dempster Lateral of the Alaska Highway Gas Pipe Line. The purpose of the electrical resistivity measurements was to delineate permafrost while seismic refraction measurements were used to determine depth to bedrock. A total of 61 sites were surveyed and the typical length of a site was 0.5 kilometres.

Most sites surveyed coincided with the location of a test hole. The interpretation of the data relies heavily on terrain typing and test hole information. In 90 percent of the sites interpretation from geophysical data agrees with test hole information. In the few areas of disagreement the reasons for the geophysical interpretation are stated. Thermistor data may be required to resolve discrepancies.

Because the Dempster Lateral alignment was in the process of revision, the percentage of occurrence of frozen and unfrozen ground has been totalled for surveyed areas only and no interpolation of results over the entire route has been made.

2.0 INTRODUCTION

Important objectives of the subsurface exploration programs for the Dempster Lateral of the Alaska Highway Gas Pipe Line Project are to determine the distribution and properties of permafrost along the route. The last point of cold flow will be north of Whitehorse and the distribution of permafrost is one of several factors determining that point.

The subsurface exploration program along the route consisted of three phases, terrain typing, geophysical surveys and placement of test holes. The role of the geophysical surveys was to interpolate subsurface information from test holes over traverses typically 0.5 kilometres long. By carefully selecting these traverses to cover specific terrain units information on permafrost distribution found in certain regional settings could be further interpolated to arrive at an approximate percentage of frozen and unfrozen ground.

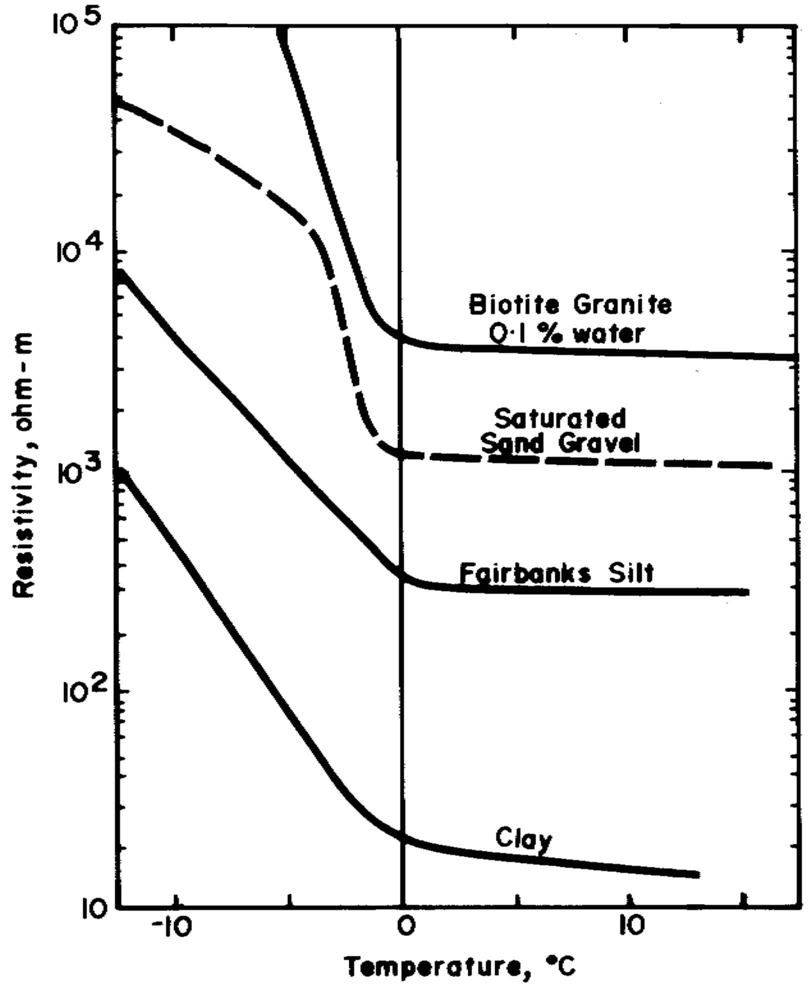
Electrical resistivity and seismic refraction measurements were conducted during the survey. Electrical resistivity measurements were made with radiohm and magnetic induction methods. A limited number of seismic refraction measurements were made mainly at sites where bedrock was expected near the surface.

A total of 61 sites were surveyed and on 55 of these sites test hole information was available to calibrate and verify the geophysical interpretations.

3.0 METHODOLOGY

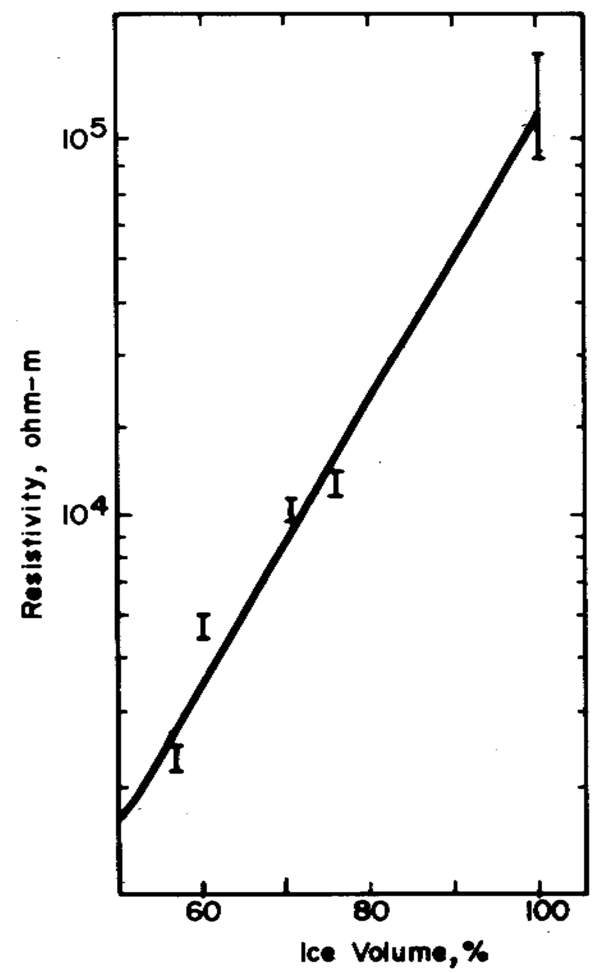
3.1 The Basis of Permafrost Mapping by Electrical Resistivity Methods

The most important objective of the geophysical survey was to map the boundaries of frozen ground. Resistivity methods are employed for that purpose because frozen and unfrozen ground differ substantially in their values of electrical resistivity. Figure 3-1A shows resistivity as a function of temperature for several soil types. Often the resistivity of frozen ground is considerably higher than shown in Figure 3-1A because the occurrence of ice lenses further increases the resistivity of the soils. Resistivity as a function of ice content, derived from in-situ measurements in a tunnel in Fairbanks Silt, is shown in Figure 3-1B. Frozen ground frequently has values of resistivity with a factor 5 or more higher than unfrozen ground. Resistivity alone can not be used as a criterion to distinguish frozen and unfrozen ground, because e.g. (see Figure 3-1A) the resistivity of unfrozen sand and gravel may exceed the resistivity of frozen clays. To remove this ambiguity in interpretation use is made of terrain typing and other geologic and test hole information.



Relationship between resistivity and temperature

A



Relationship between resistivity and ice content

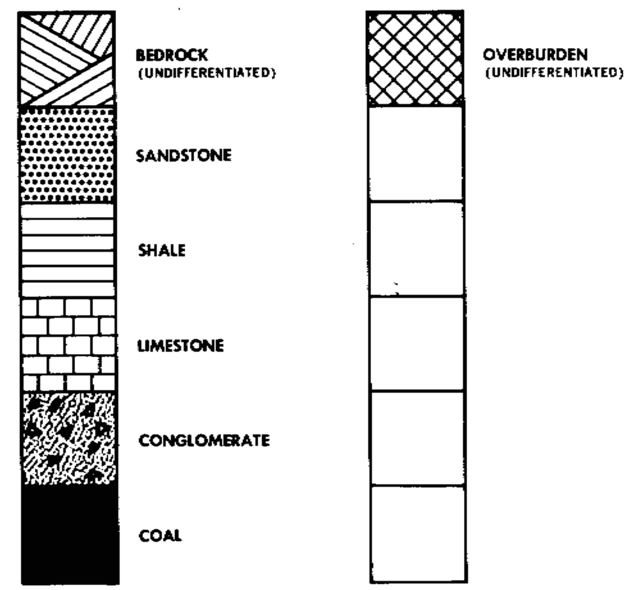
B

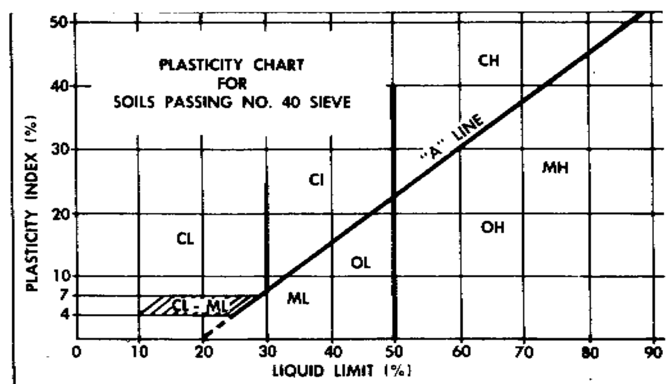
REVISIONS	REFERENCES	SCALE DATE MADE CHKD. APPD.	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	RESISTIVITY VERSUS TEMPERATURE & ICE CONTENT No. Figure 3·1

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF COARSE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW "A" LINE P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-(SILT) CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	

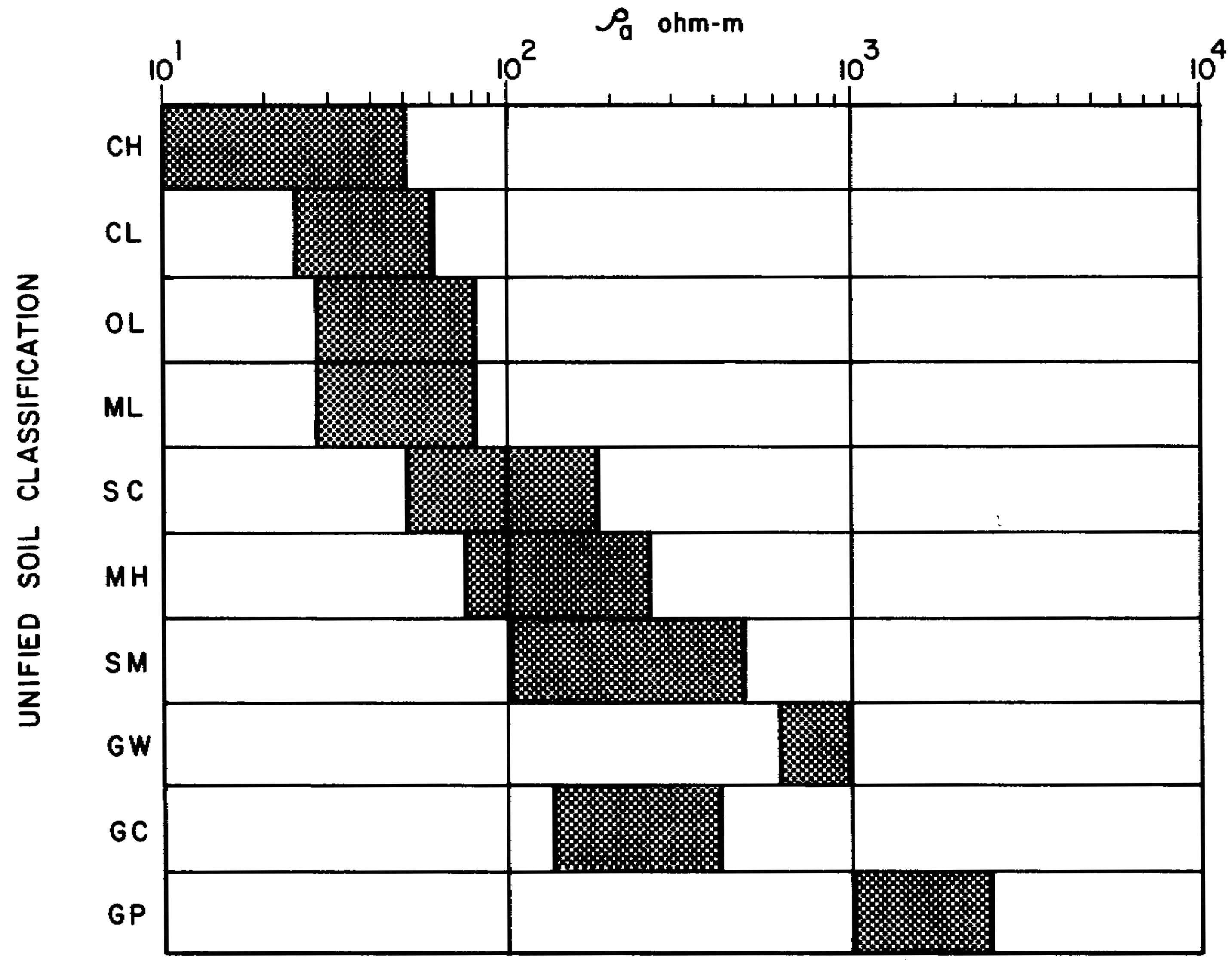
SPECIAL SYMBOLS





1. ALL SIEVE SIZES MENTIONED ON THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS A WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12%.

REVISIONS	REFERENCES	SCALE ____ DATE ____ MADE ____ CHKD. ____ APPD. ____	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	TABLE 1
				No. REV.



REVISIONS	REFERENCES	SCALE DATE MADE CHKD. APPD.	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	RESISTIVITY RANGE VERSUS SOIL TYPES No. Figure 3·2

In permafrost free areas the value of resistivity mainly relates to soil types and resistivity can be used as a rough method of classification by using the relation shown in Figure 3-2. Table 1 relates the symbols of the Unified Soil Classification used on Figure 3-2 to grain size and other soil parameters.

3.2 Methods of Electrical Resistivity Mapping

The resistivity of subsurface strata can be measured on the surface by several techniques. These techniques are schematically illustrated in Figure 3-3.

In the magnetic induction method current is induced in the ground by the electromagnetic field emitted by a transmitter coil antennae. Small eddy currents are caused to flow in the ground and these eddy currents set up a secondary magnetic field. The secondary magnetic field measured at the receiver coil antennae is related to the resistivity of the ground.

The effective depth of exploration of this method mainly depends on three parameters:

(a) the frequency of operation

(b) the orientation of the coils (either horizontal or vertical co-planar), and

(c) the separation distance of the coils.

Two magnetic induction instruments, the Geonics EM31 and EM34, were used for the surveys along the Dempster Lateral (Figure 3-4 & 5). The EM31 operates at a frequency of 39.2 kilohertz and the coils are mounted horizontally being spaced at a distance of 3.66 m in a rigid fibre glass boom. The effective depth of exploration with the EM31 is relatively independent of ground resistivity and is about 7 metres.

The EM34 operates at a frequency of 1.6 kilohertz. The coils were used in a vertical co-planar mode at a separation distance of 15 metres allowing an effective depth of exploration of about 17 metres (50 ft).

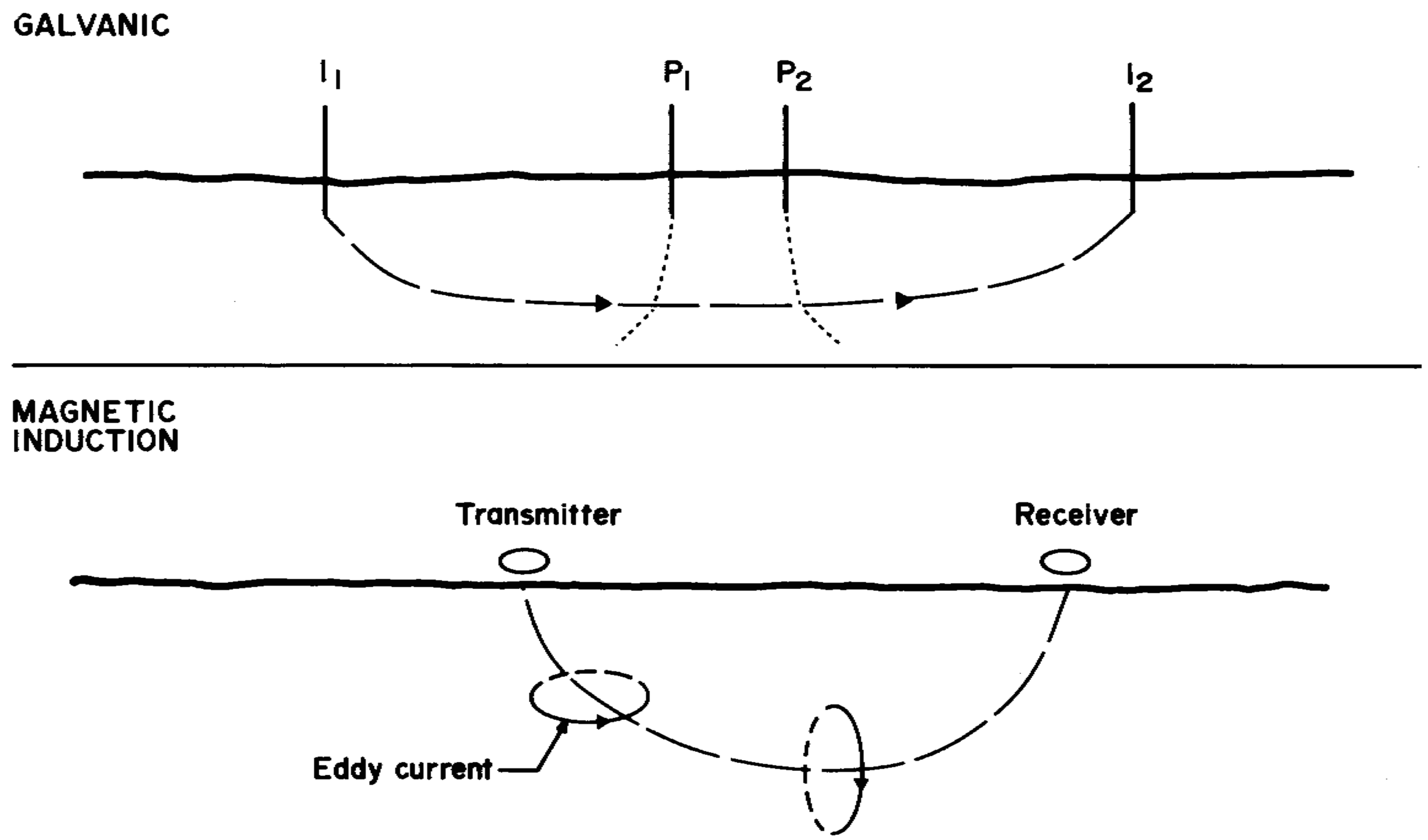
The main advantages of magnetic induction methods are its high productivity of surveying, its high degree of resolution in determining lateral changes in resistivity and the fact that it requires no contact with the ground, which removes a large source of noise.

VLF radiohm measurements were taken over 11 sites. In the VLF radiohm method measurements are made on the ground waves of distant VLF radio stations used by the navies of the world. Along the Dempster Lateral the station NLK located in Tacoma, Washington, U.S.A., operating at 18.6 kilohertz was used. The principle of obtaining a value of ground resistivity is illustrated in Figure 3-3. The ground wave has three components, a horizontal magnetic field Hy, a vertical electric field Ez, and a horizontal electric field, Ex. All three field vectors are equally influenced by the path of propagation between transmitter (in Washington) and measurement station (in the Yukon) but only the horizontal electric field, Ex, changes due to local changes in subsurface conditions. By measuring a ratio of the two vectors, Ex and Hy, the effects of events between transmitter and receiver are removed and a quantity (surface impedance) is obtained that relates to the local resistivity of the ground.

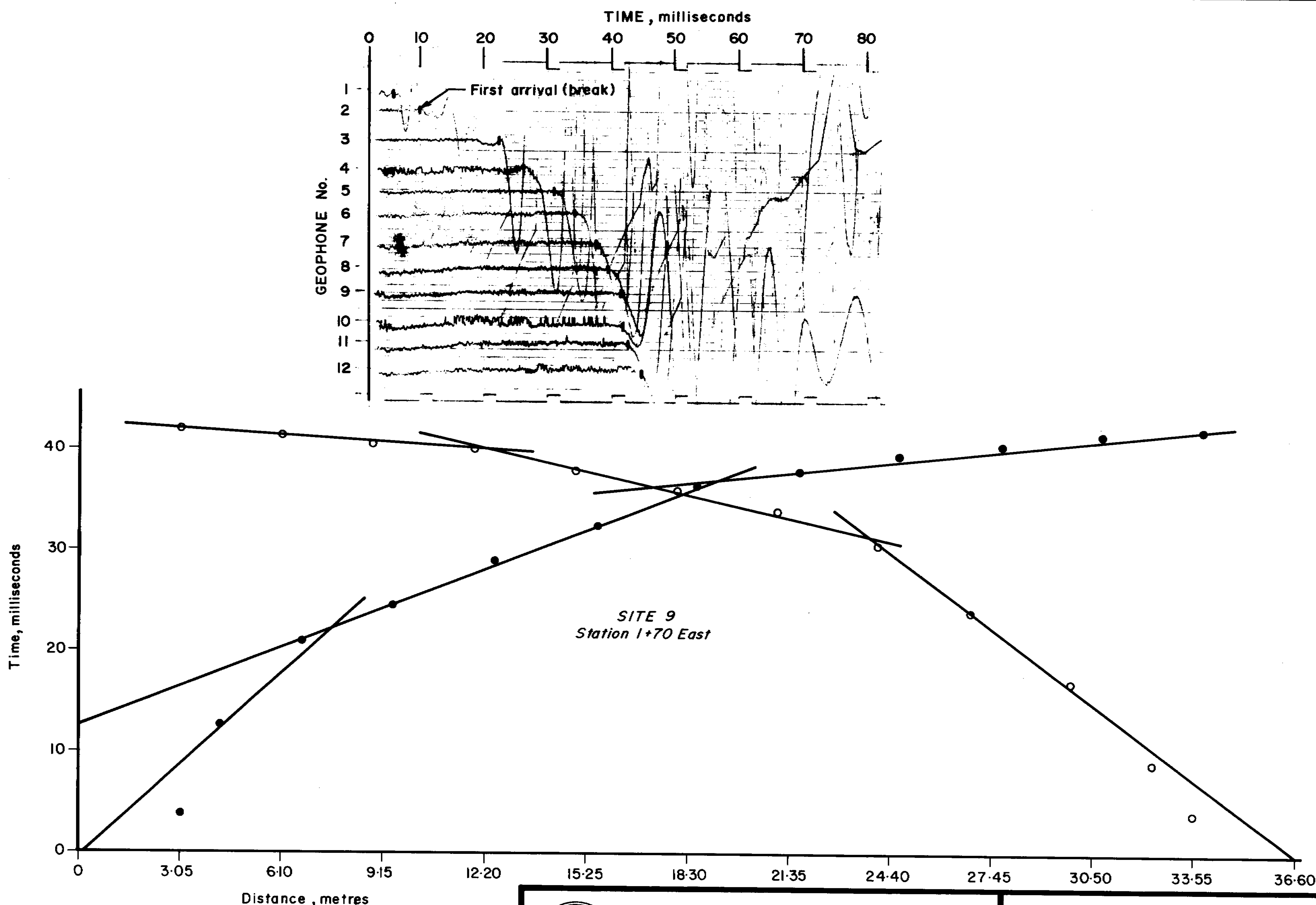
The effective depth of exploration depends mainly on the resistivity of the ground and is approximately half the skin depth of the VLF radiation (approximately 5 m in unfrozen clays, up to 30 m in gravels and permafrost). An advantage of the radiohm method is that both the phase and amplitude of the surface impedance are obtained. The phase is often helpful in resolving the type of resistivity stratification in the ground. The phase is less than 45 degrees when a conductor overlies a resistor and greater than 45 degrees when a resistor overlies a conductor.

Seismic refraction measurements were made with a Nimbus ES-1200 Signal Enhancement Seismograph. In seismic refraction measurements the time of travel of seismic waves from source to geophones placed on the surface is measured. The sources of seismic waves used on the surveys were hammer blows. In a signal enhancement seismograph the wave arrivals of successive blows can be added to obtain a better signal to noise ratio.

Figure 3-6 is a typical example of seismic records obtained. The spacing between geophones is 3.3 m (10 ft). The depth of penetration depends on the maximum separation distance used between hammer blow and geophone and is approximately 0.3 times that distance. Since the maximum distance used was 38 m (120 ft), the effective depth of exploration is about 12.0 metres (40 ft) which is clearly sufficient for mapping depth to bedrock within ditch excavations.



REVISIONS	REFERENCES	SCALE DATE MADE CHKD. APPD.	R.M. HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	PRINCIPLES OF RESISTIVITY TECHNIQUES No. Figure 3·3



R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

FOOTHILLS PIPELINES (YUKON) LTD.
TYPICAL SEISMIC RECORD &
TIME DISTANCE PLOT
DEMPSTER LATERAL

K4321

Figure 3·6

On all seismic spreads a reversed profile was run, i.e. arrival times were used from both ends of the geophone spread. This procedure is necessary to determine depth of dipping bedrock interfaces and to obtain the true velocity of the bedrock. In seismic refraction prospecting only first arrivals are used and these are shown on the sample record of Figure 3-6. Depth to bedrock and velocity of bedrock are computed from time-distance plots. An example of the time-distance plot of the sample record and its reversal are also included in Figure 3-6. Computation of depth to bedrock followed standard delay time methods.

3.3 Methods of Interpretation

Over ground uniform in resistivity with depth all instruments read true resistivity. In most instances the resistivity of ground changes with depth and the values measured at the surface are influenced by all layers within the effective depth of exploration of the instruments, approximately 7 m (20 ft) for the EM31, 15 metres (50 ft) for the EM34 and 5 m to 30 m for the VLF radiohm. The influence of each subsurface layer of different resistivity on the apparent resistivity obtained at the surface follows known mathematical relations.

When measurements are made with 2 or 3 different systems, each sampling the ground to different depth, the resistivity stratification of the ground can usually be obtained with reasonable accuracy. It is far more difficult to translate the resistivity stratification in terms of geotechnical information (frozen or unfrozen ground, granular material versus clay, and depth to bedrock) without ground truth. Test holes and terrain typing are needed to remove ambiguities. Full use has been made of available test hole information, terrain typing and field observations in the interpretation of geophysical data.

4.0 LOGISTICS AND DATA ACQUISITION

The geophysical crew consisted of four men. In general, one man conducted the clearing of the walking trail, the distance measurements and flagging along the line. The other three crewmen performed the geophysical measurements. The geophysical survey lines were placed on airphotos prior to the start of the field work and it was the task of the crew to locate the sites in the field from airphotos. Many test holes were placed ahead of the geophysical survey and in most instances the traverses were made to go over test holes or readings were taken on the test hole if it was some distance off the line.

Measurements were made at intervals of 10 metres with the Geonics EM31 and at intervals of 20 metres with Geonics EM34. VLF radiohm measurements were made at varying intervals.

The field work was begun on August 1, 1978 and completed August 18, 1978. Sites requiring access by helicopter were surveyed first. North of Chapman Lake all sites were accessed by helicopter. Two trucks were moved along day by day during the helicopter survey to the Peel River. Following completion of the helicopter work sites with surface access were surveyed going from the Peel River south.

5.0 RESULTS

5.1 General

The results of the geophysical interpretation have been grouped by physiographic regions. The reason for this grouping is that terrain types in each region are expected to have characteristic ranges of soil properties. The physiographic regions used are:

(a) Yukon Plateau, Division IX

(b) Tintina Trench, Division VIII

(c) Ogilvie Mountains, Division VII

(d) Porcupine Plateau (Eagle Plain), Division VI

(e) Richardson Mountains, Division V

(f) Peel Plateau, Division IV

(g) Peel and Anderson Plains, Divisions III and II

A list of site numbers, figure numbers, terrain type and kilometre posts is given in Table 5.1-1.

The locations and directions of the traverses are indicated on airphotos. Terrain typing in the vicinity of each site is also shown on the airphotos. Terrain typing legends for each of the physiographic regions noted above are listed in tables.

TABLE 5.1-1

List of Site Numbers, Major Terrain Types, Figure Numbers, Approximate Kilometre Posts and Physiographic Regions

Site Number	Figure Numbers Geophysics	Airphoto	Terrain Type	Approximate Kilometre Post	Physiographic Region
Ha-3	5.1.A	5.1	Gh	1154	Yukon Plateau (IX)
Ha-10	5.1.A	5.1	Gt Mv.Cv/sR	1095	Yukon Plateau (IX)
Ha-13	5.2.A	5.2	Gt	1087	Yukon Plateau (IX)
Ha-14	5.3.A	5.2	Gt	1081.5	Yukon Plateau (IX)
Ha-15	5.3.A	5.3	Gt	1077	Yukon Plateau (IX)
4	5.4.A	5.3	Gt	1002	Yukon Plateau (IX)
8	5.4.A	5.4	At	954.5	Yukon Plateau (IX)
9	5.5.A 5.5.S	5.4	Mv.Cv/vR.Mm	951.5	Yukon Plateau (IX)
10	5.5.A	5.4	Mp.pO Mv.Cv/vR.Mm	946.5	Yukon Plateau (IX)
102	5.6.A 5.6.S	5.5	Mm	942.5	Yukon Plateau (IX)
12	5.7.A 5.7.S	5.6	Mm.Mv/mR Lb	932.5	Yukon Plateau (IX)
14	5.7.A	5.6	Cm Cv.Mv/iR	912.5	Yukon Plateau (IX)
106	5.8.A	5.7	Mh.pOv/Lp	898.5	Yukon Plateau (IX)
107	5.8.A	5.7	pOv/Gp	877	Yukon Plateau (IX)

TABLE 5.1-1 - Continued

Site Number	Figure Numbers Geophysics	Airphoto	Terrain Type	Approximate Kilometre Post	Physiographic Region
111	5.9.A	5.8	Mv/iR.Mm	843	Tintina Trench (VIII)
114	5.9.A	5.8	Ap_2.fO	825.5	Tintina Trench (VIII)
18	5.10.A	5.9	At.pO pOv/At	808	Tintina Trench (VIII)
115	5.10.A	5.9	pO-K	797	Tintina Trench (VIII)
116	5.11.A	5.10	pO-K Ev/Gp	787.5	Tintina Trench (VIII)
19	5.11.A	5.10	Ev/Gp	780	Tintina Trench (VIII)
21	5.12.A	5.11	pO-K Ev/Gp	766	Tintina Trench (VIII)
117	5.12.A	5.11	Ev/Gp	750	Tintina Trench (VIII)
118	5.13.A	5.11	pOv/At	748	Tintina Trench (VIII)
22	5.13.A	5.12	Cm	743.5	Tintina Trench (VIII)
121	5.14.A	5.13	Ap_2 Cv/At.Af	727	Tintina Trench (VIII)
23	5.14.A	5.13	Mv/mqR Cv/mqR	722	Ogilvie Mtns (VII)
24	5.15.A	5.13	Cv.MV/mqR	712.5	Ogilvie Mtns (VII)
26	5.15.A	5.14	Cv/Af	703	Ogilvie Mtns (VII)
123A	5.15.A	5.14	Ap Cv/Af	698	Ogilvie Mtns (VII)
123	5.16.A	5.14	Af	696.5	Ogilvie Mtns (VII)
124	5.16.A	5.15	Af	688.5	Ogilvie Mtns (VII)
28	5.17.A	5.15	Ma.Gm	680	Ogilvie Mtns (VII)
29	5.17.A	5.16	Mm	675	Ogilvie Mtns (VII)

TABLE 5.1-1 - Continued

Site Number	Figure Numbers Geophysics	Airphoto	Terrain Type	Approximate Kilometre Post	Physiographic Region
31	5.18.A	5.16	Mm	670	Ogilvie Mtns (VII)
32	5.18.A	5.17	Mh Ev/Lp	667.5	Ogilvie Mtns (VII)
33	5.19.A	5.17	Ev/Mm	666	Ogilvie Mtns (VII)
125	5.19.A	5.17	Ev/Gp pOv/Gp Gp	660.5	Ogilvie Mtns (VII)
34	5.20.A	5.18	Af.Ct-S	654.5	Ogilvie Mtns (VII)
127	5.20.A	5.18	Mm	644	Ogilvie Mtns (VII)
132	5.21.A	5.19	Cb(P) At	607	Ogilvie Mtns (VII)
135	5.21.A	5.19	Cv/sR-R	572.5	Ogilvie Mtns (VII)
149	5.22.A	5.20	Af	536	Porcupine Plateau (VI)
152-153	5.23.A	5.20	Cv/ss,smR	523	Porcupine Plateau (VI)
154-155	5.23.A	5.21	ss,smR.Cv/sR Cm	510	Porcupine Plateau (VI)
163	5.23.A	5.21	Cv/sm,ssR Cm	448	Porcupine Plateau (VI)
165	5.24.A	5.22	Cv/sm,ssR	426.5	Porcupine Plateau (VI)
167	5.24.A	5.22	Cv/At	423.5	Porcupine Plateau (VI)
168	5.25.A	5.22	Cv/sm,ssR	407	Porcupine Plateau (VI)

TABLE 5.1-1 - Continued

Site Number	Figure Numbers Geophysics	Airphoto	Terrain Type	Approximate Kilometre Post	Physiographic Region
170	5.25.A	5.23	Cv/sm,ssR	387	Richardson Mtns (V)
173	5.25.A	5.23	Cb(P)-G	359.5	Richardson Mtns (V)
175-176	5.26.A	5.24	Cb(P)-G	334.5	Richardson Mtns (V)
179	5.27.A	5.24	Ap	311	Peel Plateau (IV)
184	5.27.A	5.25	Mv.Cv/smR - R	285.5	Peel Plateau (IV)
184A	5.27.A	5.25	Mv.Cv/smR - R	285.5	Peel Plateau (IV)
185	5.28.A	5.25	Mv/smR - R	277.5	Peel Plateau (IV)
186	5.28.A	5.25	Ap_2 - K	276	Peel Plain (III)
187	5.28.A	5.25	Mv/smR	274.5	Peel Plain (III)
188	5.29.A	5.26	Mh . Mv/smR	259.5	Peel Plain (III)
192	5.29.A	5.26	pOv/smR . pOv/Mp	230	Peel Plain (III)
195	5.30.A	5.27	Mp	207.5	Anderson Plain (II)
			Ap_2		
197	5.30.A	5.27	fOv.pOv/Mp	190.5	Anderson Plain (II)

5.2. Yukon Plateau

The terrain typing legend used for geophysical traverses in this region is given in Table 5.2-1.

Site Ha-3 (Figures 5.1, 5.1.A) crosses sands and gravels in a hummocky glaciofluvial terrain unit. Test hole 77-2 is located near the geophysical traverse and shows unfrozen sands and gravels to 6.7 metres with silt and clay till below that depth. Since the resistivities are relatively uniform across the site and too low (<200 ohm-m) for frozen sands and gravels, the entire length of the traverse is expected to be unfrozen. Resistivity variation from stations 0 to 600 m is probably due to a decreasing thickness of the granular material over till.

Site Ha-10 (Figures 5.1, 5.1.A) crosses three different terrain units. The glaciofluvial terrace (Gt) is composed of sands and gravels that are expected to be unfrozen due to the uniform and relatively low resistivities (<200 ohm-m). No test hole was drilled at the site but test hole 77-13, in the same terrain unit, indicates the presence of unfrozen gravel and sand to 6.45 metres.

The transition from granular to fine grained material over shallow bedrock is evident from the change in values of resistivities around station 200 m. Shallow bedrock (<10 m depth) is expected to be present from station 370 m to 530 m. The high resistivities between station 550 m and 600 m are expected to be due to unfrozen sands and gravels under shallow (<3 m) lake bed deposits.

Site Ha-13 (Figures 5.2, 5.2.A) traverses floodplain and glaciofluvial sands and gravels. Since the resistivities over this site are below 200 ohm-m the sands and gravels are expected to be unfrozen over the entire site. This is consistent with the information in test hole 77-13 located in a similar terrain type nearby.

Site Ha-14 (Figure 5.2, 5.3-A) lies in a glaciofluvial terrace. The resistivity values below 200 ohm-m are expected to indicate that the gravels and sands are in an unfrozen state. Test hole 77-13 is probably characteristic of subsurface conditions on this site.

Site Ha-15 (Figures 5.3, 5.3A) crosses an alluvial fan from station 0 to 60 and an active floodplain from 60 to 180 metres. In both units unfrozen granular soils are expected.

From 180 m to 480 m a glaciofluvial terrace is traversed. Since the resistivities are substantially higher (>200 ohm-m) than in unfrozen sands and gravels in the same region, permafrost is expected along this segment. This is consistent with test hole 77-15 which is located in the same terrain unit close to the site. Test hole 77-15 encountered frozen conditions below 3.2 metres.

Site 4 (Figure 5.3, 5.4.A) crosses a glaciofluvial terrace. Test hole 78-4 indicates unfrozen gravel and sands. The uniform resistivity values below 200 ohm-m for granular soils are expected to indicate unfrozen conditions along the entire traverse.

Site 8 (Figures 5.4, 5.4.A) is located on granular soils in an alluvial terrace of the Yukon River. Test hole 78-8 shows 5.45 metres of interbedded gravels and sands that are unfrozen to depth. The resistivity profile of the EM31 is below 200 ohm-m over the site and for that reason permafrost is not expected to be encountered along the traverse.

Site 9 (Figures 5.4, 5.5.A, 5.5.S) is in a compound terrain unit described as a till and colluvial veneer over bedrock with areas of thicker till. Seismic traverses were run perpendicular to the resistivity traverses at stations 170 and 240 metres. Test hole 78-9 is located at 275 metres and showed unfrozen ground and bedrock at 5 metres. The results of the seismic traverses (Figure 5.5.S) at station 170 m shows a high velocity layer (2930 m/sec) at a depth of 6.5 metres on the geophysical traverse (Station 0). This high velocity layer is interpreted to be bedrock. The velocities of the strata above bedrock are less than 855 m/sec indicative of unfrozen soils. Bedrock on the geophysical traverse at station 240 m is encountered at 5.5 m. There is a large change in bedrock velocity between station 170 m and 240 m. The resistivity values of the EM34, which mainly reflect bedrock, show a change in bedrock type at station 220 m.

Site 10 (Figures 5.4, 5.5.A) traverses three different terrain units. From 0 to 130 m rolling moraine is crossed. From 130 m to 250 m till and organic deposits are encountered, and from station 250 m to 350 m veneers of till and colluvium over bedrock are present. Test hole 78-10, at station 155 m, showed frozen ground to depth.

The EM34 reads very low over this site indicative of conductive bedrock at depth. Because the EM31 reads above 100 ohm-m, bedrock is deeper than 7 metres. Since test hole soil samples showed a high percentage of fines (>50% passing the #200 sieve), resistivity values above 100 ohm-m indicate frozen ground. Permafrost is expected over the entire site with a deeper active layer under the wet meadow.

Site 102 (Figures 5.5, 5.6.A, 5.6.S) is in a rolling till plain. Test hole 78-102 at station 190 m showed frozen clay till to 3.5 m and unfrozen sand below 3.5 m to depth. The resistivity profile shows an increase from 100 ohm-m to nearly 200 ohm-m at station 400 m. Using the test hole information as the basis for interpolation, permafrost is expected to thicken at station 380 m. To compute approximate depth of permafrost a three layer model with a constant active layer depth (0.7 m) was assumed.

The seismic spreads (Figure 5.6.S) are perpendicular to the resistivity traverse at station 100 m and 200 m. These data show a layer with low velocity (400-500 m/sec) in the first 4 m, and higher velocities below that. On the basis of the test hole data it is inferred that the layer of low velocity is frozen clay with the high velocity layer being sands and gravels.

Site 12 (Figures 5.6, 5.7.A, 5.7.S) is in a bedrock controlled terrain unit. Seismic spreads (Figure 5.7.S) were conducted at stations 0 and 60 m and test hole 78-12 is at station

75 m. The test hole shows bedrock at 4.3 metres. In the seismic spreads bedrock is observed at 3 metres at station 0 and 4.25 m at station 60 m. The EM34 shows very low resistivities indicating conductive shallow bedrock over the entire site. It is not possible to derive permafrost information at this site with conductive bedrock close to the surface.

Site 14 (Figure 5.6, 5.7.A) is in a till plain from station 0 to 35 m and in a colluvial blanket from there on. Test hole 78-14 at station 245 m shows frozen ground from 2.0 to 3.5 m. The EM34 reads below 20 ohm-m indicating the presence of bedrock within 20 metres. The EM31 shows much variation along the profile. The low value of resistivity (about 100 ohm-m) at station 310 m is over a bulldozed trail while that at station 420 coincides with the Klondike Highway. These low anomalies are expected to be due to permafrost degradation.

Site 106 (Figures 5.7, 5.8.A) is in an area of hummocky moraine and lacustrine sediments with an organic veneer. Test hole 78-106 shows frozen silt and sand to depth (9.7 m). Resistivity values on this traverse for both the EM31 and EM34 are mainly above 200 ohm-m, and deep frozen ground is expected over the entire site. Deep frozen ground (>20 m) is inferred from the fact that the EM34 and EM31 have similar values.

Site 107 (Figures 5.7, 5.8.A) is in glaciofluvial gravels and sands with an organic veneer. Test hole 78-107 shows frozen soil to depth. Because the EM31 shows uniform high resistivity values (>300 ohm-m) over the site, permafrost is expected along the entire length of the traverse.

PHYSIOGRAPHIC REGION IX: YUKON PLATEAU

(5 km S of Stewart Crossing to Haeckel Hill)

Terrain Types

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; unfrozen
- fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen
- pO - Bog: peat, flat to depressional; poor drainage; high ice content
- pOv - Bog Veneer: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

- Cf - Flow Slide: gravity-transported clay to gravel sizes; moderately sloping; fair to poor drainage; unfrozen
- Cm - Colluvial Slopewash: predominantly silt and sand; gently sloping; fair to good drainage; generally unfrozen
- Cs - Rock Slide: angular bedrock fragments; moderately to steeply sloping; good drainage; unfrozen
- Ct - Talus: angular bedrock fragments, silty sand matrix; steeply sloping; good drainage; unfrozen
- Cv - Colluvial Veneer: predominantly silt and sand; topography reflects underlying bedrock; good drainage; generally unfrozen

A - Alluvial

- Af - Alluvial Fan: poorly sorted sand and gravel; concave slope; good drainage, some subsurface flow; generally unfrozen, patches of low ice content permafrost
- Ap - Alluvial Floodplain (undifferentiated): stratified sand and gravel, minor silt, organics locally; flat to gently undulating, channelled; fair to good drainage, high water table; unfrozen
- Ap_1 - Active Floodplain: stratified sand and gravel; flat, channelled; fair drainage, open water, frequently inundated; unfrozen
- Ap_2 - Inactive Floodplain: stratified sand and gravel, silt veneer, organics locally; gently undulating, channelled; fair to good drainage, except for organics, high water table, periodically inundated; unfrozen, high ice content beneath organics
- At - Alluvial Terrace: stratified silt, sand and gravel, silt veneer; flat; good drainage; generally unfrozen
- Av - Alluvial Veneer: stratified silt and sand, minor gravel; topography reflects underlying material; good drainage; generally unfrozen

E - Eolian

- Ed - Eolian Dunes: fine sand and silt; ridges; good drainage; generally unfrozen

L - Lacustrine and Glaciolacustrine

- Lb - Lacustrine Basin: stratified silt and clay, some sand and organics; flat to depressional; poor drainage; high ice content
- Lp - Glaciolacustrine Plain: stratified silt and clay, minor sand and organics; flat to gently undulating; fair to poor drainage; high ice content
- Lv - Lacustrine Veneer: stratified silt and clay, minor sand and organics; flat; fair to poor drainage; high ice content

G - Glaciofluvial

- Gh - Hummocky Glaciofluvial Plain: stratified sand and gravel, minor silt; hummocky; good drainage; generally unfrozen
- Gm - Glaciofluvial Ridges and Hummocks: stratified sand and gravel, minor silt; undulating to hummocky, some ridges; good drainage; generally unfrozen
- Gp - Glaciofluvial Plain: stratified sand and gravel, minor silt; flat to gently undulating, good drainage; generally unfrozen
- Gt - Glaciofluvial Terrace: stratified sand and gravel, silt veneer; gently undulating; good drainage; generally unfrozen
- Gv - Glaciofluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying materials; good drainage; generally unfrozen

M - Morainal

- M - Moraine (undifferentiated): gravelly sandy till; topography obscured by overlying deposits; drainage and ice contents variable
- Mh - Hummocky Moraine: gravelly sandy till, occasional granular lenses; hummocky; good drainage, high water table locally; generally unfrozen
- Mm - Rolling Moraine: gravelly sandy till; gently rolling; good drainage, high water table locally; generally unfrozen
- Mp - Moraine Plain: gravelly sandy till; gently undulating; good drainage; generally unfrozen
- Mr - Ridged Moraine: gravelly sandy till, occasional granular lenses; undulating with ridges; generally unfrozen
- Mv - Moraine Veneer: sandy till; topography reflects underlying deposit; good drainage; generally unfrozen

R - Bedrock

- iR - Igneous (undifferentiated)
- mR - Metamorphic (undifferentiated)
- sR - Sedimentary (undifferentiated)
- ssR - Sandstone and conglomerate, minor shale
- vR - Volcanic (undifferentiated)

Modifiers

- C - Channelled
- K - Thermokarst features

Symbols

- Escarpment
- Meltwater Channel
- Borrow Pit
- Unstable Ground
- Quarry in rock
- Mine
- Esker

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the feature.

Complex Unit

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

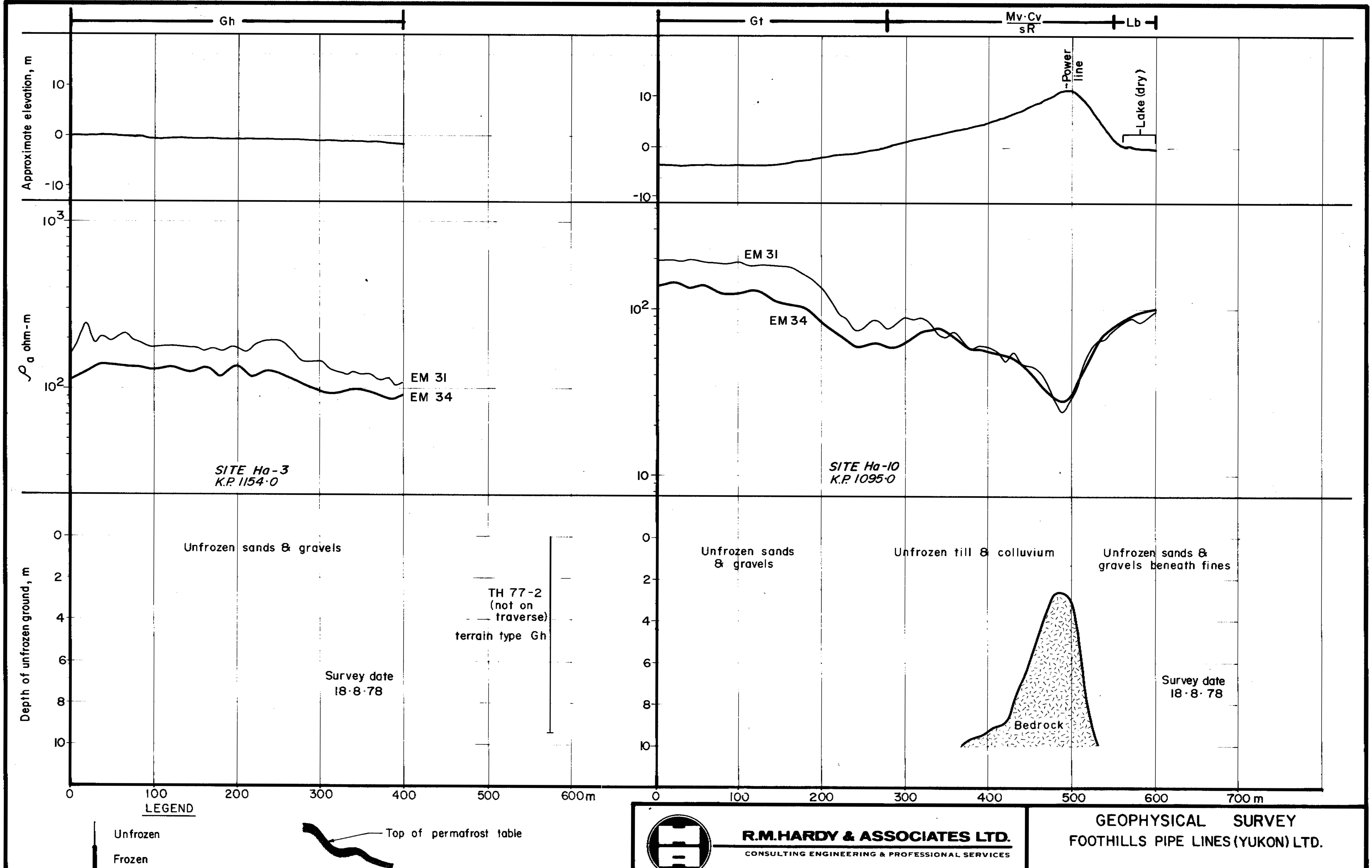
$$Lb_8 . pO_2$$

where the subscripts indicate the relative proportions of each. Where subscripts are absent, the proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

$$\text{veneer} \rightarrow \frac{Mv}{sR} . Mm - C \leftarrow \text{erosional modifier}$$

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·2·1



R.M.HARDY & ASSOCIATES LTD.

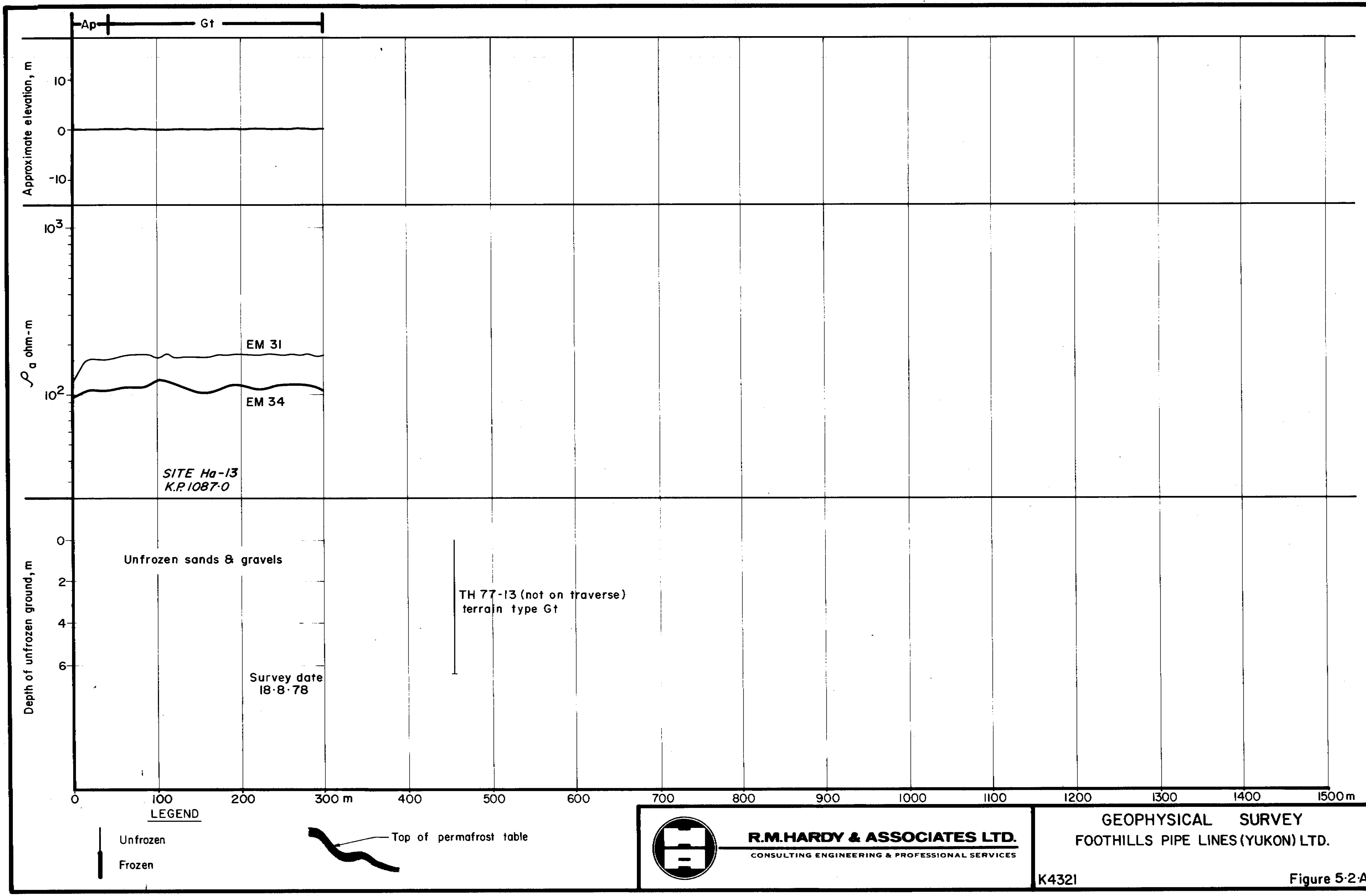
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·1·A

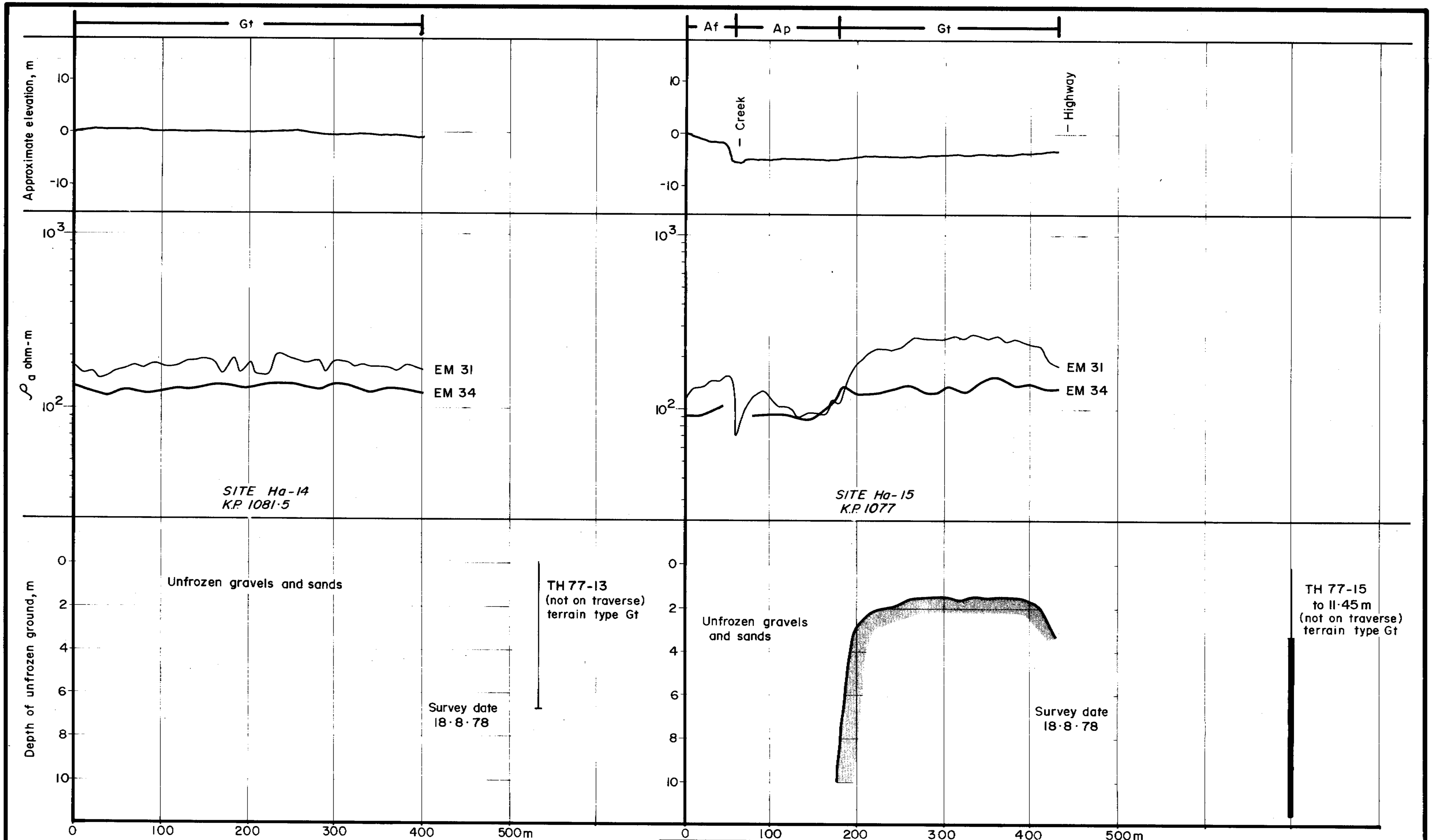


R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·2·A



R.M. HARDY & ASSOCIATES LTD.

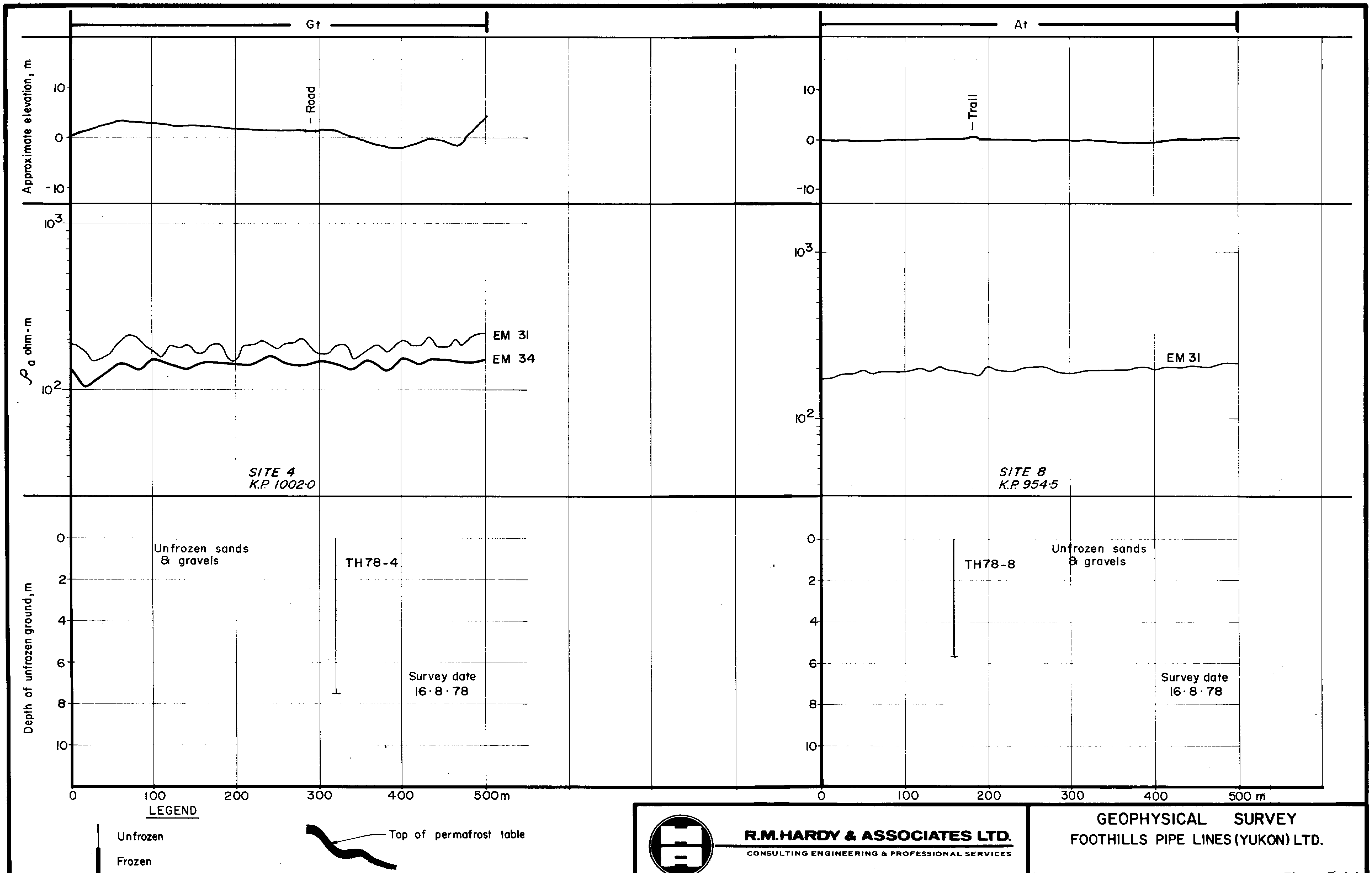
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·3·A

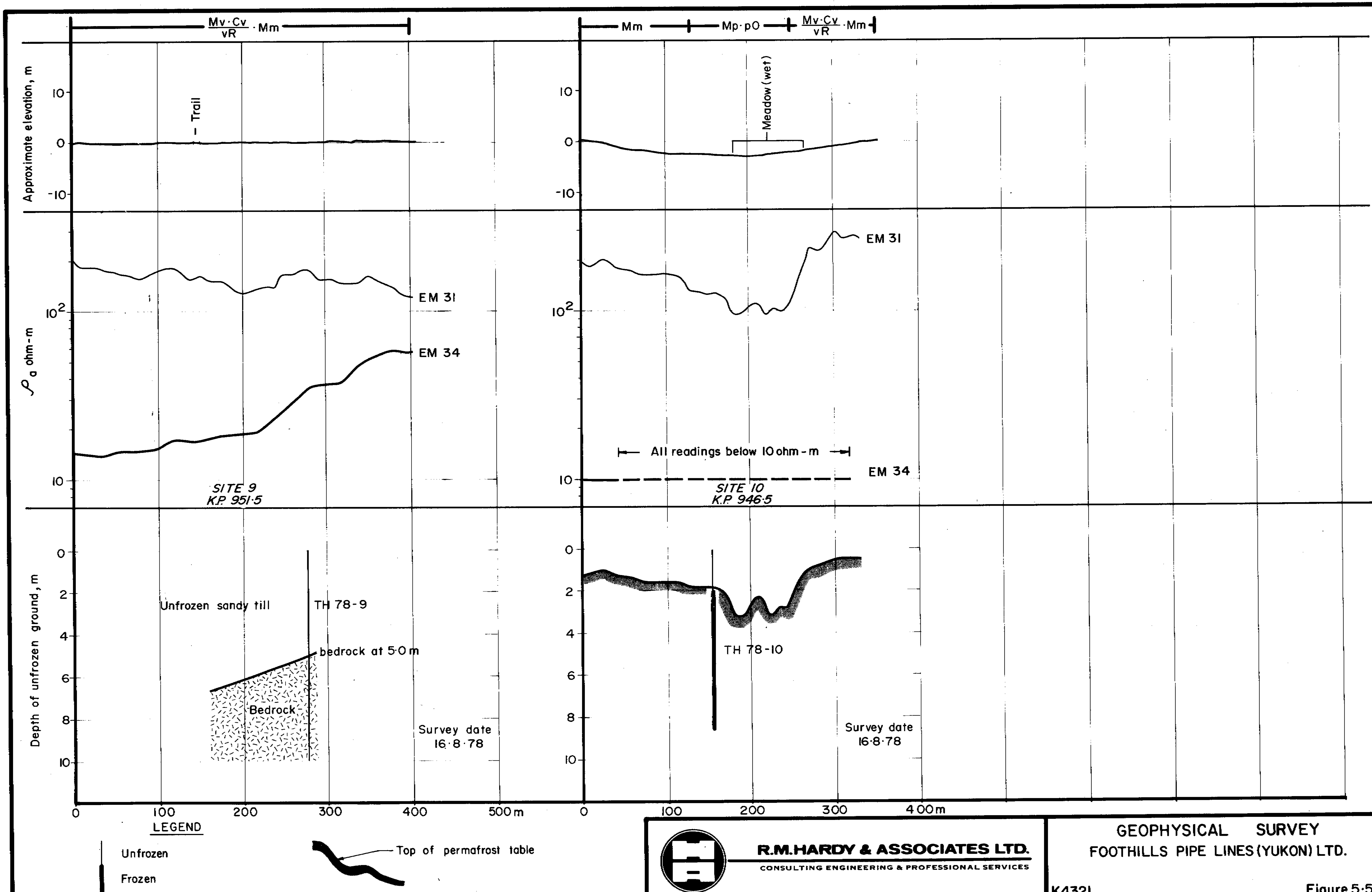


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·4·A

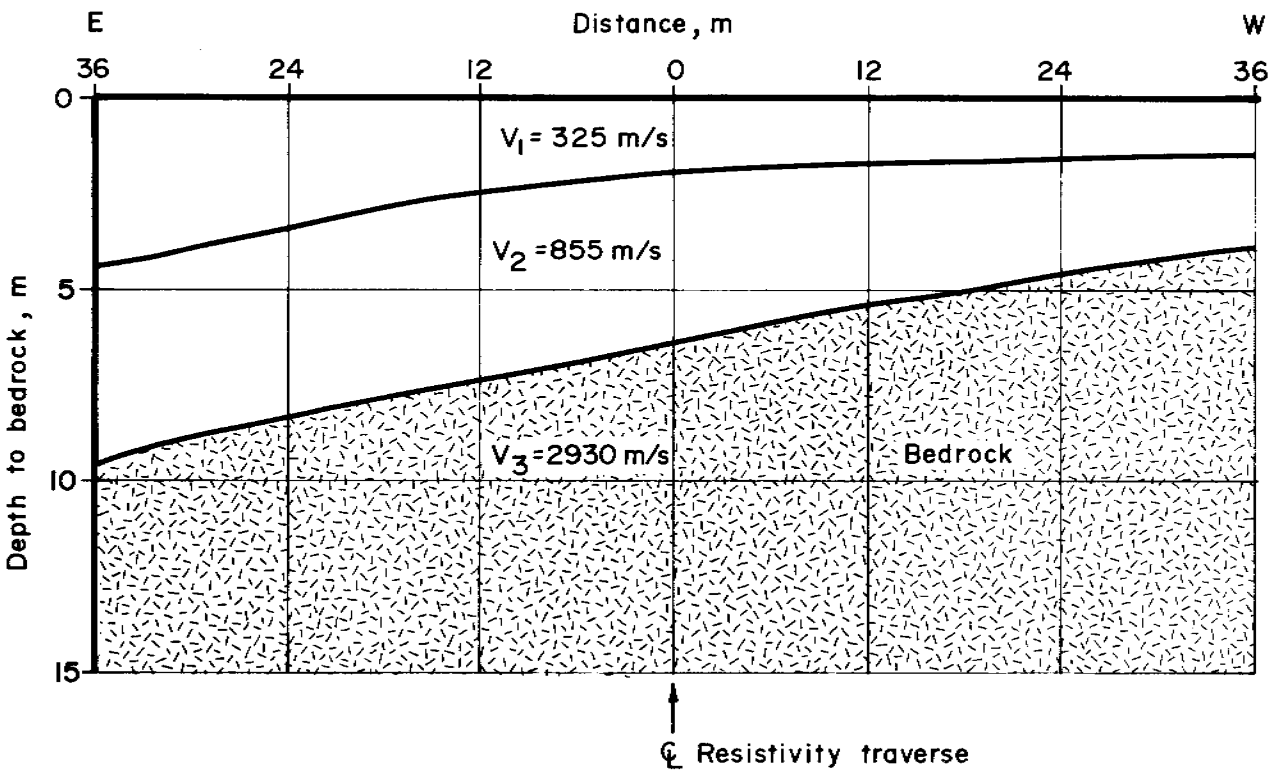


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

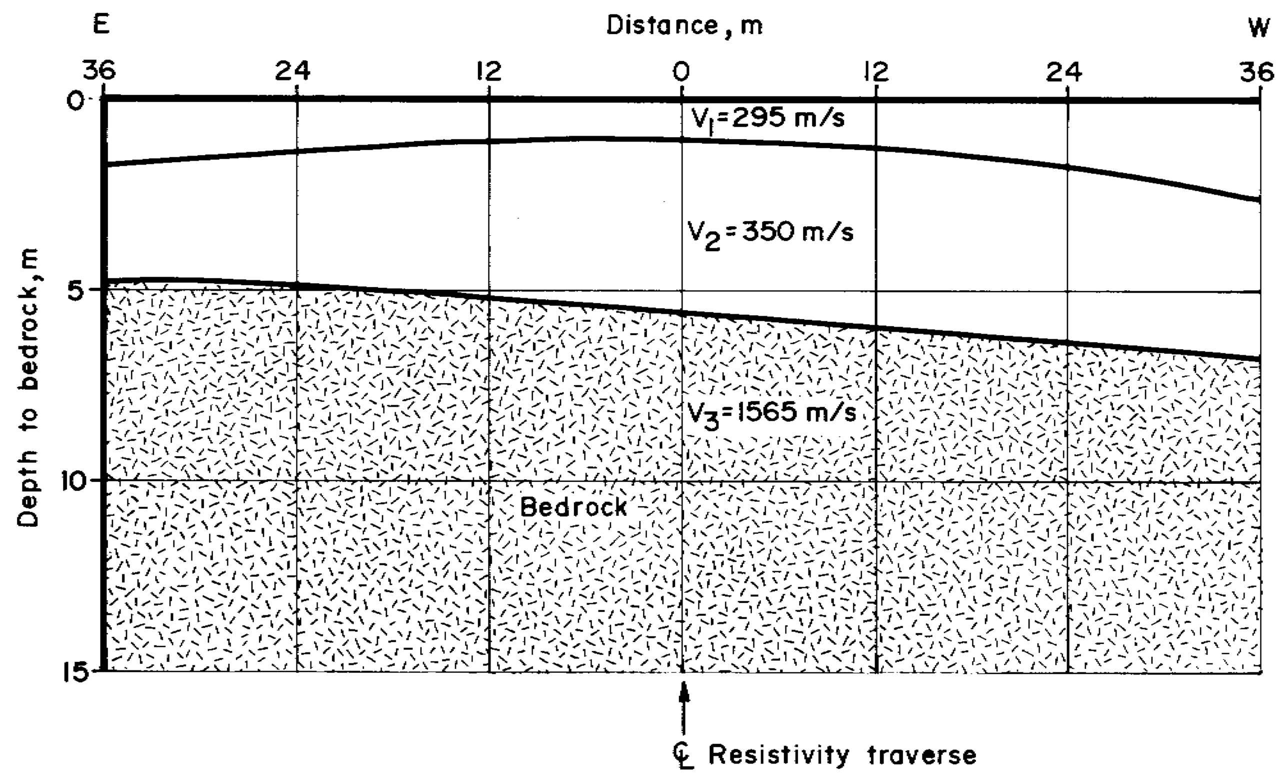
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·5·A



Station 170 m



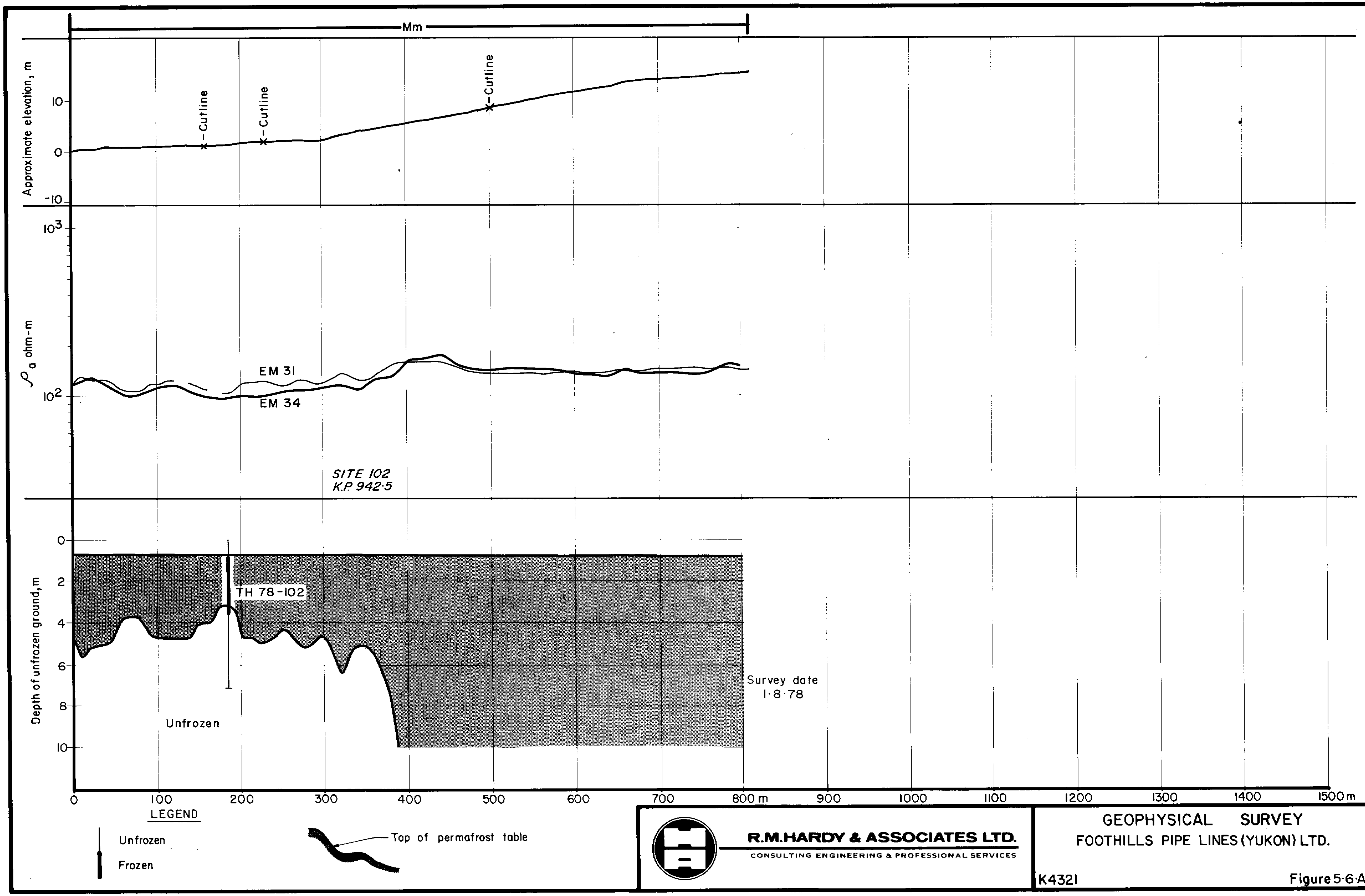
Station 240 m

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

SEISMIC REFRACTION SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE 9

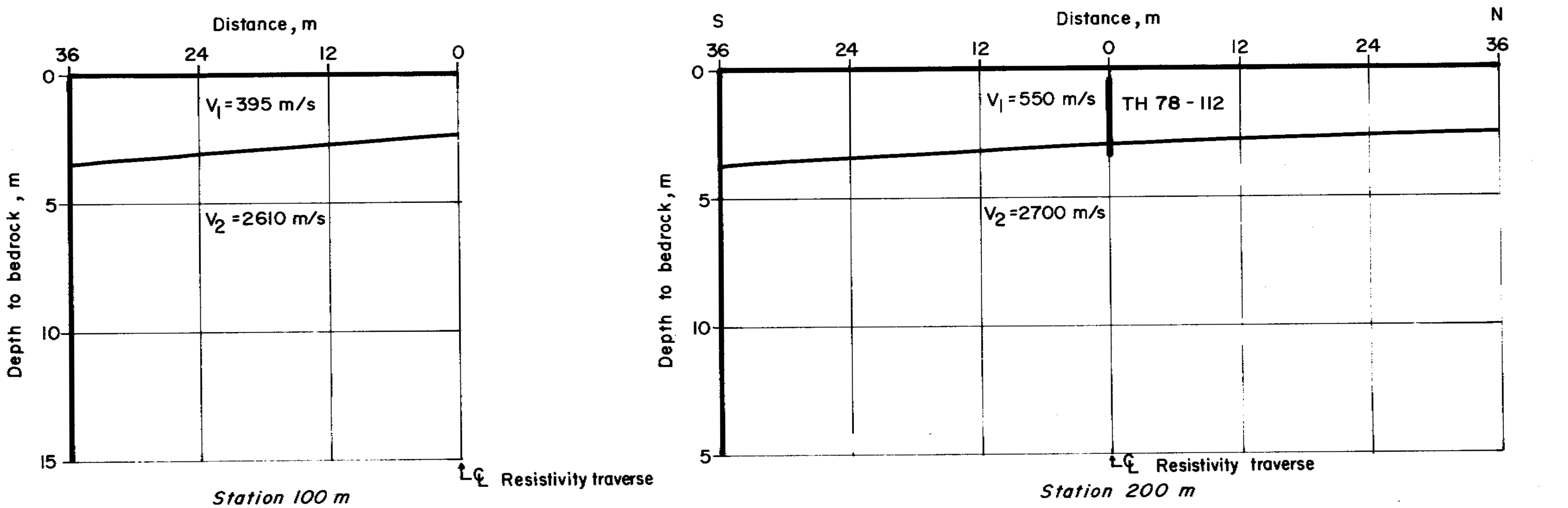
K4321

Figure 5·5·S



Mm
Approximate elevation, m
10
0
-10
Cutline
Cutline
Cutline
10^3
ρ_a ohm-m
10^2
EM 31
EM 34
SITE 102
K.P. 942.5
0
2
4
6
8
10
Depth of unfrozen ground, m
TH 78-102
Unfrozen
Survey date
1·8·78
0
100
200
300
400
500
600
700
800 m
900
1000
1100
1200
1300
1400
1500 m
LEGEND
Unfrozen
Frozen
Top of permafrost table
R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
K4321

Figure 5·6·A



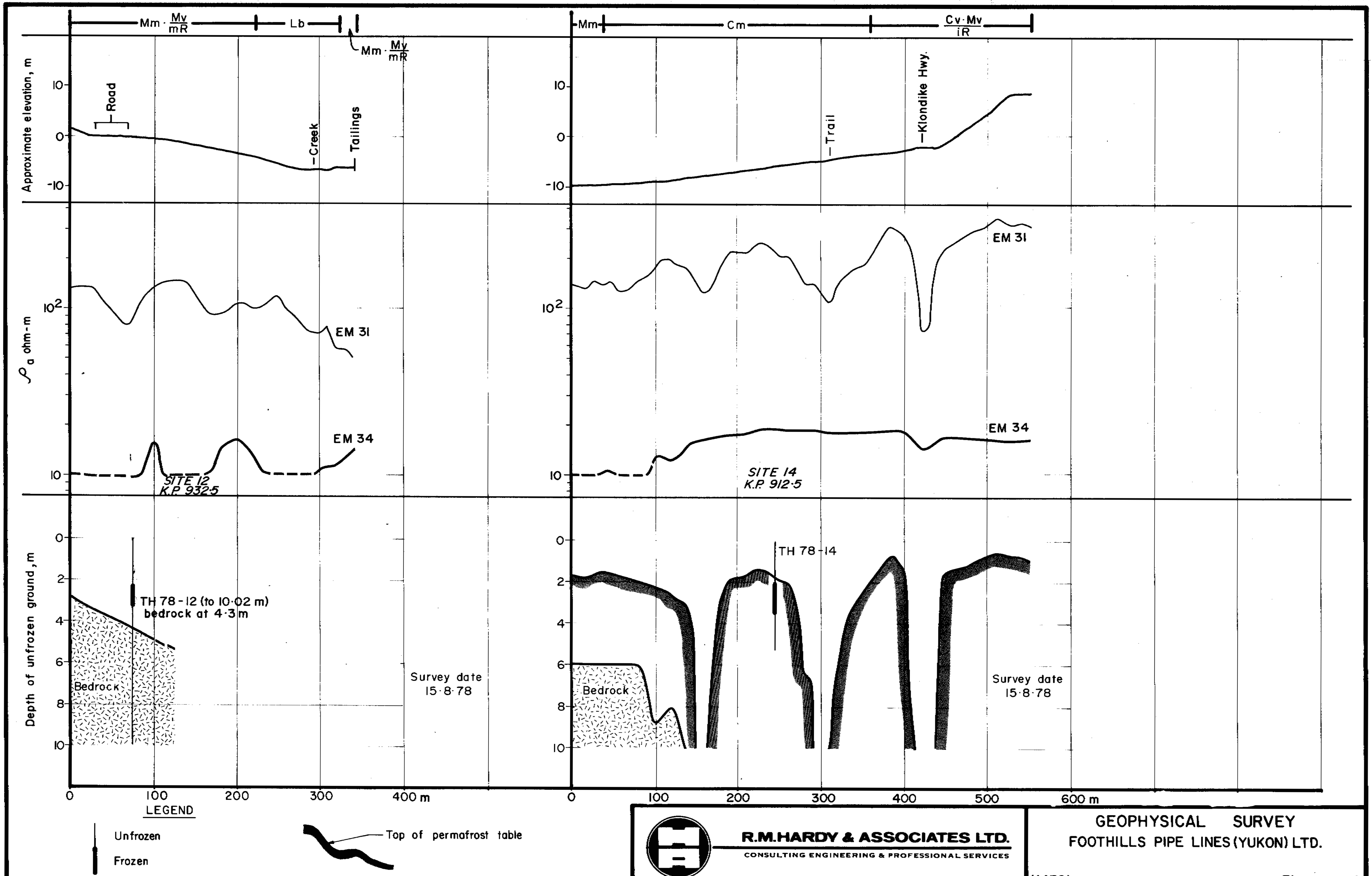
R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

SEISMIC REFRACTION SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE 102

K 4321

Figure 5·6·S

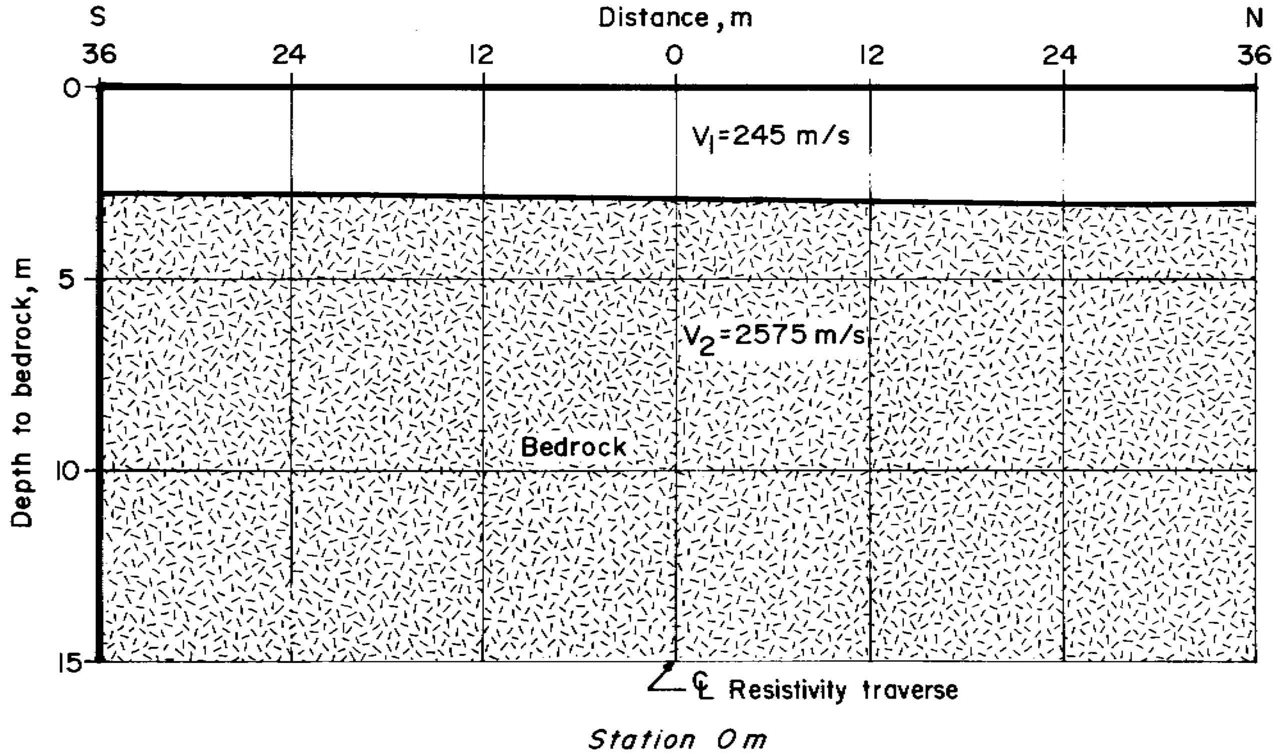


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

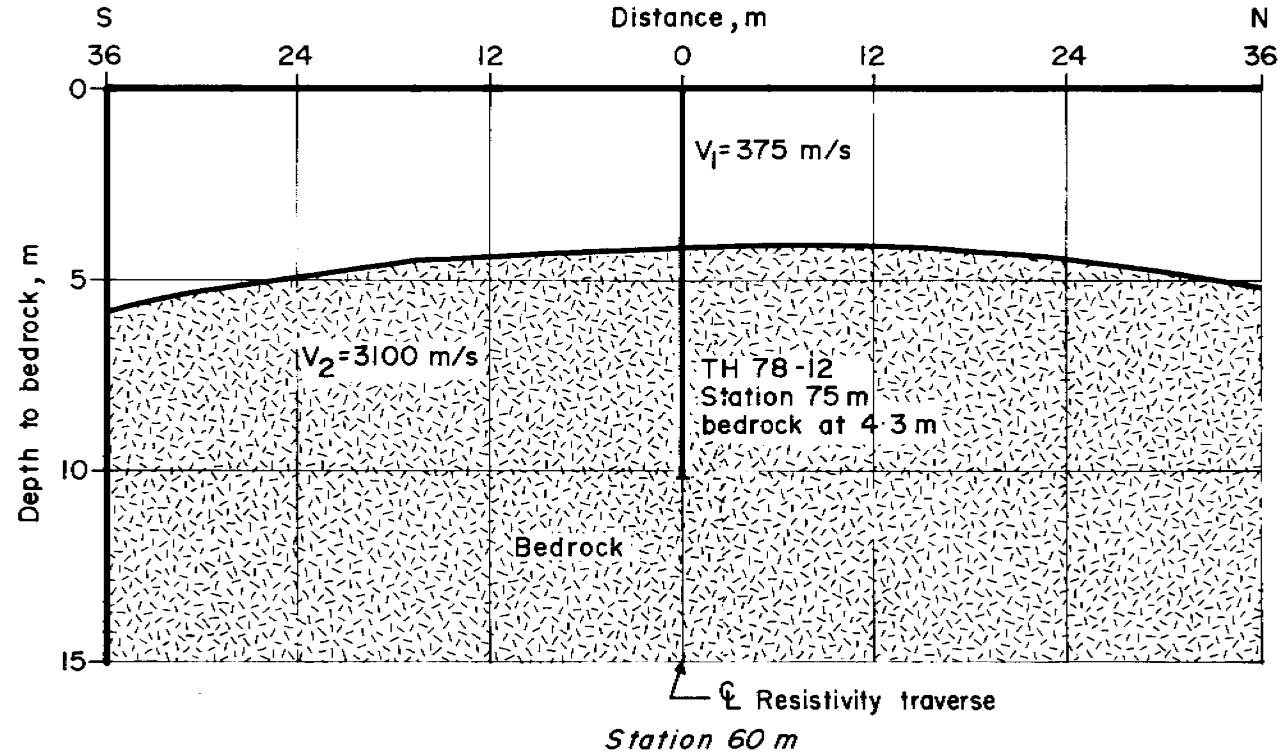
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·7·A



Station 0 m



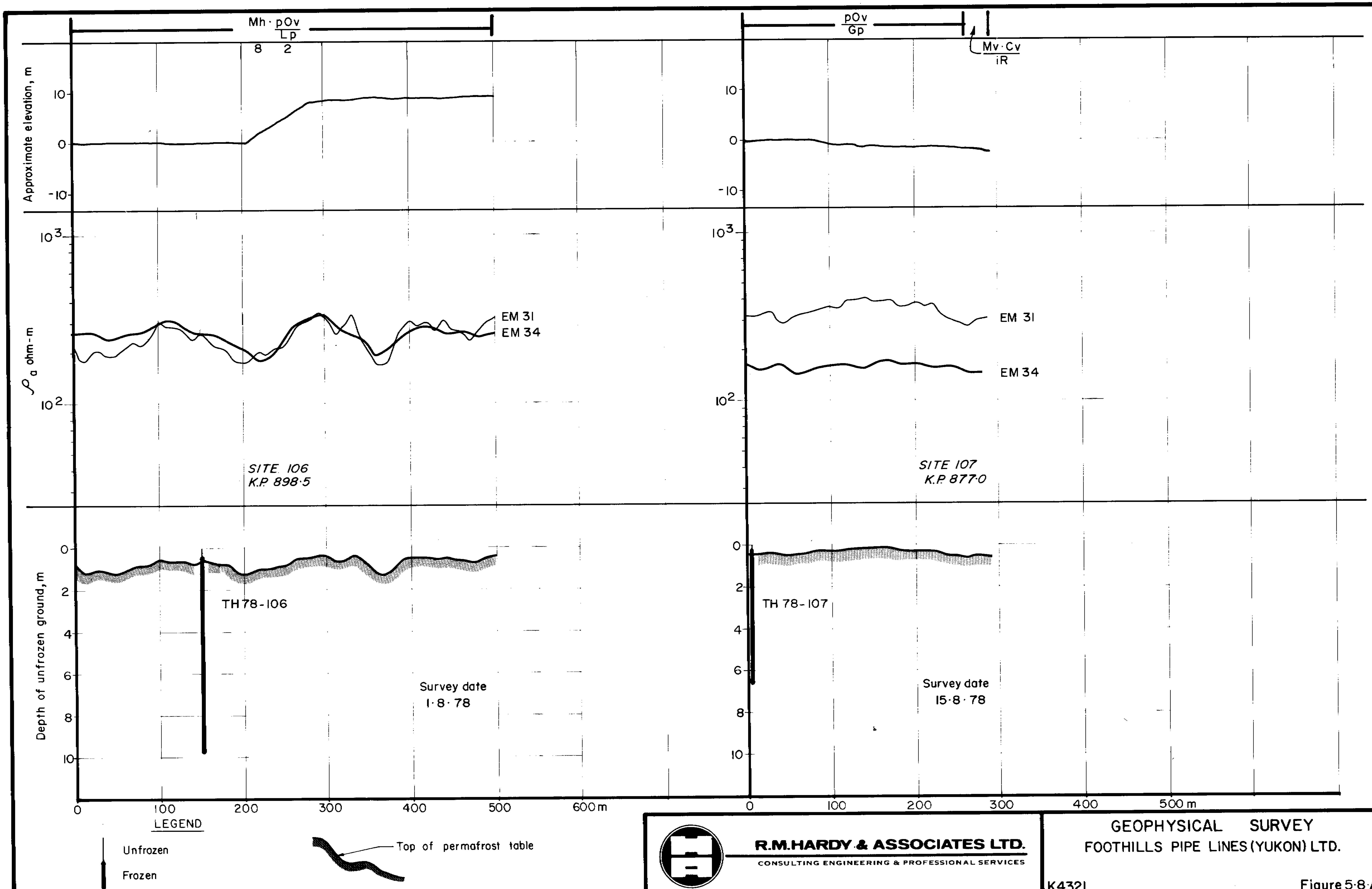
Station 60 m

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

SEISMIC REFRACTION SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE 12

K 4321

Figure 5·7·S



R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·8·A

5.3 Tintina Trench

The terrain typing legend used for geophysical traverses in this region is given in Table 5.3-1.

Site 111 (Figures 5.8, 5.9.A) is in till. The resistivity data are above 200 ohm-m over a considerable length of the site. The resistivity low around station 200 m is in a clearing. Because of the high EM31 readings deep frozen ground is expected over the entire site. Test hole 78-111 encountered some frozen ground, but showed mainly unfrozen silts.

Site 114 (Figures 5.8, 5.9.A) is in an alluvial terrace with some organic terrain. The EM31 resistivities are very high (300 to 400 ohm-m) and for that reason frozen ground is expected over the entire site. Test hole 78-114 shows low water content unfrozen gravel and sands. At this site the interpretation from geophysical surveys does not agree with the test hole data. The organic layer of 0.25 m over the site would tend to support a frozen state. It is difficult to form an organic surface over well drained, unfrozen sands and gravels.

Site 18 (Figures 5.9, 5.10.A) is located on an alluvial terrace with varying depths of peat cover. Test hole 78-18 indicates 1.28 m of peat and silt cover over gravel and is frozen at 0.1 metres. The uniformity and magnitude of the resistivity profiles indicates that frozen gravels are to be found along the entire traverse.

Site 115 (Figures 5.9, 5.10.A) crosses organic terrain with some thermokarst degradation. Near the end of the traverse glaciofluvial gravels with a veneer of windblown silts and sands are encountered. Test hole 78-115 indicates 2.15 metres of peat over frozen silts, sands and gravels. The uniform, high values of resistivity from 0 m to 380 m indicate frozen ground over that length. The resistivity values show clearly a change in terrain type at station 400 m. The sands and gravels from station 420 m on are expected to be unfrozen.

Site 116 (Figures 5.10, 5.11.A) is located on a glaciofluvial plain with a veneer of windblown silts and sands. From station 360 m to 560 metres thick organic deposits with some thermokarst degradation are encountered. Test hole 78-116 is in organic terrain, and shows 1.9 metres of peat over frozen silts, sands and gravels. The depth of thaw at the drill site is 0.3 metres. From the uniformity of the resistivity profiles it is expected that the site is in permafrost along the entire traverse. The variation in resistivities is likely to be due to variable thicknesses of the organic layer. Note that the direction of the traverse as shown in Figure 5.10 should be reversed.

Site 19 (Figures 5.10, 5.11.A) is located on a gravelly glaciofluvial plain with a veneer of windblown silts and sands. The high values of EM31 resistivities (>200 ohm-m) indicate frozen ground over the entire site. Under the Klondike Highway the resistivity decrease is probably due to permafrost degradation. Test hole 78-19 shows only a limited thickness of frozen ground.

Site 21 (Figures 5.11, 5.12.A) traverses organic terrain with thermokarst features for the first 140 m and a sand and gravel glaciofluvial plain from there on. Test hole 78-21 shows frozen ground to depth (9.3 m). The traverse crosses swampy terrain between station 50 m and 100 m and this is reflected in low values of resistivity. Unfrozen ground is expected under the swamp and frozen ground over the remaining portion of the site.

Site 117 (Figures 5.11, 5.12.A) crosses a sand and gravel glaciofluvial plain with a veneer of windblown silts and sands. Test hole 78-117 shows unfrozen sand and gravel to depth (9.8 m). Since the resistivities of the EM31 are below 100 ohm-m, unfrozen sands and gravels are expected along the entire site.

Site 118 (Figures 5.11, 5.13.A) traverses an alluvial terrace with an organic surface cover. Test hole 78-118 shows frozen peat, gravel and clay. The resisitivity is uniform from station 100 m to 400 m and for that reason frozen ground with a shallow (0.5 m) active layer is expected. The traverse crosses a burned area between 0 and 100 m and a thawed surface layer up to 2 metres thick is expected along that segment.

Site 22 (Figure 5.12, 5.13.A) is in thick colluvial sediments. The resistivities are below 100 ohm-m (EM31) at the beginning and at the end of the traverse. The resistivity variation is expected to be caused by different depths to the permafrost table. Test hole 78-22 is at station 0 and shows the permafrost table at a 4 metre depth.

Site 121 (Figures 5.12, 5.14.A) traverses an alluvial floodplain and terrace and fan with a colluvial veneer. Because of the high resistivity values obtained with the EM31 (>300 ohm-m) frozen ground is expected over the entire site. Test hole 78-121 shows frozen peat and gravel to depth (5.6 m).

PHYSIOGRAPHIC REGION VIII: TINTINA TRENCH

(Benson Creek to 5 km S of Stewart Crossing)

Terrain Types

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; unfrozen
- fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen
- pO - Bog: peat; flat to depressional; poor drainage; high ice content
- pOv - Bog Veneer: peat, flat to depressional; poor drainage; high ice content

C - Colluvial

- Cm - Colluvial Slopewash: predominantly silt and sand; gently to steeply sloping; fair to good drainage; generally unfrozen, patches of low to medium ice content permafrost
- Ct - Talus: angular bedrock fragments, silt and sand matrix; steeply sloping; good drainage; low ice content permafrost locally
- Cv - Colluvial Veneer: predominantly silt and sand; topography reflects underlying bedrock; good drainage; generally unfrozen, patches of low ice content permafrost

E - Eolian

- Ev - Eolian Veneer: wind-blown silt and sand (locally thick); topography generally reflects underlying material; good drainage; frozen and unfrozen, low to high ice content permafrost

A - Alluvial

- Af - Alluvial Fan: poorly sorted sand and gravel; concave slope; good drainage, some subsurface flow; generally unfrozen, patches of low ice content permafrost
- Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to gently undulating, channelled; fair to good drainage, high water table; unfrozen
- Ap_1 - Active Floodplain: stratified sand and gravel; flat, channelled; fair drainage, open water, frequently inundated; unfrozen
- Ap_2 - Inactive Floodplain: stratified sand and gravel; flat, channelled; fair to good drainage, high water table, periodically inundated; generally unfrozen, high ice content permafrost beneath organics
- At - Alluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; unfrozen
- Av - Alluvial Veneer: stratified silt, sand and gravel; flat to gently undulating; good drainage; unfrozen

L - Lacustrine and Glaciolacustrine

- Lb - Lacustrine Basin: stratified silt and clay, some sand and organics; flat to depressional, poor drainage; high ice content
- Lp - Glaciolacustrine Plain: stratified silt and clay, minor sand and organics; flat to gently undulating; fair to poor drainage; high ice content

G - Glaciofluvial

- Gm - Glaciofluvial Ridges and Hummocks: stratified sand and gravel, minor silt; undulating to hummocky, some ridges; good drainage; generally unfrozen, patches of low ice content permafrost
- Gp - Glaciofluvial Plain: stratified sand and gravel, minor silt; flat to gently undulating; good drainage; generally unfrozen, patches of low ice content permafrost
- Gt - Glaciofluvial Terrace: stratified sand and gravel, silt veneer; gently undulating; good drainage; generally unfrozen, patches of low ice content permafrost
- Gv - Glaciofluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying material; good drainage; generally unfrozen, patches of low ice content permafrost

M - Morainal

- M - Moraine (undifferentiated): gravelly sandy till; topography obscured by overlying deposits; drainage and ice contents variable
- Ma - Ablation Moraine: gravelly sandy till, granular lenses; rolling with some ridges; good drainage; generally unfrozen, patches of low to medium ice content permafrost
- Mm - Rolling Moraine: gravelly sandy till; undulating to gently rolling; good drainage, high water table locally; patches of low to medium ice content permafrost
- Mp - Moraine Plain: gravelly sandy till; flat to gently undulating; good drainage; generally unfrozen, patches of low to medium ice content permafrost
- Mv - Moraine Veneer: gravelly sandy till; topography reflects underlying bedrock; good drainage; generally unfrozen, patches of low to medium ice content permafrost

Moraine deposits within this region are pre-Wisconsin in origin.

R - Bedrock

- R - Bedrock with little or no soil cover. Lower case prefix indicates rock type, where known, e.g.
  - i - Igneous (undifferentiated)
  - m - Metamorphic (undifferentiated)
  - ss - Sandstone, conglomerate

Erosional Modifiers

- K - Thermokarst features
- C - Channelled

Symbols

- Escarpment
- Borrow pit in drift and rock

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the feature.

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

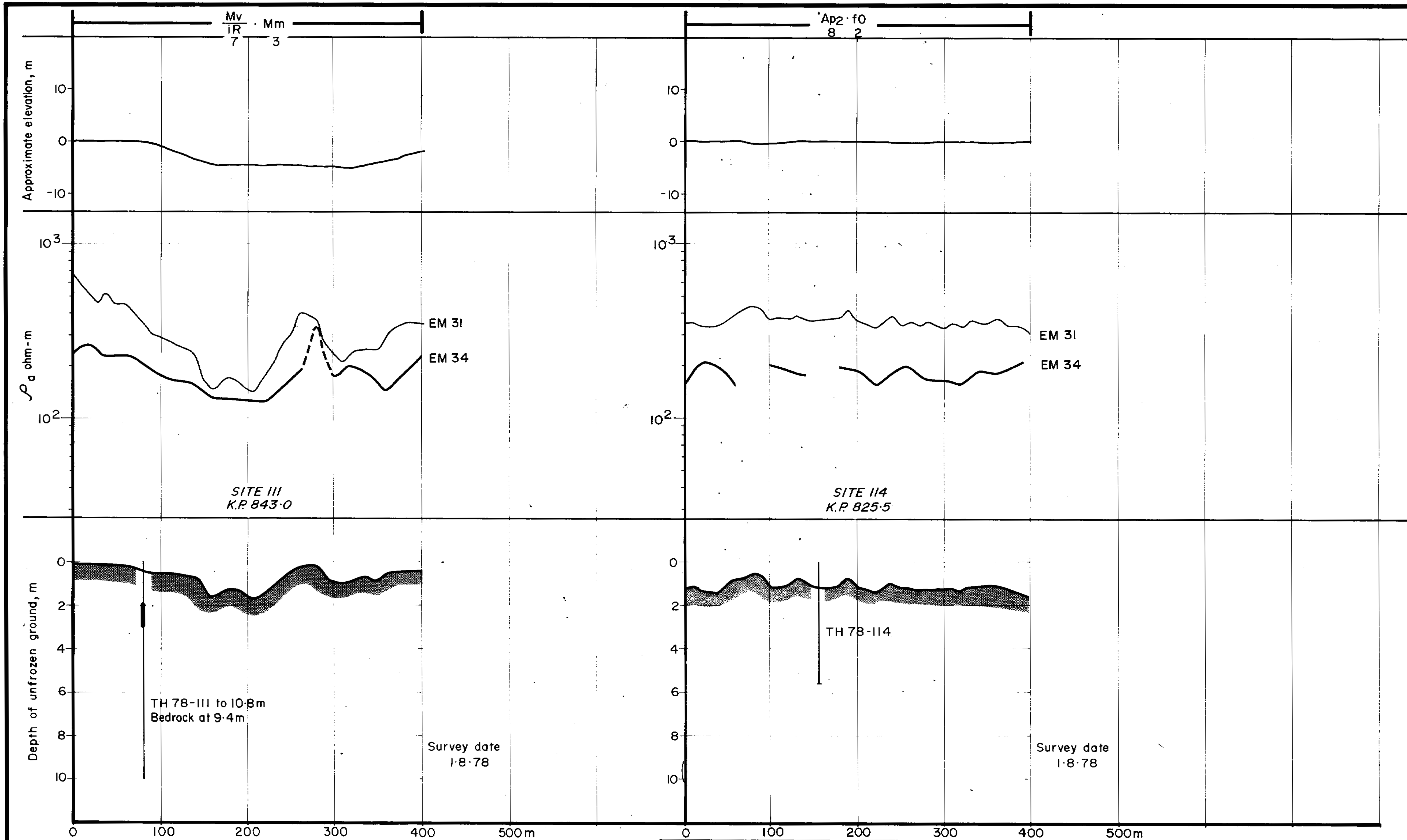
$$Lb_8.pO_2$$

where the subscripts indicate the relative proportions of each. Where subscripts are absent, the proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

$$\text{veneer} \longrightarrow \frac{Ev}{Gp},\ pO\text{-}K \longleftarrow \text{erosional modifier}$$

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·3·1



LEGEND

Unfrozen

Frozen

Top of permafrost table

R.M.HARDY & ASSOCIATES LTD.

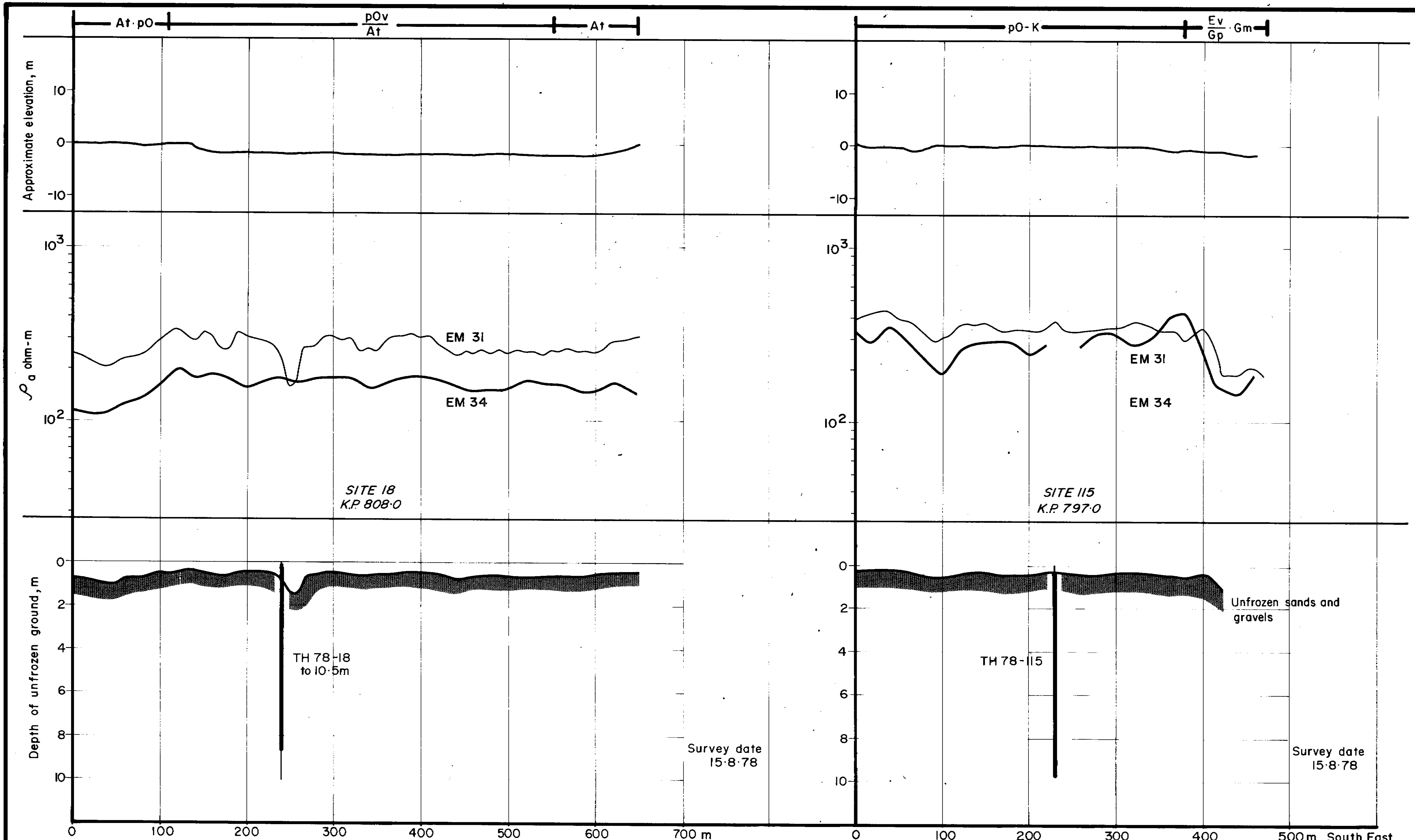
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·9·A



LEGEND

Unfrozen

Frozen

Top of permafrost table

R.M.HARDY & ASSOCIATES LTD.

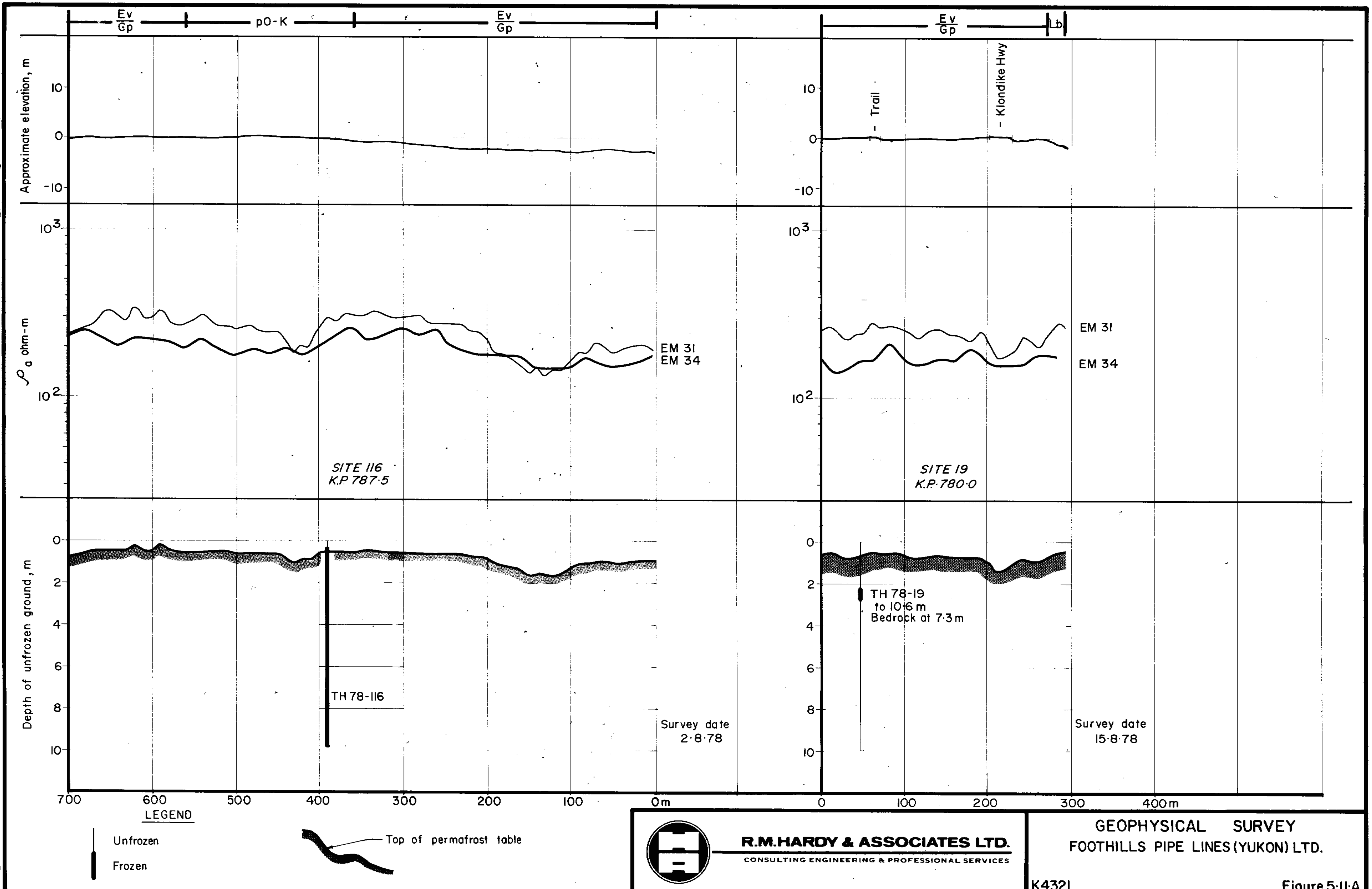
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

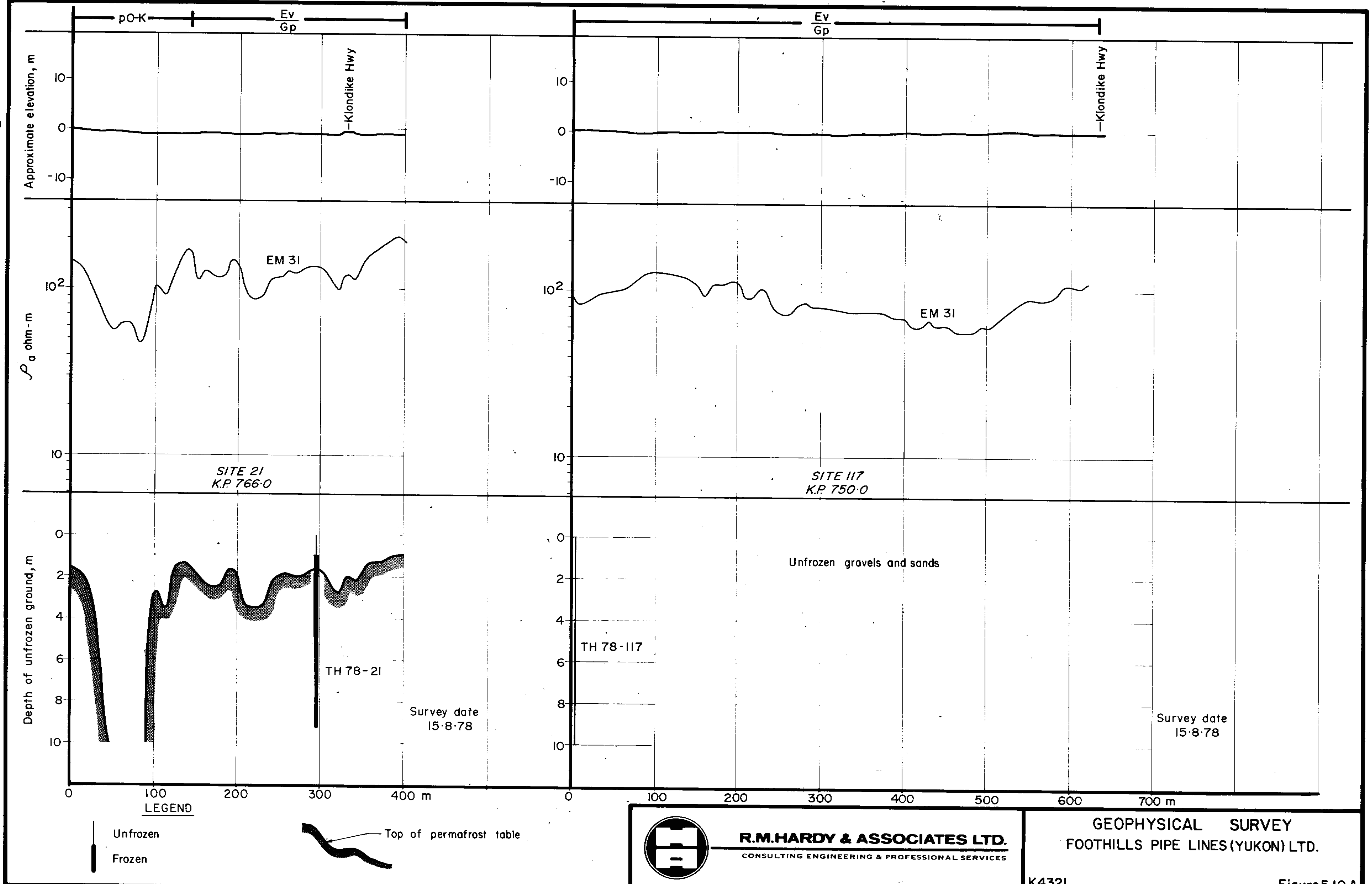
K4321

Figure 5·10·A

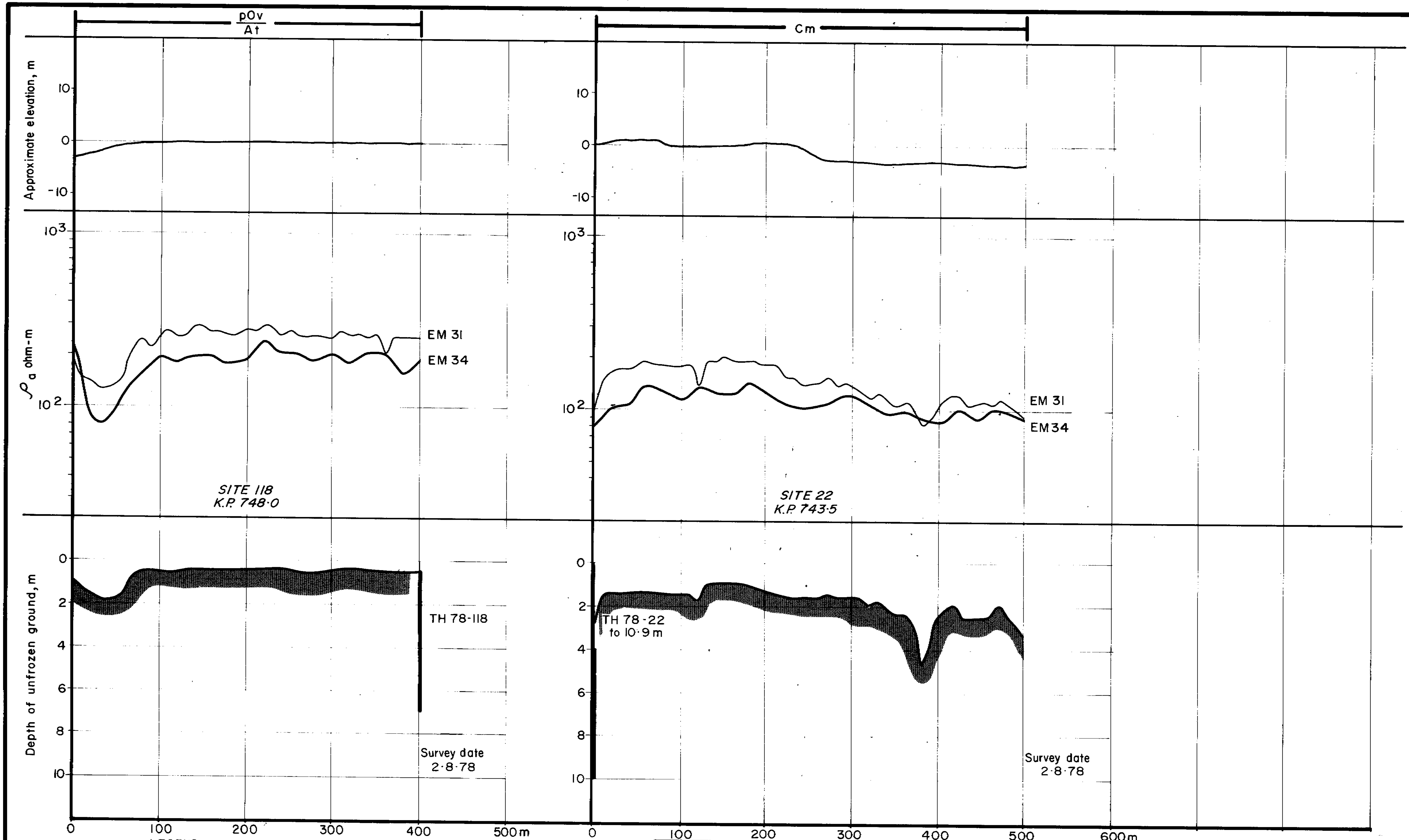


GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

Figure 5·11·A



pO-K
Ev/Gp
Approximate elevation, m
10
0
-10
Klondike Hwy
ρa ohm-m
10^2
10
EM 31
SITE 21
K.P. 766·0
SITE 117
K.P. 750·0
Depth of unfrozen ground, m
0
2
4
6
8
10
TH 78-21
TH 78-117
Unfrozen gravels and sands
Survey date
15·8·78
0
100
200
300
400 m
500
600
700 m
LEGEND
Unfrozen
Frozen
Top of permafrost table
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
K4321
Figure 5·12·A

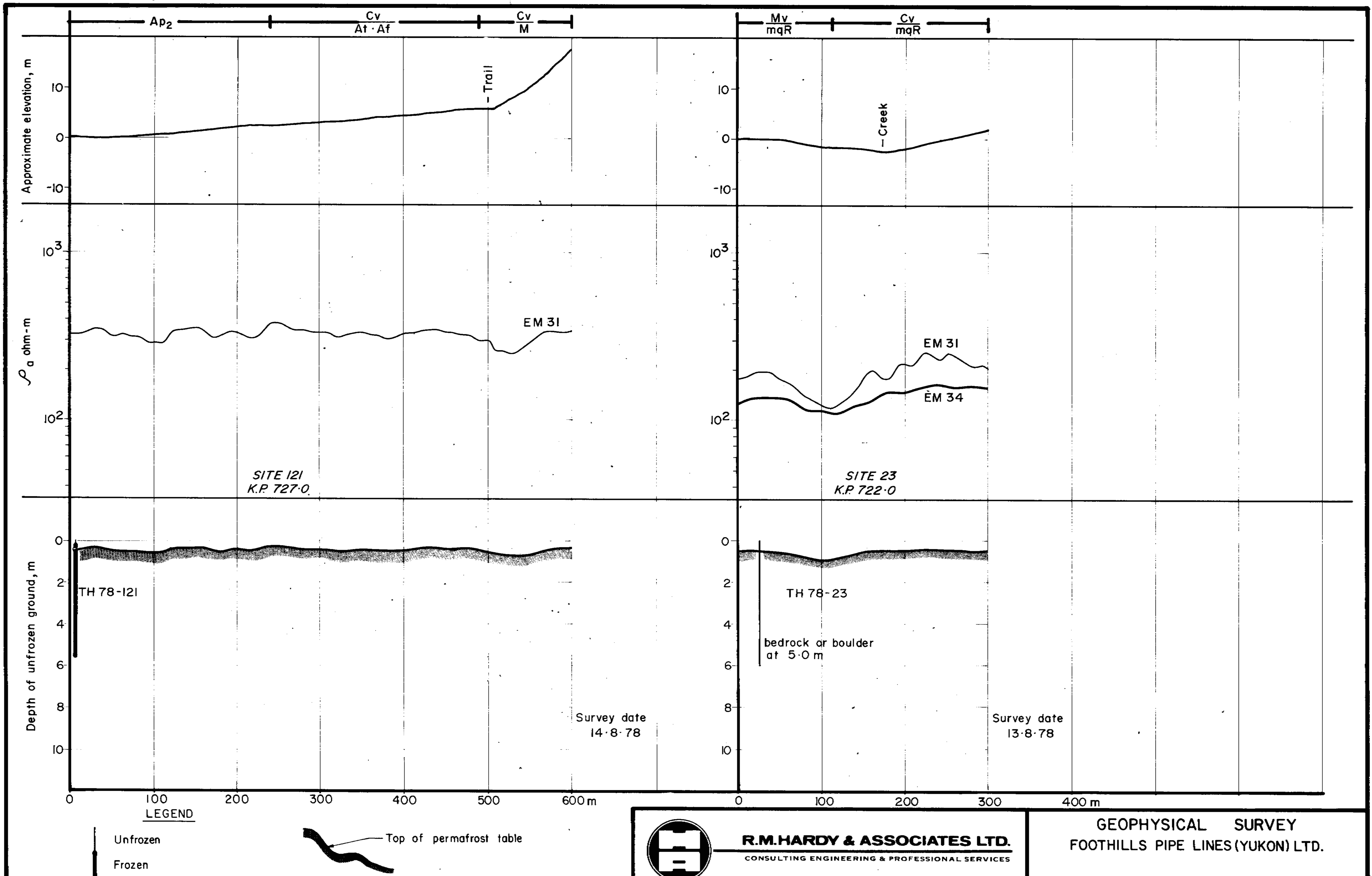


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·13·A



R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·14·A

5.4 Ogilvie Mountains

The terrain typing legend used for geophysical traverses in this region is given in Table 5.4-1.

Site 23 (Figures 5.13, 5.14.A) is in morainal and colluvial terrain. Test hole 78-23 shows silt and clay to 5 m overlying bedrock. The clay apparently has a low water content (~10 percent). The resistivities on this site are high for clays (>100 ohm-m) and for that reason the site is expected to be in permafrost. The survey at site 23 was conducted along the edge of a trail. Permafrost degradation was evident on the centre of the trail by settlement and ponding. Several traverses were run across the trail with the EM31 and these data are shown in Figures 5.14-B and C. These data clearly show the decrease in resistivity over the trail due to permafrost degradation and provide further evidence for the existence of permafrost on this site. Permafrost degradation over the center of the trail is on the order of 1 to 2 metres.

Sites 24, 26, and 123A (Figures 5.13, 5.14, 5.15.A) are over sands and gravel with a veneer of silt. The resistivities are predominantly below 200 ohm-m which would indicate unfrozen sands and gravel. Test holes 78-24 and 78-26 show unfrozen ground.

Site 123 (Figures 5.14, 5.16.A) traverses an active floodplain in the first 20 m and an alluvial fan for its remaining length. The resistivity values over most of the site are about 250 ohm-m and, for that reason, the ground is expected to be in permafrost for most of its length. Unfrozen ground is expected in the first 20 m. Test hole 78-123 shows sands and gravels. In these relatively dry gravels probably only thermistor installations can resolve the contradiction between high resistivity values and test hole logs showing unfrozen gravels.

Site 124 (Figures 5.15, 5.16.A) is in an alluvial floodplain and fan. The soil type was found to be sand and gravel in test hole 78-124 overlain by thin layers of peat and silt. Permafrost is expected over the alluvial fan and unfrozen ground on the floodplain.

Site 28 (Figures 5.15, 5.17.A) traverses morainal and glaciofluvial terrain. Test hole 78-28 shows silt and clay to 2 metres over sand and gravel and is unfrozen. Considering the resistivity data there are several reasons to believe that the ground at this site is frozen. They are:

(a) high EM31 readings (about 300 ohm-m)

(b) EM31 readings higher than EM34 readings, even though there is 2.0 m of clay overlying the gravel. If the clay is unfrozen it would invariably result in EM31 readings well below 100 ohm-m and lower than the EM34 readings.

(c) field observations showed the vegetation to be peat, tussocks and scrub alder typical of permafrost terrain in this region.

(d) Site 31 shows similar soil conditions and resistitivities but the ground in test hole 78-31 is frozen.

Site 29 (Figures 5.16, 5.17.A) traverses rolling moraine terrain. Test hole 78-29 shows 3.5 m of silt and clay overlying sand and gravel. The test hole shows unfrozen ground. The ground at this site is expected to be frozen for the same reasons outlined for site 28.

Site 31 (Figures 5.16, 5.18.A) is in rolling moraine terrain with some patterned ground. Test hole 78-31 shows silt and clay to 3.0 m underlain by gravel. This test hole shows frozen ground. The resistivity values are high so that the entire site is expected to be in permafrost.

Site 32 (Figures 5.17, 5.18.A) is on hummocky moraine and lacustrine terrain. Test hole 78-32 is frozen and shows silt to 5.45 m underlain by gravel. Frozen ground is expected over the entire site.

Site 33 (Figures 5.17, 5.19.A) is in rolling moraine terrain with a veneer of windblown sand and silt. Test hole 78-33 is frozen below 1 m and bedrock was encountered at 4.6 m. From the resistivity data the entire site is expected to be frozen for the first 3 metres and uniform high ice content conditions are expected in the top 3 metres.

Site 125 (Figures 5.17, 5.19.A) is in a glaciofluvial plain with a veneer of organics or windblown silts. Test hole 78-125 is frozen with high ice content silt to 3.55 m with gravels and sands below that depth. The resistivity values (EM31) are very high along this site and uniform high ice content conditions are expected in the upper layers.

Site 34 (Figures 5.18, 5.20.A) crosses an alluvial fan and colluvial terrace with solifluction features. Test hole 78-34 shows 1.5 m of frozen peat underlain by frozen gravel. The high and uniform EM31 values indicate permafrost conditions over the entire site with uniform high ice content conditions near the surface.

Site 127 (Figures 5.18, 5.20.A) is in rolling moraine terrain. On this traverse both EM31 and EM34 values are high and relatively uniform over the site indicating high resistivities to depths in excess of 20 m. Test hole 78-127 shows the high resistivity to be caused by high ice content silts. These high ice content silts are, therefore, expected to a depth of 20 m or more.

Site 132 (Figures 5.19, 5.21.A) crosses a pediment slope and an alluvial terrace. Test hole 78-132, in the pediment slope, shows 2.85 m of frozen peat and silt over frozen gravels. Unfrozen gravels are expected in the old river channel. The EM34 data appear to indicate a fault in the bedrock. Apparently the river coincides with the fault.

Site 135 (Figures 5.19, 5.21.A) is over colluvial terrain. Test hole 78-135 shows organic, high ice content silt to 7.4 m underlain by frozen gravel. A slightly thicker active layer is expected in the resistivity low at station 400 m.

PHYSIOGRAPHIC REGION VII: OGILVIE MOUNTAINS

(Churchward Hill to Benson Creek)

Terrain Types

O - Organic

fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas with high ice content

fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen

pO - Bog: peat; flat to depressional; poor drainage; high ice content

pOv - Bog Veneer: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

Cb(P) - Pediment: silt, sand and clay, with some organics and angular coarse material, overlying bedrock; depth to bedrock from 1 to 12 m, depending on location on pediment surface; gently to moderately sloping; fair drainage; medium to high ice content

Cm - Colluvial Slopewash: predominantly silt and sand; gently to steeply sloping; fair to good drainage; medium to high ice content

Cr - Rock Glacier: angular bedrock fragments, interstitial ice; gently to steeply sloping; good drainage; medium to high ice content; potentially active

Ct - Talus: angular bedrock fragments; steeply sloping; good drainage; low ice content

Cs - Rock Slide: angular bedrock fragments; moderately to steeply sloping; good drainage; low ice content

Cv - Colluvial Veneer: predominantly silt and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

E - Eolian

Ev - Eolian Veneer: wind-blown silt and sand (locally thick); topography generally reflects underlying material; good drainage; medium to high ice content

A - Alluvial

Af - Alluvial Fan: poorly sorted sand and gravel; concave slope; good drainage, some subsurface flow; low ice content

Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to gently undulating, channeled; fair to good drainage, high water table; unfrozen or low ice content

Ap_1 - Active Floodplain: stratified sand and gravel; flat, channelled; fair drainage, open water, frequently inundated; generally unfrozen

Ap_2 - Inactive Floodplain: stratified sand and gravel, silt veneer; gently undulating, channelled; good drainage, periodically inundated; low ice content

At - Alluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; low ice content

Av - Alluvial Veneer: stratified sand, gravel and silt; flat to gently undulating; good drainage; low ice content

L - Lacustrine and Glaciolacustrine

Lb - Lacustrine Basin: stratified silt and clay, some sand and organics; flat to depressional; poor drainage; high ice content

Lp - Glaciolacustrine Plain: stratified silt and clay, minor sand and organics; flat to gently undulating; fair to poor drainage; high ice content

Lv - Lacustrine Veneer: stratified silt and clay, minor sand and organics; flat; fair to poor drainage; high ice content

G - Glaciofluvial

Gm - Glaciofluvial Ridges and Hummocks: stratified sand and gravel, minor silt; undulating to hummocky (kames), some ridges (eskers); good drainage; unfrozen or low ice content permafrost

Gp - Glaciofluvial Plain: stratified sand and gravel, minor silt; level to gently undulating; good drainage; unfrozen or low ice content permafrost

Gt - Glaciofluvial Terrace: stratified sand and gravel, silt veneer; gently undulating; good drainage; unfrozen or low ice content permafrost

Gv - Glaciofluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying material; good drainage; unfrozen or low ice content permafrost

M - Morainal

M - Moraine (undifferentiated): gravelly sandy till; topography obscured by overlying deposits; drainage and ice contents variable

Ma - Ablation Moraine: gravelly sandy till; well drained hummocks, poorly drained depressions; medium to high ice content

Mh - Hummocky Moraine: gravelly sandy till, occasional granular lenses; hummocky; well drained hummocks, poorly drained depressions; medium to high ice content

Mm - Rolling Moraine: gravelly sandy till, organic veneer in depressions; undulating to rolling; fair to good drainage; low to medium ice content

Mr - Ridged Moraine: gravelly sandy till; ridged; well drained; medium to high ice content

Mv - Moraine Veneer: gravelly sandy till; topography reflects underlying material; good drainage; low to medium ice content

R - Bedrock

R - Bedrock with little or no soil cover. Lower case prefix indicates rock type, where known, e.g.

- s - Sedimentary (undifferentiated)
- sc - Limestone, dolomite
- sm - Siltstone, mudstone, shale, argillite
- ss - Sandstone, conglomerate
- m - Metamorphic (undifferentiated)
- mq - Quartzite
- v - Volcanic (undifferentiated)

Erosional Modifiers

K - Thermokarst features

R - Rills

S - Solifluction features

Symbols

- Escarpment
- Canyon
- Meltwater Channel (small)
- Patterned Ground
- Rock glacier
- Esker
- Landslide
- Bedrock Quarry
- Borrow Pit in drift and rock
- Cirque

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the feature.

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

$$Lb_8.pO_2$$

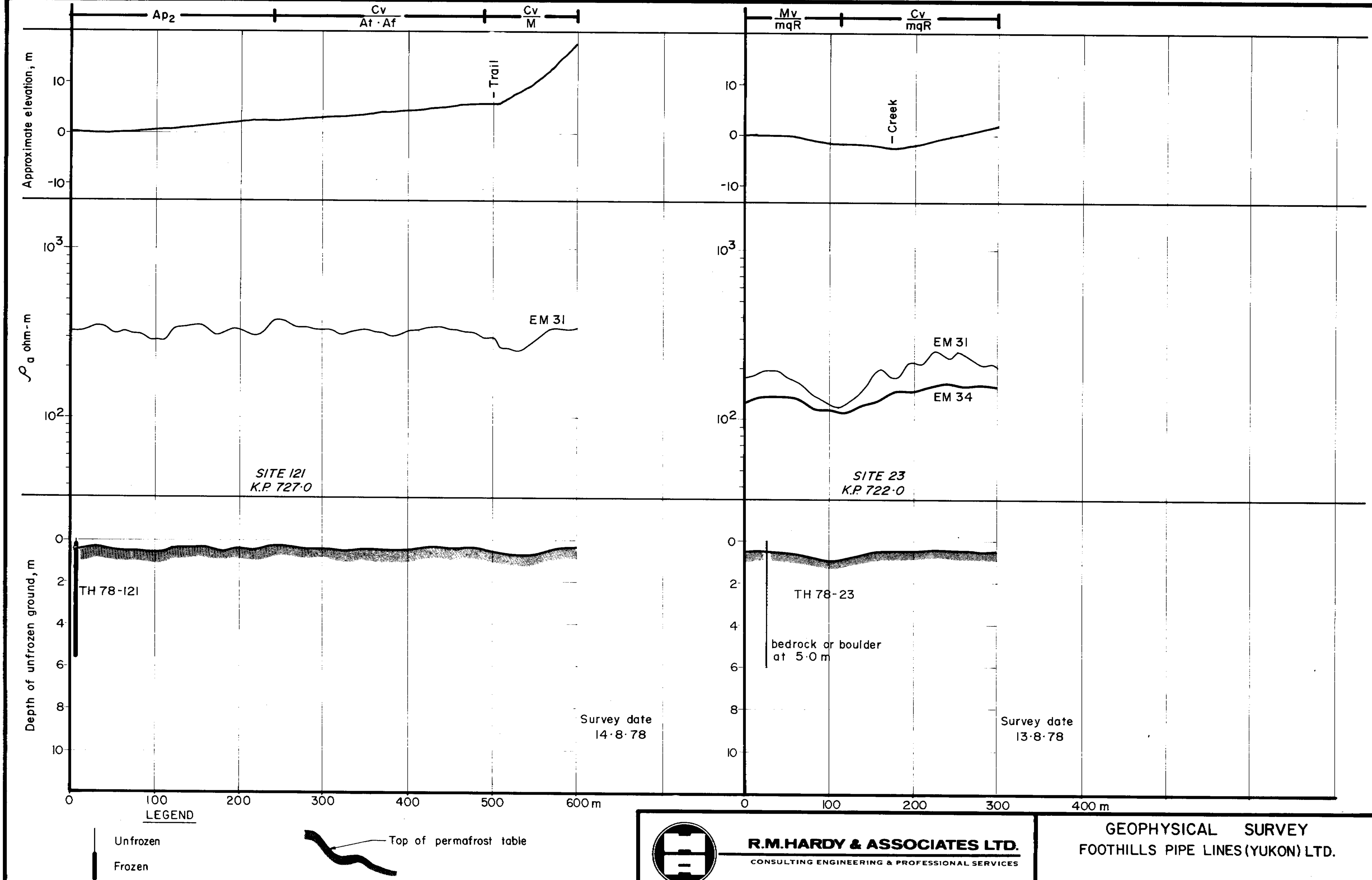
where the subscripts indicate the relative proportions of each. Where subscripts are absent, the proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

veneer $\longrightarrow \frac{Cv}{sR}$, Cb(P)-R

erosional modifier

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·4·1

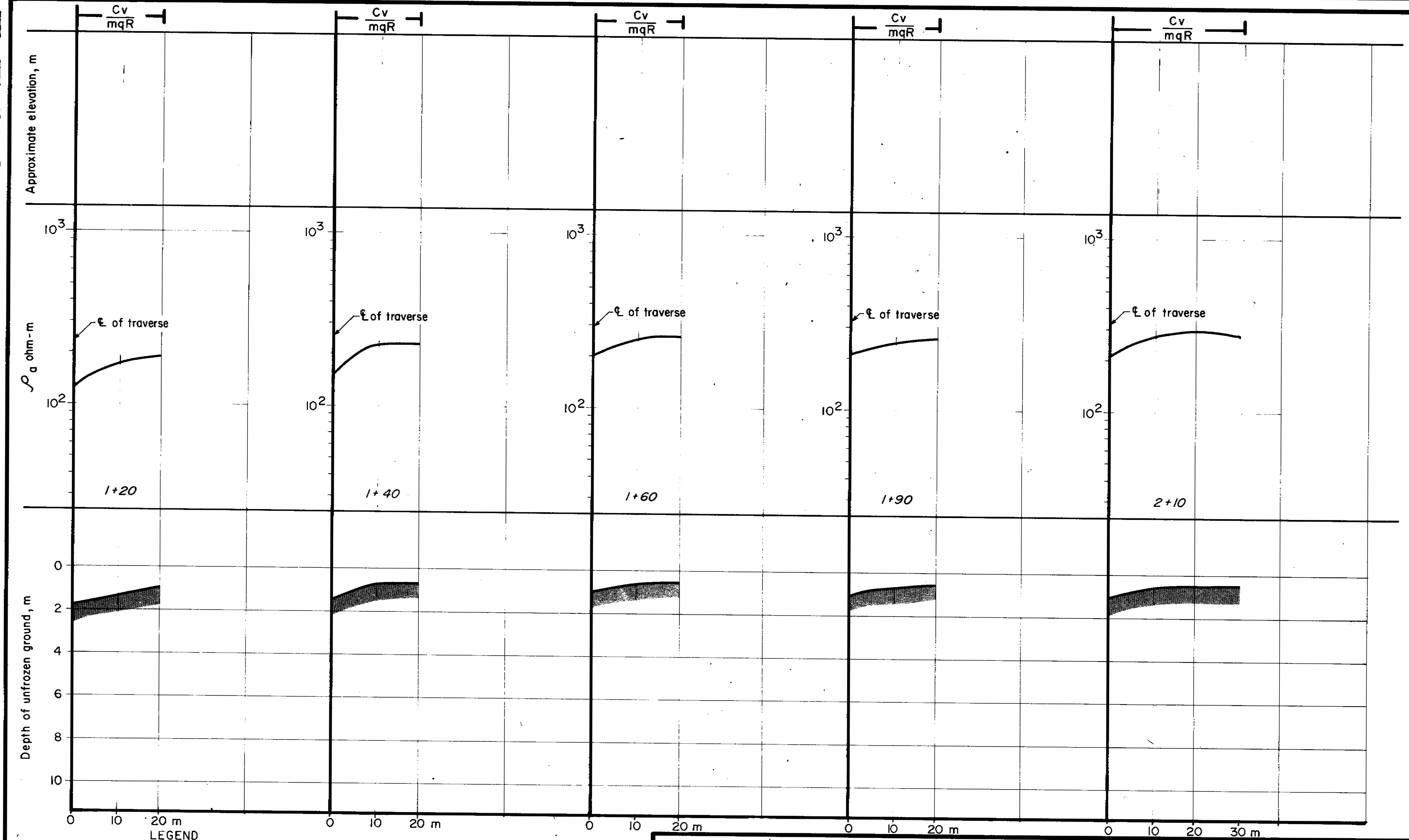


R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5-14A

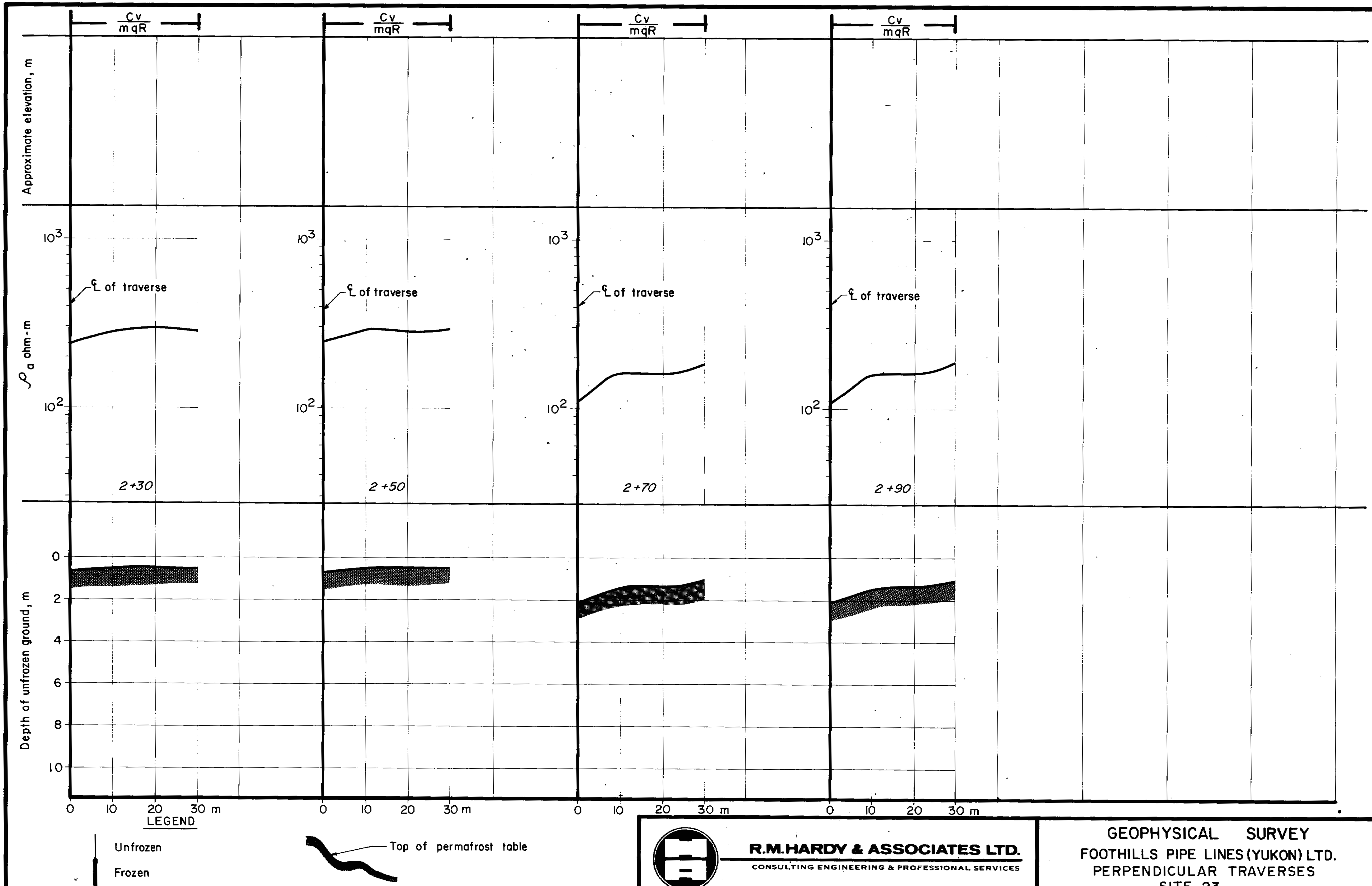


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
PERPENDICULAR TRAVERSES
SITE 23

K4321

Figure 5-14-B

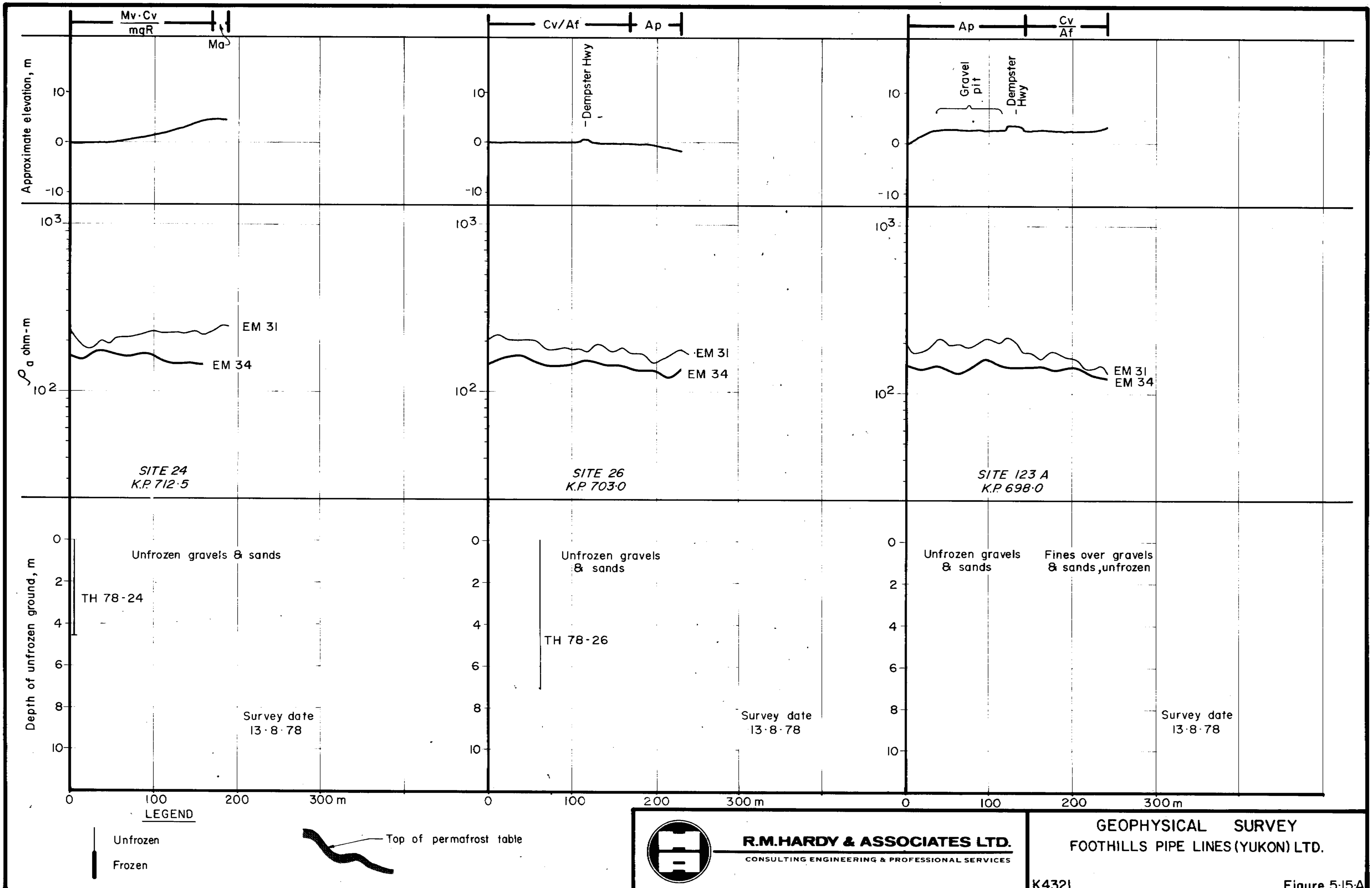


R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
PERPENDICULAR TRAVERSES
SITE 23

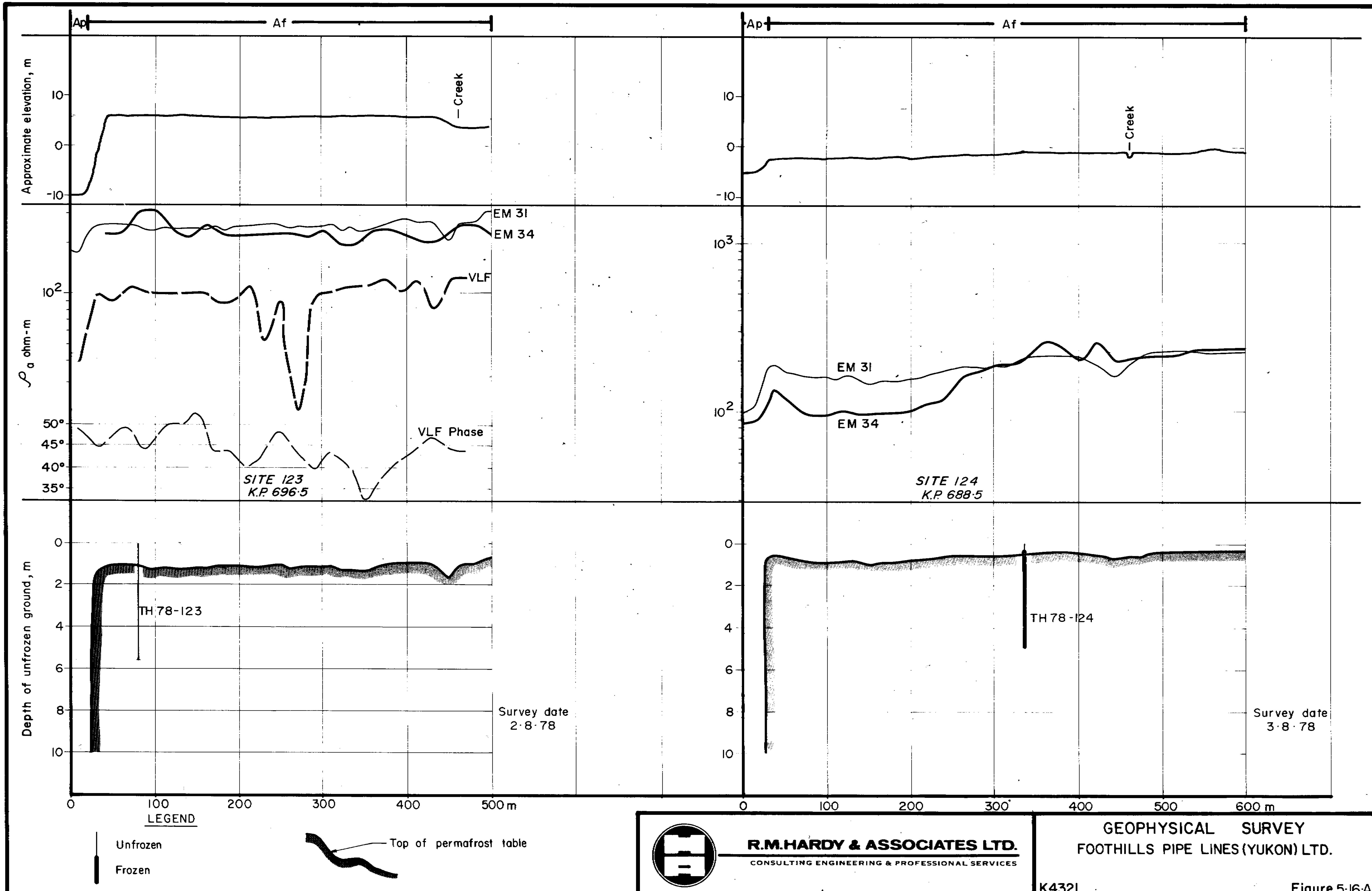
K4321

Figure 5·14·C



Mv·Cv / mgR
Ma
Cv/Af
Ap
Ap
Cv / Af
Approximate elevation, m
10
0
-10
Dempster Hwy
Gravel pit
Dempster Hwy
10^3
10^2
ρ_a ohm-m
EM 31
EM 34
SITE 24
K.P. 712·5
SITE 26
K.P. 703·0
SITE 123 A
K.P. 698·0
Depth of unfrozen ground, m
0
2
4
6
8
10
Unfrozen gravels & sands
TH 78-24
Unfrozen gravels & sands
TH 78-26
Unfrozen gravels & sands
Fines over gravels & sands, unfrozen
Survey date 13·8·78
0
100
200
300 m
LEGEND
Unfrozen
Frozen
Top of permafrost table
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
K4321

Figure 5·15·A

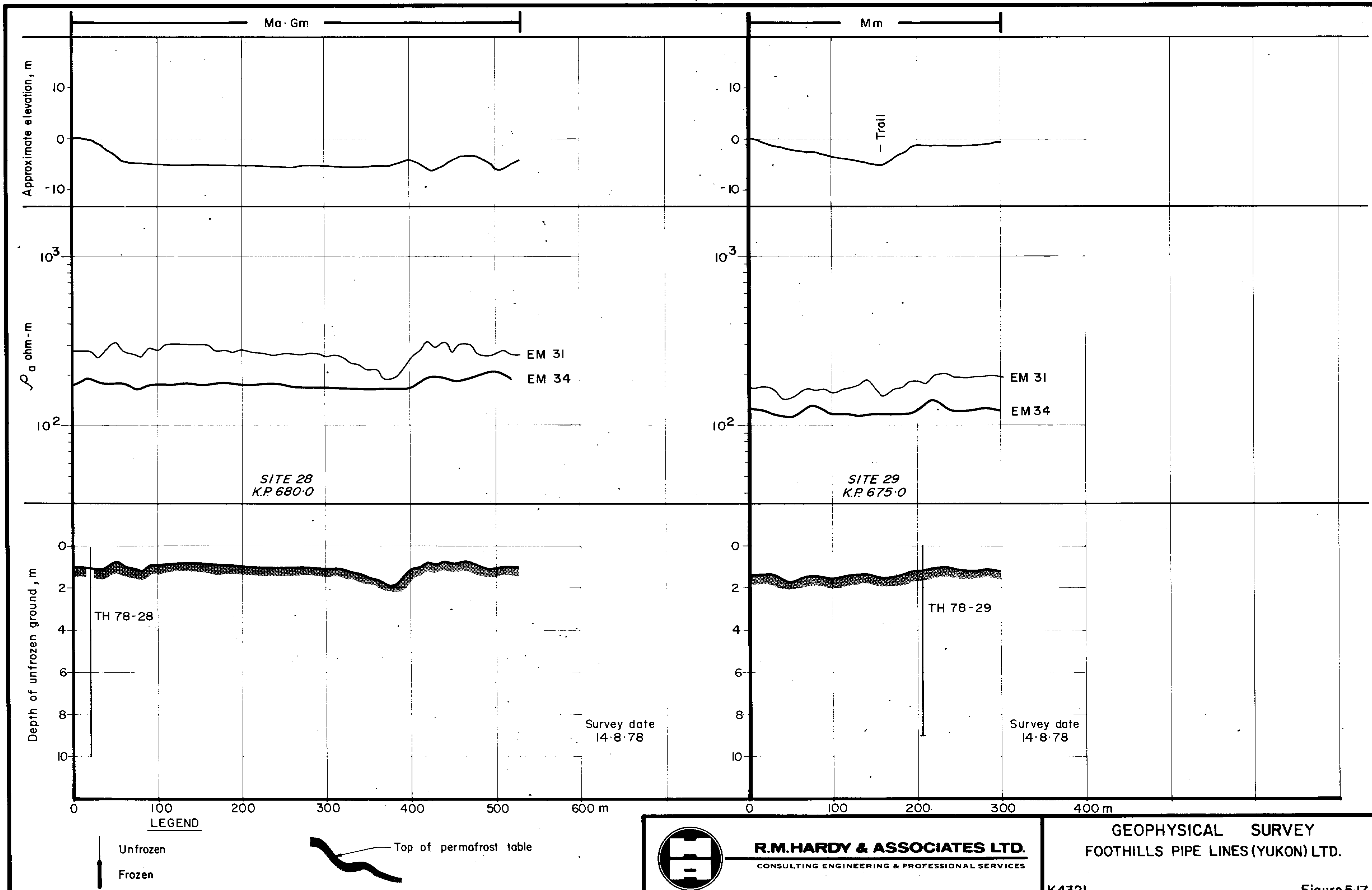


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·16·A



R.M.HARDY & ASSOCIATES LTD.

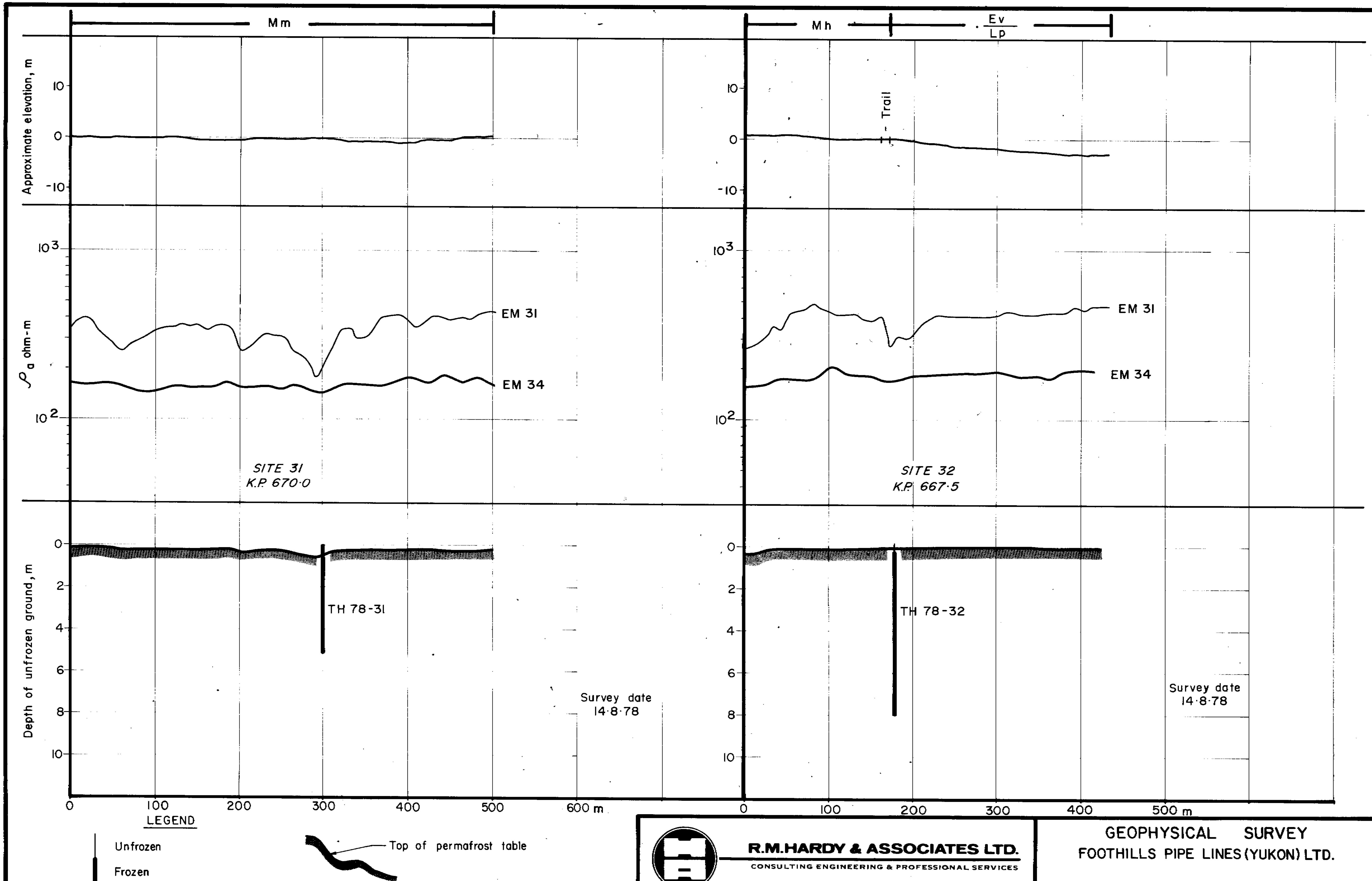
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·17·A

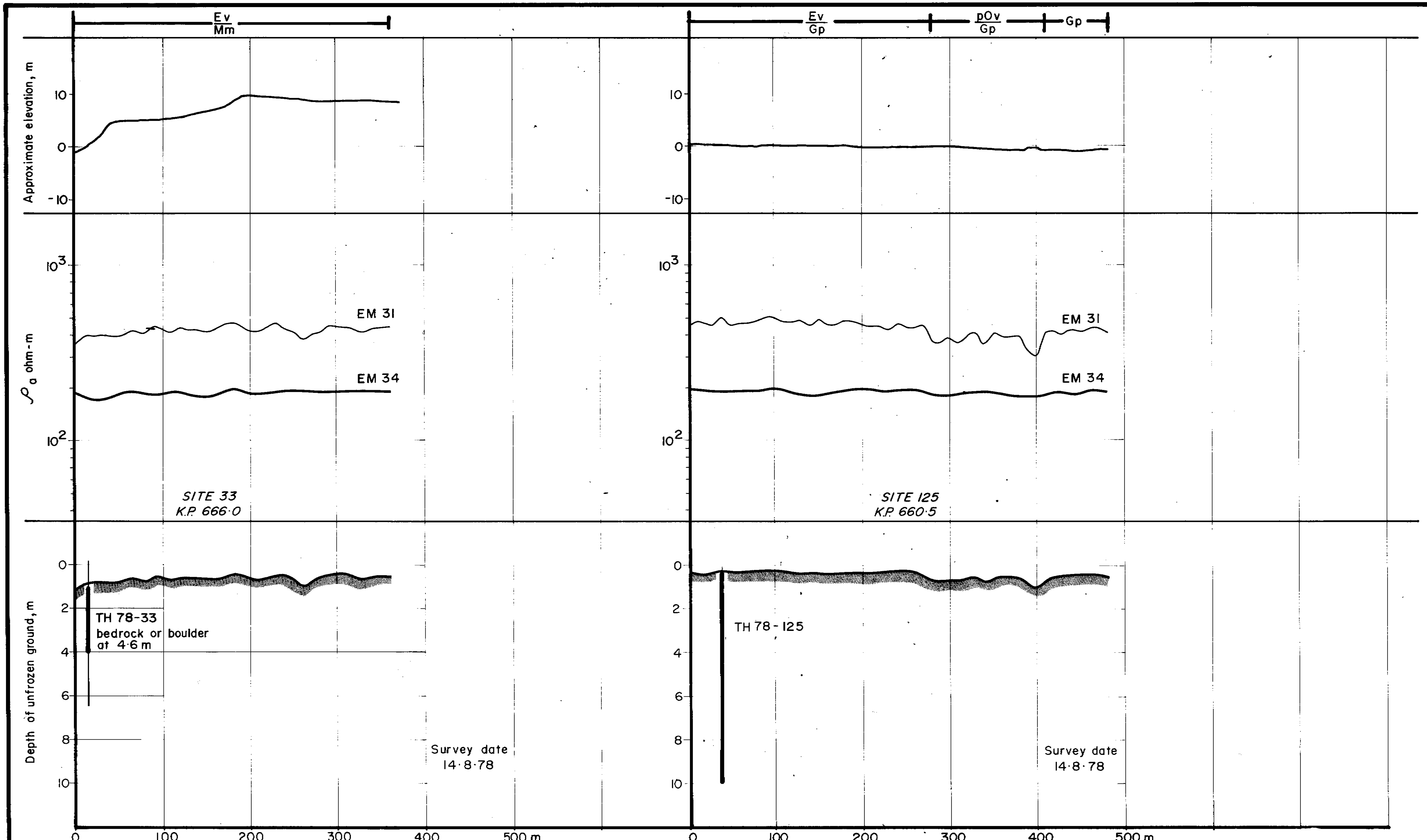


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·18·A

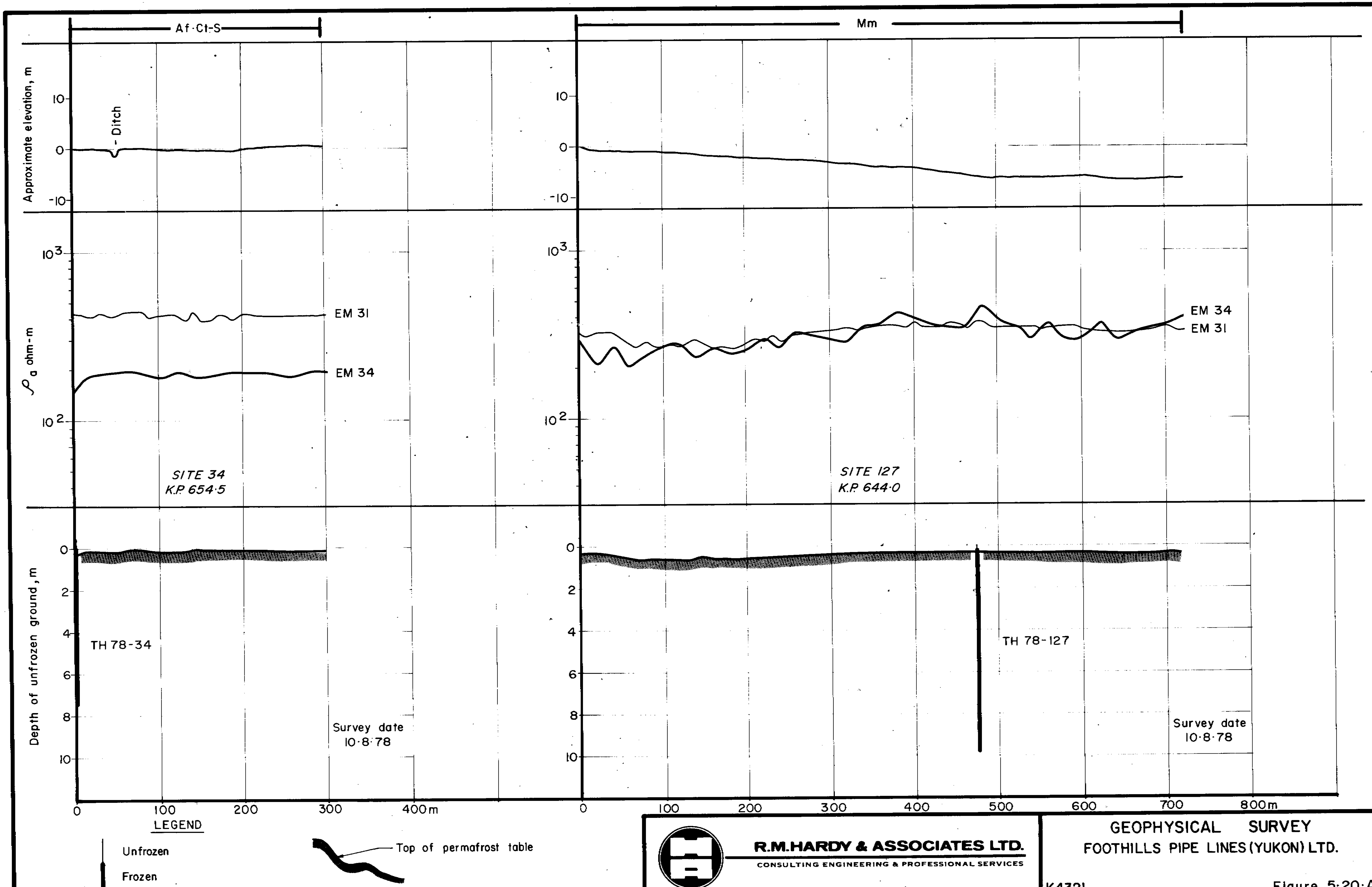


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·19·A

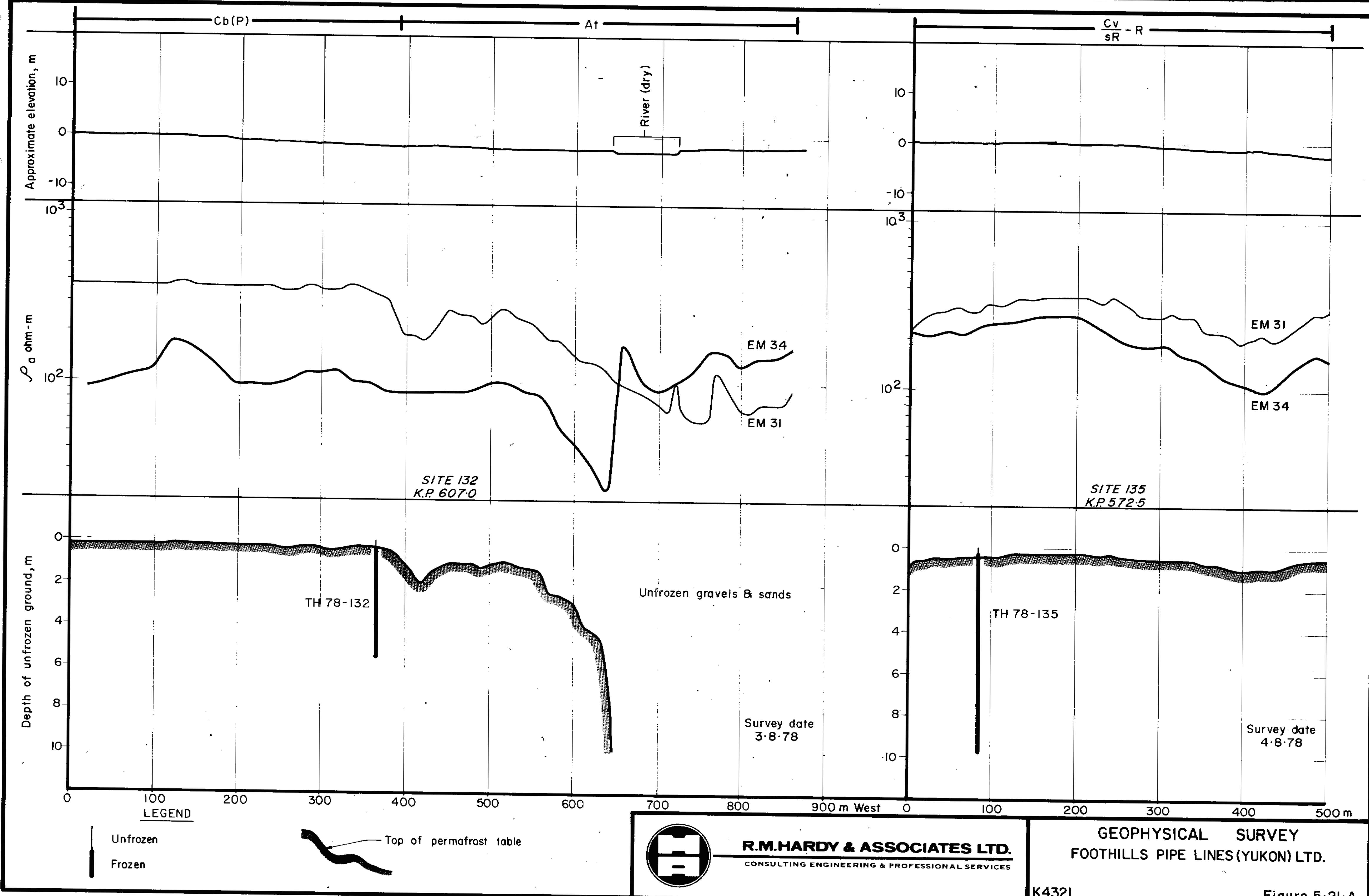


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·20·A



R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·21·A

5.5 Porcupine Plateau

The terrain typing legend used for geophysical traverses in this region is given in Table 5.5-1.

Site 149 (Figures 5.20, 5.22.A) crosses an alluvial fan with a thin layer of organic material. Test hole 78-149 shows frozen organics to 0.8 m underlain by frozen gravel. The resistivities observed would indicate that the frozen materials of the fan are relatively dirty gravels.

Site 152 and 153 (Figures 5.20, 5.22.A) traverses colluvial material in bedrock controlled terrain. On this site VLF measurements were made in addition to magnetic induction soundings. The VLF measurements have been used (particularly the phase) to compute depth to bedrock. Bedrock was encountered in test hole 78-153 at 11 m and at test hole 78-152 bedrock was not encountered to depth (10.3 m).

Site 154 and 155 (Figures 5.21 and 5.23.A) is mapped as a colluvial blanket over bedrock controlled terrain. Shale bedrock was encountered in test hole 78-154 at 4.25 m and sandstone over shale in test hole 78-155 at 5 m. The colluvial cover was frozen in both test holes. VLF radiohm data, particularly the VLF phase, and EM34 data have been used to estimate depth to bedrock. There is probably a change in bedrock type between station 400 m and 600 m.

Site 163 (Figures 5.21, 5.23.A) traverses a colluvial veneer over shallow bedrock and then thicker colluvial deposits. Test hole 78-163 encountered bedrock at 8.5 m. The VLF radiohm data has been mainly used to estimate depth to bedrock.

Site 165 (Figures 5.22, 5.24.A) is in colluvium over bedrock. Bedrock was encountered in test hole 78-165 at 16 m. The VLF radiohm data has mainly been used to map depth to bedrock along the profile. Bedrock is expected closer (<10 m) to the surface from station 200 m on. Under the Dempster Highway degradation in permafrost is expected and this is mainly reflected in the EM31 data.

Site 167 (Figures 5.22, 5.24.A) is in an alluvial terrace with a thin colluvial veneer. Test hole 78-167 encountered bedrock (shale) at 6.8 metres. The VLF radiohm data was used to arrive at a bedrock profile.

Site 168 (Figures 5.22, 5.25.A) is in shallow bedrock with a colluvial veneer. Test hole 78-168 encountered shale and siltstone at 4.85 m. Bedrock is expected to outcrop between stations 400 m and 500 m.

PHYSIOGRAPHIC REGION VI: PORCUPINE PLATEAU (EAGLE PLAIN)

(20 km N of Eagle River to Churchward Hill)

Terrain Types

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas of high ice content
- fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen
- pO - Bog: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

- Cb(P) - Pediment: silt, sand and clay, with some organics and angular coarse material, overlying bedrock; depth to bedrock from 1 to 12 m, depending on location on pediment surface; gently to moderately sloping; fair drainage; medium to high ice content
- Cm - Colluvial Slopewash: predominantly silt and sand; gently to steeply sloping, fair to good drainage; medium to high ice content
- Ct - Talus: angular bedrock fragments, silt and sand matrix; steeply sloping; good drainage; low ice content
- Cv - Colluvial Veneer: colluvium, predominantly silt and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

A - Alluvial

- Af - Alluvial Fan: poorly sorted sand and gravel; concave slope; good drainage, some subsurface flow; low ice content
- Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to gently undulating, channelled; fair to good drainage, high water table; unfrozen or low ice content
- Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat, channelled; fair drainage, open water; frequently inundated; generally unfrozen
- Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; gently undulating, channeled; fair to good drainage, periodically inundated; low ice content
- At - Alluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; low ice content
- Av - Alluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying material; good drainage; low ice content

L - Lacustrine

- Lv - Lacustrine Veneer: stratified silt and clay, minor sand and organics; flat to depressional; fair to poor drainage; high ice content

R - Bedrock

- R - Bedrock, with little or no soil cover. Lower case prefix indicates rock type, where known, e.g.
  - s - Sedimentary (undifferentiated)
  - sm - Siltstone, mudstone, shale, argillite
  - sm,ss - Siltstone, mudstone, shale and argillite, some sandstone and conglomerate
  - ss,sm - Sandstone and conglomerate, minor siltstone, mudstone, argillite and shale

Erosional Modifier

- K - Thermokarst features

Symbols

- Escarpment
- Quarry in rock
- Spoil Pile
- Slide

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the features.

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

$$Lb_8.pO_2$$

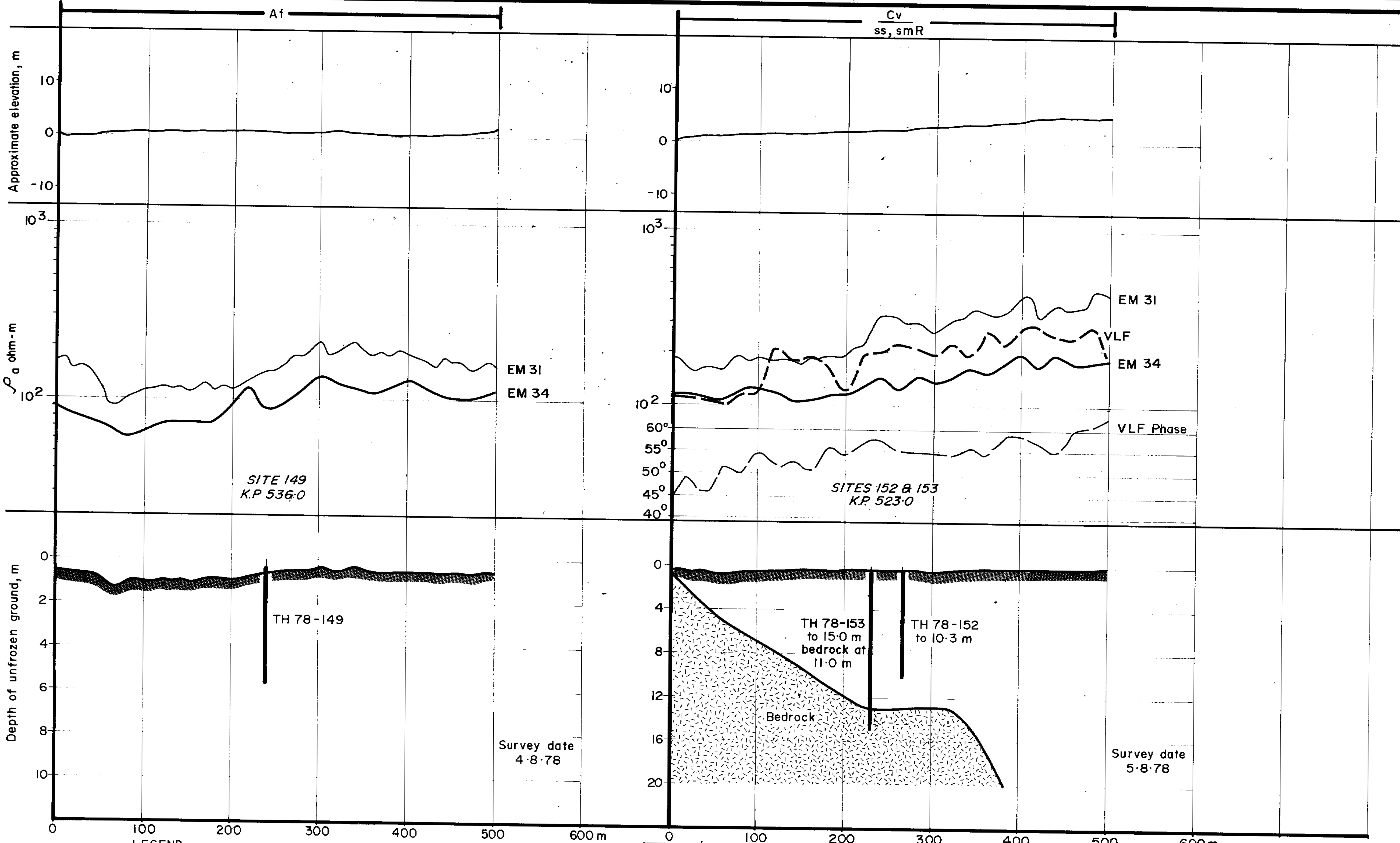
where the subscripts indicate the relative proportions of each. Where subscripts are absent, proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

$$\text{veneer} \longrightarrow \frac{Cv}{ss,smR}, \; Cm.Ap.pO\text{-}K$$

erosional modifier

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·5·1



LEGEND

Unfrozen

Frozen

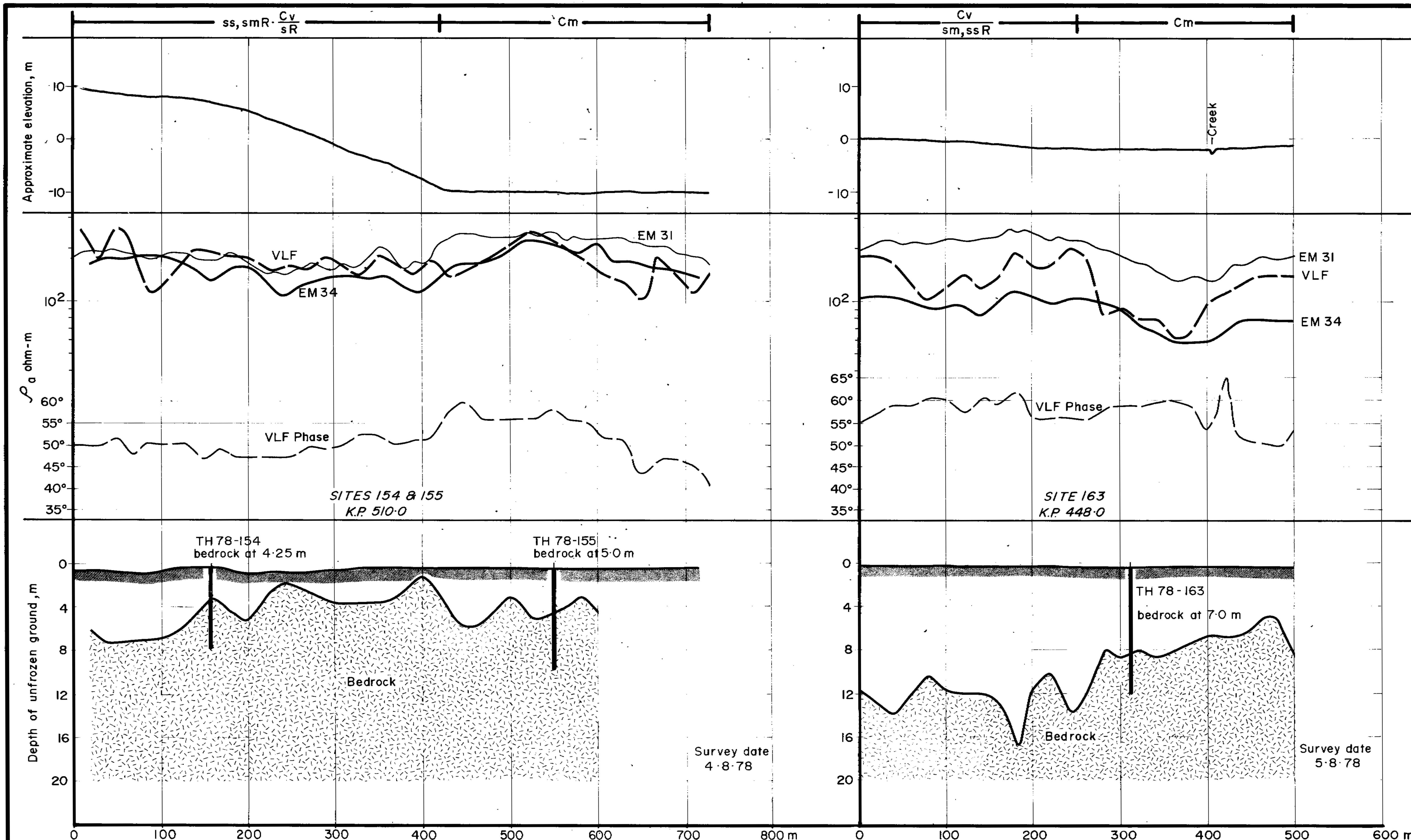
Top of permafrost table

R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·22·A



LEGEND

Unfrozen

Frozen

Top of permafrost table

R.M. HARDY & ASSOCIATES LTD.

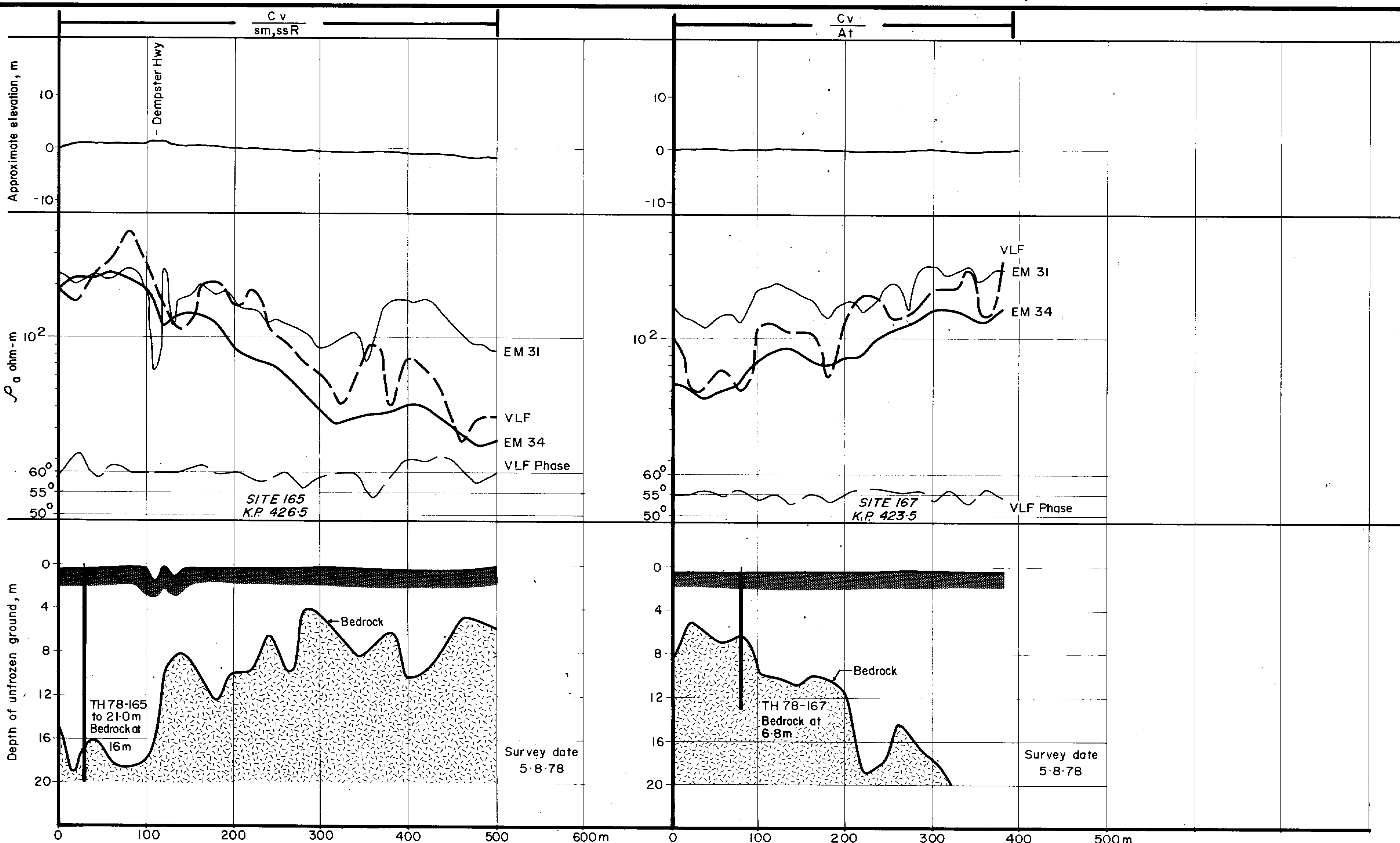
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·23·A



LEGEND

Unfrozen

Frozen

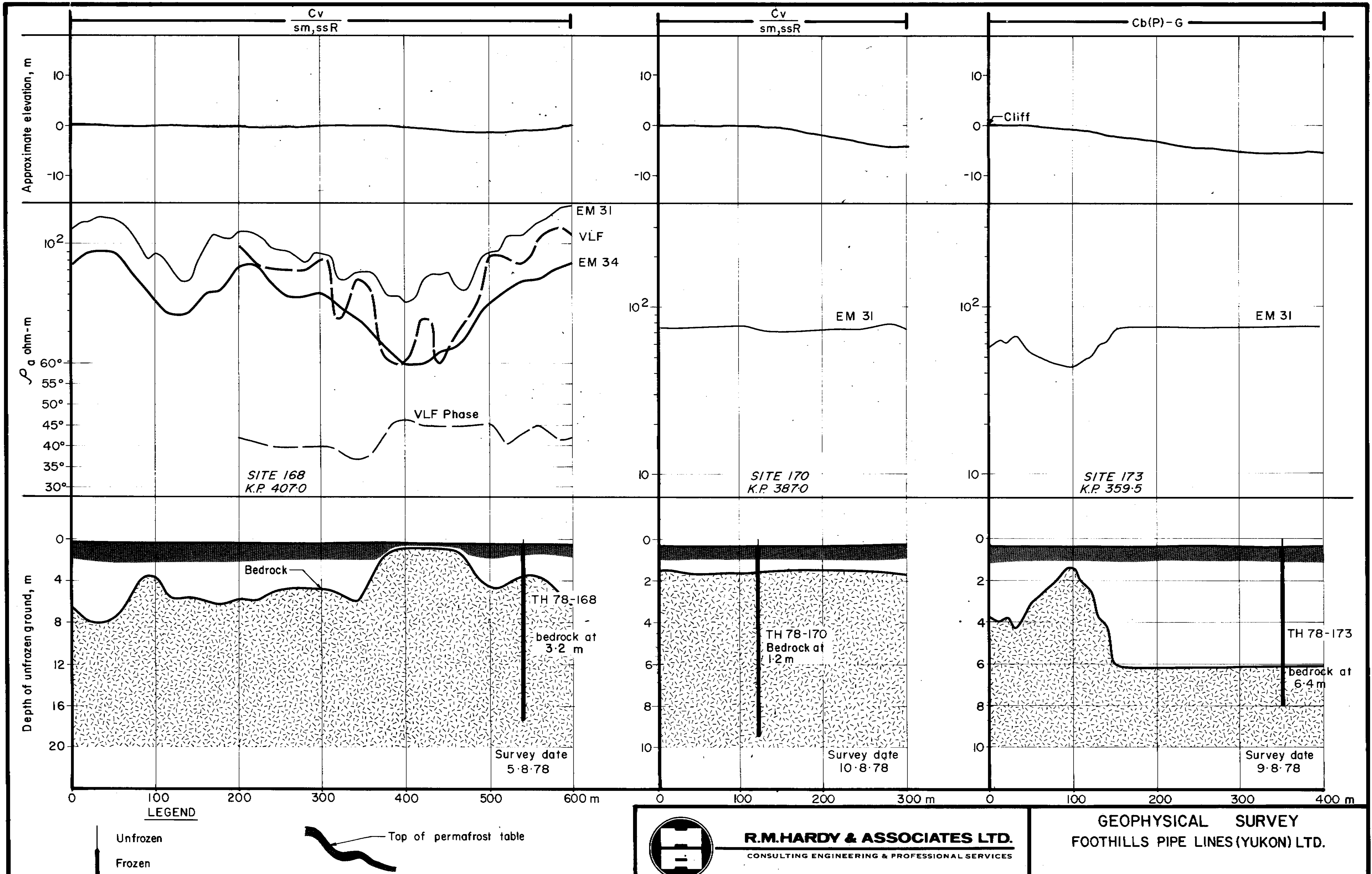
Top of permafrost table

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·24·A



R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·25·A

5.6 Richardson Mountains

The terrain typing legend used for geophysical traverses in this region is shown on Table 5.6-1.

Site 170 (Figures 5.23, 5.25.A) is in shallow bedrock with a colluvial veneer. Only EM31 data is available at this site. Because the resistivities are uniform over the site bedrock is expected uniformly near the surface.

Site 173 (Figure 5.23, 5.25.A) is in a pediment with bedrock expected near the surface. Test hole 78-173 encountered bedrock at 6.4 metres. Bedrock is expected closer to the surface around station 100 m and is exposed in the cliff adjacent to station 0.

Site 175 and 176 (Figures 5.24, 5.26.A) is in a pediment with shallow bedrock. Test holes 78-175 and 78-176 encountered bedrock at 2.0 m and 2.5 m, respectively. Since both the EM31 and EM34 resistivities are uniform across the site, bedrock is expected within 2 m to 3 m depths along the entire traverse.

PHYSIOGRAPHIC REGION V: RICHARDSON MOUNTAINS

(40 km W of Peel River to 20 km N of Eagle River)

Terrain Types

O - Organic

pOv - Bog Veneer: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

Cb(P) - Pediment: silt, sand, and clay, with some organics and coarse angular material, overlying bedrock; depth to rock from 1 to 12 m, depending on location on pediment surface; gently to moderately sloping; fair drainage; medium to high ice content

Cm - Colluvial Slopewash: predominantly silt, clay and sand; gently to steeply sloping; fair to good drainage; medium to high ice content

Ct - Talus: angular bedrock fragments, silt and sand matrix; steeply sloping; good drainage; low ice content

Cv - Colluvial Veneer: predominantly silt, clay and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

A - Alluvial

Af - Alluvial Fan: poorly sorted sand and gravel; concave slope; good drainage, some subsurface flow; low ice content

Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to undulating, locally channelled; fair to good drainage, high water table; unfrozen or low ice content

Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat to undulating; fair drainage, with open water; frequently inundated; generally unfrozen

Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; fair to good drainage, periodically inundated; low ice content

At - Alluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; low ice content

Av - Alluvial Veneer: stratified sand and gravel, minor silt; topography reflects underlying material; good drainage; low ice content

G - Glaciofluvial

Gp - Glaciofluvial Plain: stratified sand and gravel, minor silt; level to gently undulating; good drainage; low ice content

M - Morainal

Mv - Moraine Veneer: silty, clay till; topography reflects underlying bedrock; fair to good drainage; low to medium ice content

R - Bedrock

R - Bedrock with little or no cover. Lower case prefix indicates rock type where known, e.g.

- s - Sedimentary rock (undifferentiated)
- sm - Siltstone, mudstone, shale, argillite
- ss - Sandstone and conglomerate
- ss,sm - Sandstone and conglomerate, some siltstone, mudstone, shale and argillite
- sm,ss - Siltstone, mudstone, shale and argillite, some sandstone and conglomerate

Erosional Modifiers

G - Gullied

S - Solifluction features

R - Rills

Symbols

Escarpment

Slide

Quarry in rock

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the feature.

Complex Units

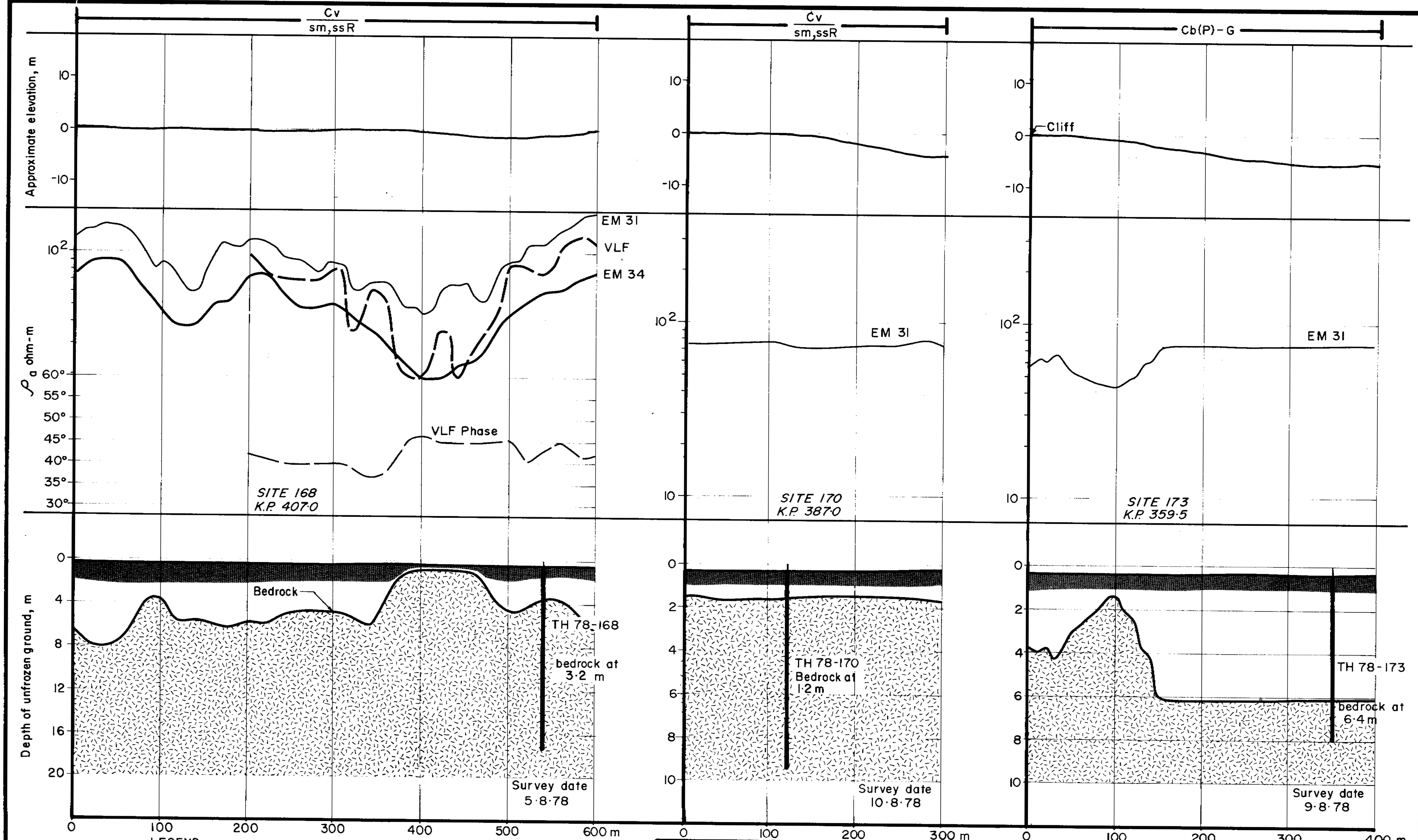
Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

$$Lb_8.pO_2$$

where the subscripts indicate the relative proportions of each. Where subscripts are absent, the proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers, are indicated as follows:

$$\text{veneer} \longrightarrow \frac{Cv}{ss,smR}\text{, Cb(P)-G}$$

erosional modifier



LEGEND

Unfrozen

Frozen

Top of permafrost table

R.M.HARDY & ASSOCIATES LTD.

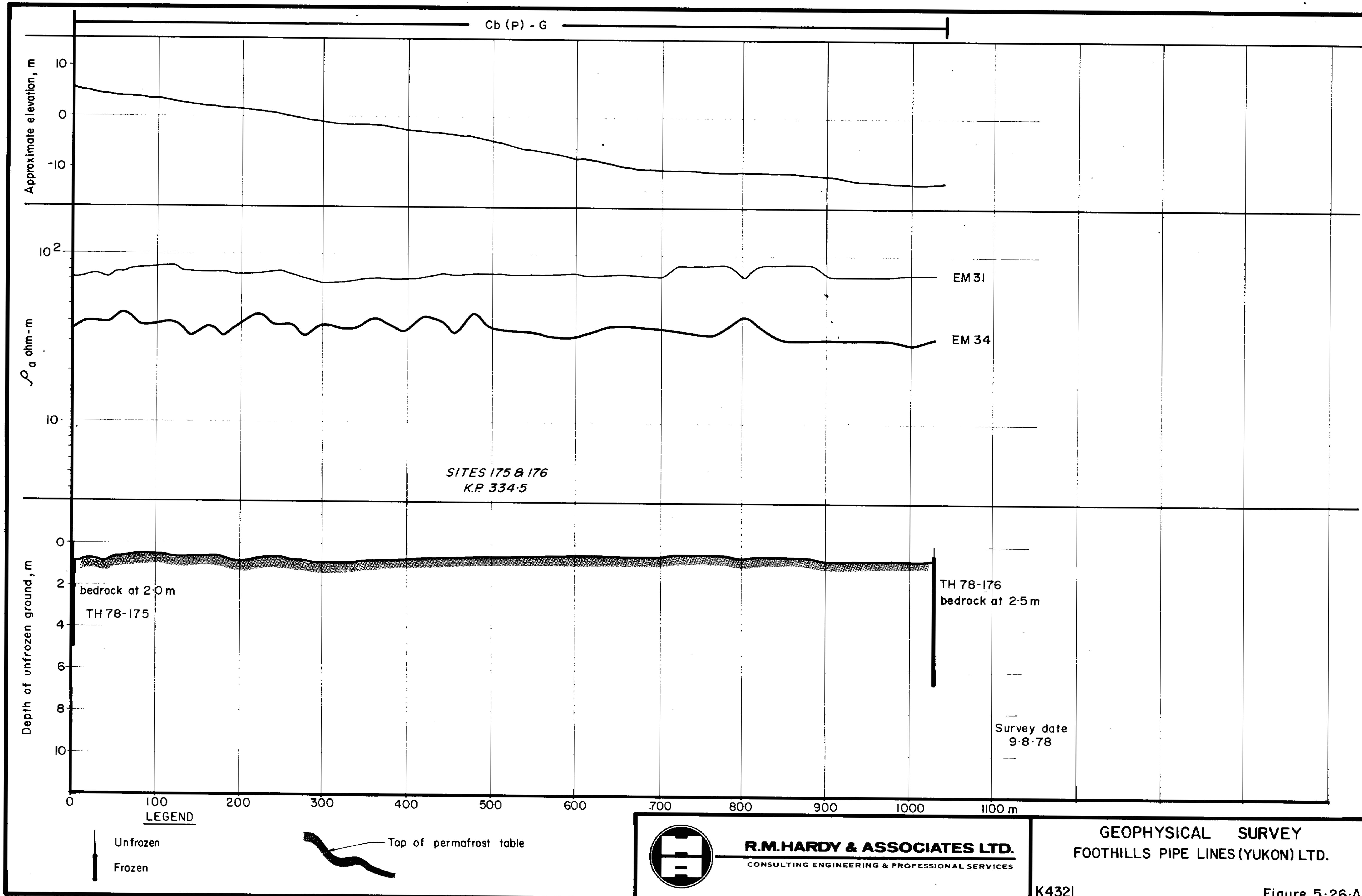
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·25·A


Cb (P) - G
Approximate elevation, m
10
0
-10
10^2
ρ_a ohm-m
10
EM 31
EM 34
SITES 175 & 176
K.P. 334·5
Depth of unfrozen ground, m
0
2
4
6
8
10
bedrock at 2·0 m
TH 78-175
TH 78-176
bedrock at 2·5 m
Survey date
9·8·78
0
100
200
300
400
500
600
700
800
900
1000
1100 m
LEGEND
Unfrozen
Frozen
Top of permafrost table
R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
K4321
Figure 5·26·A

5.7 Peel Plateau

The terrain typing legend used for geophysical traverses in this region is listed on Table 5.7-1.

Site 179 (Figures 5.24, 5.27.A) is in an alluvial floodplain. Test hole 78-179 shows high ice content silts, sands and clays to depth (15.2 m). The very high EM31 resistivities (>300 ohm-m) reflect this high ice content. The variation in EM31 resistivity is expected to relate to ice content with the highest ice contents expected at resistivities above 1000 ohm-m. Because both VLF and EM34 data are considerably lower than EM31 data, high ice content is expected for the first 10 m only.

Sites 184 and 184A (Figures 5.25, 5.27.A) are in thin till and colluvium over bedrock. Test hole 78-184 encountered bedrock at 2.0 m. Depth to bedrock has been modeled from both EM31 and EM34 data.

Site 185 (Figures 5.25, 5.28.A) is in till over shallow bedrock. Test hole 78-185 encountered bedrock at 11.9 m. To model depth to bedrock the same resistivity stratification as employed on site 184 was used.

PHYSIOGRAPHIC REGION IV: PEEL PLATEAU

(2.1 km W of Peel River to 40 km W of Peel River)

Terrain Types

O - Organic

fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas with high ice content

C - Colluvial

Cb(P) - Pediment: silt, sand and clay, with some organics and angular coarse material, overlying bedrock; depth to bedrock from 1 to 12 m, depending on location on pediment surface; gently to moderately sloping; fair drainage; medium to high ice content

Cf - Flow Slide: gravity-transported clay to gravel sizes; moderately sloping; fair to poor drainage; medium to high ice content

Cm - Colluvial Slopewash: predominantly silt, clay and sand; gently to steeply sloping; fair to good drainage; medium to high ice content

Cv - Colluvial Veneer: predominantly silt, clay and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

A - Alluvial

Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat to undulating, channelled; fair to good drainage, high water table; unfrozen or low ice content

Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat to undulating, channelled; fair drainage with open water, frequently inundated; generally unfrozen

Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; flat to undulating, channelled; fair to good drainage, periodically inundated; low to medium ice content

M - Morainal

Mm - Rolling Moraine: silty clay till, organic veneer common in depressions; undulating to rolling; fair to good drainage; medium to high ice content

Mp - Moraine Plain: silty clay till; flat to gently undulating; fair to good drainage; low to high ice content, mostly medium

Mv - Moraine Veneer: silty clay till; topography reflects underlying bedrock; fair to good drainage; low to high ice content, mostly medium

R - Bedrock

R - Bedrock with little or no cover. Lower case prefix indicates rock type, where known, e.g.

- s - Sedimentary rock (undifferentiated)
- sm - Siltstone, mudstone, shale, argillite
- ss,sm - Sandstone and conglomerate; some shale, siltstone, mudstone and argillite

Modifiers

K - Thermokarst features

G - Gullied

R - Rills

Symbols

Escarpment

Borrow Pit in drift and rock

Quarry in rock

Symbols indicate the location of prominent features and do not necessarily correspond to the size of the feature.

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

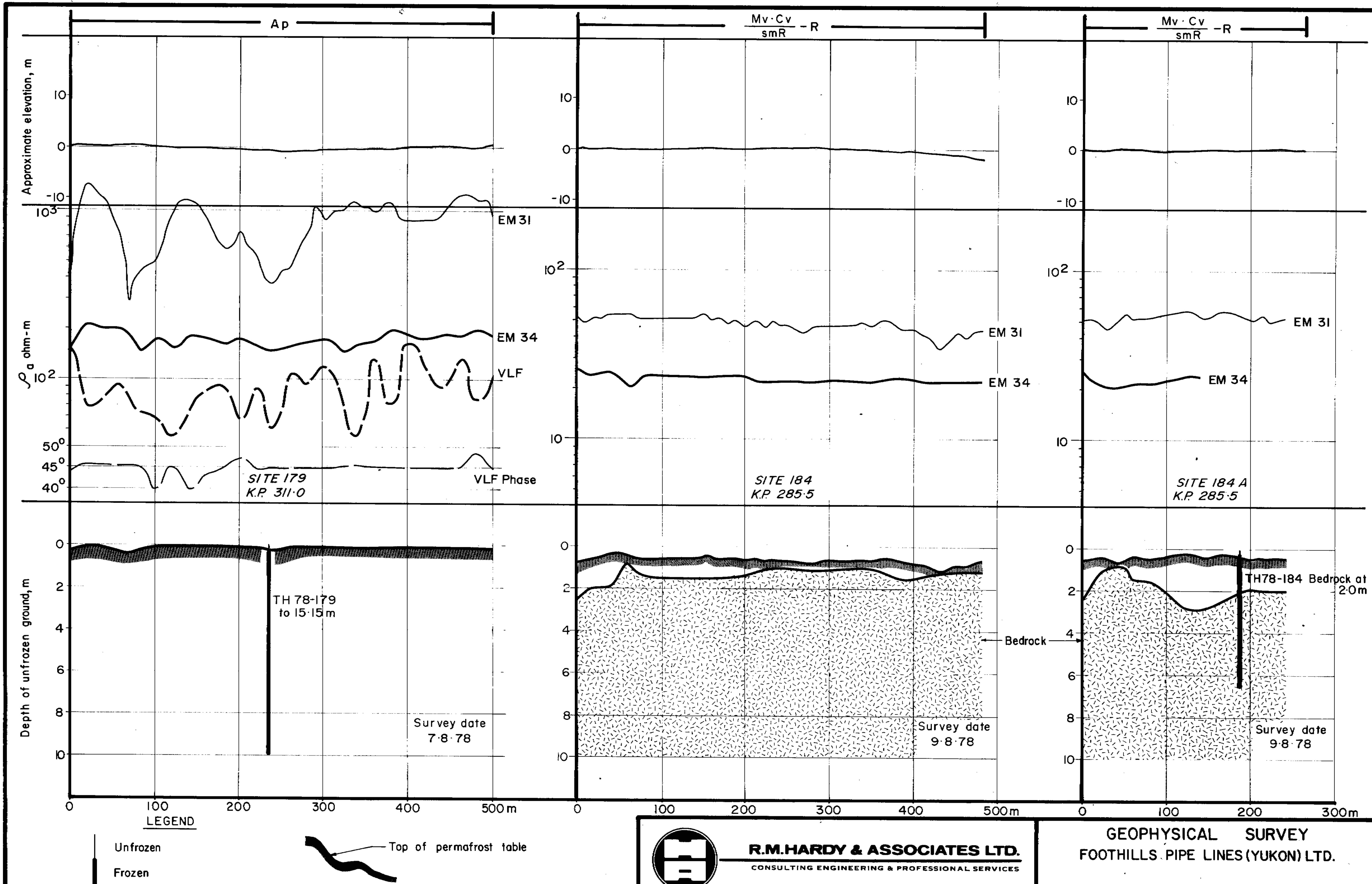
$$Lb_8.pO_2$$

where the subscripts indicate the relative proportions of each. Where subscripts are absent, the proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

$$\text{veneer} \rightarrow \frac{Mv.POv}{sR} - R \leftarrow \text{erosional modifier}$$

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·7·1

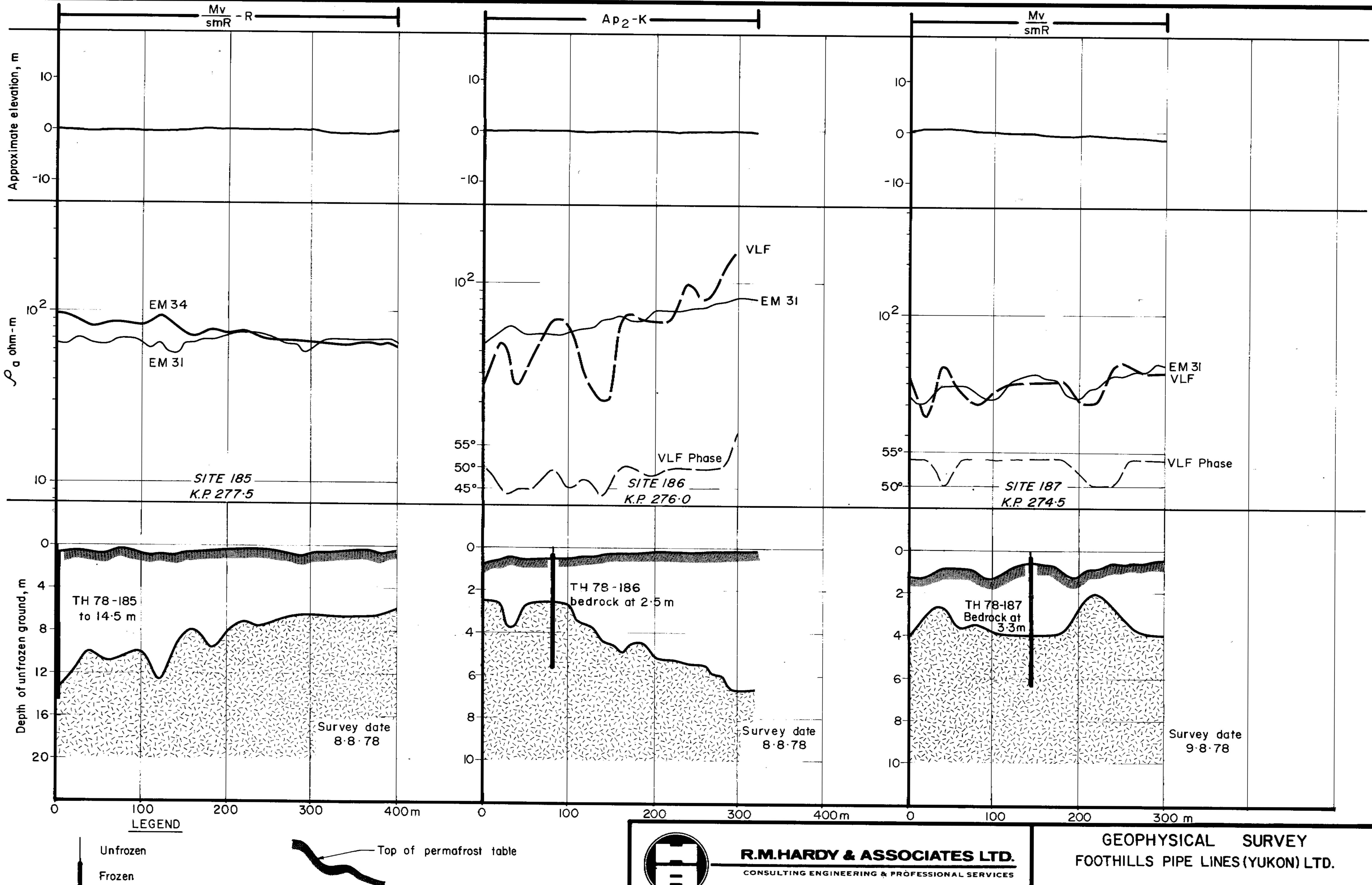


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·27·A



R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·28·A

5.8 Peel and Anderson Plains

The terrain typing legends used for geophysical traverses in these regions is listed on Table 5.8-1.

Site 186 (Figures 5.25, 5.28.A) is on a floodplain with thermokarst features. Test hole 78-186 encountered bedrock at 2.5 m. From the resistivity data bedrock is expected to dip towards the end of the traverse.

Site 187 (Figures 5.25, 5.28.A) is in terrain with a thin layer of till over bedrock. Test hole 78-187 encountered bedrock at 3.3 m. Depth to bedrock has been mainly modeled from the VLF data.

Site 188 (Figures 5.26, 5.29.A) is in hummocky moraine terrain with bedrock expected near the surface in some areas. Test hole 78-188 encountered no bedrock to depth (8.5 m). From the resistivity data bedrock is expected below 10 m depth over the entire site. Since the resistivity data are relatively low (<100 ohm-m), high ice content is not expected below 1 or 2 m.

Site 192 (Figures 5.26, 5.29.A) has an organic cover over till and bedrock. Test hole 78-192 encountered bedrock at 3.3 m. Depth to bedrock has been interpolated over the site using a model similar to that used for site 184.

Site 195 (Figures 5.27, 5.30.A) traverses three terrain types: a till plain between station 0 and 130 m, a colluvial slope from station 130 to 180 m, and an alluvial floodplain from station 180 m on. Test hole 78-195 encountered bedrock at 2.0 m. Depth to bedrock has been estimated over the entire site.

Site 197 (Figures 5.27, 5.30.A) is in an organic terrain on till. Test hole 78-197 encountered frozen till to depth. Because the resistivity values are well below 100 ohm-m, high ice contents are not expected below 1 or 2 metres over this site.

PHYSIOGRAPHIC REGION III: PEEL PLAIN

(W side of Mackenzie River to 2.1 km W of Peel River)

Terrain Types

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas with high ice content
- fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen
- pO - Bog: peat; flat to depressional; poor drainage; high ice content
- pOv - Bog Veneer: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

- Cm - Colluvial Slopewash: predominantly silt and sand; gently to steeply sloping; fair to good drainage; low to medium ice content

A - Alluvial

- Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat; fair to good drainage, high water table; medium to high ice content, locally unfrozen
- Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat; fair drainage with open water, frequently inundated; generally unfrozen
- Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; flat; fair to good drainage, periodically inundated; medium to high ice content

M - Morainal

- Mh - Hummocky Moraine: silty clay till, occasional sand and gravel lenses; hummocky; good drainage and medium to high ice content in hummocks, poor drainage with high ice content in depressions
- Mm - Rolling Moraine: silty clay till; undulating to rolling; fair to good drainage; medium to high ice content
- Mp - Moraine Plain: silty clay till; flat to undulating; fair to good drainage; low to high ice content, mostly medium
- Mv - Moraine Veneer: silty clay till; topography reflects underlying material; good drainage; low to high ice content, mostly medium

R - Bedrock

- R - Bedrock with little or no soil cover. Lower case prefix indicates type, where known, e.g.

  sm - Siltstone, mudstone, shale, argillite

Modifiers

- G - Gullied
- K - Thermokarst features
- R - Rills

Symbols

Escarpment

Borrow Pit in drift and rock

Meltwater Channel (large)

Spoil Pile

Rock Slide Debris

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the features.

Complex Units

Two or more terrain types which cannot be differentiated at the scale of mapping are shown as a complex, e.g.

$$Lb_8.pO_2$$

where the subscripts indicate the relative proportions of each. Where subscripts are absent, proportions are approximately equal. Veneers, generally less than 2 m thick, and erosional modifiers are indicated as follows:

$$\text{veneer} \rightarrow \frac{pOv}{Mp},\ Mp\text{-}R \leftarrow \text{erosional modifier}$$

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·8·1

PHYSIOGRAPHIC REGION II: ANDERSON PLAIN

(4.4 km S of Noell Lake to E side of Mackenzie River)

Terrain Types

O - Organic

- fO - Fen: peat and organic silt; flat to depressional; poor drainage; generally unfrozen, small areas with high ice content
- fOv - Fen Veneer: peat and organic silt; flat to depressional; poor drainage; unfrozen
- pO - Bog: peat; flat to depressional; poor drainage; high ice content
- pO - Bog Veneer: peat; flat to depressional; poor drainage; high ice content

C - Colluvial

- Cm - Colluvial Slopewash: predominantly silt and sand; gently to steeply sloping; fair to good drainage; low to medium ice content
- Cv - Colluvial Veneer: predominantly silt and sand; topography reflects underlying bedrock; fair to good drainage; medium to high ice content

A - Alluvial

- Ap - Alluvial Floodplain (undifferentiated): stratified silt, sand and gravel; flat; fair to good drainage, high water table; generally medium to high ice content, locally unfrozen
- Ap_1 - Active Floodplain: stratified silt, sand and gravel; flat; fair drainage with open water, frequently inundated; generally unfrozen
- Ap_2 - Inactive Floodplain: stratified silt, sand and gravel, silt veneer; flat; fair to good drainage, periodically inundated; medium to high ice content
- At - Alluvial Terrace: stratified silt, sand and gravel, silt veneer; flat; good drainage; low to medium ice content

L - Lacustrine and Glaciolacustrine

- Lb - Lacustrine Basin: stratified silt and clay, minor sand and organics; flat to depressional; poor drainage; high ice content
- Lp - Glaciolacustrine Plain: stratified silt and clay, minor sand and organics; flat to gently undulating; fair to poor drainage; high ice content
- Lv - Lacustrine Veneer: stratified silt and clay, minor sand and organics; flat to gently undulating; fair to poor drainage; high ice content

G - Glaciofluvial

- Gm - Eskers and Kames: stratified sand and gravel, minor silt; irregular ridges and hummocks; good drainage; low ice content, locally high ice content
- Gt - Glaciofluvial Terrace: stratified sand and gravel, silt veneer; flat; good drainage; low ice content, some ice wedges

M - Morainal

- M - Moraine (undifferentiated): silty clay till; topography obscured by overlying deposits; drainage and ice contents variable
- Md - Drumlinoid Moraine: silty clay till; flat to undulating with ridges; generally good drainage with low ice content in ridges, poor drainage and higher ice content in depressions.
- Mh - Hummocky Moraine: silty clay till, occasional sand and gravel lenses; hummocky; good drainage and medium to high ice content in hummocks, poor drainage with high ice content in depressions
- Mm - Rolling Moraine: silty clay till; undulating to rolling; fair to good drainage; medium to high ice content
- Mp - Moraine Plain: silty clay till; flat to undulating; fair to good drainage; low to high ice content, mostly medium
- Mv - Moraine Veneer: silty clay till; topography reflects underlying material; good drainage; low to high ice content, mostly medium

R - Bedrock

- R - Bedrock with little or no soil cover. Lower case prefix indicates rock type, where known, e.g.
  - s - Sedimentary (undifferentiated)
  - sm - Siltstone, mudstone, shale, argillite
  - ss - Sandstone, conglomerate

Modifiers

- K - Thermokarst features
- R - Rills

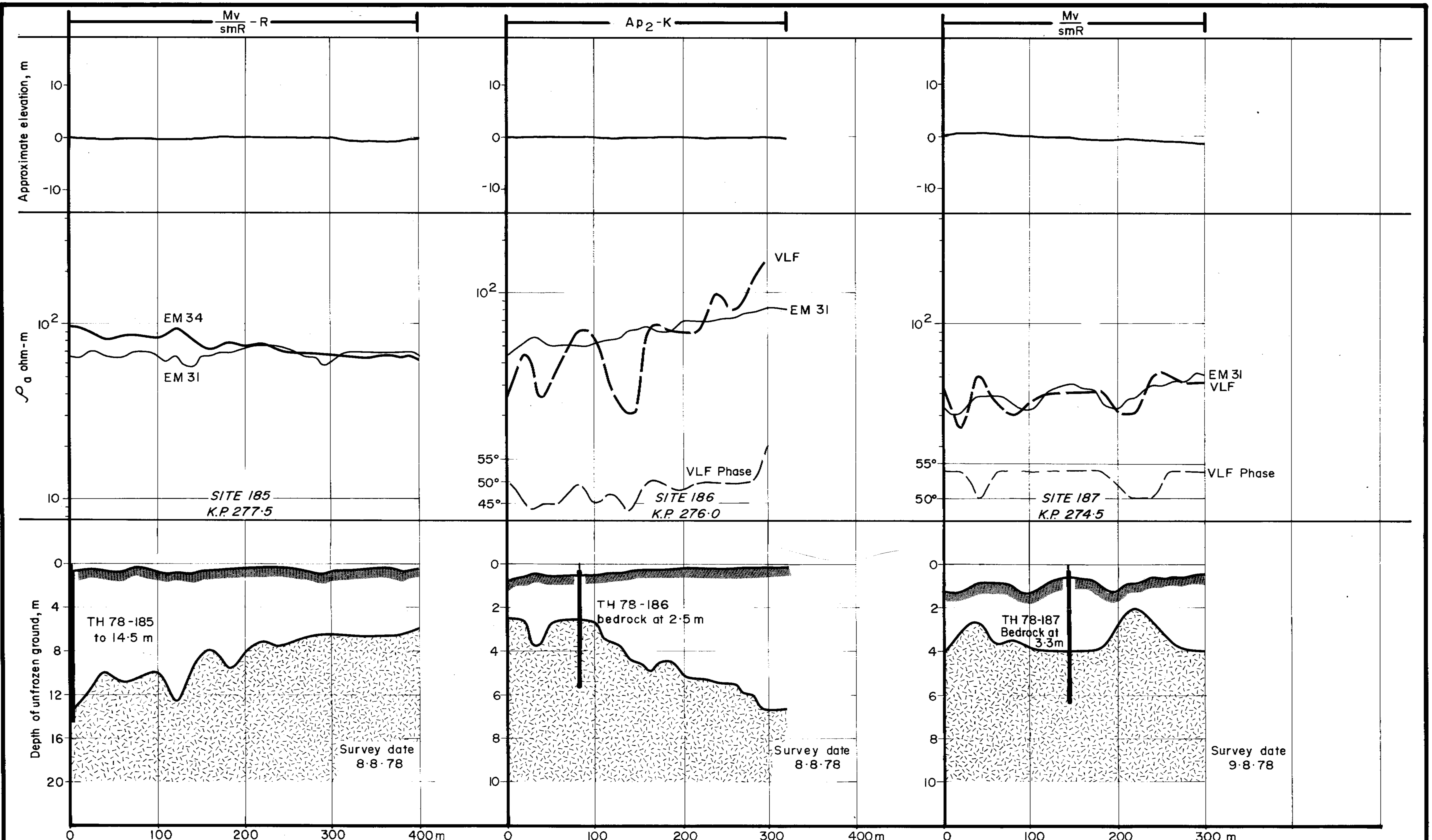
Symbols

- Borrow Pit in drift and rock
- Spoil Pile
- Escarpment
- Esker

Symbols indicate the location of prominent features and do not necessarily correspond to the exact size of the feature.

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

TABLE 5·8·1

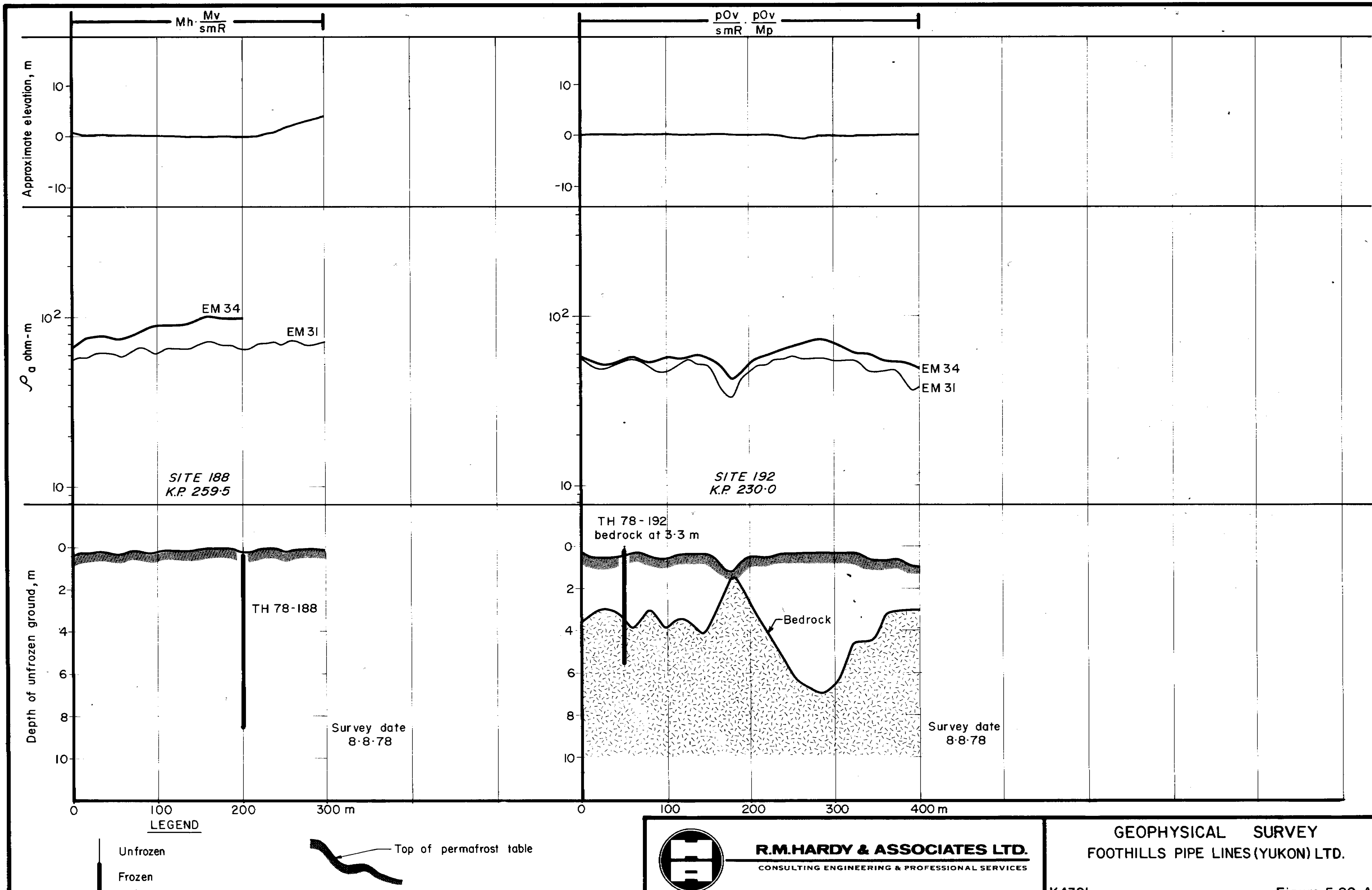


R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·28·A



R.M.HARDY & ASSOCIATES LTD.

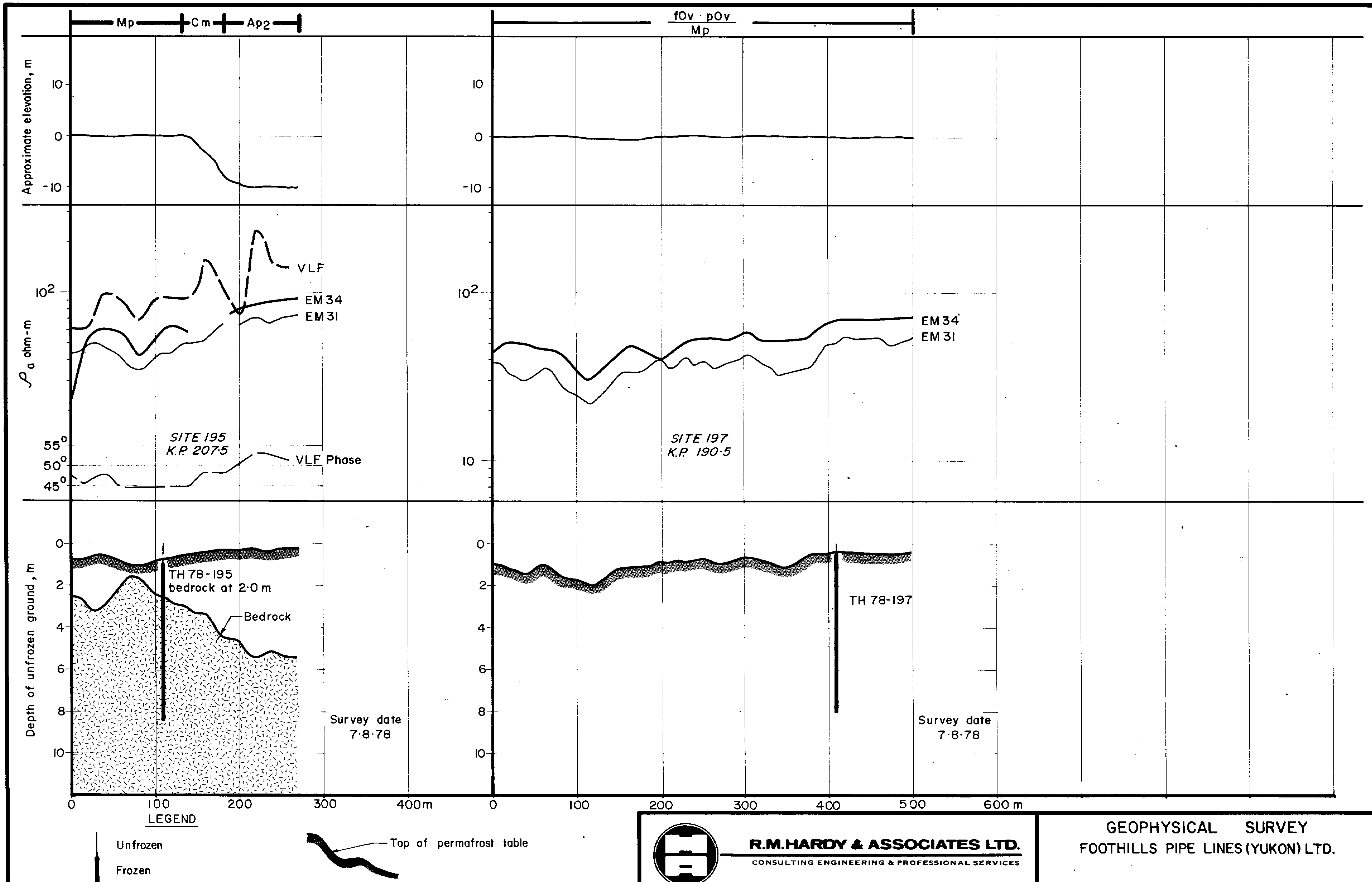
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·29·A



R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.

K4321

Figure 5·30·A

6.0 CONCLUSIONS

6.1 Yukon Plateau

The lengths of terrain surveyed (6350 m) in this region are summarized in Table 6-1. For the fourteen sites on the Yukon Plateau deep permafrost was encountered along 40 percent of the site lengths while shallow permafrost (<10 m thickness) accounted for another 6 percent. Generally, permafrost was encountered in fine grained sediments of morainal, lacustrine and colluvial origins. Some permafrost was also encountered in coarse grained deposits having an insulative organic mat. Permafrost was absent along 54 percent of the site lengths including all alluvial and most glacio-fluvial deposits. At this stage no determination has been made of the occurrence of different terrain units along the pipe line right-of-way in this region.

TABLE 6-1

Summary of Distances of Geophysical Surveys and Major Findings -
Dempster Lateral - Physiographic Region IX - Yukon Plateau

Terrain Type	Frozen (<3m unfrozen layer)		Unfrozen (>3m unfrozen layer)		Shallow Permafrost (<10m thick)		Bedrock (<3m depth)		Total Length (m)
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Cm	215	67	105	33	-	-	-	-	320
Ap	-	-	180	100	-	-	-	-	180
At	-	-	500	100	-	-	-	-	500
Af	-	-	50	100	-	-	-	-	50
Lb	100	67	50	33	-	-	-	-	150
Gh	-	-	400	100	-	-	-	-	400
Gt	250	15	1430	85	-	-	-	-	1680
pOv/Gp	260	100	-	-	-	-	-	-	260
Mm	595	61	-	-	380	39	-	-	975
Mv.Cv/vR . Mm	80	17	400	83	-	-	-	-	480
Mm . Mv/mR	240	100	-	-	-	-	-	-	240
Mp.pO	120	100	-	-	-	-	-	-	120
Mh . pOv/Lp	500	100	-	-	-	-	-	-	500
Mv.Cv/sR	-	-	245	91	-	-	25	9	270
Cv.Mv/iR	185	82	40	18	-	-	-	-	225
	2545	40	3400	54	380	6	25	-	6350

6.2 Tintina Trench

The lengths of sites surveyed in this region (5440 m) are summarized in Table 6-2. In the Tintina Trench unfrozen conditions are mainly encountered in coarse grained glaciofluvial plains and occur to a minor extent in colluvial and organic terrain. In the areas surveyed the percentage occurrence of frozen ground was 86 percent with 14 percent unfrozen. No determination has been made of the occurrence of different terrain units along the pipe line right-of-way in this region.

6.3 Ogilvie Mountains

The lengths of surveyed areas in this region (7270 m) are summarized in Table 6-3. For the sixteen sites in the Ogilvie Mountains unfrozen ground is most often found in alluvial deposits. The percentage occurrence of unfrozen ground was found to be 13 percent of the area surveyed. Frozen ground is found in a variety of terrain units and active layers are generally less than 1.0 metres except in frozen alluvial deposits where deeper active layers are present. Bedrock was not encountered above a 3 metre depth along any of the traverses in this region. At

TABLE 6-2

Summary of Distances of Geophysical Surveys and Major Findings - Dempster Lateral - Physiographic Region VIII - Tintina Trench

Terrain Type	Frozen (<3m unfrozen layer)		Unfrozen (>3m unfrozen layer)		Shallow Permafrost (<10m thick)		Bedrock (<3m depth)		Total Length (m)
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
pO-K	665	93	50	7	-	-	-	-	715
Cm	475	95	25	5	-	-	-	-	500
Ap_2	240	100			-	-	-	-	240
Ap_2.fO	400	100	-	-	-	-	-	-	400
At	100	100			-	-	-	-	100
At.pO	110	100			-	-	-	-	110
pOv/At	840	100	-	-	-	-	-	-	840
Cv/At.Af	250	100	-	-	-	-	-	-	250
Lb	20	100	-	-	-	-	-	-	20
Ev/Gp	1030	62	630	38	-	-	-	-	1660
Ev/Gp . Gm	50	53	45	47	-	-	-	-	95
Cv/M	110	100	-	-	-	-	-	-	110
Mv/iR . Mm	400	100	-	-	-	-	-	-	400
	4690	86	750	14	-	-	-	-	5440

TABLE 6-3

Summary of Distances of Geophysical Surveys and Major Findings - Dempster Lateral - Physiographic Region VII - Ogilvie Mountains

Terrain Type	Frozen (<3m unfrozen layer)		Unfrozen (>3m unfrozen layer)		Shallow Permafrost (<10m thick)		Bedrock (<3m depth)		Total Length (m)
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Cb(P)	390	100	-	-	-	-	-	-	390
Af	1060	100	-	-	-	-	-	-	1060
At	250	52	230	48		-	-	-	480
Ap	-	-	230	100	-	-	-	-	230
Af.Ct-S	300	100	-	-	-	-	-	-	300
Cv/Af	-		270	100		-	-	-	270
Ev/Lp	260	100	-	-	-	-	-	-	260
Ev/Gp	280	100	-	-	-	-	-	-	280
pOv/Gp	130	100			-	-	-	-	130
Gp	70	100		-	-	-	-	-	70
Mh	170	100		-	-	-	-	-	170
Ma	-	-	20	100	-	-	-	-	20
Ma.Gm	530	100	-	-	-	-	-	-	530
Mm	1520	100	-	-	-	-	-	-	1520
Ev/Mm	360	100	-	-	-	-	-	-	360
Mv/R	110	100	-	-	-	-	-	-	110
Cv/mqR	420	100	-	-	-	-	-	-	420
Cv.Mv/mqR	-	-	170	100	-	-	-	-	170
Cv/sR - R	500	100	-	-	-	-	-	-	500
	6350	87	920	13	-	-	-	-	7270

this time no determination has been made concerning the occurrence of different terrain units along the pipeline right-of-way through the Ogilvie Mountains.

6.4 Porcupine Plateau (Eagle Plain)

The lengths of surveyed areas in this region (3720 m) are summarized in Table 6-4. On the Porcupine Plateau permafrost was found to be present along all seven traverses. Active layers were determined to be less than 1 metre. Bedrock within 3 metres of the surface was encountered along 5 percent of the site lengths being located in those terrain units having a thin veneer of colluvium over bedrock. No determination has been made concerning the occurrence of different terrain units along the pipe line right-of-way in this region.

6.5 Richardson Mountains

The lengths of surveyed areas (1665 m) in this region are summarized in Table 6-5. In the Richardson Mountains permafrost was encountered along all three traverses at a shallow depth (<1 m). Near surface bedrock (<3 m depth) was found along 85 percent of the site lengths. No determination has been made concerning the occurrence of different terrain units along the pipe line right-of-way in this region.

TABLE 6-4

Summary of Distances of Geophysical Surveys and Major Findings -
Dempster Lateral - Physiographic Region VI - Porcupine Plateau (Eagle Plain)

Terrain Type	Frozen (<3m unfrozen layer)		Unfrozen (>3m unfrozen layer)		Shallow Permafrost (<10m thick)		Bedrock (<3m depth)		Total Length (m)
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Cm	560	100	-	-	-	-	-	-	560
Af	500	100			-	-			500
Cv/At	390	100	-	-	-	-	-	-	390
Cv/ss,smR	470	91	-	-	-	-	30	9	500
Cv/sm,ssR	1230	91	-	-	-	-	120	9	1350
ss,smR.Cv/sR	370	88	-	-	-	-	50	12	420
	3520	95	-	-	-	-	200	5	3720

TABLE 6-5

Summary of distances of Geophysical Surveys and Major Findings - Dempster Lateral

Terrain Type	Frozen (<3m unfrozen layer) Length (m)	%	Unfrozen (>3m unfrozen layer) Length (m)	%	Shallow Permafrost (<10m thick) Length (m)	%	Bedrock (<3m depth) Length (m)	%	Total Length (m)
	- Physiographic Region V - Richardson Mountains -								
Cb(P)-G	250	18	-	-	-	-	115	82	1365
Cv/sm,ssR	-	-	-	-	-	-	300	100	300
	250	15	-	-	-	-	1415	85	1665
	- Physiographic Region IV - Peel Plateau -								
Ap	500	100	-	-	-	-	-	-	500
Mv.Cv/smR - R	-	-	-	-	-	-	740	100	740
Mv/smR - R	400	100	-	-	-	-	-	-	400
	900	55	-	-	-	-	740	45	1640

6.6 Peel Plateau

The lengths of the areas surveyed (1640 m) in this region are summarized in Table 6-6. The four sites located on the Peel Plateau were all found to be frozen at shallow depth (<1.0 metre). Near surface bedrock (<3.0 metres depth) has been estimated to occur over 45 percent of the site lengths. At this stage no determination has been made concerning the occurrence of different terrain units along the pipe line right-of-way in this region.

6.7 Peel and Anderson Plains

The lengths of the areas surveyed (2090 m) in these similar regions are summarized in Table 6-7. The six sites surveyed were all found to have permafrost within 2.0 metres of the surface. Near surface bedrock (<3.0 metres depth) comprises about 15 percent of the total site

TABLE 6-6

Summary of Distances of Geophysical Surveys and Major Findings - Dempster Lateral - Physiographic Regions III & II - Peel and Anderson Plains

Terrain Type	Frozen (<3m unfrozen layer)		Unfrozen (>3m unfrozen layer)		Shallow Permafrost (<10m thick)		Bedrock (<3m depth)		Total Length (m)
	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	
Cm	50	100	-	-	-	-	-	-	50
Ap_2	90	100	-	-	-	-	-	-	90
Ap_2-K	235	73	-	-	-	-	85	27	320
Mp	130	100	-	-	-	-	-	-	130
fOv.pOv/Mp	380	76	-	-	-	-	120	24	500
Mh . Mv/smR	300	100	-	-	-	-	-	-	100
Mv/smR	225	75	-	-	-	-	75	25	300
pOv/smR . pOv/Mp	360	90	-	-	-	-	40	10	400
	1770	85	-	-	-	-	320	15	2090

lengths investigated. At this stage no determination has been made concerning the occurrence of different terrain units along the pipe line right-of-way in this region.

Respectfully submitted,

HARDY ASSOCIATES (1978) LTD.

Per: Tony Sartorelli

T. Sartorelli, B.Sc.

Per:

P. Hoekstra, Ph.D., P.Eng.

Calgary, Alberta
December, 1978
Project No. K4321

On October 27, 1978 the name of R. M. Hardy & Associates Ltd. was changed to Hardy Associates (1978) Ltd.
No change in ownership or scope of services is involved.

Dempster Lateral Gas Pipeline Project

Permafrost Delineation

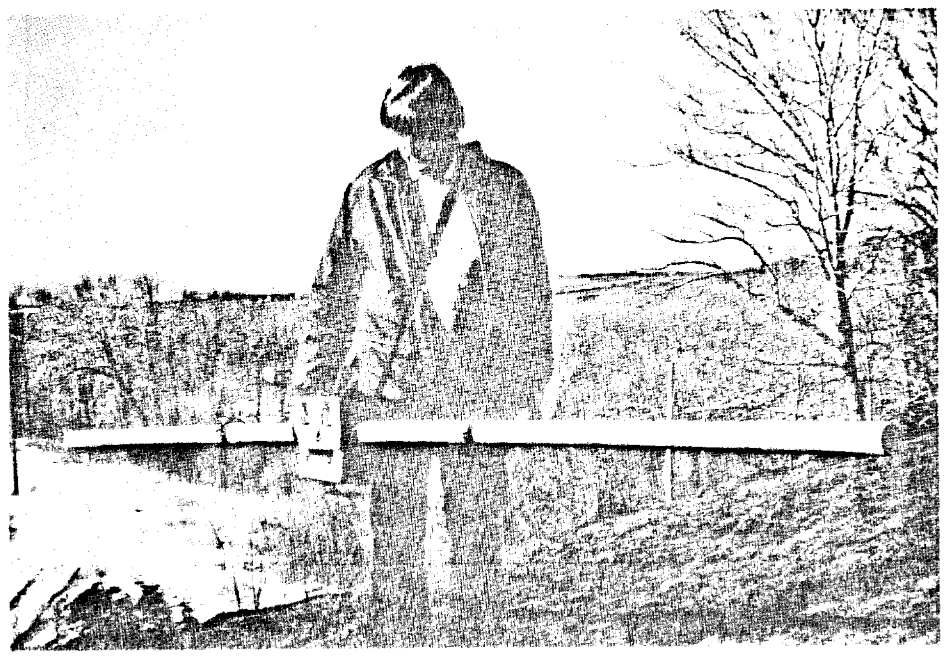
Geophysical Survey

PREPARED FOR

Foothills Pipe Lines (Yukon) Ltd.

Calgary, Alberta

HARDY ASSOCIATES (1978) LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
• GEOTECHNICAL DIVISION



GEONICS EM 31

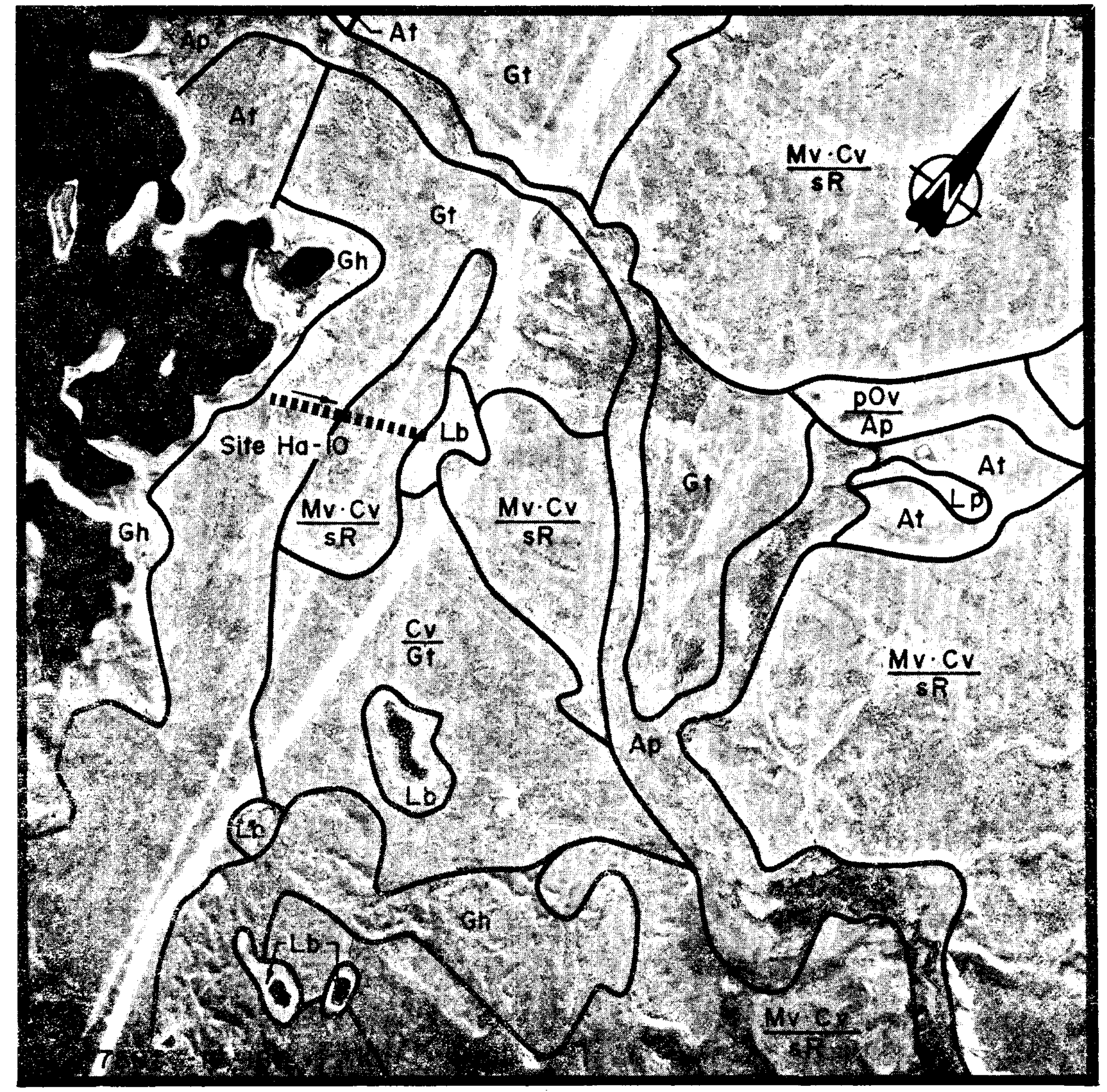
Figure 3·4

GEONICS EM 34

Figure 3·5

REVISIONS	REFERENCES	SCALE DATE MADE CHKD. APPD.	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	PHOTOGRAPHS OF GEONICS EM 31 & GEONICS EM 34
				No. Figure 3·4 & 3·5

SITE Ha-3



SITE Ha-10

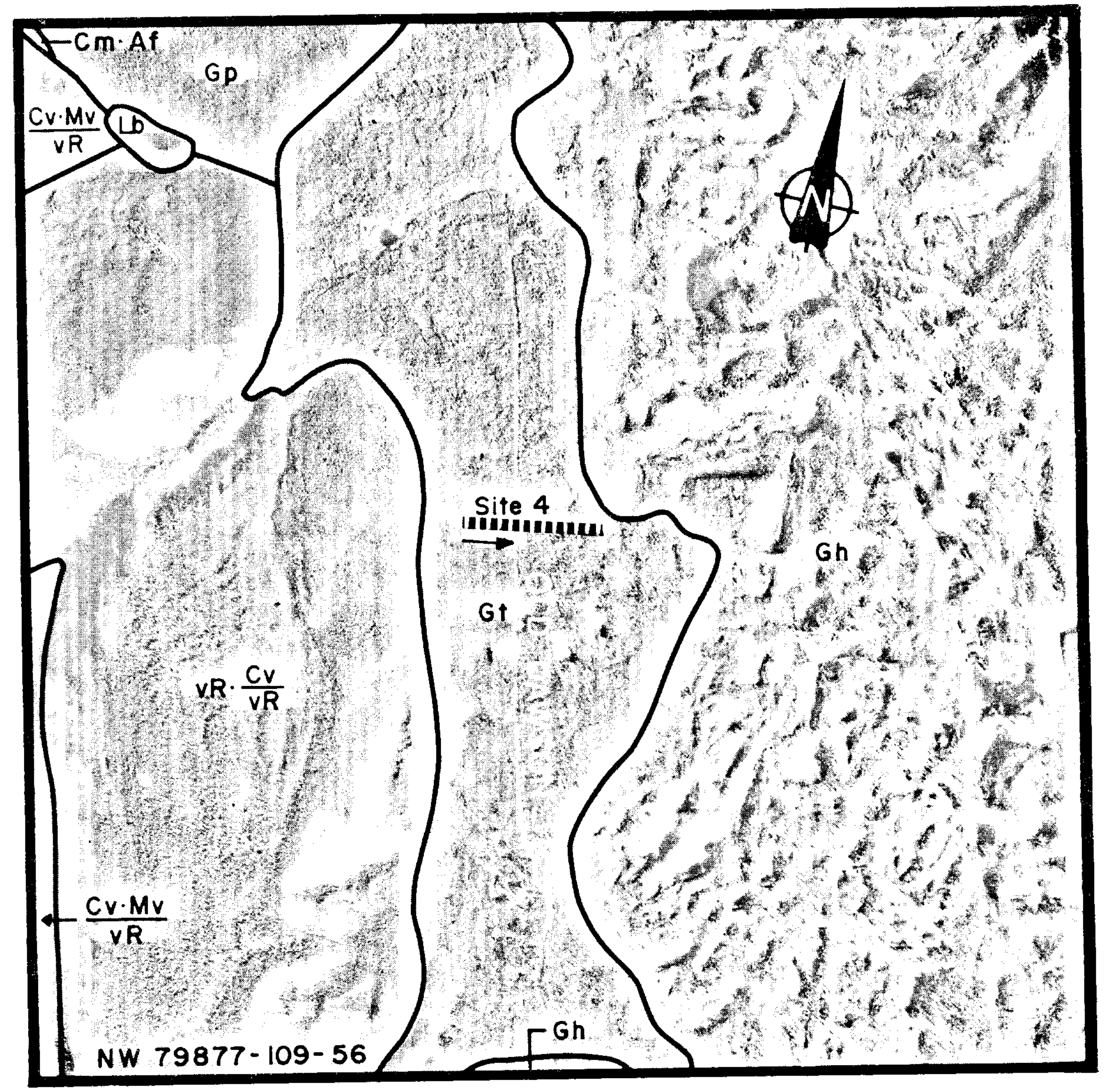
Legend			
Test hole location ● 107 Geophysical traverse and direction ▪▪▪▪▪▪ → Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS K 4321 Figure 5·1

SITE Ha-13

SITE Ha-14

Legend				
Test hole location — ● 107 Geophysical traverse and direction — Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS	K 4321 Figure 5·2

SITE Ha-15



SITE 4

Legend

Test hole location ● 107

Geophysical traverse and direction → Site 107

0 500 1000 metres

0 2000 4000 feet

Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING

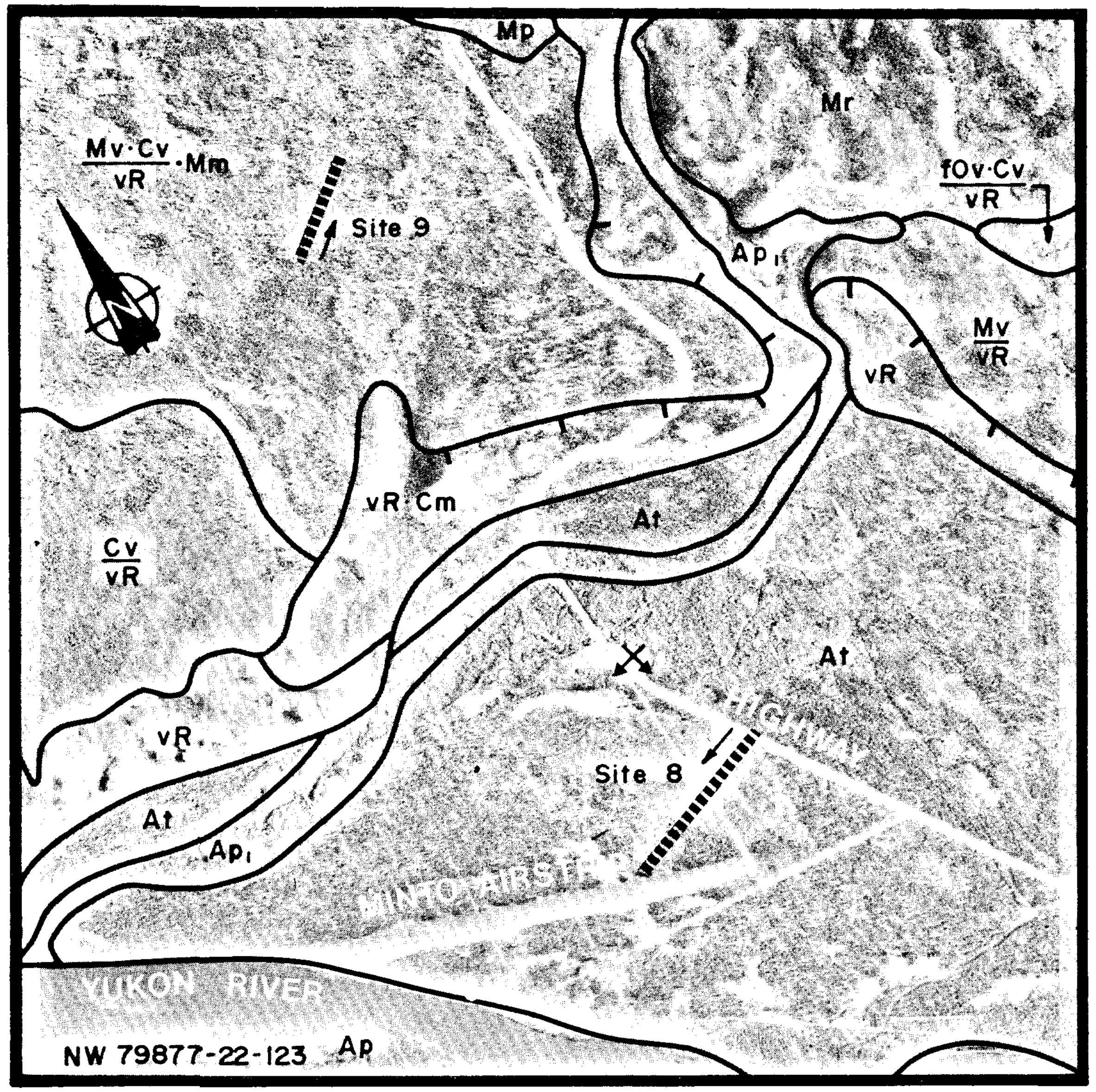
GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

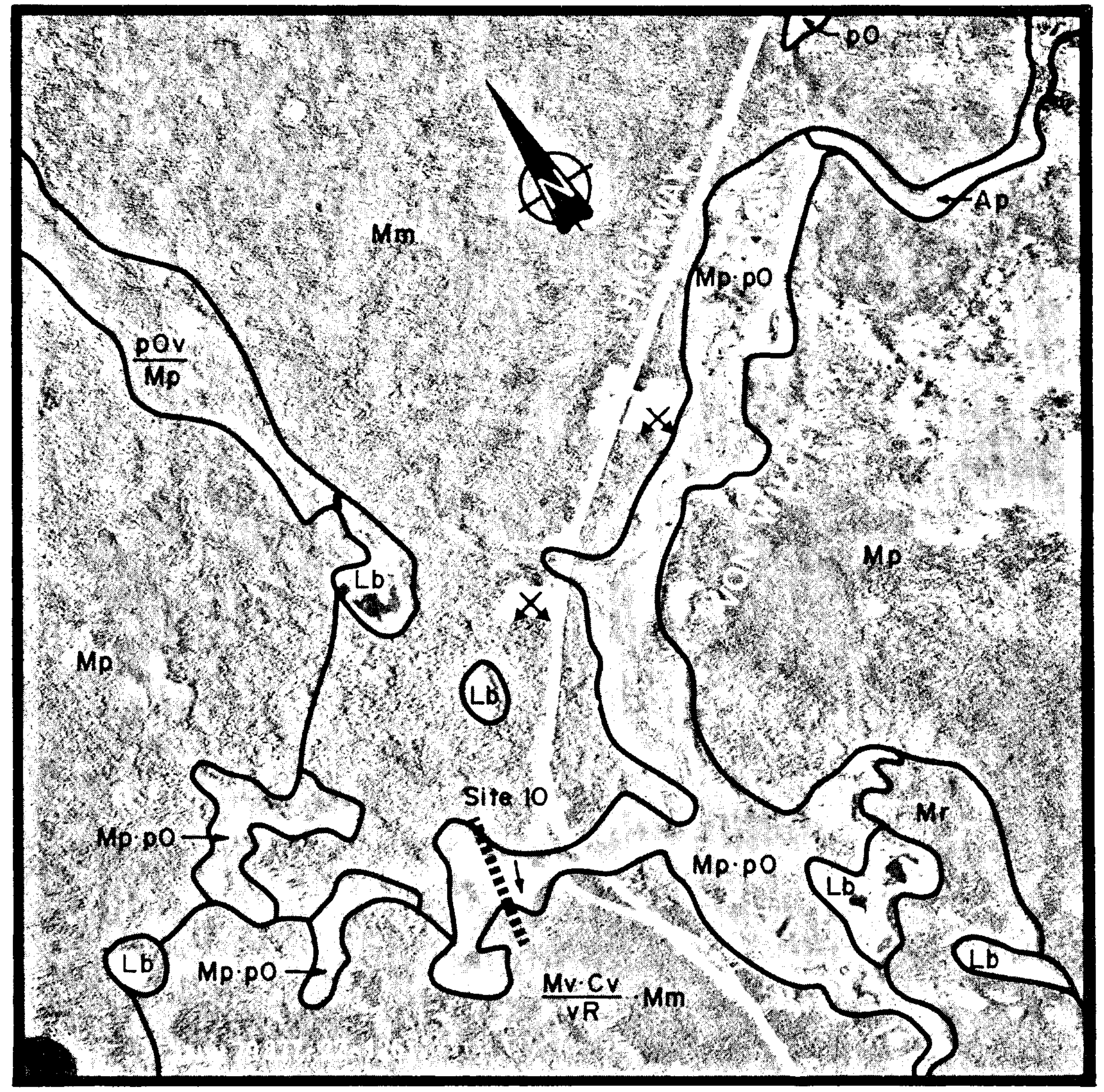
SITE LOCATIONS

K 4321

Figure 5·3



SITE 8 and 9



SITE 10

Legend

Test hole location	• 107
Geophysical traverse and direction	→ Site 107

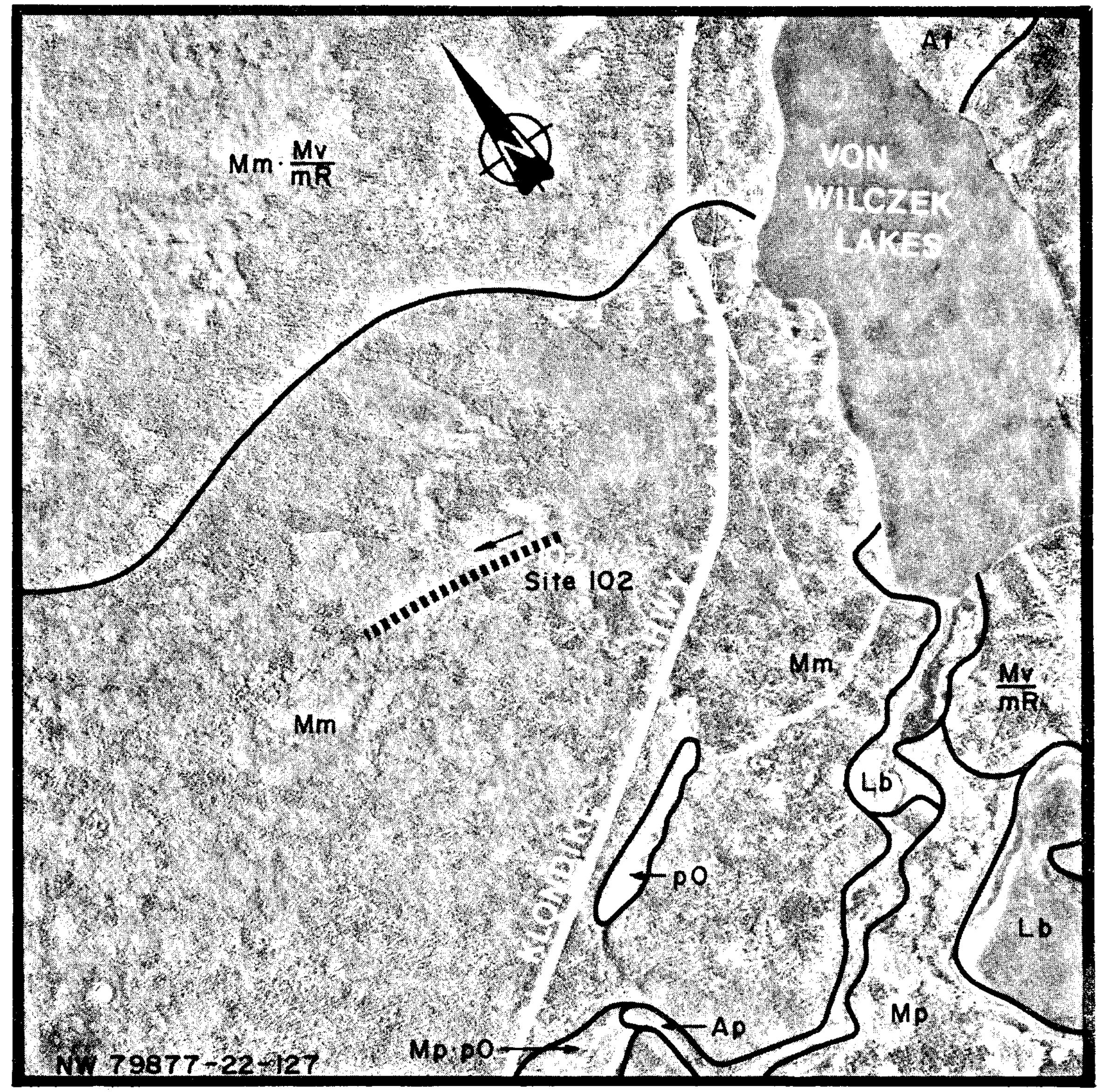
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·4



SITE 102

Legend	
Test hole location	● 107
Geophysical traverse and direction	▪▪▪▪▪▪▪ → Site 107

0 500 1000 metres

0 2000 4000 feet

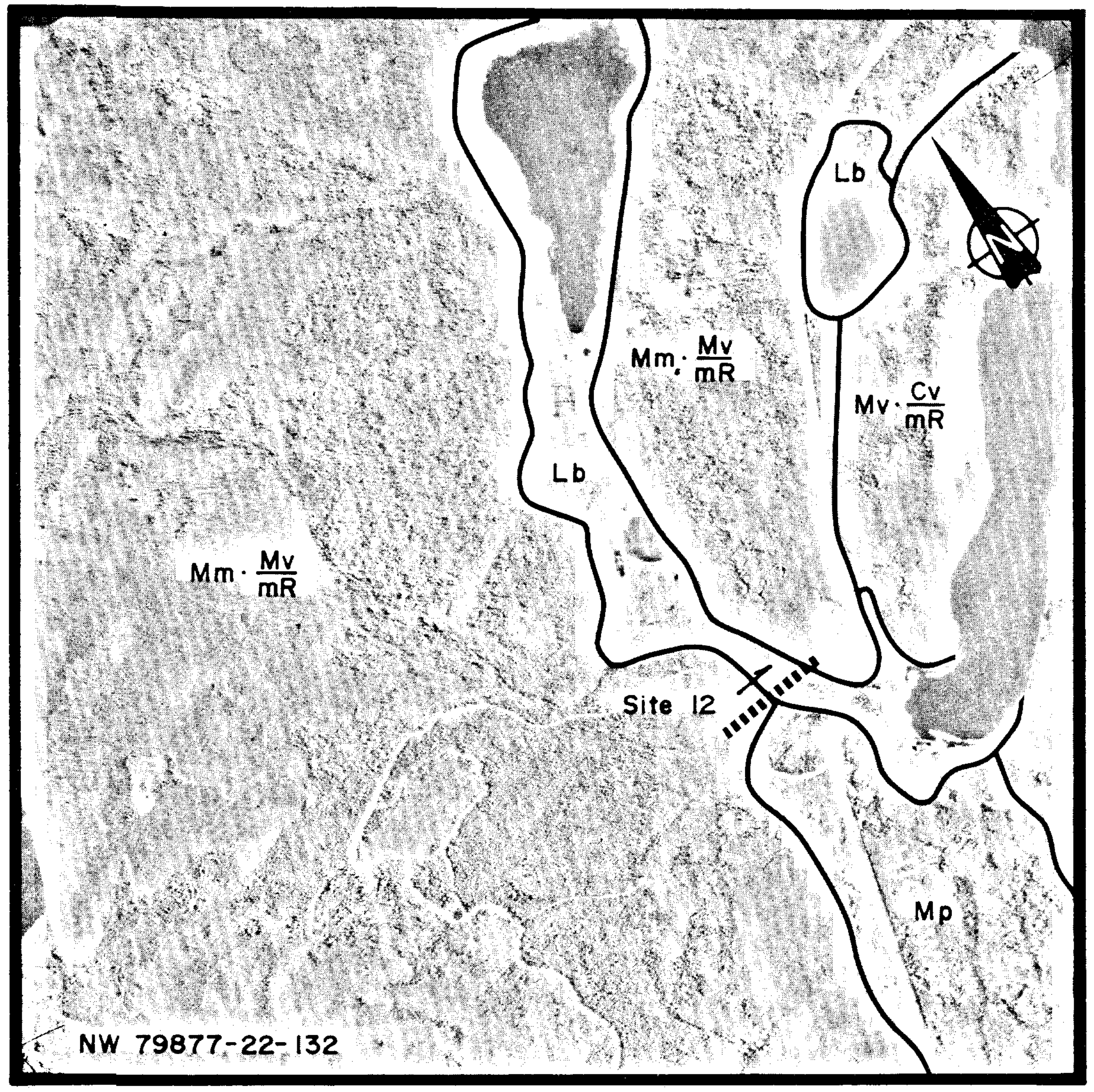
Approximate scale 1:24000

R.M. HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

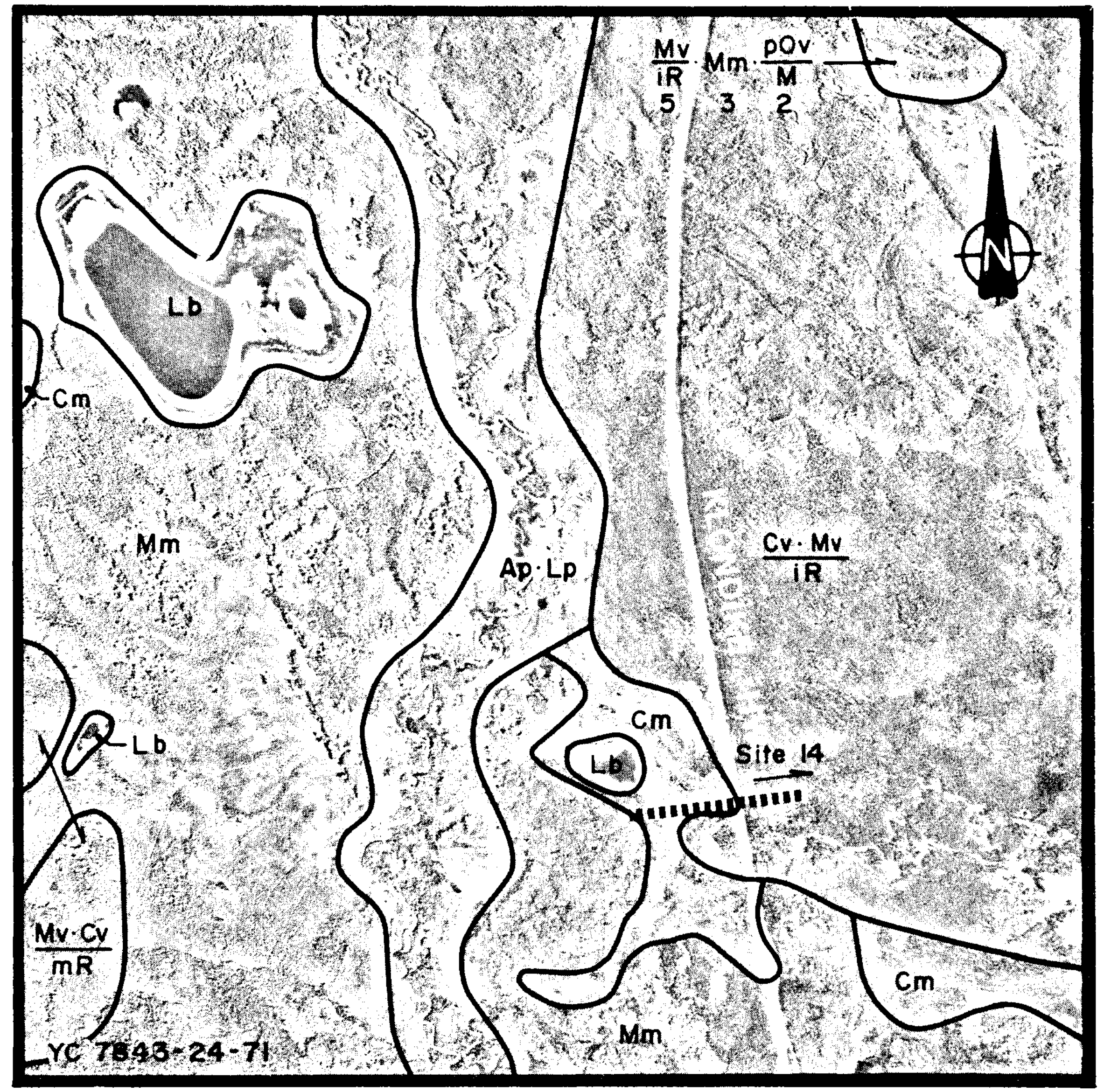
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·5



SITE 12



SITE 14

Legend

Test hole location • 107

Geophysical traverse and direction → Site 107

0 500 1000 metres

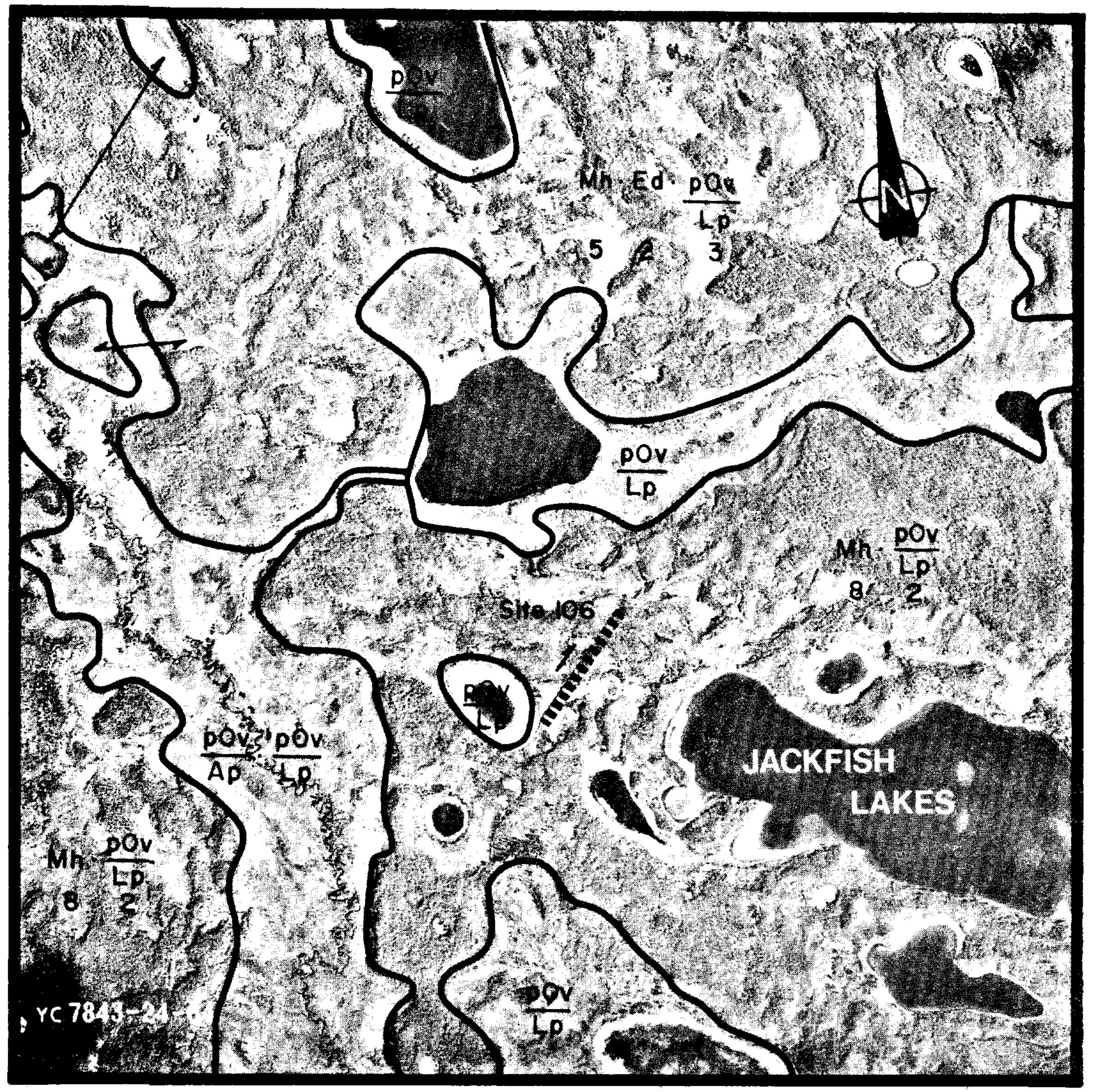
0 2000 4000 feet

Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321 Figure 5·6



SITE 106

SITE 107

Legend

Test hole location	• 107
Geophysical traverse and direction	▮▮▮▮▮▮ → Site 107

0 500 1000 metres

0 2000 4000 feet

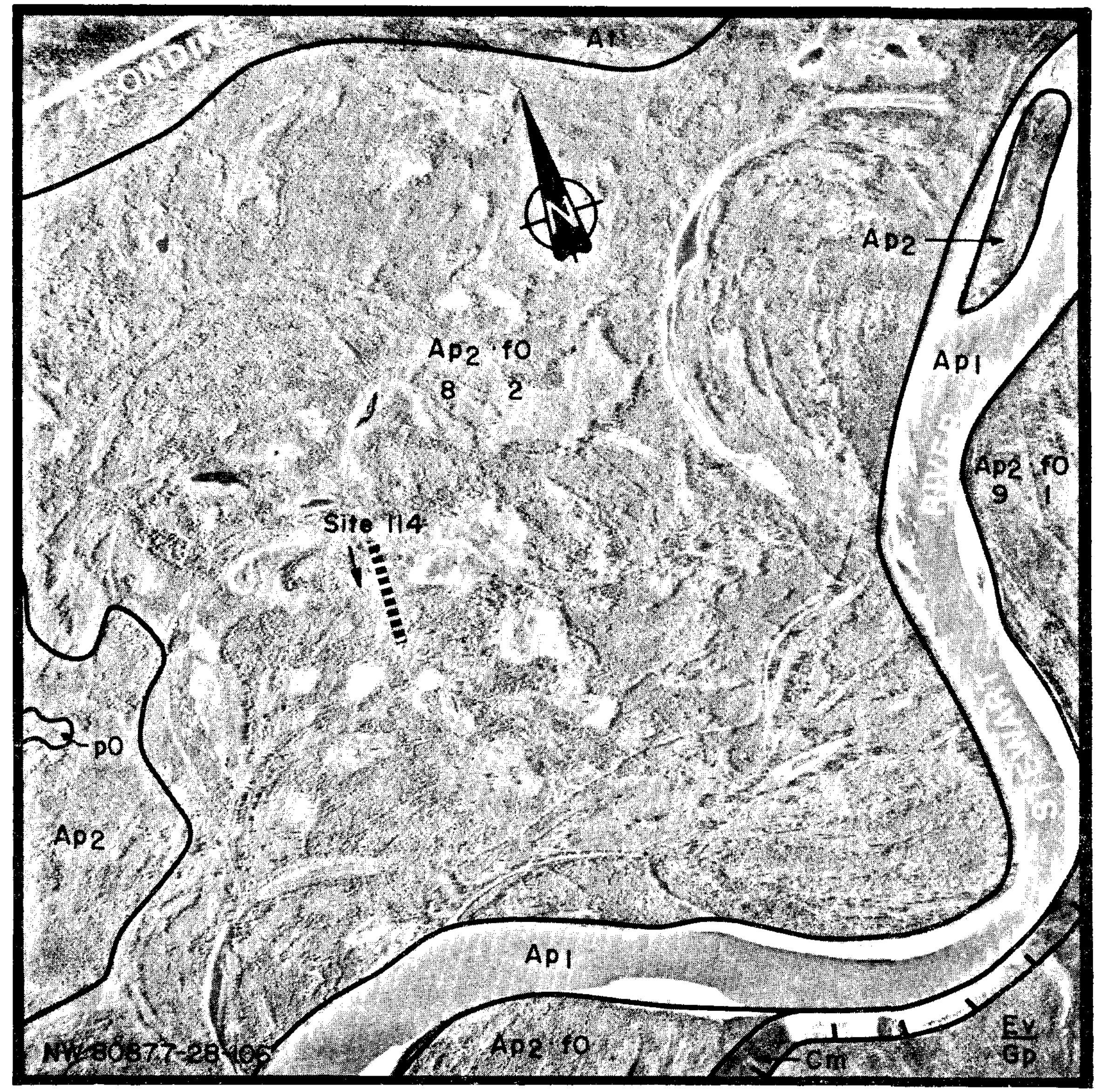
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321 Figure 5·7

SITE 111



SITE 114

Legend

Test hole location	• 107
Geophysical traverse and direction	→ Site 107

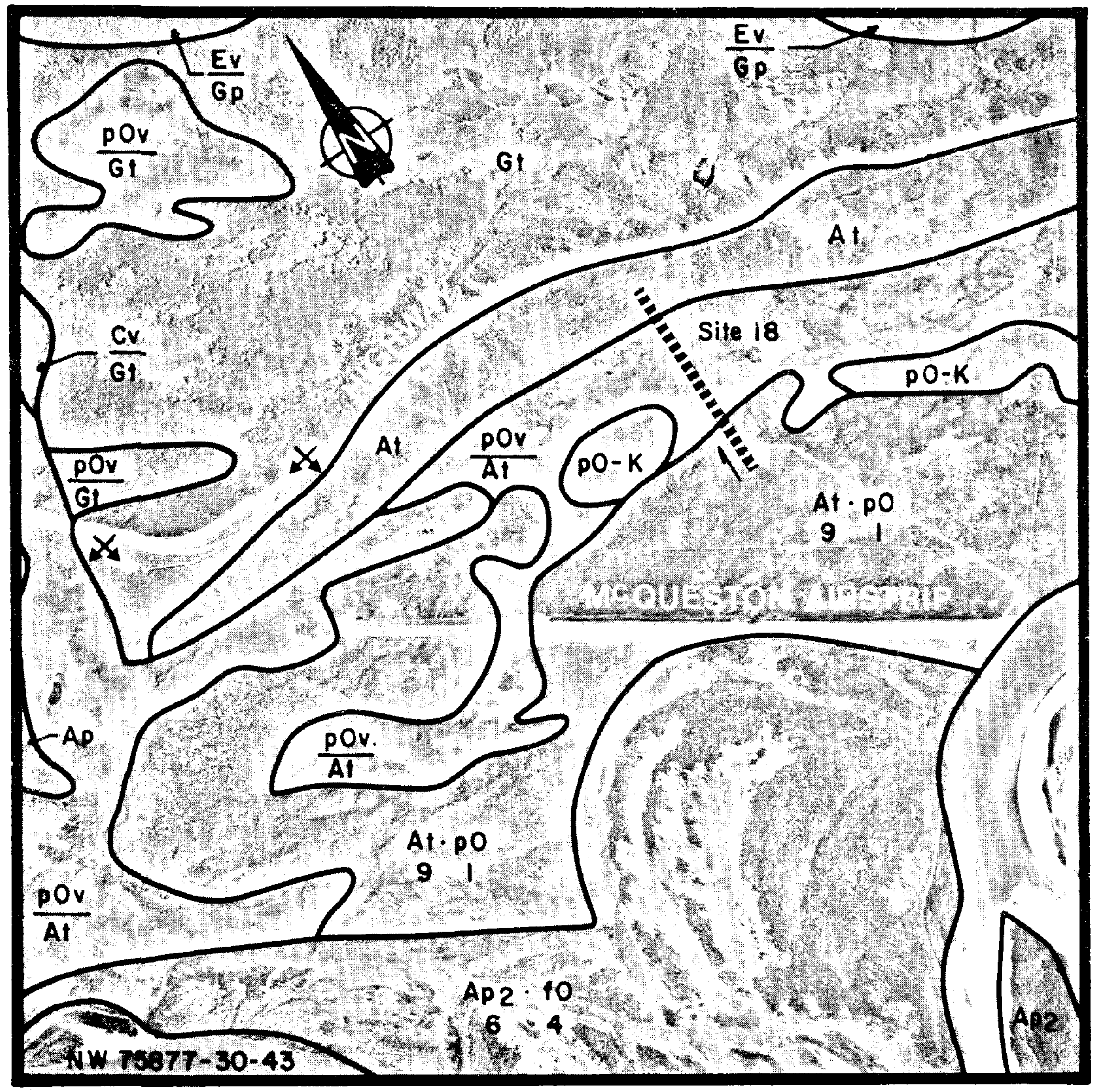
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·8



SITE 18

SITE 115

Legend

Test hole location ● 107

Geophysical traverse and direction → Site 107

0 500 1000 metres

0 2000 4000 feet

Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING

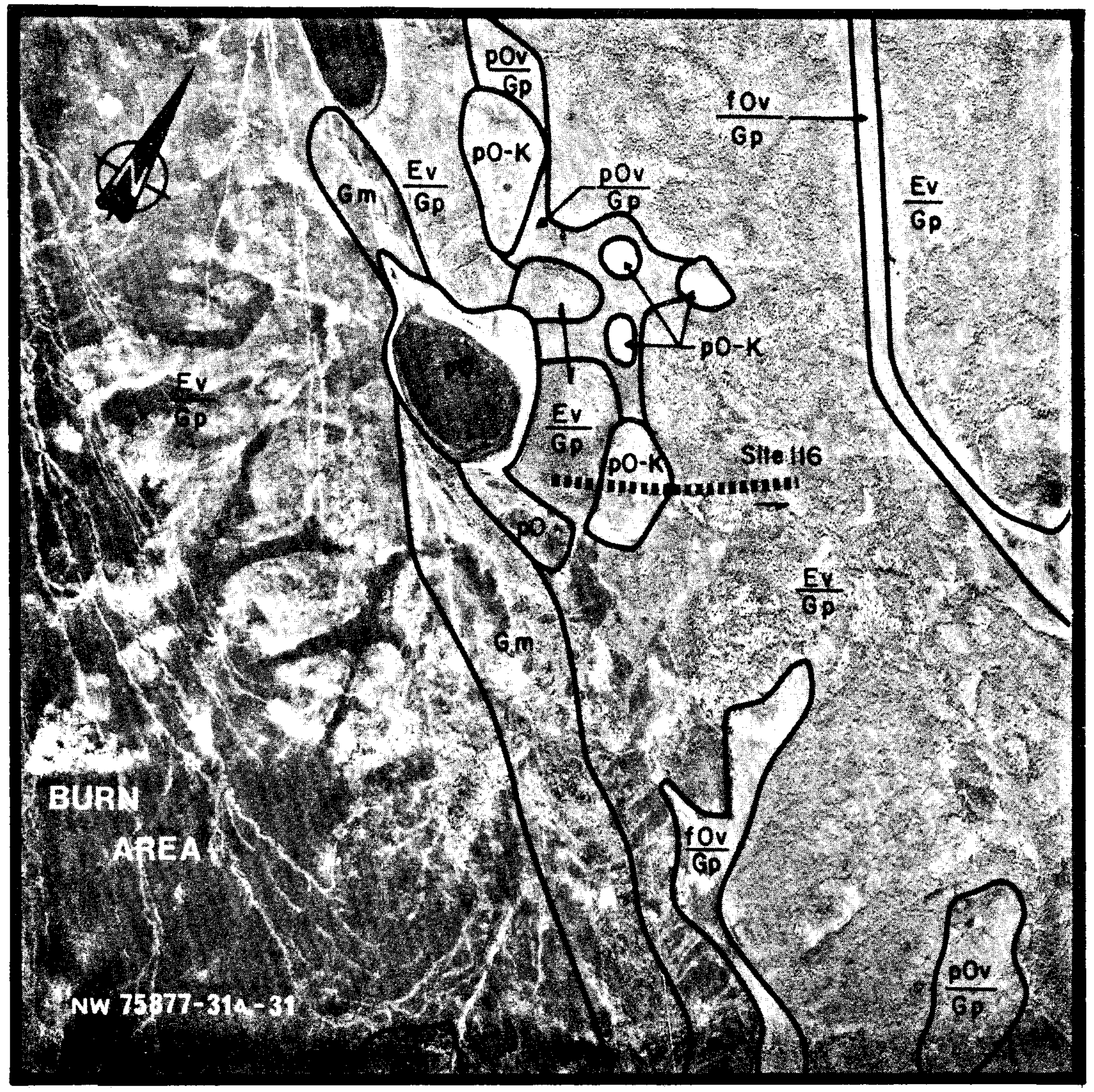
GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

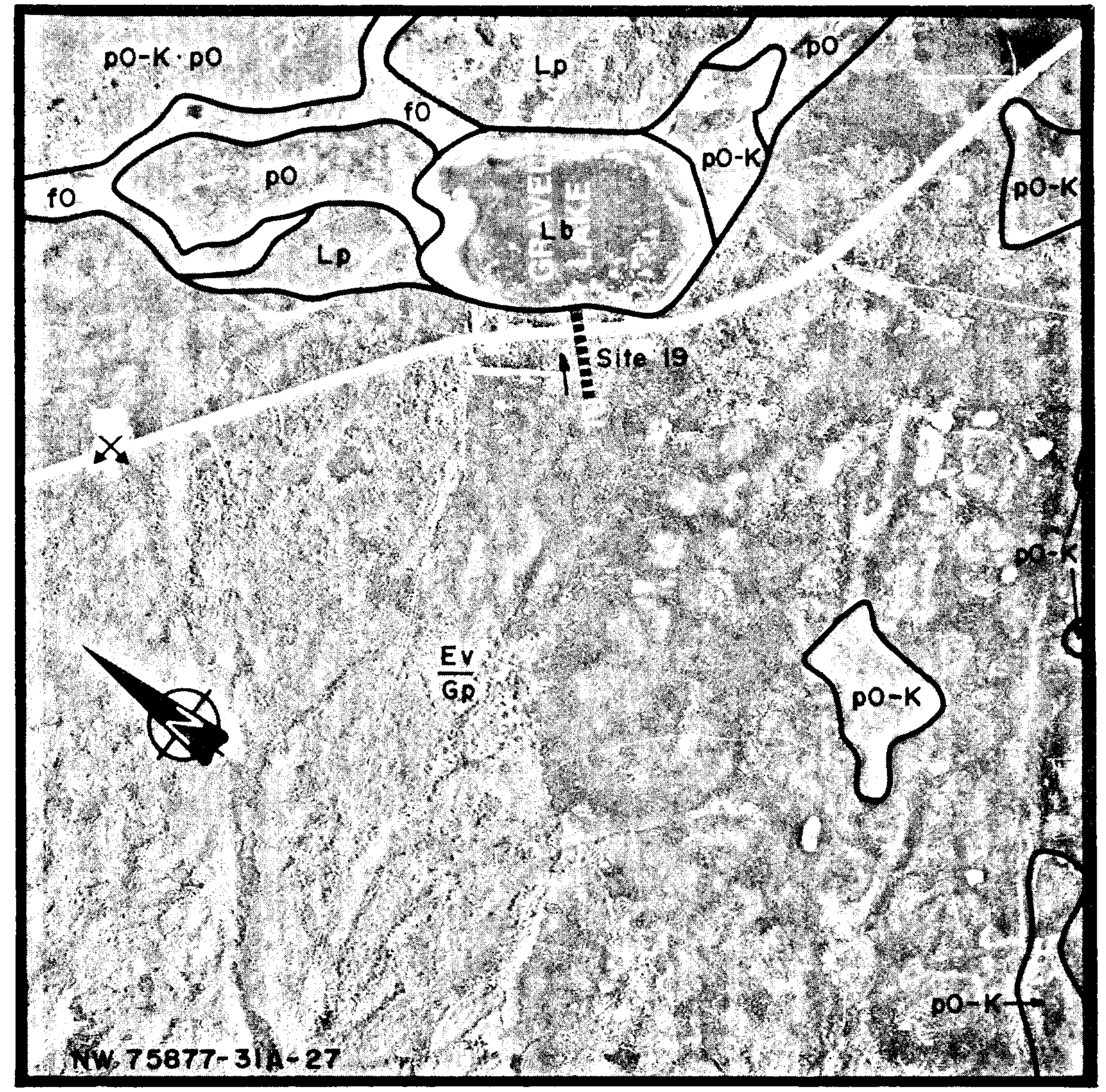
SITE LOCATIONS

K 4321

Figure 5·9



SITE 116



SITE 19

Legend	
Test hole location	● 107
Geophysical traverse and direction	▪▪▪▪▪▪▪▪ → Site 107

0 500 1000 metres

0 2000 4000 feet

Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY

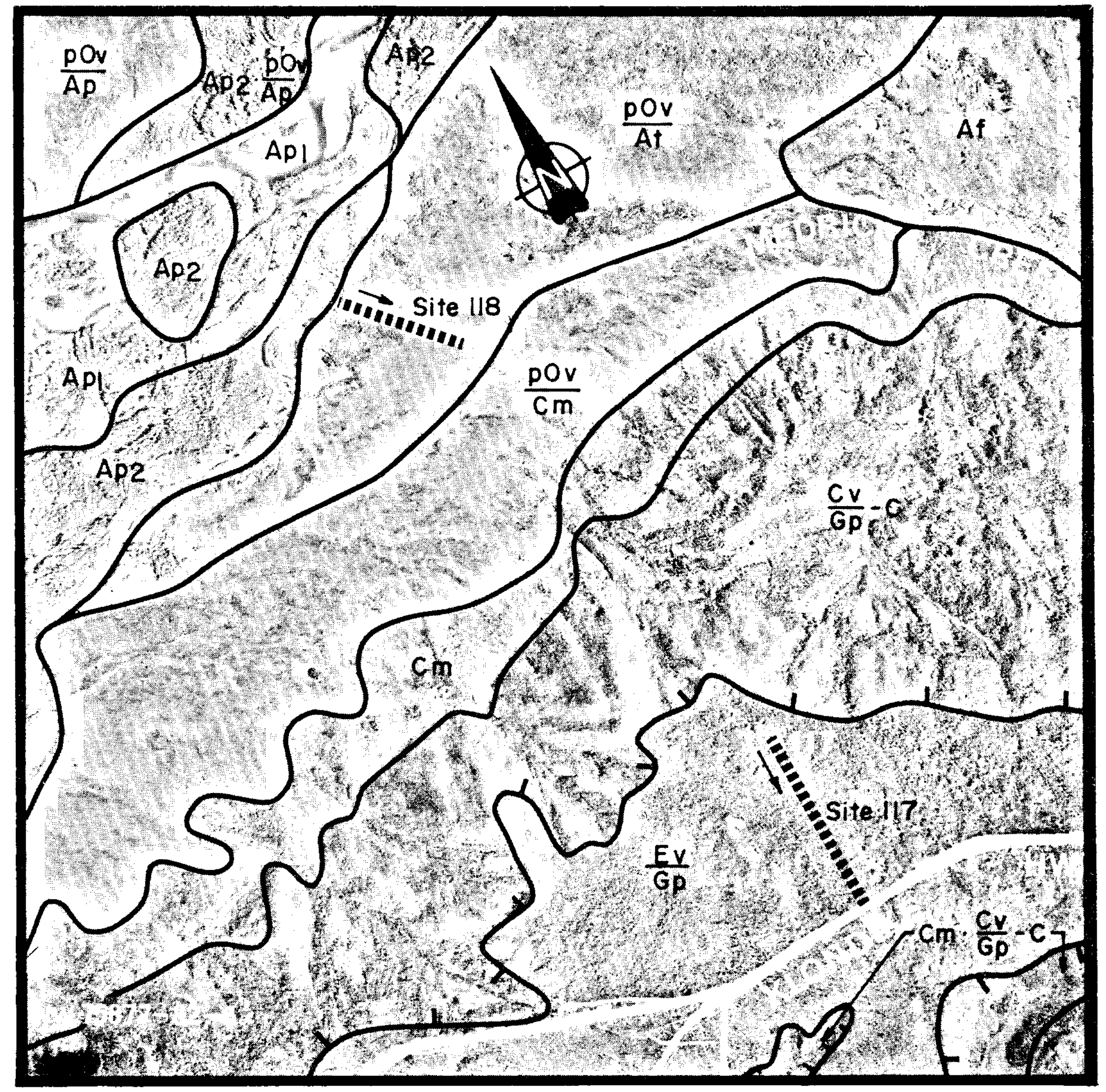
FOOTHILLS PIPE LINES (YUKON) LTD.

SITE LOCATIONS

K 4321

Figure 5·10

SITE 21



SITE 117 and 118

Legend Test hole location • 107 Geophysical traverse and direction → Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS K 4321 Figure 5·11

SITE 22

SITE 121

Legend

Test hole location	• 107
Geophysical traverse and direction	▮▮▮▮▮▮▮▮ → Site 107

0 500 1000 metres

0 2000 4000 feet

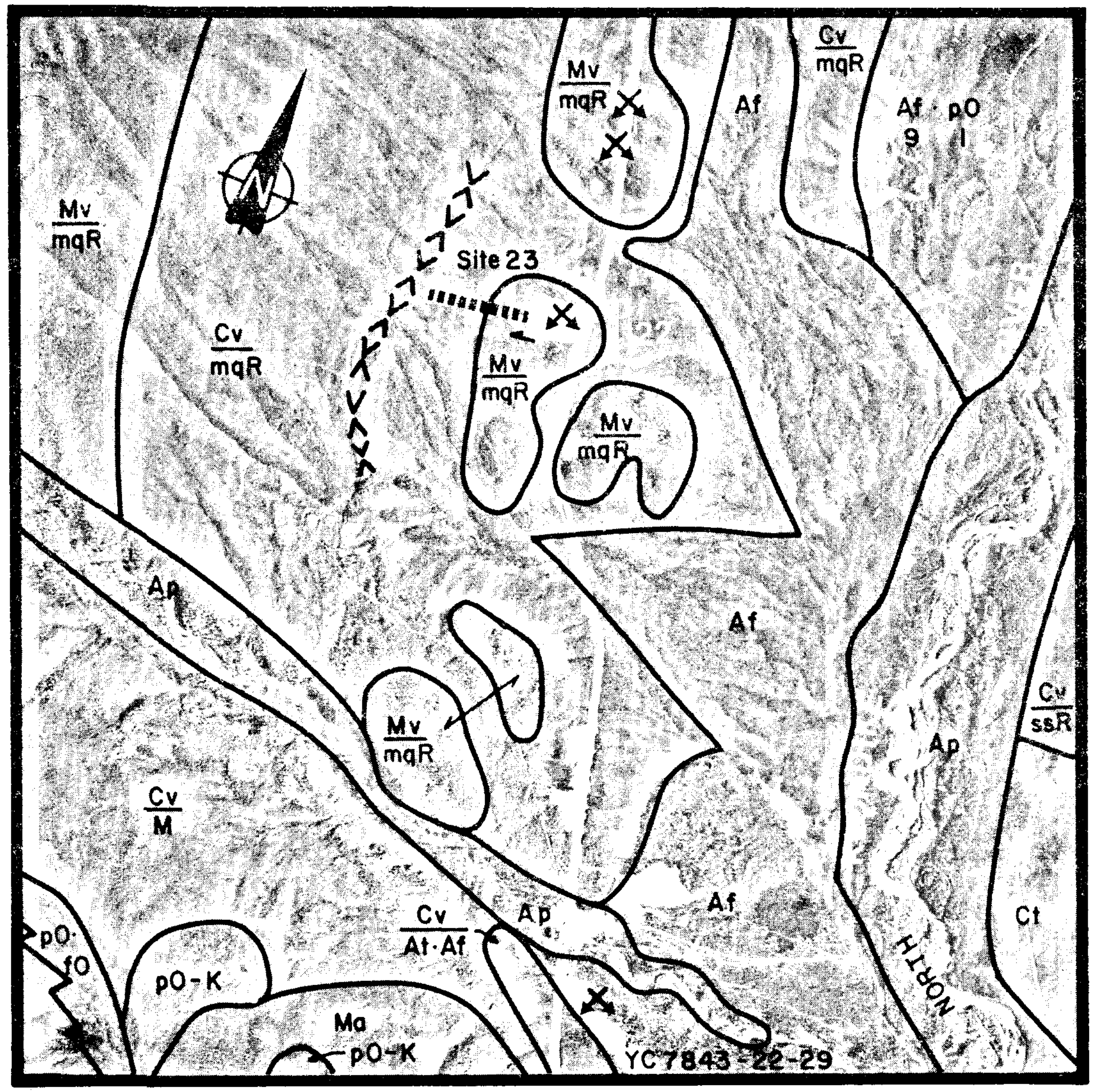
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

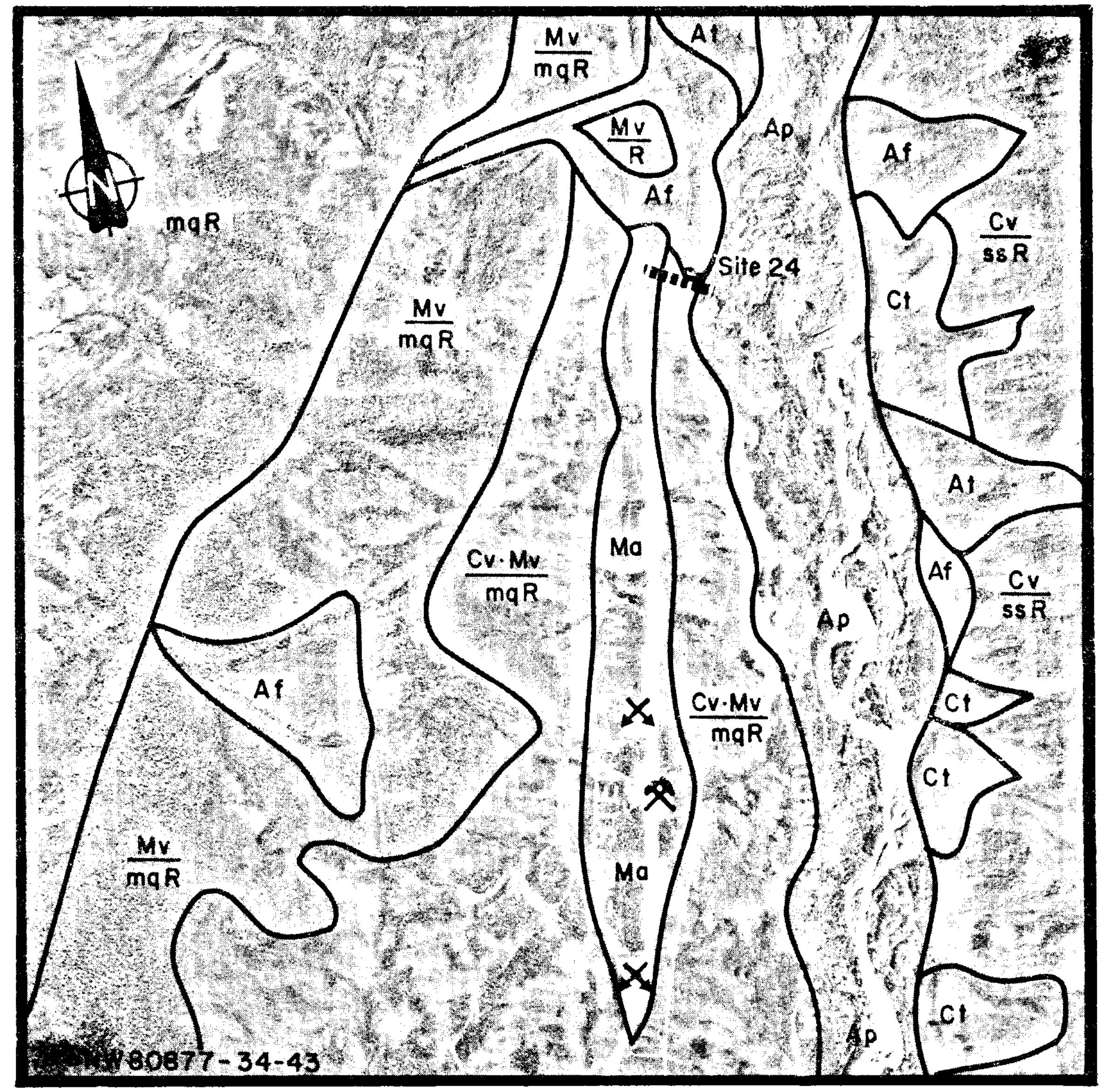
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·12

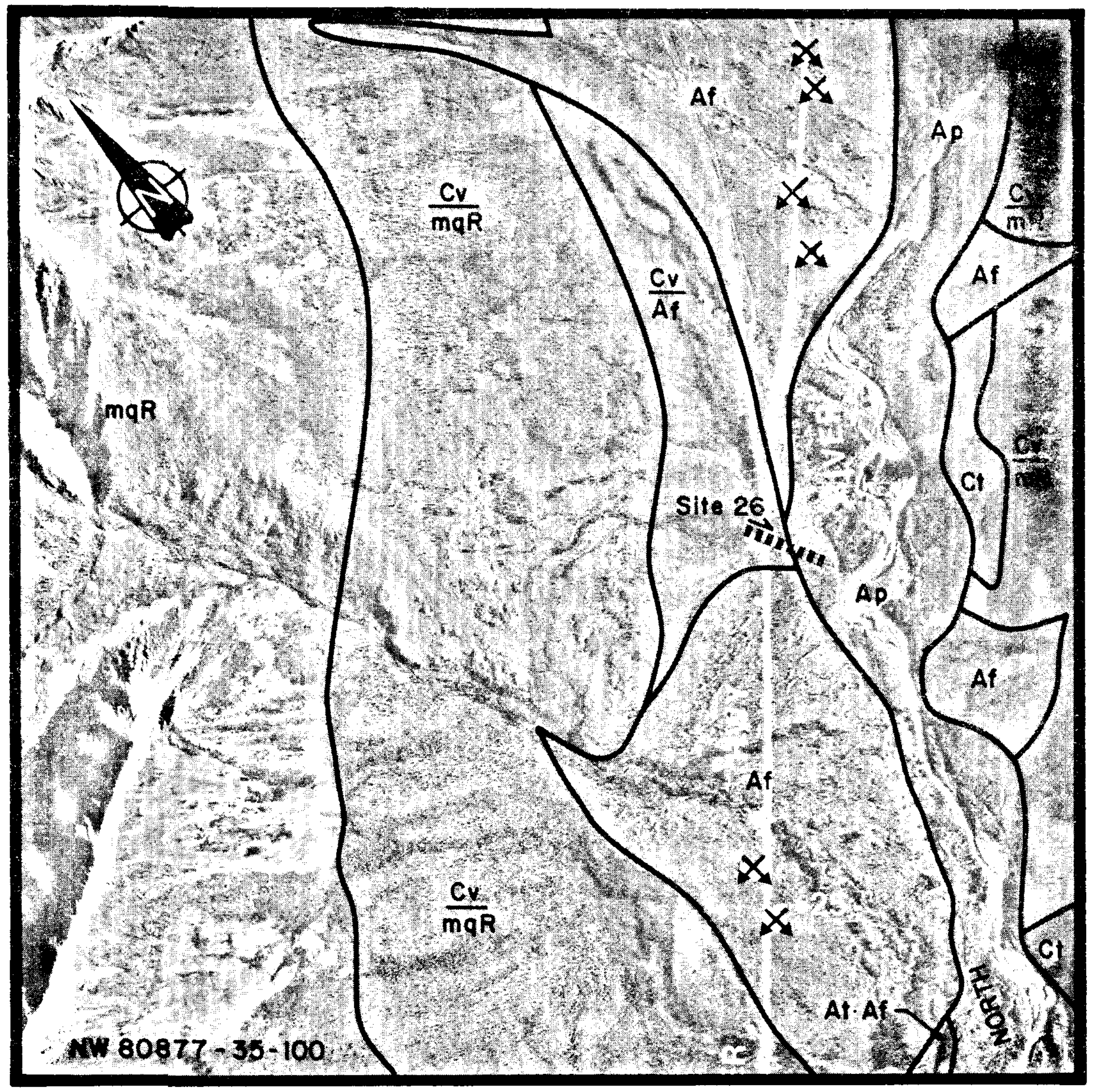


SITE 23

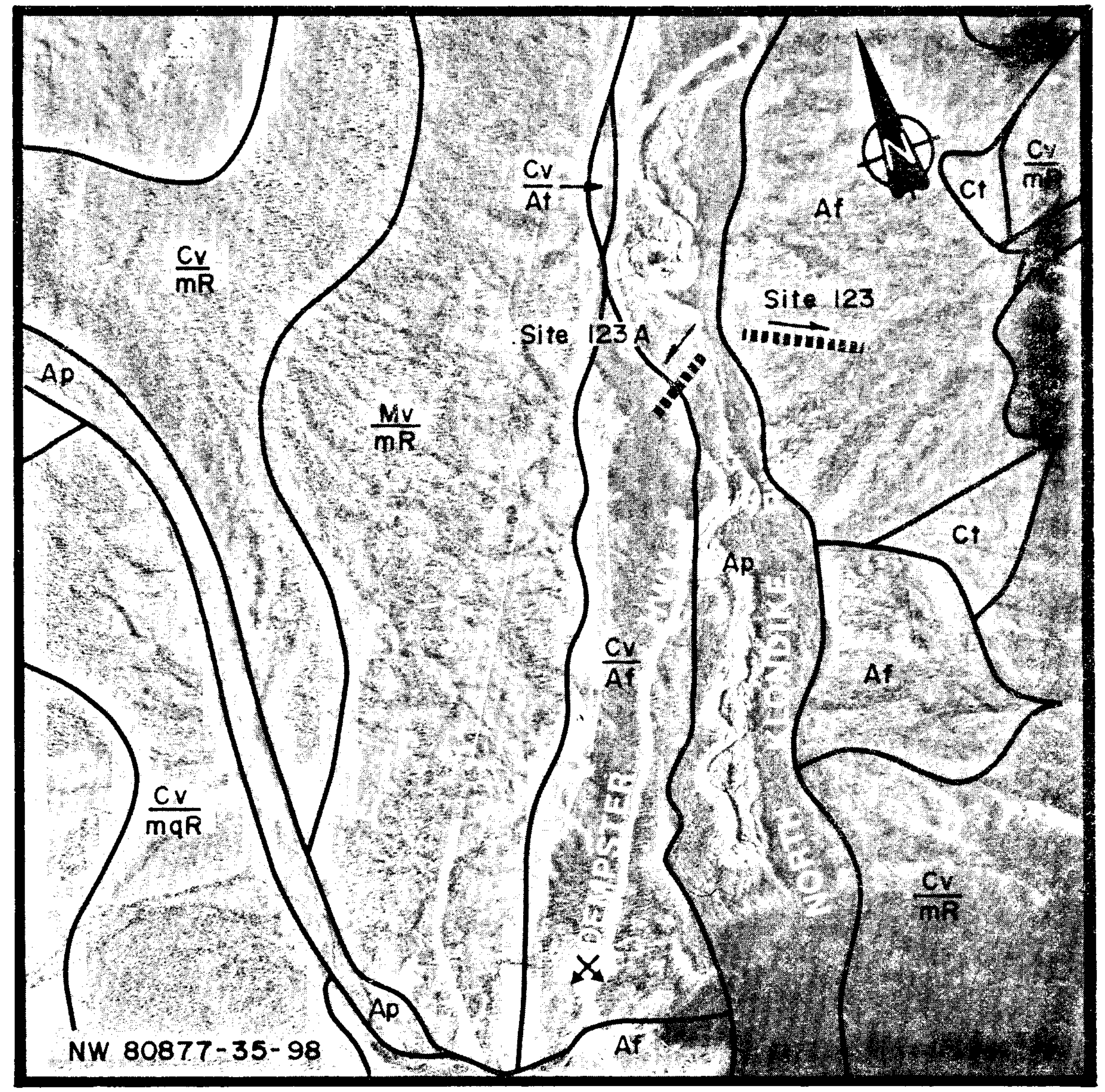


SITE 24

Legend				
Test hole location • 107 Geophysical traverse and direction ▪▪▪▪▪▪ → Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS K 4321 Figure 5·13

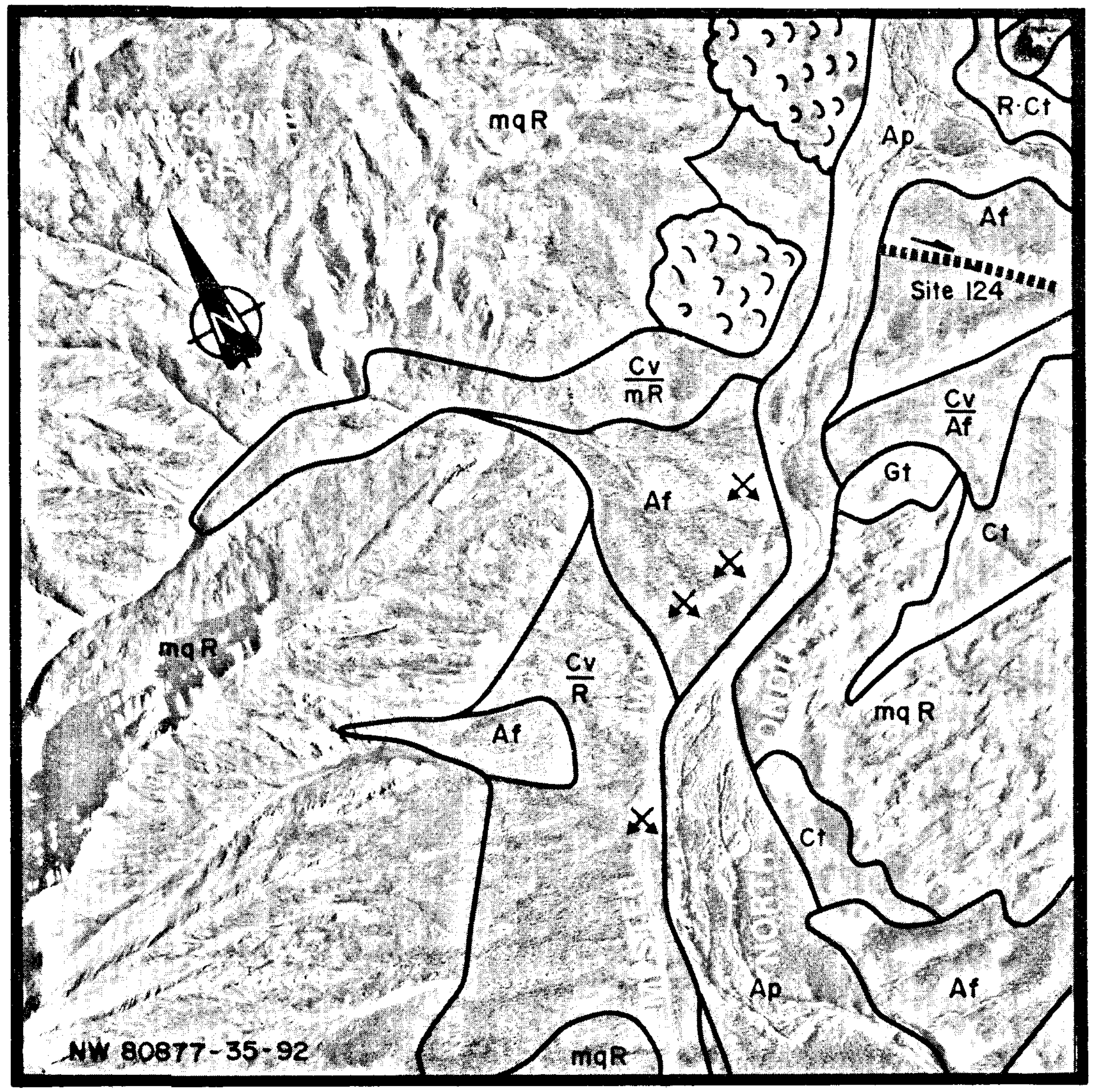


SITE 26



SITE 123A and 123

Legend Test hole location ● 107 Geophysical traverse and direction → Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS K 4321 Figure 5·14



SITE 124

SITE 28

Legend

Test hole location ● 107

Geophysical traverse and direction → Site 107

0 500 1000 metres

0 2000 4000 feet

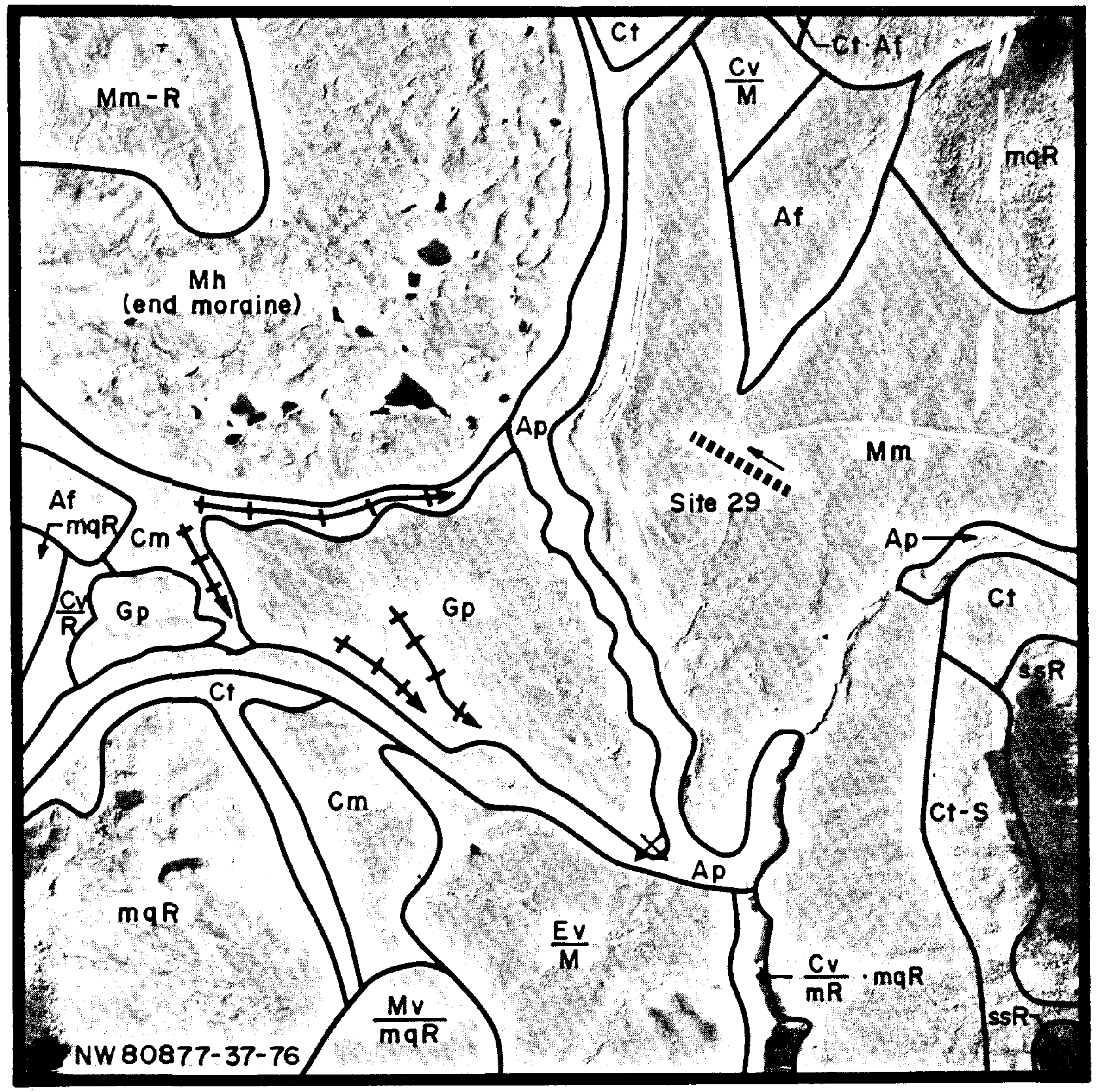
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·15



SITE 29

SITE 31

Legend

Test hole location	• 107
Geophysical traverse and direction	▮▮▮▮▮▮▮▮ → Site 107

0 500 1000 metres

0 2000 4000 feet

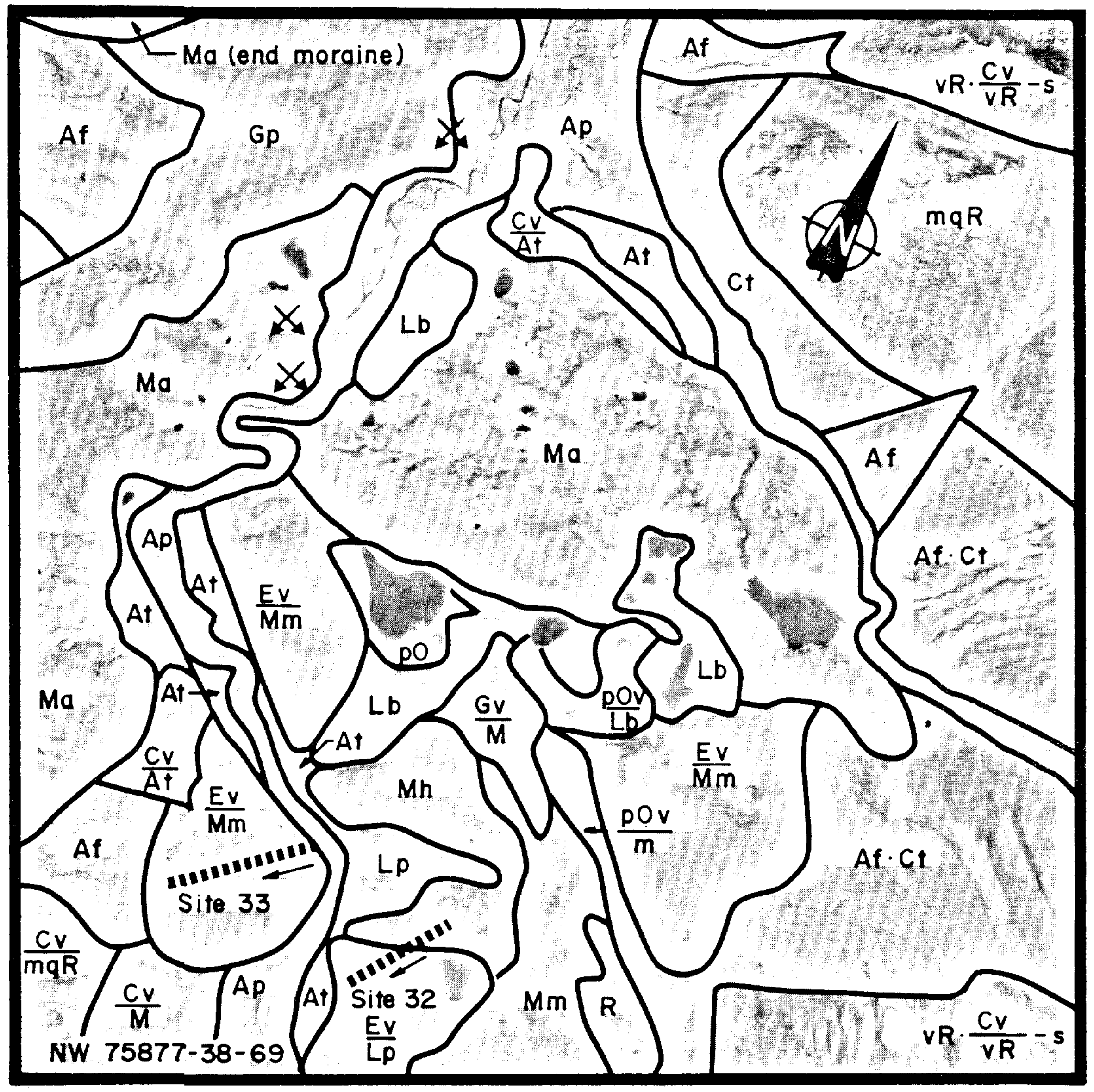
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

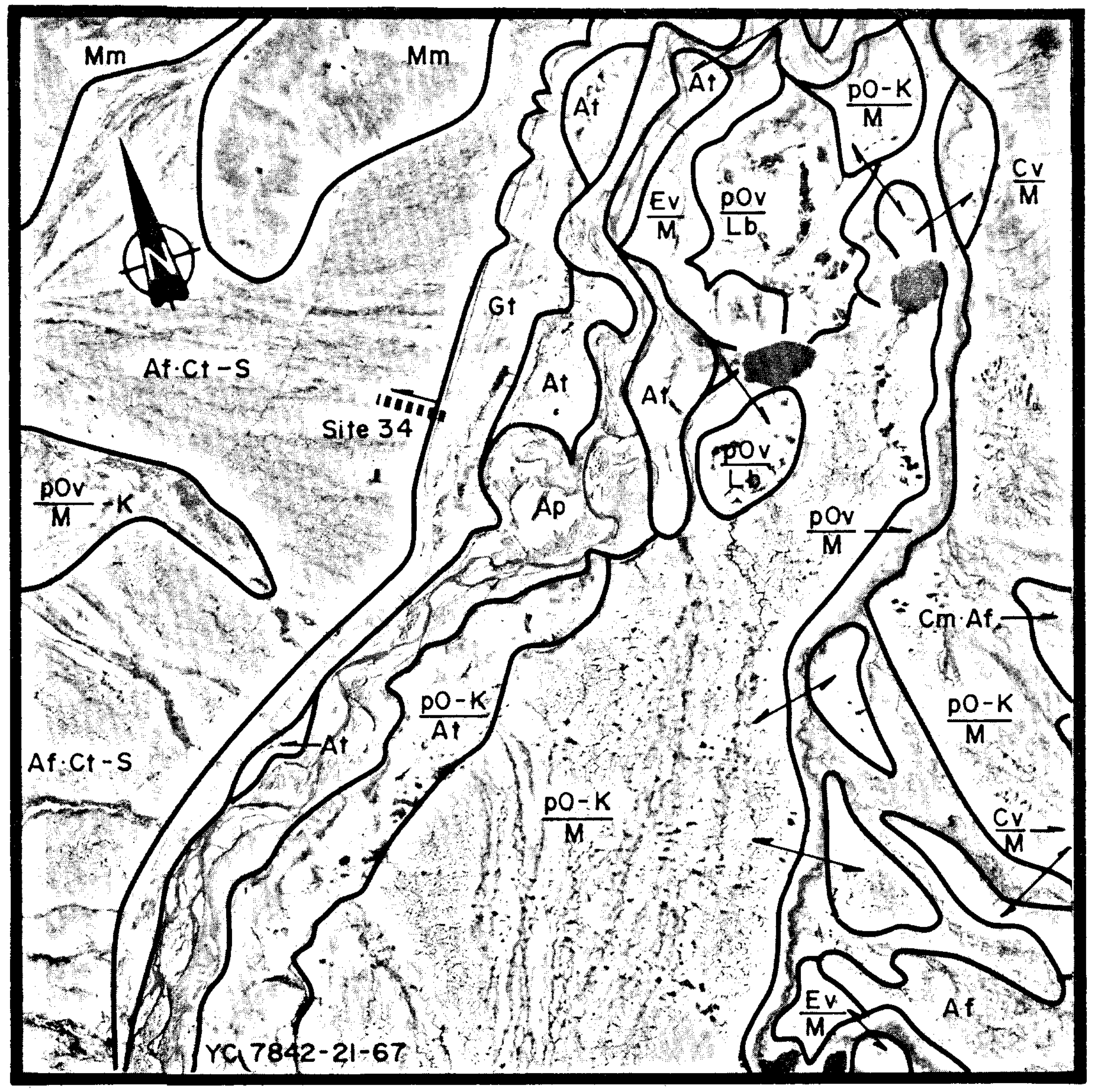
Figure 5·16



SITE 32 and 33

SITE 125

Legend Test hole location ● 107 Geophysical traverse and direction ▪▪▪▪▪ → Site 107	0 500 1000 metres 0 2000 4000 feet Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS K 4321 Figure 5·17



SITE 34

SITE 127

Legend

Test hole location	• 107
Geophysical traverse and direction	→ Site 107

0 500 1000 metres

0 2000 4000 feet

Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.

CONSULTING ENGINEERING & TESTING

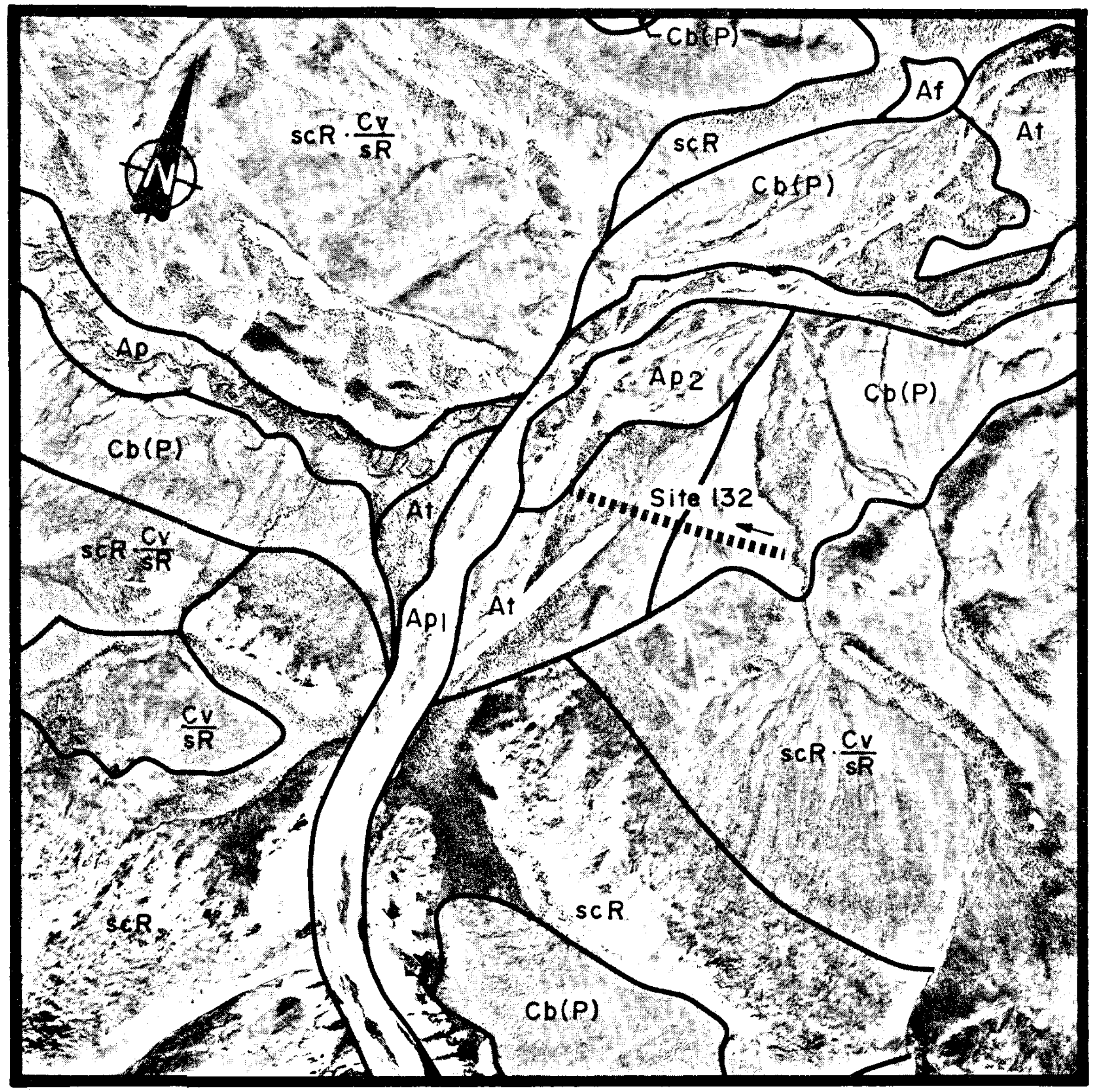
GEOPHYSICAL SURVEY

FOOTHILLS PIPE LINES (YUKON) LTD.

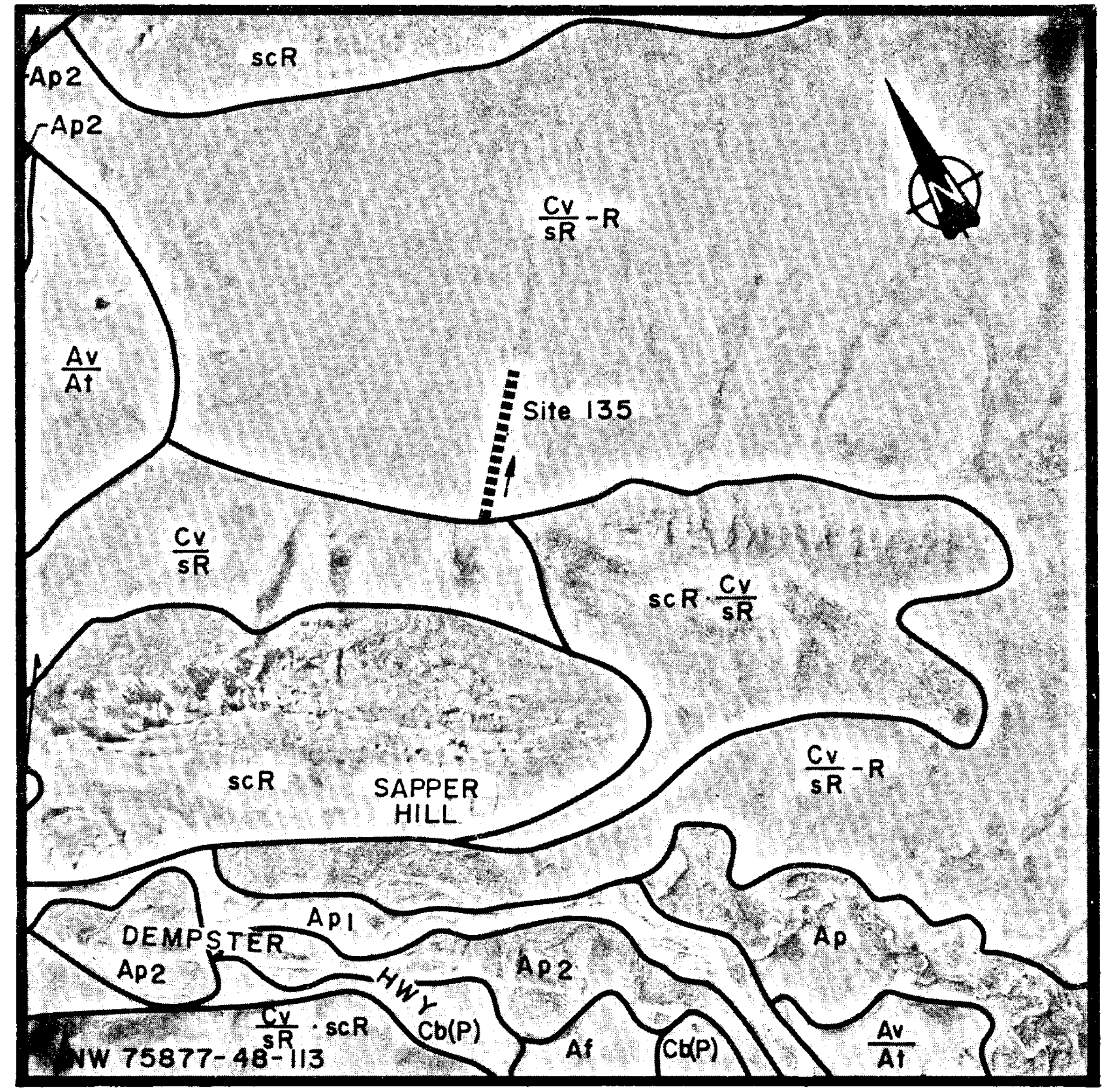
SITE LOCATIONS

K 4321

Figure 5·18



SITE 132



SITE 135

Legend	
Test hole location	• 107
Geophysical traverse and direction	→ Site 107

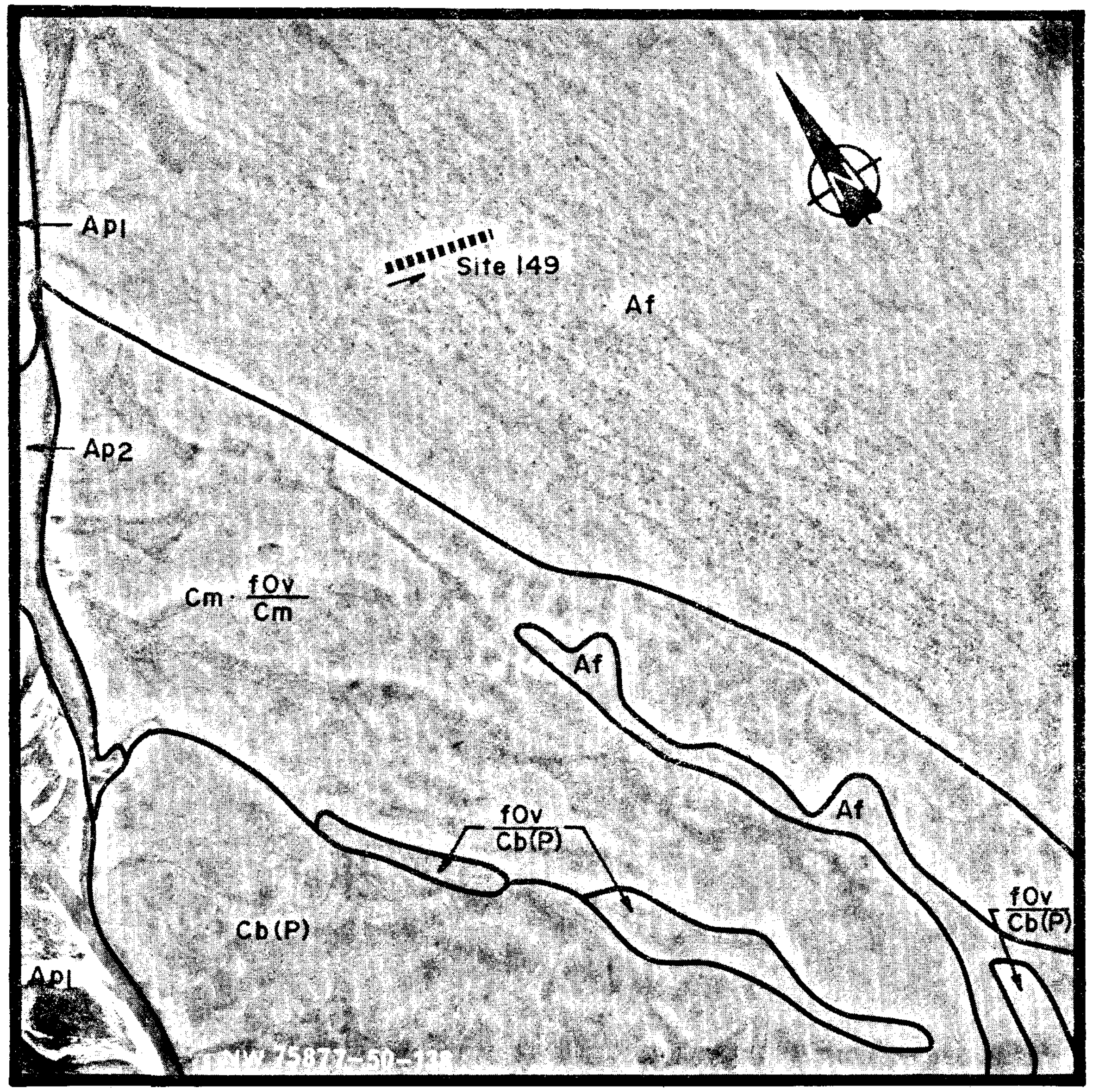
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

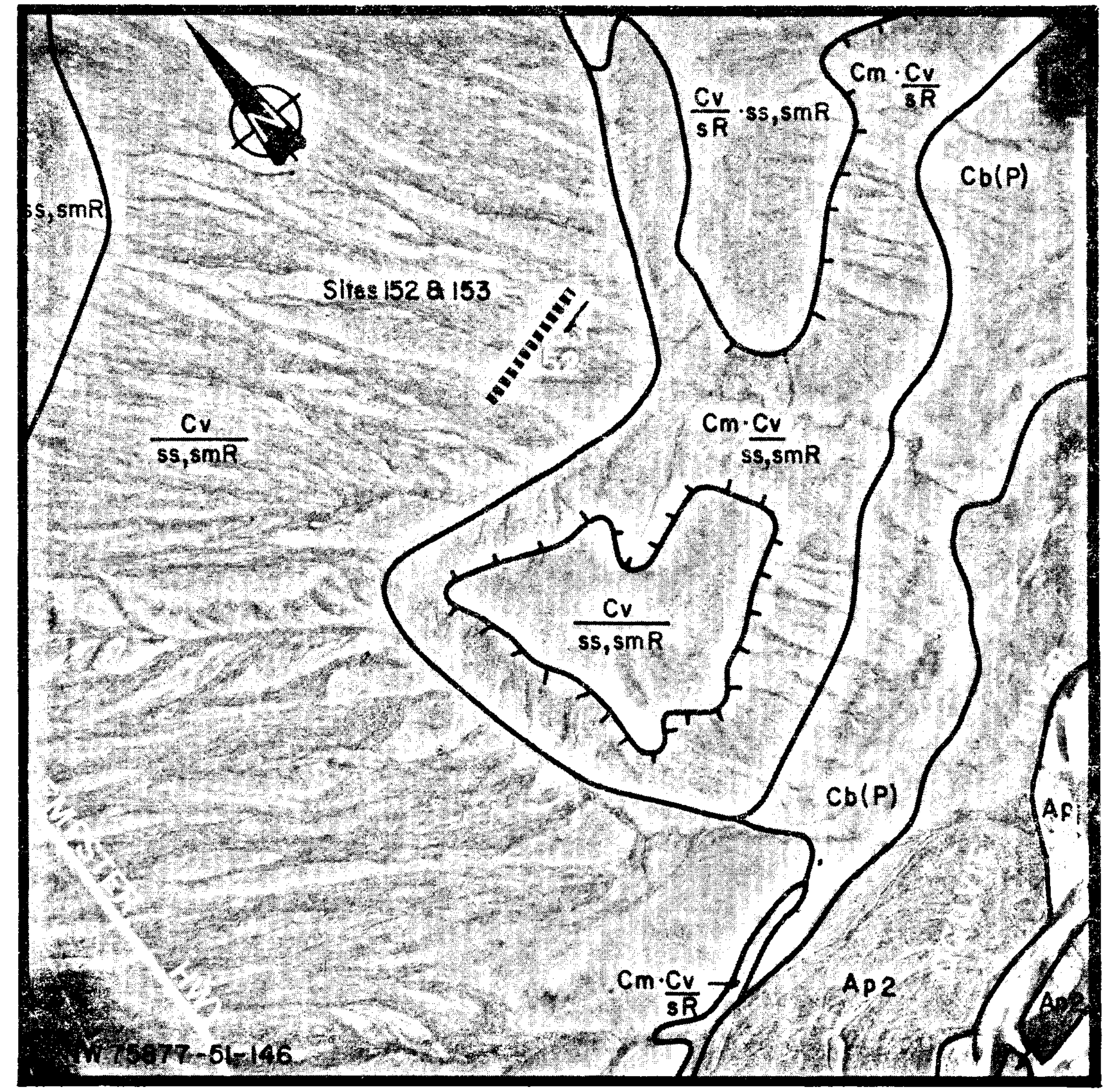
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·19



SITE 149



SITE 152 and 153

Legend

Test hole location • 107

Geophysical traverse and direction → Site 107

0 500 1000 metres

0 2000 4000 feet

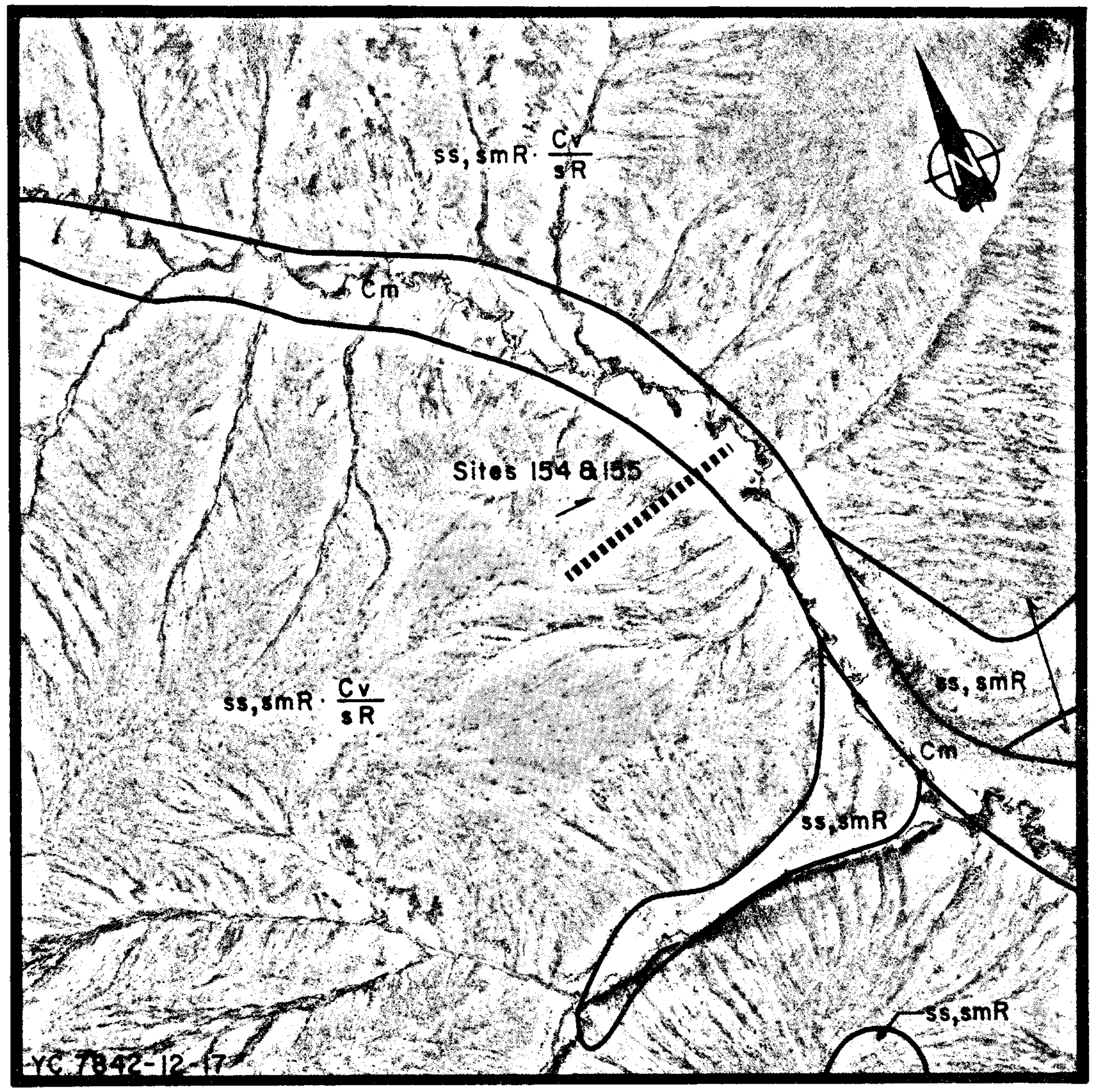
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

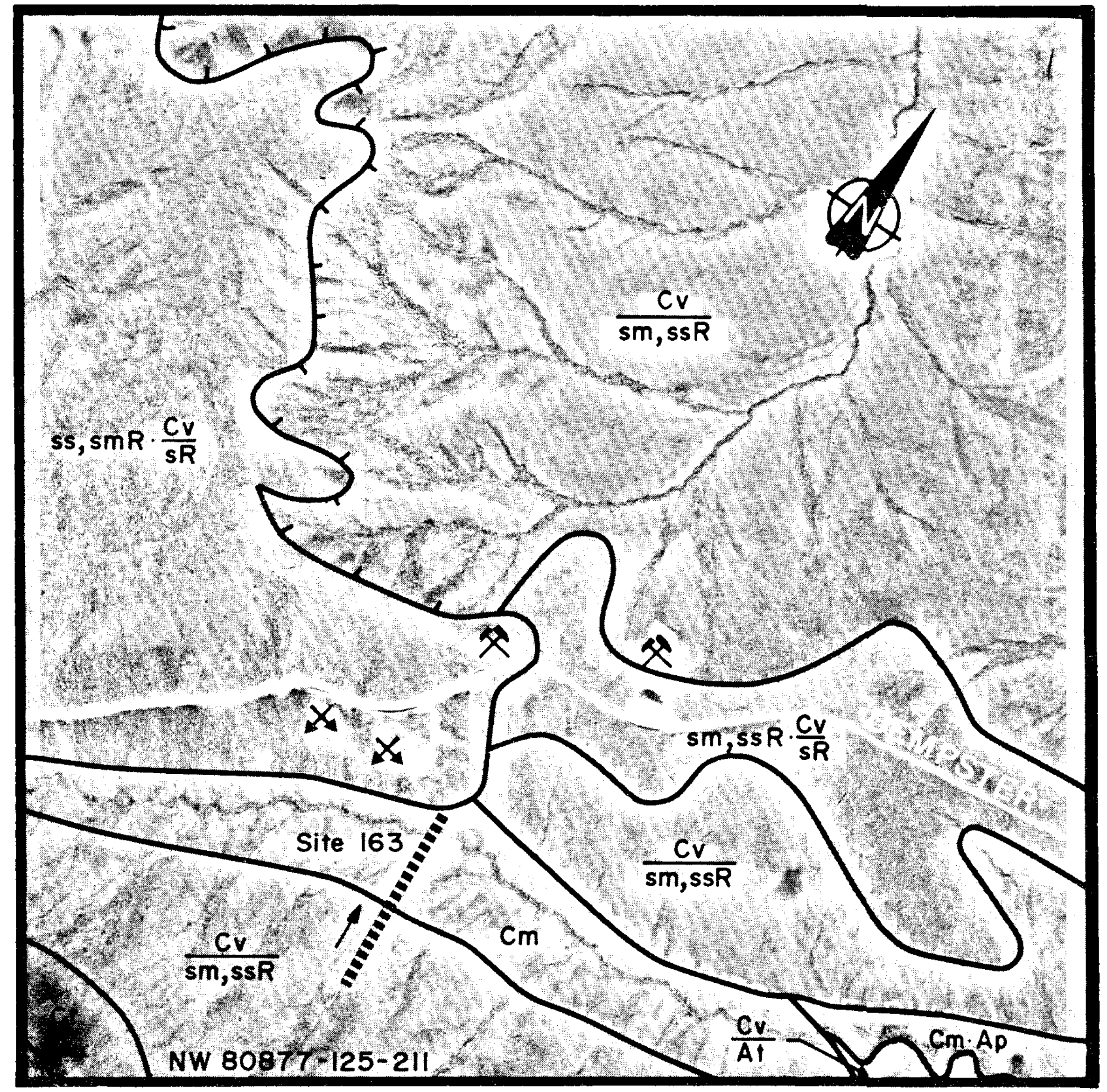
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·20



SITE 154 and 155



SITE 163

Legend	
Test hole location	• 107
Geophysical traverse and direction	▮▮▮▮ → Site 107

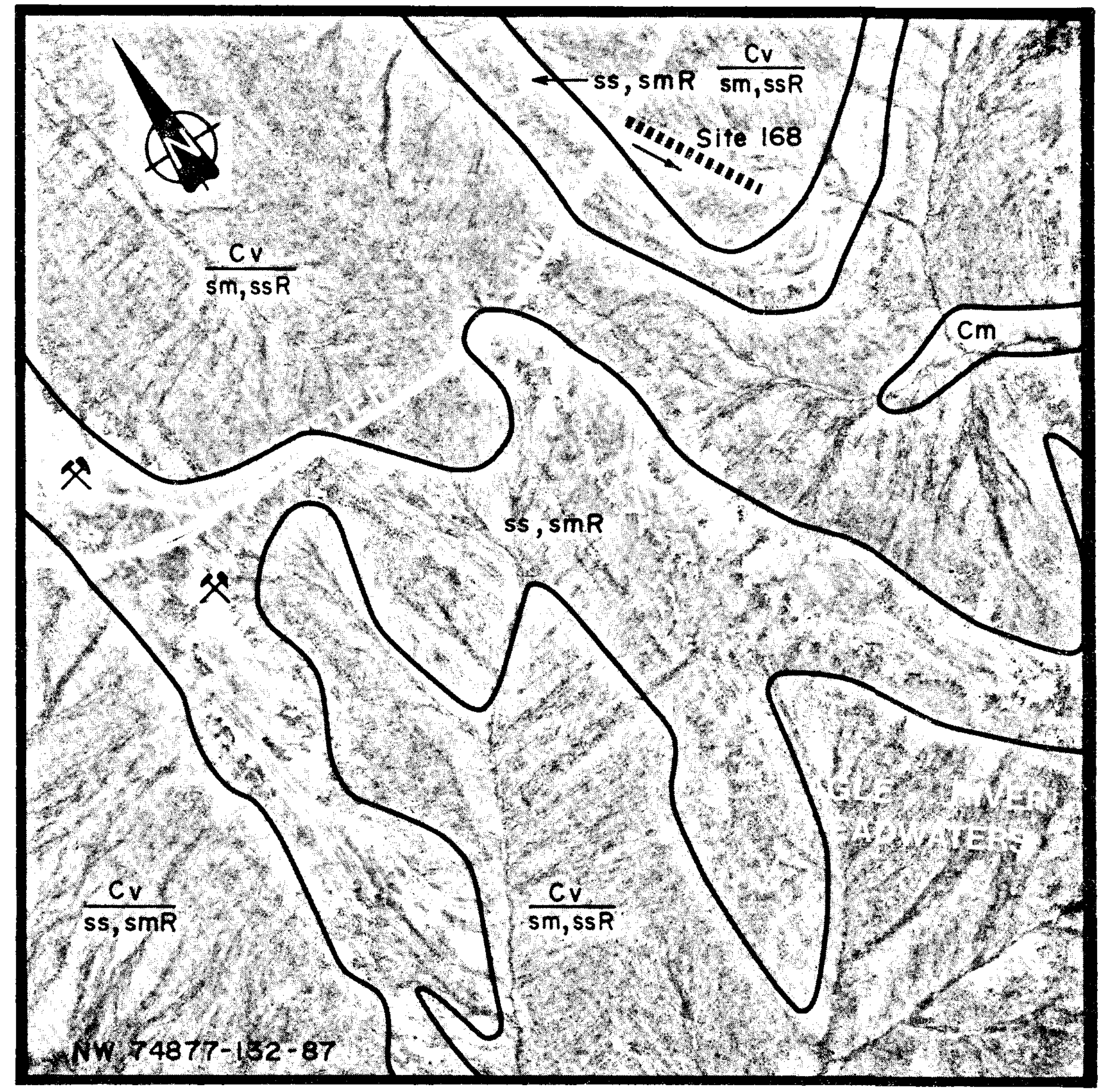
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321 Figure 5·21

SITE 165 and 167



SITE 168

Legend	
Test hole location	• 107
Geophysical traverse and direction	→ Site 107

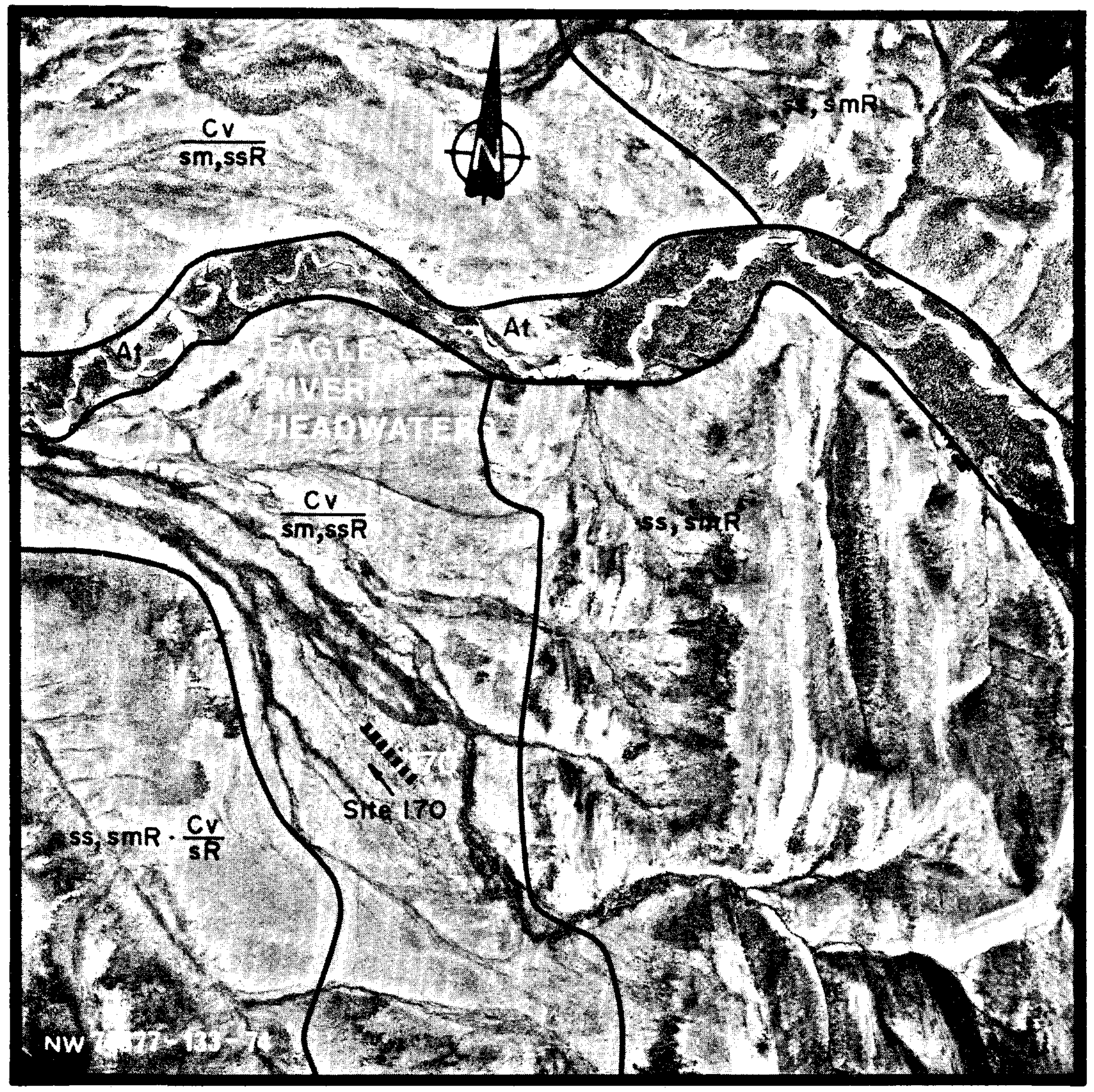
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

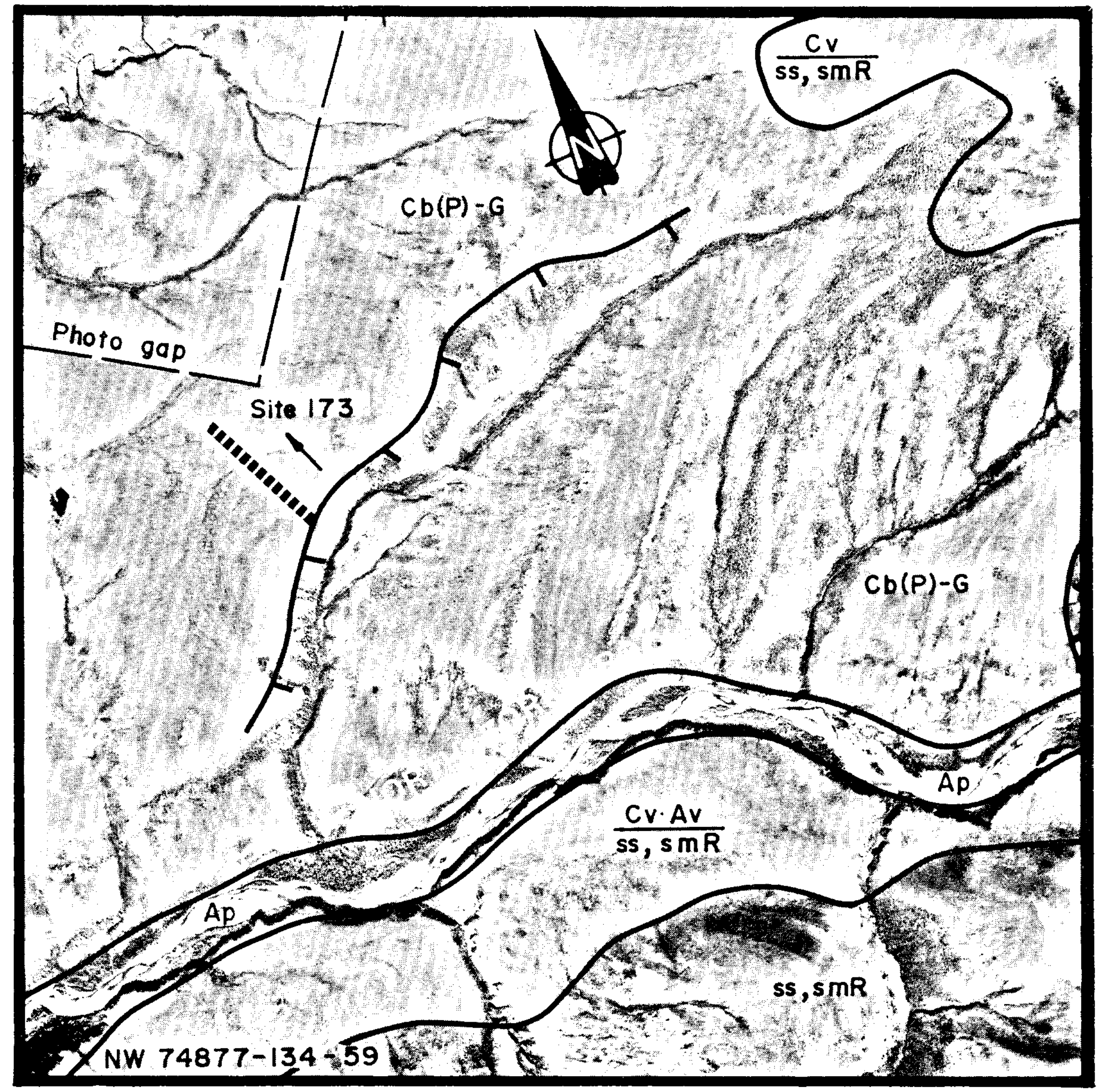
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·22



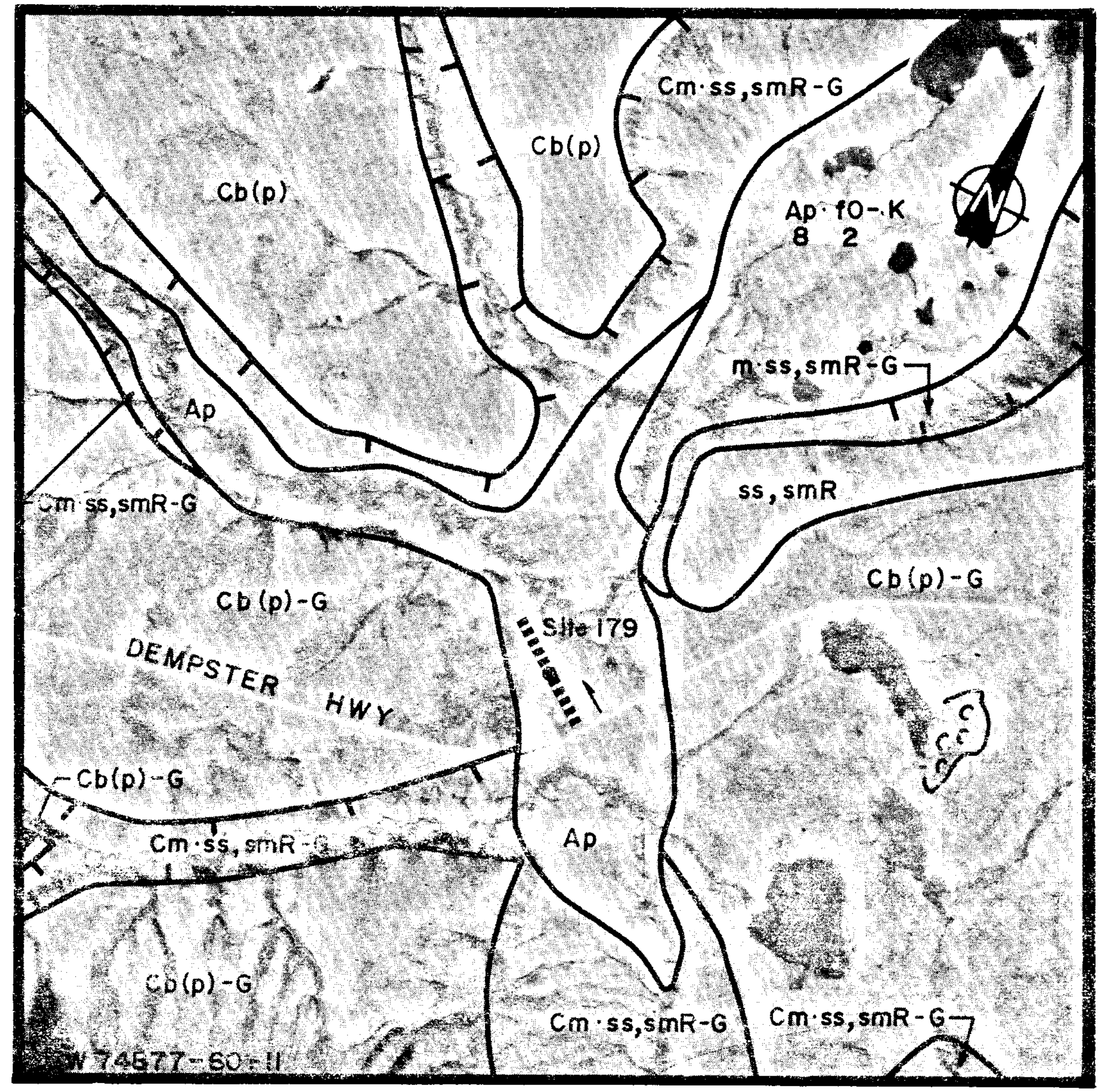
SITE 170



SITE 173

Legend		Approximate scale 1:24000 (0 – 500 – 1000 metres; 0 – 2000 – 4000 feet)	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS
Test hole location	● 107			K 4321
Geophysical traverse and direction	▮▮▮▮▮▮ → Site 107			Figure 5·23

SITE 175 and 176



SITE 179

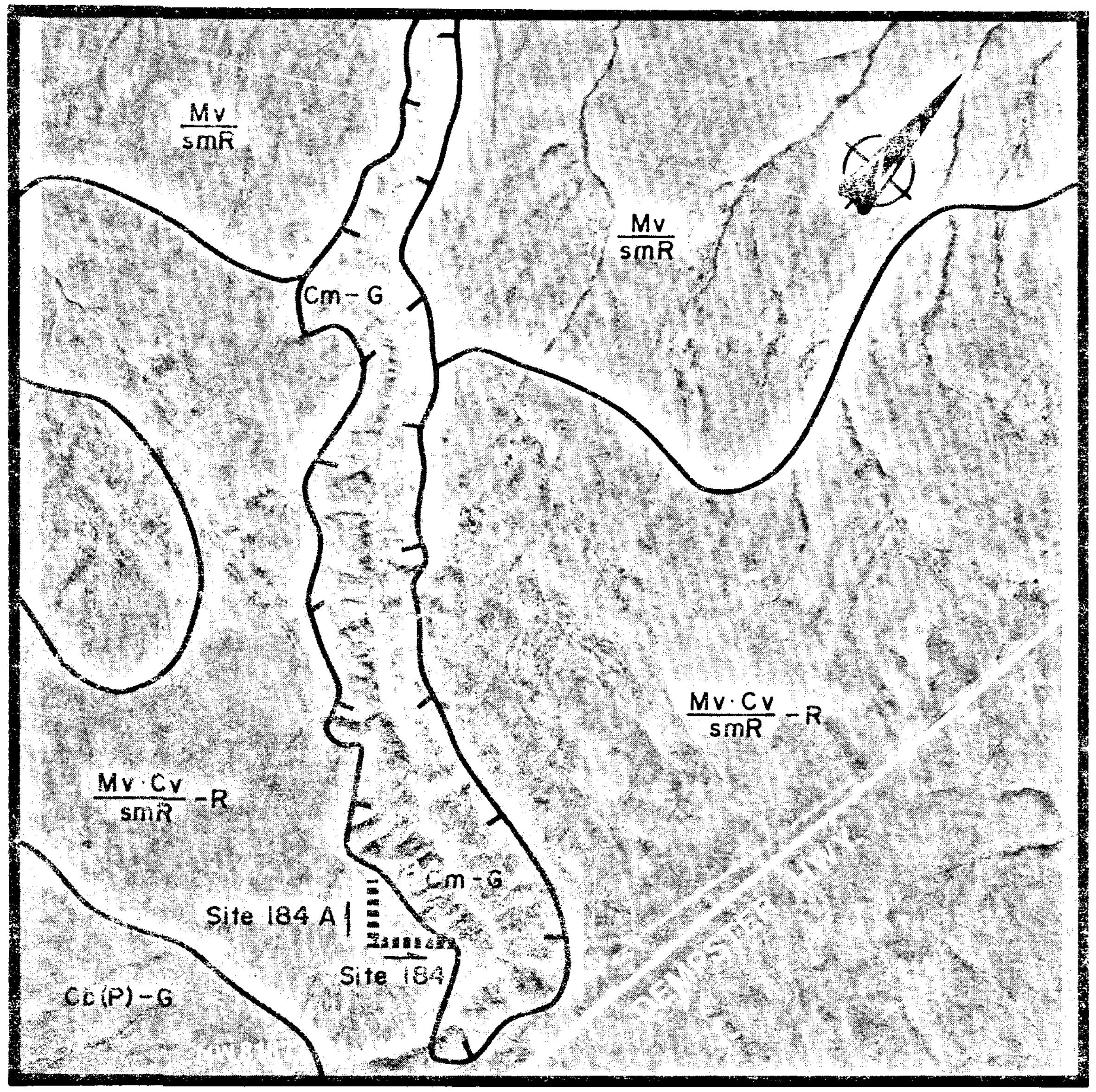
Legend		
Test hole location	● 107	
Geophysical traverse and direction	→ Site 107	

0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

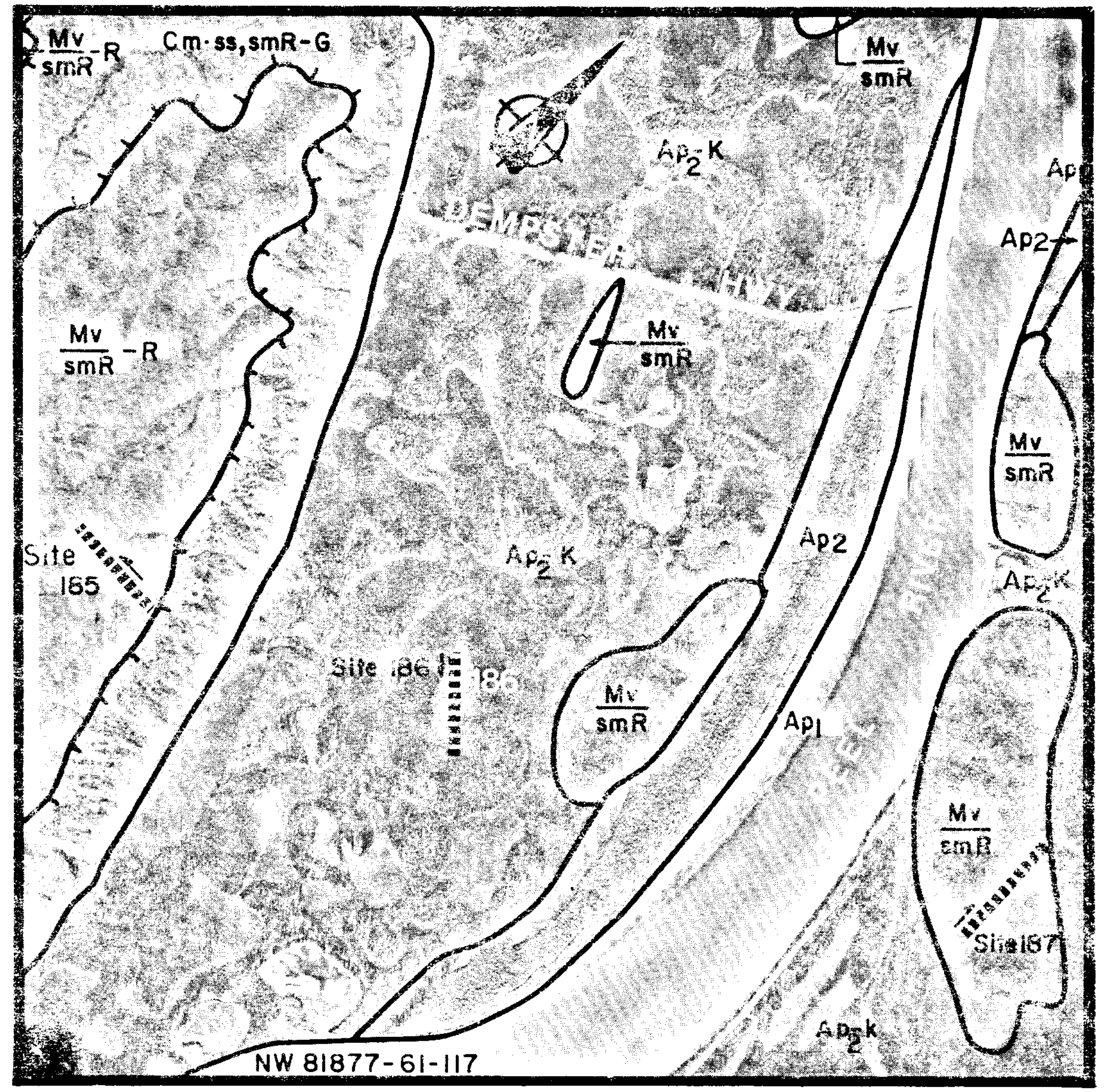
R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321 Figure 5·24



SITE 184 and 184A



SITE 185, 186 and 187

Legend	
Test hole location	● 107
Geophysical traverse and direction	▪▪▪▪▪▪ → Site 107

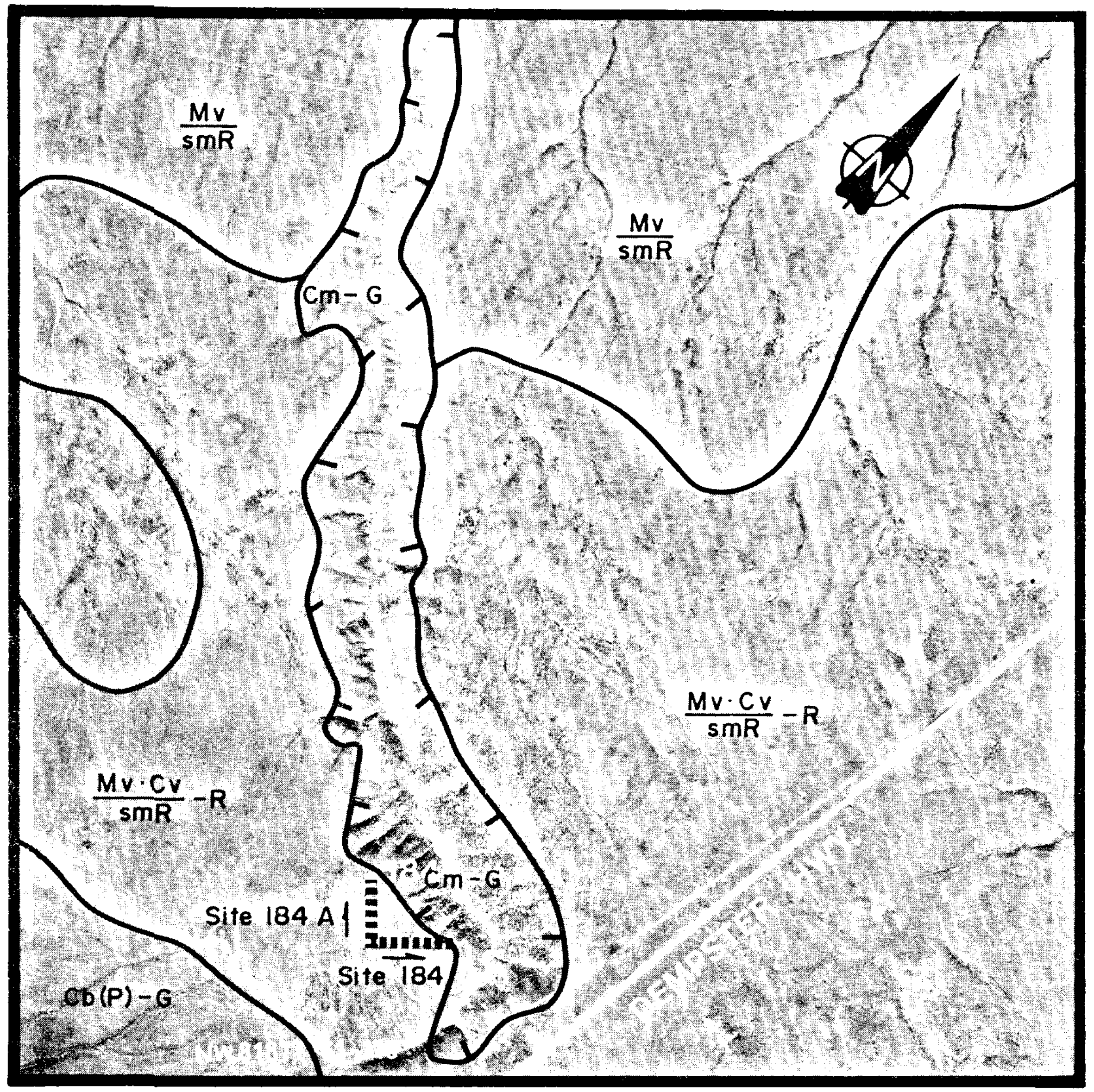
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

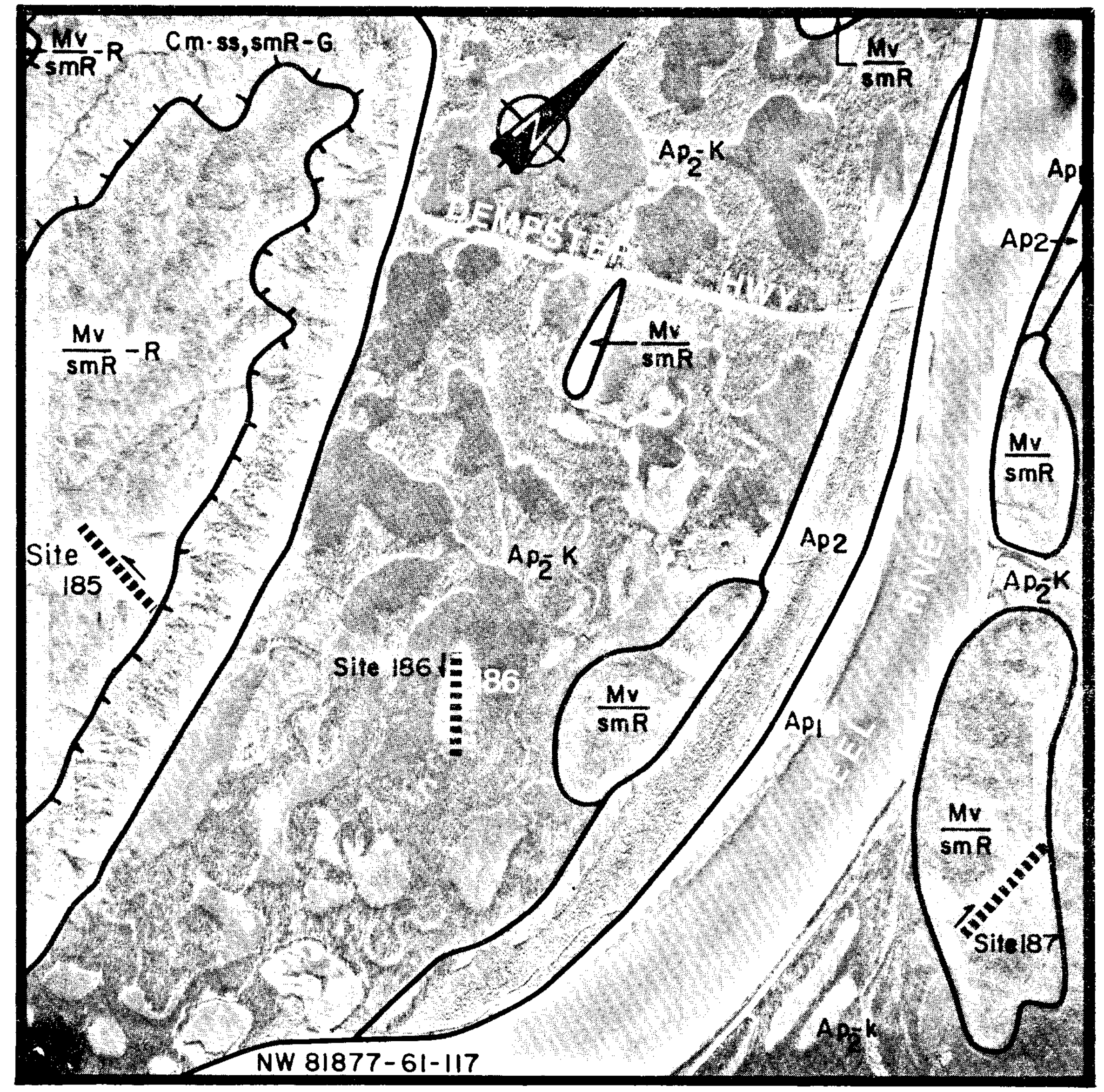
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·25



SITE 184 and 184A



SITE 185, 186 and 187

Legend

Test hole location	• 107
Geophysical traverse and direction	→ Site 107

0 500 1000 metres

0 2000 4000 feet

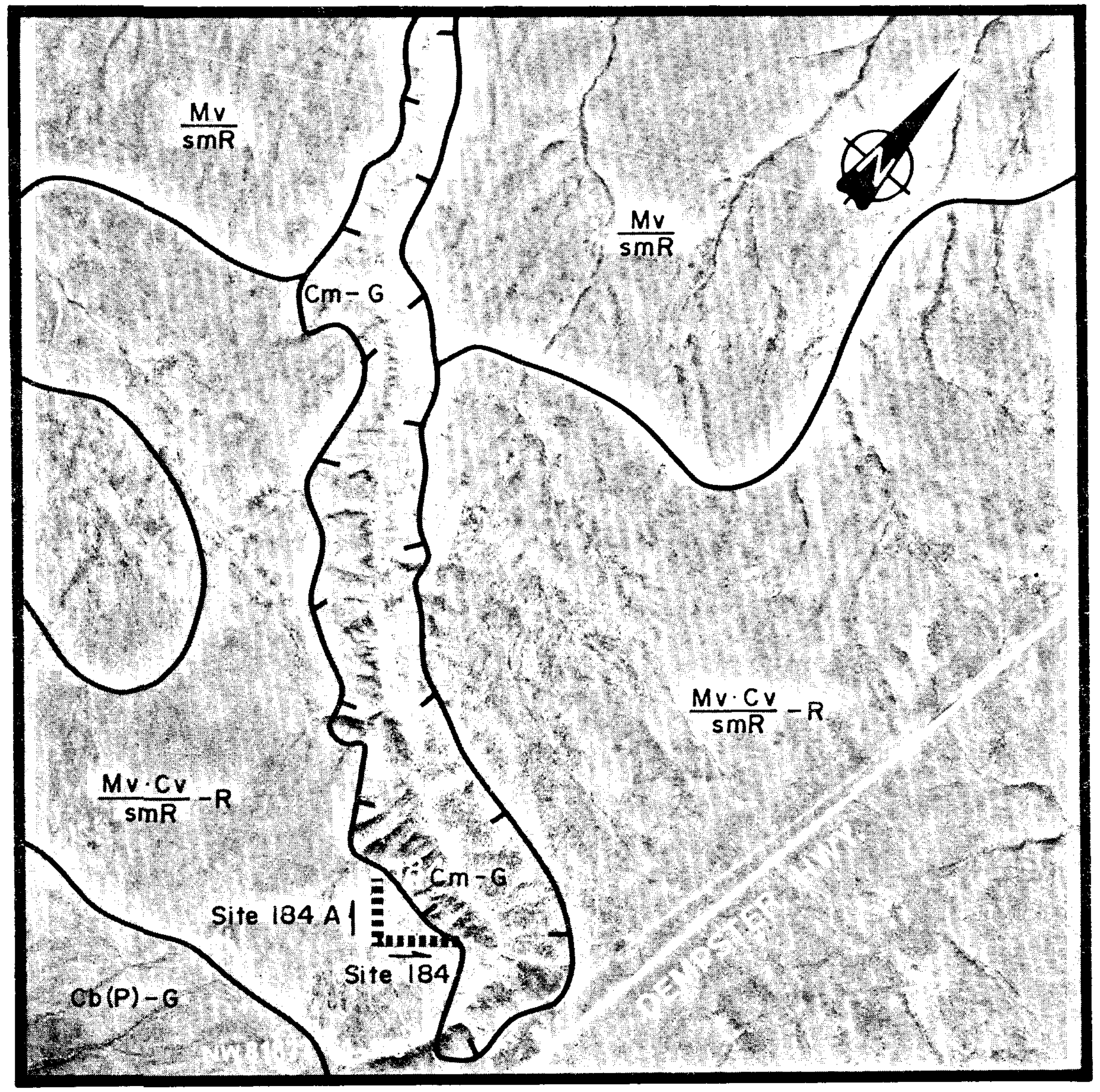
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

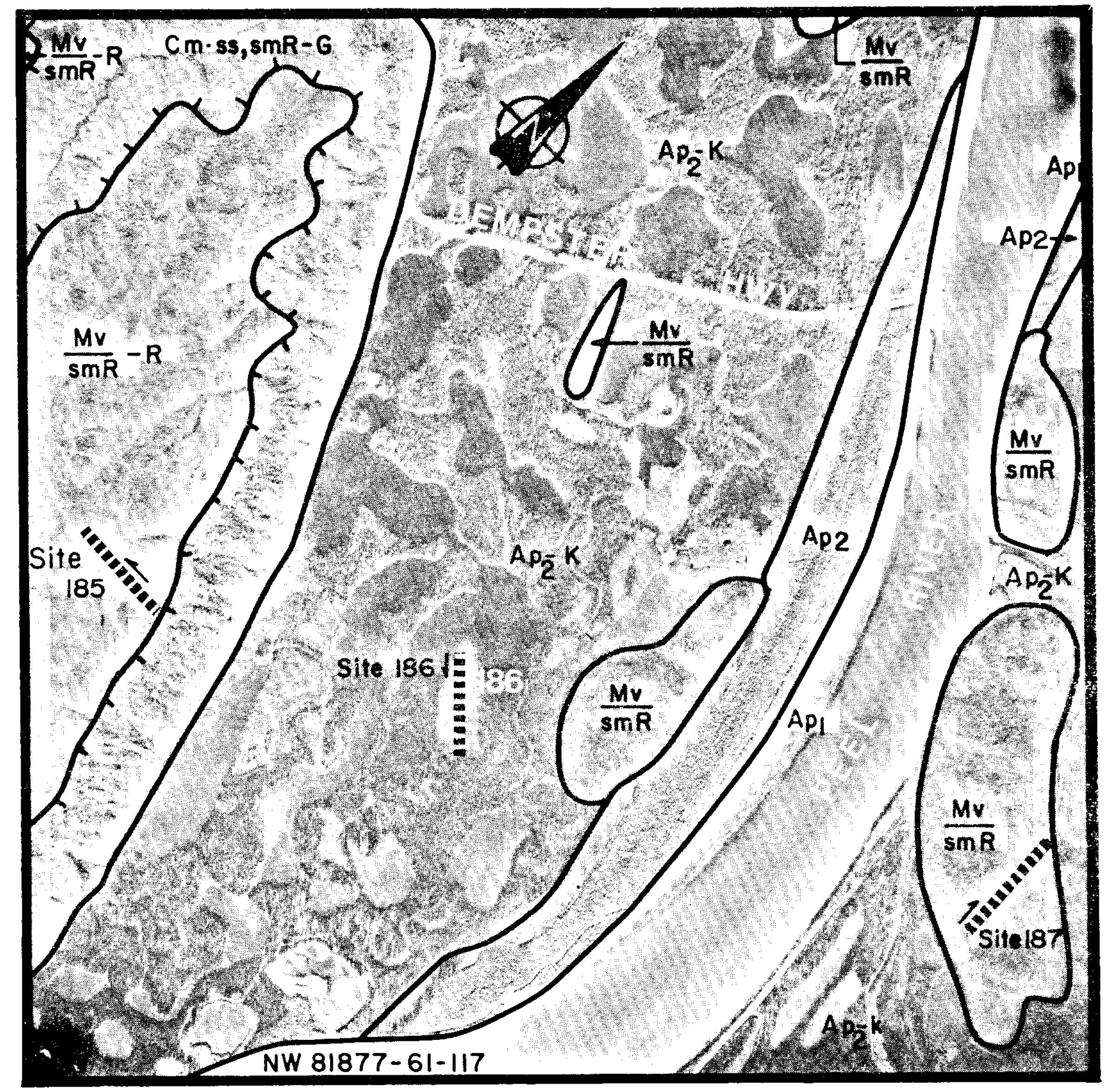
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·25



SITE 184 and 184A



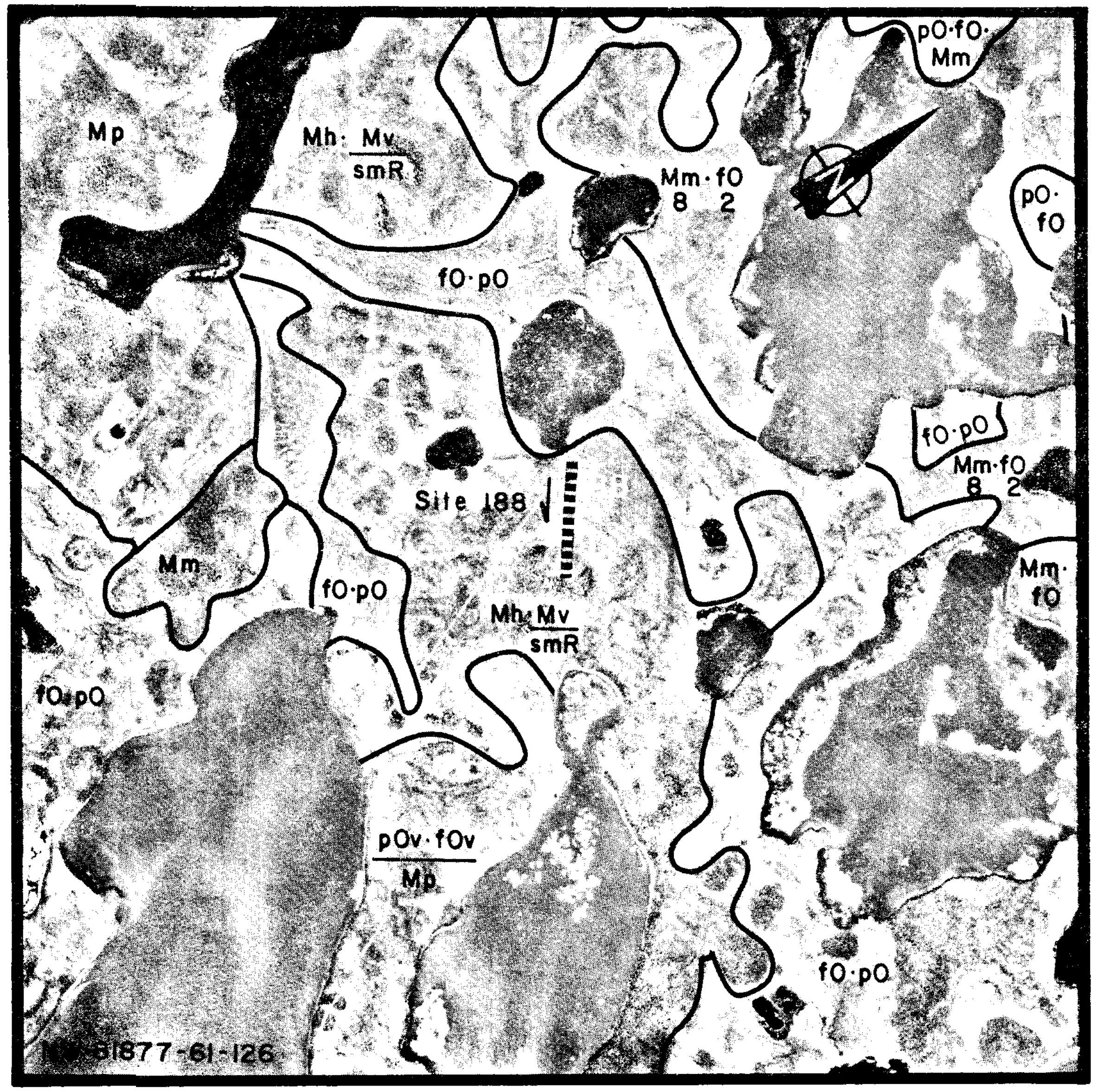
SITE 185, 186 and 187

Legend	
Test hole location	• 107
Geophysical traverse and direction	→ Site 107

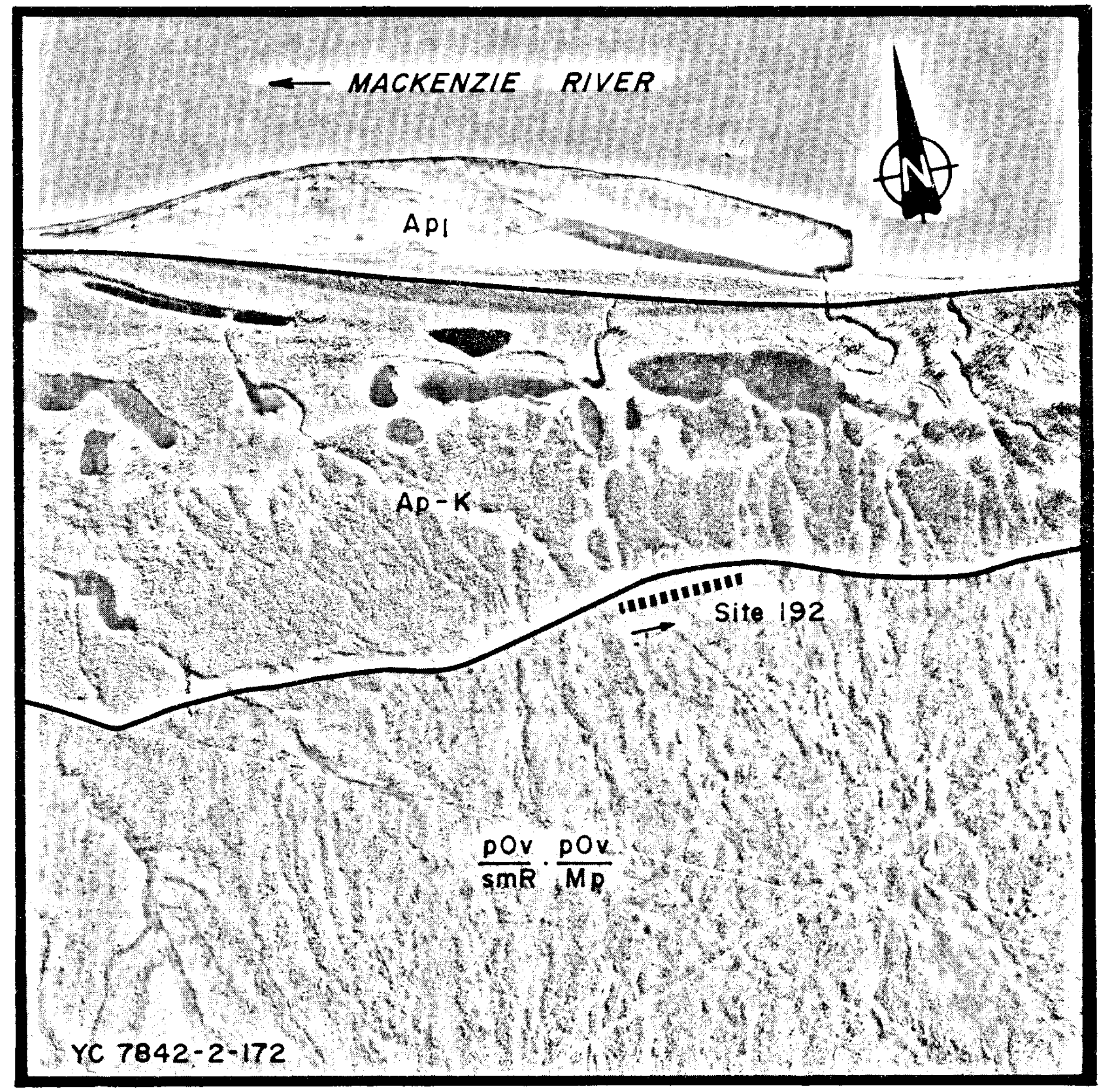
0 500 1000 metres
0 2000 4000 feet
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS
K 4321 Figure 5·25



SITE 188



SITE 192

Legend	
Test hole location	● 107
Geophysical traverse and direction	Site 107

0 500 1000 metres

0 2000 4000 feet

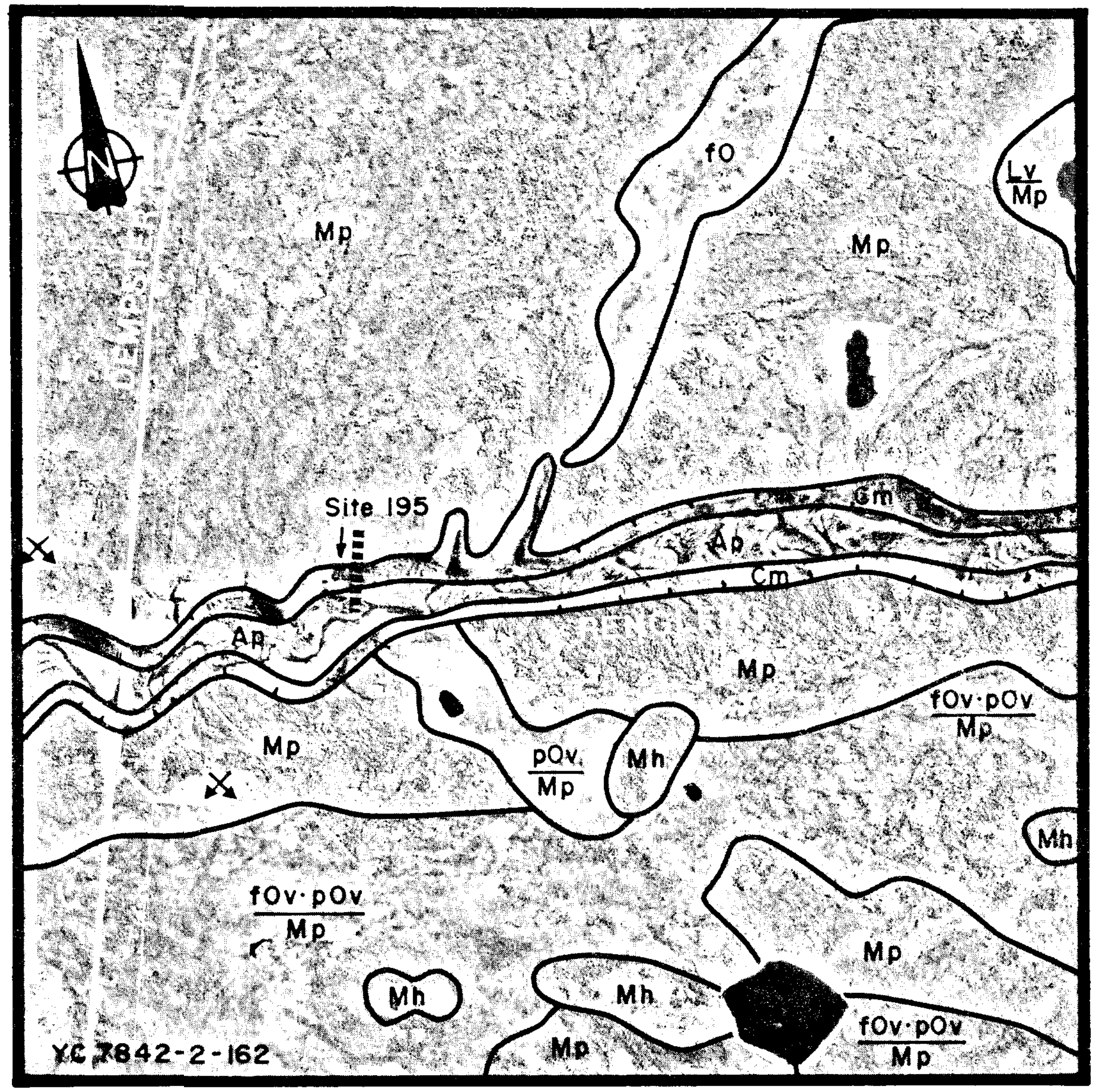
Approximate scale 1:24000

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & TESTING

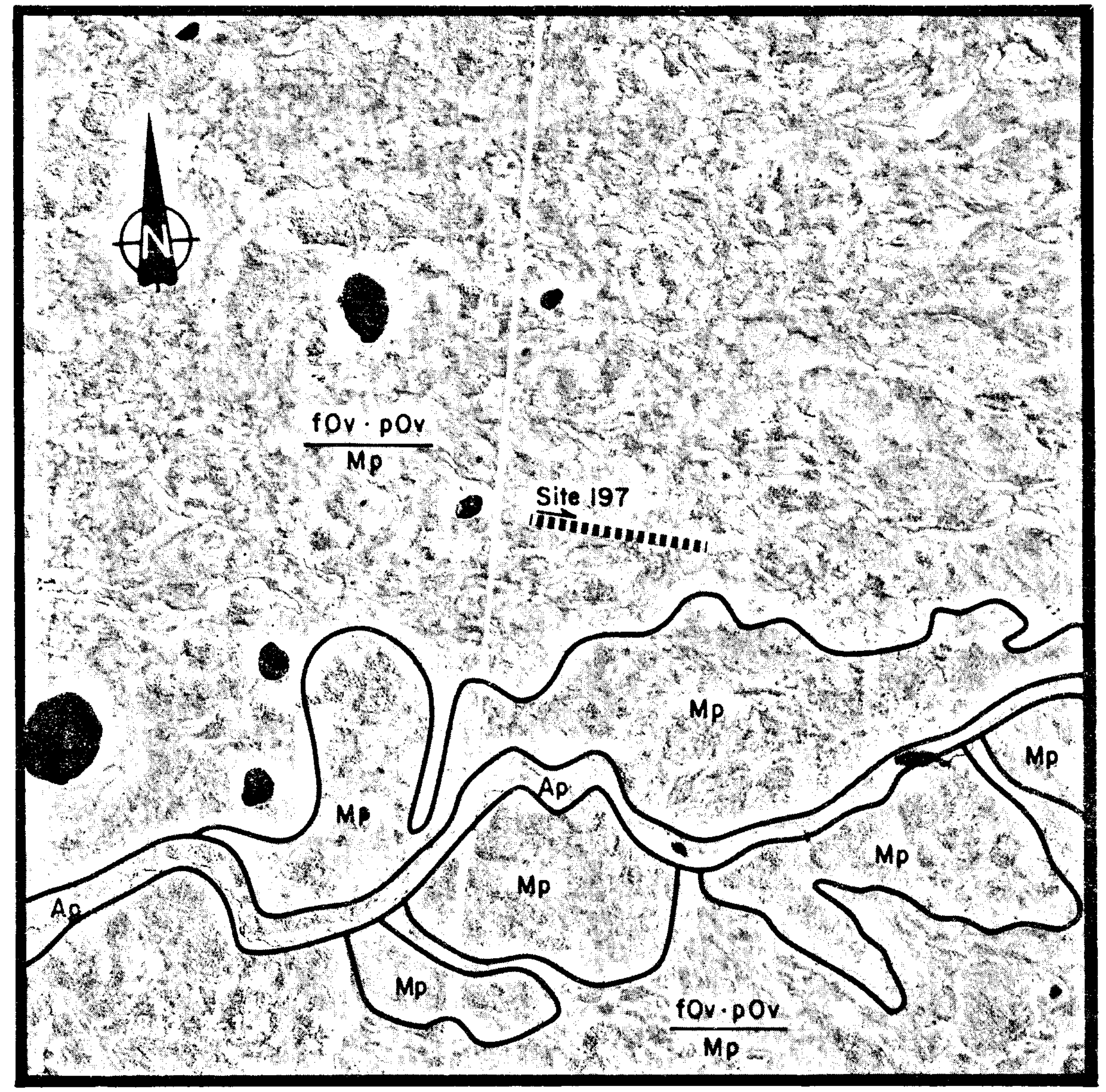
GEOPHYSICAL SURVEY
FOOTHILLS PIPE LINES (YUKON) LTD.
SITE LOCATIONS

K 4321

Figure 5·26



SITE 195



SITE 197

Legend		Approximate scale 1:24000	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	GEOPHYSICAL SURVEY FOOTHILLS PIPE LINES (YUKON) LTD. SITE LOCATIONS
Test hole location	● 107	0 500 1000 metres		K 4321
Geophysical traverse and direction	→ Site 107	0 2000 4000 feet		Figure 5·27