VII

Appendix VII
Seismic Refraction Surveys

Terratech

APPENDIX VII

Seismic Refraction Surveys

Report by Geophysics GPR International Inc. # M-04958, dated March 2005

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Subject: **<u>Geophysical Investigation at Lévis, QC – Rabaska Project</u>**

Dear Sir,

Please find attached two (2) bound copies and one copy not bound of the final report with regard to the above mentioned subject.

We hope everything is to your satisfaction. Do not hesitate to contact us for any further information.

Yours truly,

Jean-Luc Arsenault, Eng., M.A.Sc.

JLA/vsg

Enclosure

GEOPHYSICAL INVESTIGATIONS AT LÉVIS (Qc), RABASKA PROJECT

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1. INTRODUCTION

Geophysics GPR International Inc. was commissioned by Terratech (Ref.: T-1050-A 603333-RABA) to carry out a seismic refraction survey at the Lévis-Beaumont site. This work was required to complement the methane storage tanks site feasibility studies. The surveyed site was located at the North-East extremity of the Lévis City and approximately 15 km from Québec City, between the Rive-Sud boulevard (North) and the Jean-Lesage highway (South).

The purpose of the investigation was to produce seismic velocity and depth profiles for the overburden layers and bedrock, and especially to identify zones of alteration or weaknesses within the bedrock by seismic velocities variations. Seismic data were collected along 4 profiles for a total of 3,43 km of bedrock profiles. The geophysical surveys were realized in two consecutive phases (4th and 18th to 21st October and 11th to 13th November 2004). The second one was planned in accordance with the geophysical results from the first campaign and the known (or expected) geological structural trends. This report deals with the various aspects of the geophysical surveys including field techniques, interpretation techniques and presents the seismic interpretation in the form of bedrock profiles.

2. SCOPE OF WORK

The seismic refraction technique was chosen for this project because of the amount of information the technique provides, such as: rock profiling, rock seismic velocities associated to its mechanical quality and degree of alteration. The locations of the seismic profiles were chosen in order to verify and/or locate some possible fault zones as expected from the available regional geological maps. Seismic refraction is rapid, cost efficient and not particularly intrusive, allowing a more effective targeting for the subsequent geotechnical investigations. As the geophysical surveys were realized in two consecutive phases, the second phase also included a new geophysical investigation method known as seismic resonance ("*TISAR*"). TISAR serves to map the mechanical changes frontiers within the rock.

Seismic refraction consists of recording the length of time taken for an artificially generated surface vibration to propagate through the ground. By processing the data, the seismic velocities and depths of the underlying rock layer can be determined. These velocities, of the compressional seismic wave (or "V_P"), are characteristic of the nature and the mechanical quality of the rock. A fissured, fractured or sheared rock will be characterized by reduced seismic velocities.

3. BASIC DATA

Details relevant to the location of the surveyed site, the organization of the survey, the crew and the equipment used are described in this section.

3.1 Investigation Site

The surveyed site was located at the North-East extremity of the city of Lévis, and approximately 15 km from Québec City, between the "Rive-Sud" boulevard or the 132 road (North) and the Jean-Lesage highway or Highway 20 (South). Figure 1 presents the geophysical investigations site location. The site was accessible by car.

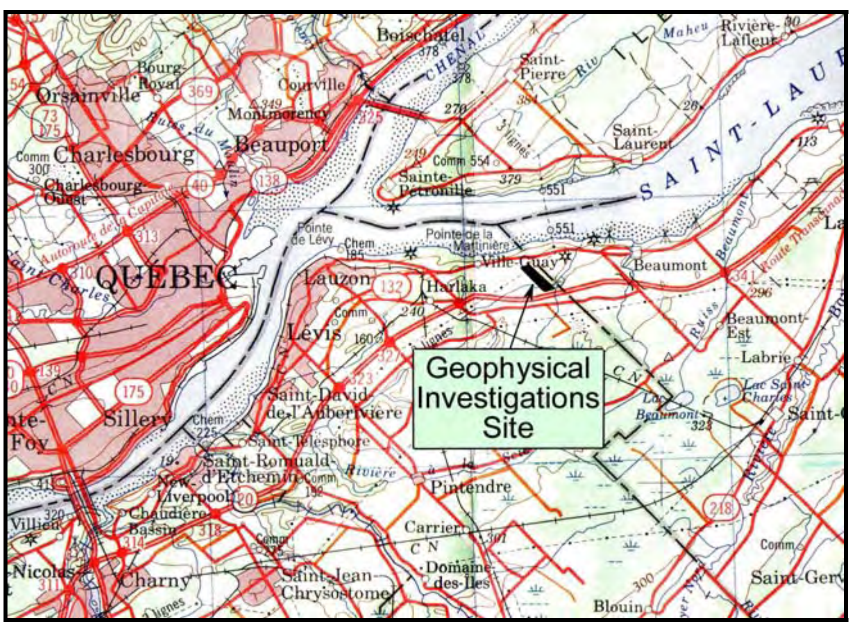


Figure 1: Site location, Lévis (Qc, Can.)

3.2 Personnel and Equipment

The seismic surveys were performed with a specialized crew of two persons, assisted by local helpers. For the data processing, two other persons were involved in the project. The GPR personnel in this project are outlined below:

TABLE 1 Personnel involved in the 2004 Seismic Surveys

October Campaign

Personal	Activity
Mr. Réjean Paul, Eng.	Project Geophysicist, and Q.C.
Mr. Daniel Campos, jr. Eng.	Field Geophysicist, and Assistant Calculator
Mr. Sébastien Meunier	Licensed Blaster
Mr. Jean-Luc Arsenault, Eng.	Assistant Project Geophysicist, and Calculator
Helpers (2)	Labourers

November Campaign

Personal	Activity
Mr. Réjean Paul, Eng.	Project Geophysicist, and Q.C.
Mr. Benjamin McClement, Eng.	Field Geophysicist
Mr. Normand Fournier	Licensed Blaster
Mr. Jean-Luc Arsenault, Eng.	Assistant Project Geophysicist, and Calculator
Mr. Daniel Campos, jr. Eng.	Assistant Calculator
Helpers (2)	Labourers

The geophysical equipment used for the seismic survey consisted of an ABEM Terraloc Mark 6 and a 24 channel seismograph. A description of the equipment used is presented in Appendix A.

4. METHODOLOGY

The basic operating principles and methodology of the geophysical techniques utilized during these investigations are outlined in the following sections.

4.1 Seismic Refraction

Basic Theory

The conventional seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the shot-point to each geophone. The fastest seismic waves are the compressional ("P") or acoustic waves, where displaced particles oscillate in the direction of wave propagation. This seismic wave type consideration is usually preferred for its easiness of reconnaissance, which ensures a higher quality and confidence of processing results. The energy manifestations that follow the first direct and refracted arrivals, such as reflected ("P") waves and transverse ("S") waves, is not considered under routine seismic refraction interpretation. The figure 2 illustrates the basic operating principle for refraction surveys. A more detailed description of the theory can be found in Appendix B.

Survey Design

An engineering seismic spread typically consists of 24 vibration monitoring devices (geophones) connected in line (spread) to a seismograph (ABEM Terraloc Mark 6) by two 12 connector cables. Seismic pulses (shots) are then generated at various locations with respect to the spread. The seismic investigation realized at Lévis-Beaumont, used a 5 metres spacing between geophones. Typically seven shots were executed: five shots within the profile to obtain the lateral velocity variation in the overburden and two far shots on either extremety of the spread to provide the true seismic wave velocity ("V_P") of the bedrock surface.

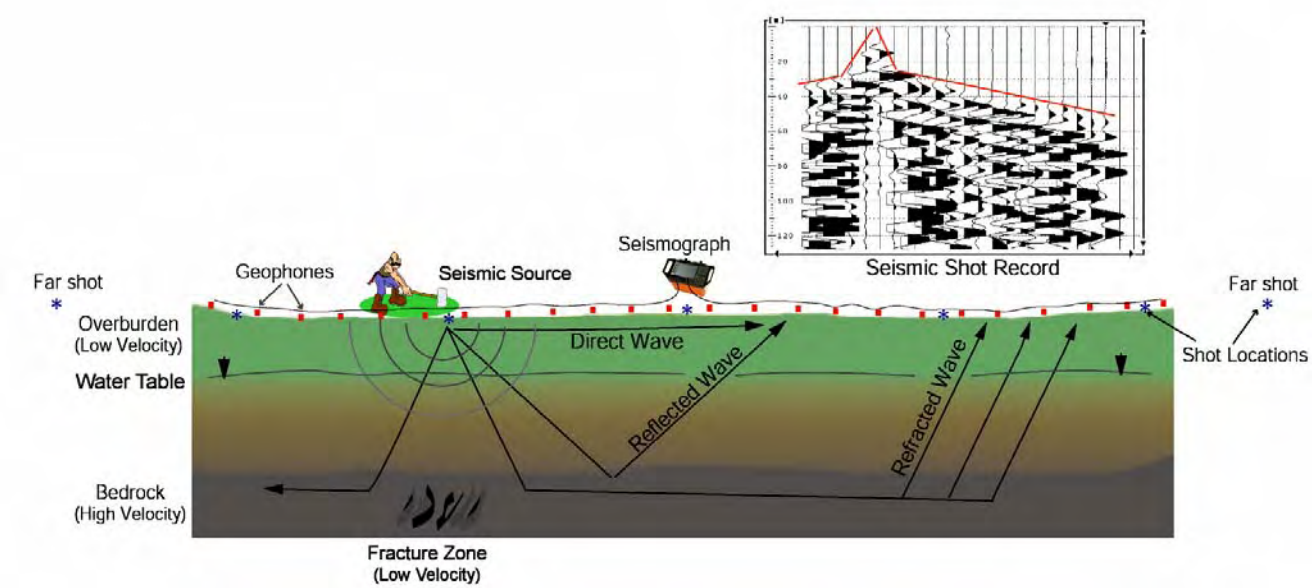


Figure 2: Seismic Method Operating Principle

Explosives were used as the seismic energy source, as they produce an excellent signal and high quality recordings. *Powerfrac* dynamite sticks (1 x 8 inches) were used as energy source. The small holes produced by the blasts during the surveys were filled in with shovels at the end of each spread. Some more important holes were filled using a small dozer, after completion of the first geophysical October campaign, but it had to be postponed to the 2005 Spring thaw for the November Campaign given that approximately half a metre of snow covered the area few days after the completion of the lasts surveys.

Interpretation Method and Accuracy of Results

Interpretation of the seismic data was done using the Hawkins method (a Common Reciprocal Method, or *CRM*). This method allows the computation of rock depth and rock quality below each geophone. It is based on the closure times of the inner shots. It permits the calculation of the true velocities of the rock using the apparent seismic velocities, with the information provided by the outer shots. A brief description of both Hawkins' and the critical distance methods is presented in Appendix B-1. A basic description of Hawkins' method can also be found in the article *Seismic Refraction Surveys for Civil Engineering* (by L. Hawkins, 1961), and a more explicit one is presented through the technical report (ER-73-4) of the NTIS (by B. B. Redpath, 1973) *Seismic Refraction Exploration for Engineering Site Investigation*.

Usually, the seismic refraction method allows the determination of the bedrock profile with a precision of approximately ±10% for depths greater than 10 m, and ±1 m for depths less than 10 m.

The precision in the determination of rock velocities is usually ±5%. The vertical contacts (lateral velocity changes), usually associated with faults and deep valleys, are generally accurate within 5 m width; although this is somewhat site, and field acquisition set-up, specifics.

4.2 Seismic Resonance

Basic Theory

The seismic resonance, or *TISAR (*an acronym for *Testing & Imaging using Seismic Acoustic Resonance),* is a method based on the frequency analysis of seismic records.

It considers the seismic resonance within the signal. The method was originally developed for geological sub-surface profiling (1 to 15 meters deep); however it has been shown to be effective for ranges smaller than 0,1 metre on concrete/asphalt structures testing, as well as for more than 100 metres deep geological investigations.

The method uses the information from an induced seismic signal in the frequency domain instead of the direct time domain as with classic seismic reflection. However, for both methods the principal physical parameter involved remains the acoustic impedance contrast, which is the product of the seismic velocity and the volumetric mass of the investigated materials. At the interface between two materials with different acoustic impedance, the seismic signal is partially reflected back to the surface. Under specific conditions, the repetition of such reflections leads to the build-up of a resonance signal, whose frequency is related to the thickness of two consecutive interfaces and the seismic velocity of the material. The resonance frequency is inversely proportional to the reflection time. The first advantage of the use of frequencies instead of reflection times is the amplitude and the repetitive signal, which is less sensitive to the ambient noise and produces a resolution that increases with shallow depths. The second advantage of using resonance frequencies is the ability to resolve very thin layers or reflectors (contrary to standard seismic reflection).

Survey Design

The resonance survey utilized a similar setup to the refraction/reflection investigations with the biggest differences being in the length of the recorded traces, the type of seismic source signals and the pattern of seismic sources emission. Resonances shots were recorded for approximately 1,6 second as opposed to the refraction records being recorded for less than 500 ms (0,2 to 0,5 second). A repeated strike of sledge hammer on a metallic plate was used as the primary energy source with traces being recorded at 10 m intervals along the lines. Resonance data were collected during the second campaign of geophysical investigations, along the lines GN-001A-04 and GN-001B-04.

Interpretation Method and Accuracy of Results

The seismic resonance method (TISAR) allows the measurement of the depth of very thin features, as cracks, or subtle rock contacts or thin beds (as intrusive sills or gritty layers within the schist rock, etc.) that could not be measured from conventional seismic methods. Similarly to the seismic reflection method, the higher the amplitude, the stronger the reflector is. The reflectors mapped could illustrate the lithologic variations through the stratigraphy, a thin sandstone bed within the shale, as well as a set of millimetric cracks or joints, or a different facies associated to a shear zone. All these reflectors appear the same on the seismic resonance cross-section, and they have to be correlated with known information for a probable identification. Even if the seismic resonance method was developed for mapping sub-horizontal reflectors, it allows the reconnaissance of dipping structures, but with a fuzzy signature.

The rock surface circumscribed “reflectors” could be associated with surface rock weathering or alteration, while the SE dipping reflectors, generally from 45° to sub-vertical could be related to the general expected lithologic layering or structures (shear zones, faults, etc.), and the sub-horizontal and NW dipping reflectors could be associated with set of joints or discordant intrusive occurrences, or other.

The accuracy of the resonance results is directly related to the basic geological model inputted for the computations. As basis, the seismic resonance method needed an adequate geological model and seismic velocities that made used of the seismic refraction calculations. The frequency analysis of the seismic records utilized the *Fast Fourier transform* (FFT). The accuracy (related to the accuracy of the geological model inputted) and especially the vertical resolution of the seismic features obtained with the seismic resonance method cannot be achieved from conventional seismic methods. From the results acquired at the Lévis site, one can estimate the depth accuracy of the reflectors to be approximately 5 to 15%.

4.3 Quality Control

Throughout the seismic refraction surveys, a strict procedure for quality control including field work and interpretation was followed. The purpose of implementing the following measures is to ensure the acquisition of high quality seismic refraction data:

- The first arrival times on each seismic record must be clean and precise. The quality of the records is increased if the geophones are firmly planted into the ground;
- No more than two traces should be absent;
- No end traces (Geophone G1, G2, G23, G24), which are used for the time-distance curve closure, should be absent;
- Closure times should be within +/- 2milliseconds;
- Each successive set-up overlaps the previous set-up by two (2) geophones. This overlap allows the correlation of arrival times at the same point from two different set-ups.

5. RESULTS

The seismic profiles are presented in the form of cross-sections and of a plan view. These results are presented on the drawing 04-11-822-00 in Appendix C, using horizontal scale of 1 : 1500 and vertical scale of 1 : 500 for the cross-sections, and 1 : 5000 for the plan view. The topographic data and profile coordinates were provided by Terratech. The coordinates are expressed in metres with the projection M.T.M. ("SCoPQ", NAD-83, zone 7), and the elevations are relative to the Mean Sea Level.

The profiles also identify the measured seismic velocities along the seismic spreads. Seismic ("V_P") velocities can be used as a general indicator of rock quality. Appendix B-2 contains a discussion of seismic velocities and a general chart of seismic velocity ranges for different rock and soil types.

The seismic velocities ("V_P") for the rock will be used to describe the rock quality. We assumed a single and anisotropic material in order to roughly qualify the possible mechanical property of the rock. For this site, we considered the following classification, and one can refer to appendix B-3 for details:

$Vp \geq 3700$ m/s	→	Sound rock
$3100 \leq Vp < 3700$ m/s	→	Intermediate
$Vp < 3100$ m/s	→	Low velocity

The reader should however remain warned that refracted seismic waves have an evanescent nature, which implies that it is confined to the surface of the rock (or any refractors), and that it allows a preferential and limited effective material volume for the propagation of the seismic signal, and thus that the seismic velocities measured are related to the superficial part of the rock (or any refractors). Our experience showned that the most important portion of the rock conducting the seismic signal is generally included within the firsts 4 to 6 metres from its surface.

GN-001-04 (North part)

This line was surveyed during the first phase of the investigations (October 2004) to verify (and locate) the existence of a known fault or shear zone, and to verify (and locate) the southward extension of a second fault or shear zone. The survey line was along a dirt road, passing under a high voltage power line, and through a swamp. It started (0+000) at its North-West extremity. The pictures 1 and 2 illustrate portions of GN-001-04.

Picture 1:

Outcrop along the road.

Picture 2 :

GN-001-04 under the power lines.

According to the seismic surveys results, even with a gentle topographic raises, the rock smoothly dips from 0+000 to 0+235, with depths from 1 to 4 m. A first intermediary seismic velocity zone (3400 m/s) was measured between 0+037 and 0+145. Similarly to the surface topography, it then gradually raise in elevation until the topographic plateau, where it should be outcropping for around 5 m at chainage 0+385, and a low seismic velocity zone (2900 m/s) was measured between 0+358 and 0+378.

Independently of the surface topography, the rock then describes a local depression between 0+385 and 0+520, where a depth of 5,5 m happens in the midst of an other intermediary seismic velocity zone (3200 m/s, from 0+427 to 0+491). The rock should then be almost outcropping between 0+520 and 0+545. An intermediary seismic velocity zone (3400 m/s) was measured from 0+520 to 0+550. Even if the surface topography is almost flat until 1+085 (elevation 77,5m), the rock topography calculated shows two levels. From 0+560 to 0+855 it roughly appears to be around the elevation of 77 m (approximately 3 metres deep), while from 0+855 to 1+085, the calculated rock appeared to be at a mean elevation of 75,5m (approximately 2 metres deep). For this segment, a low seismic velocity zone (3000 m/s) was measured between the chainages 0+664 and 0+726. Fortunately, the borehole W-003-04 was produced in the middle of this low velocity zone. It revealed that the rock was at 5,6 m from the surface; it was severely fractured until 10,6 m; and it was moderately jointed from 10,6 m to 15,3 m deep . Another intermediary seismic velocity zone (3300 m/s) was calculated between 0+985 and 1+033. The beginning of this zone almost matches the location of the borehole W-005-04, which shown that the rock was at 2,3 metres deep, it was severely fractured until 5,8 m; and it was moderately jointed from 5,8 m to 15 m deep.

Then, the rock seems again to control the surface topography, as its dips down until 1+200, with depths ranging from 1 to 4 metres. Its minimal depth should appear around the chainage 1+165. A last intermediary seismic velocity (3500 m/s) was calculated between 1+100 and 1+1121.

The following table presents the suspect seismic velocity zones measured for the rock surface over the seismic profile GN-001-04. It also includes the intermediary neighboring seismic velocities, for a more complete appreciation of the actual seismic refraction results.

TABLE 2 : Intermediate and low seismic velocities measured on GN-001-04

Location (m)	Seismic velocity (m/s)	Comments
0+037 to 0+145	**3400**	Intermediate rock competence
0+145 to 0+325	3800	Intermediate rock competence (fair)
0+358 to 0+378	**2900**	Low velocity (poor)
0+427 to 0+491	**3200**	Intermediate rock competence
0+520 to 0+550	**3400**	Intermediate rock competence
0+664 to 0+726	**3000**	Low velocity (poor)
0+985 to 1+033	3800	Intermediate rock competence (fair)
1+033 to 1+100	**3300**	Intermediate rock competence
1+033 to 1+100	3700	Intermediate rock competence
1+100 to 1+121	**3500**	Intermediate rock competence

GN-001A-04 (North part)

This line was surveyed during the second phase of the geophysical investigations (November 2004) to verify and eventually to locate the existence of two possible faults, as suggested from the first phase seismic results. The survey line was along a dirt road, and passing under a high voltage power line. It started (0+000) at its North-West extremity. This seismic line was located approximately 100 metres South-West to the GN-001-04. From 0+000 to 0+230, the rock depth oscillates between 2,5 and 8 m, and it could be slightly deeper if a water table was present as a hidden layer. Two intermediary seismic velocity zones (3400 and 3200 m/s) were respectively measured between 0+038 and 0+063, and between 0+157 and 0+178. The rock becomes shallower (1 to 3,5 m) from 0+230 to 0+470, a low seismic velocity (2500 m/s) and an intermediary one (3500 m/s) were respectively measured between 0+262 and 0+277, and between 0+337 and 0+383. From 0+470 to the end of the line (0+700) the surface topography was fairly flat. However, the rock appeared to be dipping to more than 10 m deep at 0+550, and then raise (0+560) from 6 to 2,5 m deep. An intermediary seismic velocity zone (3200 m/s) was measured between 0+492 and 0+522.

The following table presents the suspect seismic velocity zones measured for the rock surface over the seismic profile GN-001A-04. It also includes the intermediary neighboring seismic velocities, for a more complete appreciation of the actual seismic refraction results.

TABLE 3 : Intermediate and low seismic velocities measured on GN-001A-04

Location (m)	Seismic velocity (m/s)	Comments
0+000 to 0+038	3800	Intermediate rock competence (fair)
0+038 to 0+063	**3400**	Intermediate rock competence
0+157 to 0+178	**3200**	Intermediate rock competence
0+178 to 0+227	3800	Intermediate rock competence (fair)
0+262 to 0+277	**2500**	Low velocity (poor)
0+277 to 0+337	3800	Intermediate rock competence (fair)
0+337 to 0+383	**3500**	Intermediate rock competence
0+402 to 0+447	3700	Intermediate rock competence (fair)
0+492 to 0+522	**3200**	Intermediate rock competence

The seismic resonance results are presented as a cross-section at the figure 3. The surface topography and the rock topography (as calculated from seismic refraction surveys) are add to ease a more complete evaluation of the results. One can observe numerous groups of reflectors, but three of them seem to be most obvious. The first one is located between 0+238 and 0+280, corresponding to the low seismic velocity in surface (2500 m/s), with a general dip of 45° to 58° SE. This dipping family corresponds with the expected geological structural features (expected lithology, faults, etc.) dipping range. One can identify this group of reflectors as calculated to be present from the surface to at least 75 m deep. The second one presents a mix of dipping and sub-horizontal signatures. Among this group reflectors alignment is observable from 0+375 (at surface) to 0+415 around 70 m deeper. This feature presents an apparent dip of 65° SE, and corresponds with the southern part of the 3500 m/s zone measured with seismic refraction surveys. The northern part of this rock surface 3500 m/s zone corresponds with a short reflector dipping 25° NW and mainly limited to the first 10 m below the rock surface. The next and third intermediary seismic velocity (from refraction) coincides with a 55° NW dipping reflectors (from 0+425 at the rock surface, to 0+340 at 75 metres deep), as well as with a sub-vertical important group of reflectors.

A syncline shape is observable between 0+480 and 0+610, from the rock surface to 45 m deep. It could be a syncline shape, as well as a set of three major reflectors (or structural features) : the first one showing a curly dip SE, from 0+480 at the rock surface to 0+585 at around 43 m deep; the second one showing an apparent dip close to 50° NW, from 0+612 at

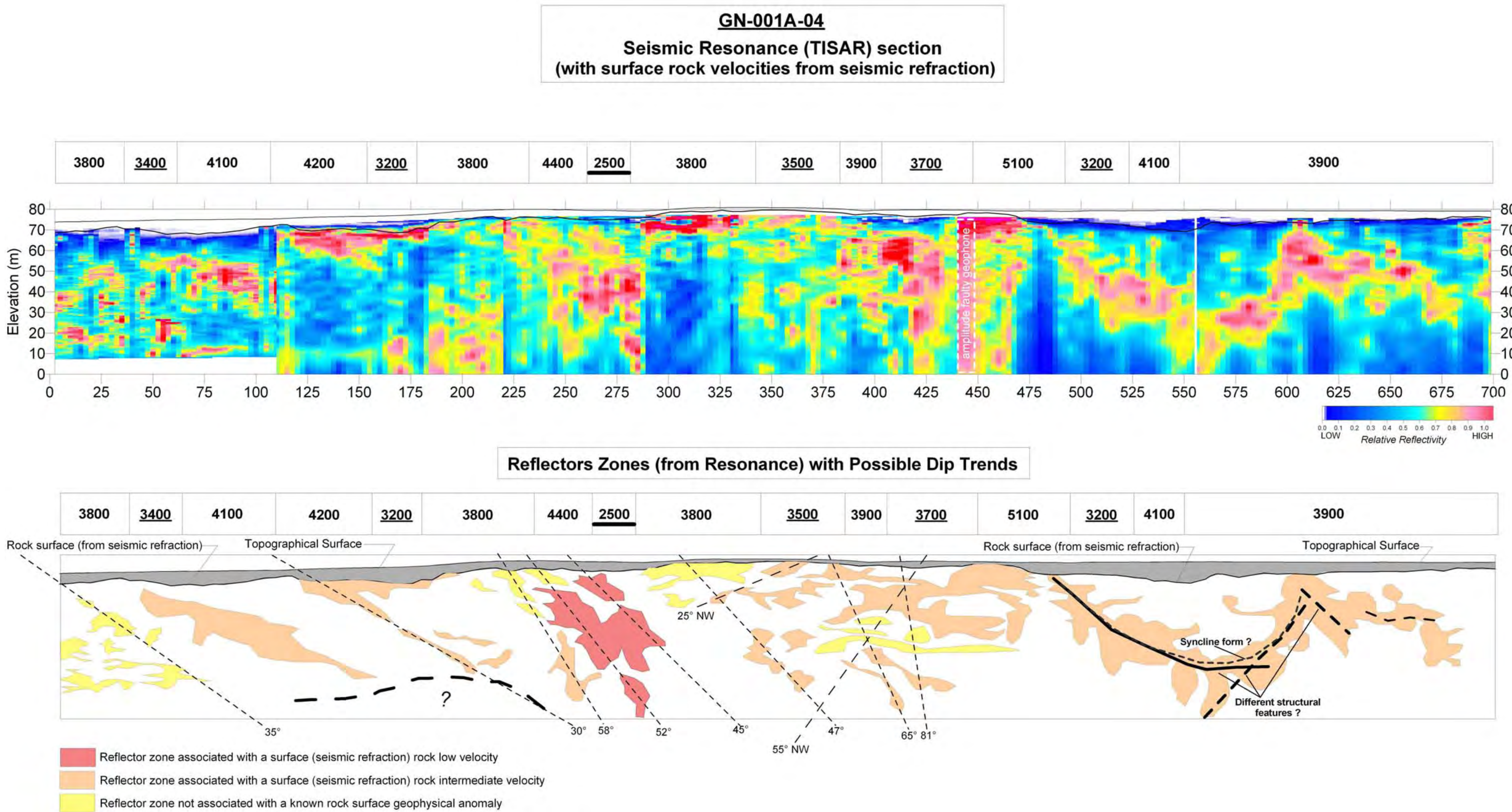


Figure 3: Seismic resonance section of GN-001A-04 and interpretation

the rock surface; and the third one being a set of discontinuous sub-horizontal reflectors between 0+600 and 0+690, ranging from 12 to 35 m below the rock surface and slightly dipping SE.

Numerous other reflectors can also be observed, but they shown generally sub-horizontal, NW dip or a very limited extension downward from the rock surface. These features appeared with a second degree of interest, as they can be related to a rock surface weathered zone (eg. 0+290 to 0+385), or set of joints or other.

The last coherent resonance signature is not correlated with a bad rock velocity (from seismic refraction). It presents an apparent dip of 30° SE, from 0+125 (rock surface) to 0+230 (68 m deep).

GN-001B-04 (South-West part)

This line was surveyed during the second phase (November 2004) of the geophysical investigations to verify (and locate) the existence of two to three possible faults, as suggested from the first phase seismic results. The geophysical survey line was along a dirt road, passing under a high voltage power line and a bush area. It started (0+000) at its North-West extremity. This seismic line was located approximately 470 metres South-West to the GN-001A-04.

The seismic refraction surveys produced a noisy (difficult) data from 0+000 to 0+250, due to the electromagnetic induction of the high-voltage power-line (0+055 to 0+200). This phenomenon happened only once during the whole survey. It was due to a very humid air while it was lightly snowing. A strong electrical “hum” could be heard at that time.

The seismic refraction results indicated that from 0+000 to 0+190, the rock surface appears sound and overlaid by two layers of overburden: 4 to 5 m of a dry and loose material (550 to 600 m/s), over 1 to 5 m of a saturated and/or denser material (1500 to 2000 m/s). Only one layer of overburden was measured between 0+190 and 0+224, over an intermediary rock velocity of 3500 m/s. From 0+220 to 0+330, the rock topography seems to be relatively flat (elevation: 73 m), while the surface topography presents a small hill. Two layers of overburden were measured: a 400 m/s dry and loose material, overlaying a denser material (1100 m/s). The rock surface shows a low velocity zone (2200 m/s) from 0+224 to 0+239, and an intermediary seismic velocity (3200 m/s) between 0+284 and 0+310. Between 0+330 and 0+470, one to two layers of overburden covers a shallow rock (0,5 to 3,5 m deep), except from 0+335 to 0+360, corresponding to an intermediate seismic velocity. Two intermediate seismic velocity zones (3500 and 3100 m/s) were located respectively from 0+331 to 0+358 and from 0+382 to 0+416.

A depression to the rock was located between 0+470 and 0+625. Two layers of overburden were calculated, the upper one being a 1 to 3 m of dry and loose material (375 to 500 m/s), and the lower one (1800 to 2000 m/s) could probably be associated with a till. The bottom of this depression (0+489 to 0+592) oscillates around the elevation of 65 m (10 to 13 m deep). For this segment, the rock seismic velocities (3800 and 4300 m/s) suggest a good mechanical quality.

The rock than rises in elevation and is shallow (generally 1 to 3 m deep) from 0+625 to 0+665. At this portion the rock appears as sound (4300 m/s). For the section 0+665 to 0+795, the rock describe a depression (23 m deep) centered over a low seismic velocity zone. This depression is filled with two layers of overburden, the main one being probably a till (1950 to 2000 m/s). A low seismic velocity zone of 2400 m/s was measured from 0+694 to 0+736, and an intermediary one of 3300 m/s was measured from 0+736 to 0+750.

The line GN-001B-04 was extended SE with an extra profile. For the seismic calculations purposes, the surface topography was assumed flat from visual observations. One layer of overburden (450 to 900 m/s) was measured with a thickness varying from 1 to 4 m. The rock underneath could be considered fair to sound, with seismic velocities of 3800 to 4400 m/s.

The following table presents the suspect seismic velocity zones measured for the rock surface over the seismic profile GN-001B-04. It also includes the intermediary neighboring seismic velocities, for a more complete appreciation of the actual seismic refraction results.

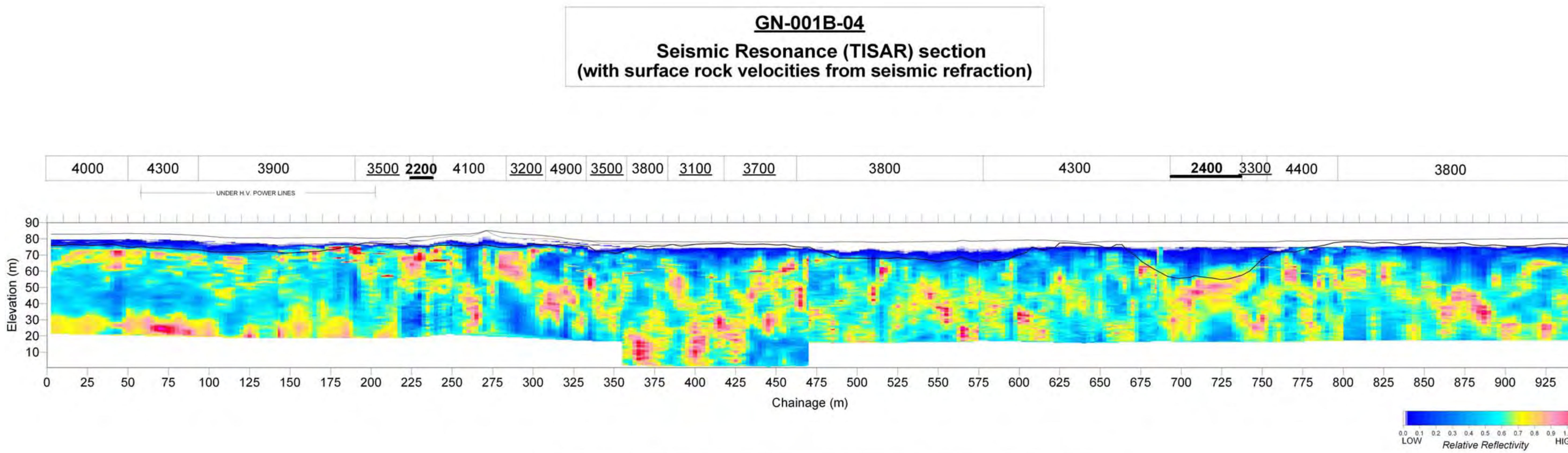
TABLE 4 : Intermediate and low seismic velocities measured on GN-001B-04

Location (m)	Seismic velocity (m/s)	Comments
0+190 to 0+224	**3500**	Intermediate rock competence
0+224 to 0+239	**2200**	Low velocity (poor)
0+284 to 0+310	**3200**	Intermediate rock competence
0+331 to 0+358	**3500**	Intermediate rock competence
0+358 to 0+382	3800	Intermediate rock competence (fair)
0+382 to 0+416	**3100**	Intermediate rock competence
0+416 to 0+463	3700	Intermediate rock competence (fair)
0+463 to 0+578	3800	Intermediate rock competence (fair)
0+694 to 0+736	**2400**	Low velocity (poor)
0+736 to 0+750	**3300**	Intermediate rock competence
0+797 to 0+944	3800	Intermediate rock competence (fair)

This seismic line was also surveyed for seismic resonance. These results are presented as cross-section at the figure 4. The surface topography and the rock topography (as calculated from seismic refraction surveys) are add to ease a more complete evaluation of the results. Several reflectors present a South-East dip, which match with the general lithological trend and the general structural trend as well. Most of them correspond with intermediate to low seismic velocities measured at the rock surface by seismic refraction. One can also observe few (four) discordant reflector trends dipping 57° to 73° North-West, but their rock surface intercept does not match with measured intermediate to low seismic velocities.

The first reflector zones appear as related with the 3500 and 2200 m/s (0+190 to 0+239) rock surface measured velocities. They are dipping roughly between 55° and 65° SE, and they are very clear for the first 30 m below the rock surface. As they are spatially associated with the 2200 m/s low velocity, one could reasonably suggest that it could be the response of a probable shear zone or fault.

Two groups of reflectors seem to be associated with the 3200 m/s intermediate seismic velocity (0+284 to 0+310), and they are dipping from 57° to 61° SE. A surface reflector could be related with a possible rock surface weathering from 0+277 to 0+330, and especially between 0+295 and 0+330.



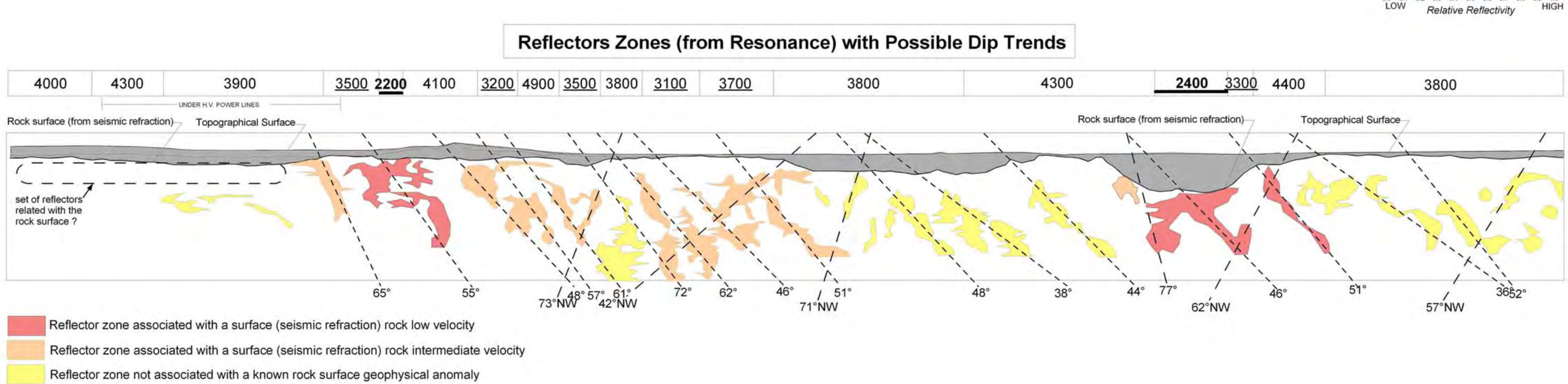


Figure 4: Seismic resonance section of GN-001A-04 and interpretation

Three groups of aligned dipping reflectors seem to be associated with the 3500 m/s intermediate seismic velocity (0+331 to 0+358), and they are dipping from 72° to 62° SE and 73° NW.

The intermediate seismic velocities measures in surface 3100 and 3700 m/s (0+382 to 0+463) correlate with three reflector groups with apparent dips of 46° and 51° SE, and 42°NW. The next surface seismic velocity zone (3800 m/s, from 0+463 to 0+578) is also associated with two reflector groups with SE dip (48° and 38°) and a NW one (71°). It is somewhat interesting to notice that the SE dipping reflectors appears only 10 to 15 m below the rock surface.

For the line GN-001B-04, the last group of low seismic velocities (2400 and 3300 m/s, from 0+694 to 0750) which is also associated with a deep and local rock depression, appears related to a large group of reflectors at the bottom of the depression (possibly a rock weathering) with a 46° SE down-dip extension. The 3300 m/s zone match with a set of reflectors almost reaching the rock surface, and dipping around 51° SE.

The last family of reflectors presents various dip directions and different depths of occurrence. They do not start from the rock surface. Located between 0+800 and 0+944 (the end of the line) the higher manifestations are generally 15 to 25 m below the rock surface.

GW-002-04 (South part)

This line was surveyed to verify (and locate) the existence of a known fault or shear zone. The survey line was through a wooden area and crossing two small creeks. It started (0+000) at the South-East extremity, beside the Jean-Lesage Highway (20).

The seismic refraction results show that the rock varies from sub-outcrop to 4 m deep, for the 0+000 to 0+295 portion. The seismic velocities are high, except for the 0+000 to 0+064 segment where a seismic velocity of 3600 m/s was calculated. At 0+295, the rock seems to suddenly drop from sub-outcrop to 4,7 m deep and its topography is uneven. A low velocity zone (2900 m/s) was calculated between 0+317 and 0+351, just at the south part of a creek. It could be associated with a fault or a shear zone.

For the chainage 0+390 and higher, the rock dips for approximately 14 m down. A denser sediment material was also measured with velocities varying from 1450 to 2025 m/s. It could be associated with a dense glacial till. The seismic velocities calculated for the rock varies from 4900 to 3700 m/s. This last one is considered as the lower value associated with sound rock.

The following table presents the suspect seismic velocity zones measured over the seismic profile GW-002-04. It also includes the intermediary neighboring seismic velocities, for a more complete appreciation of the actual seismic refraction results.

TABLE 5 : Intermediate and low seismic velocities measured on GW-002-04

Location (m)	Seismic velocity (m/s)	Comments
0+000 to 0+064	**3600**	Intermediate rock competence
0+317 to 0+351	**2900**	Low velocity (poor)
0+351 to 0+460	3700	Intermediate rock competence
0+507 to 0+581	3700	Intermediate rock competence

6. GENERAL APPRECIATION

The seismic refraction surveys revealed some low and intermediate seismic velocity zones which can be associated with several possible causes (cf. appendix B-2); one of them could be related with shear and/or fault zones; another one could express superficial rock alteration. It is also possible to assume various interesting trends regarding the measured rock surface seismic velocities, as well as for the rock surface topography. These results could be defined with more precision and confidence if additional seismic surveys are carried out. Nevertheless, they present possible patterns for the shear and/or fault zones option (figure 5), and possible patterns as well for the rock topography (figure 6).

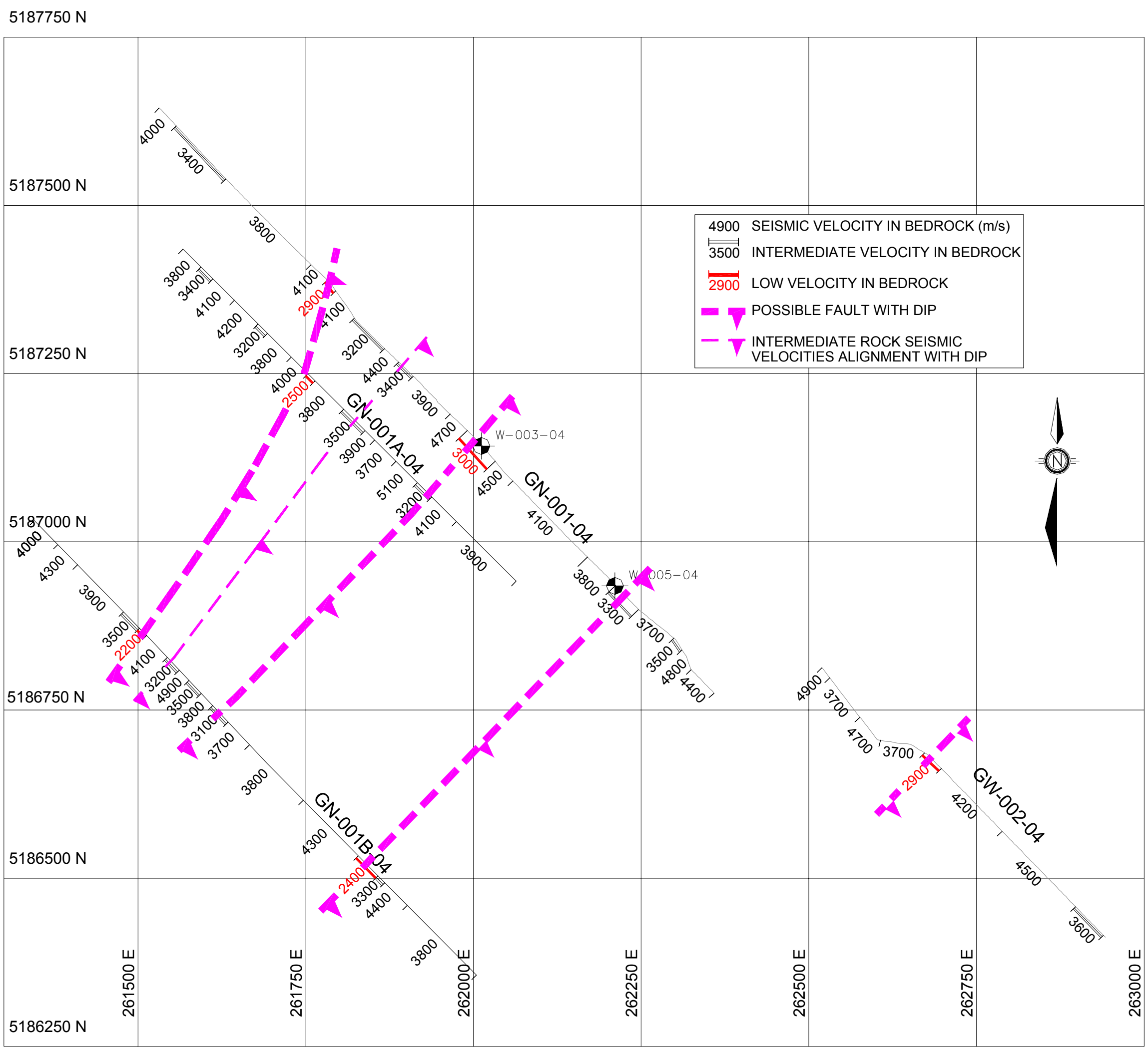


Figure 5: Surface rock low seismic velocities and possible trends

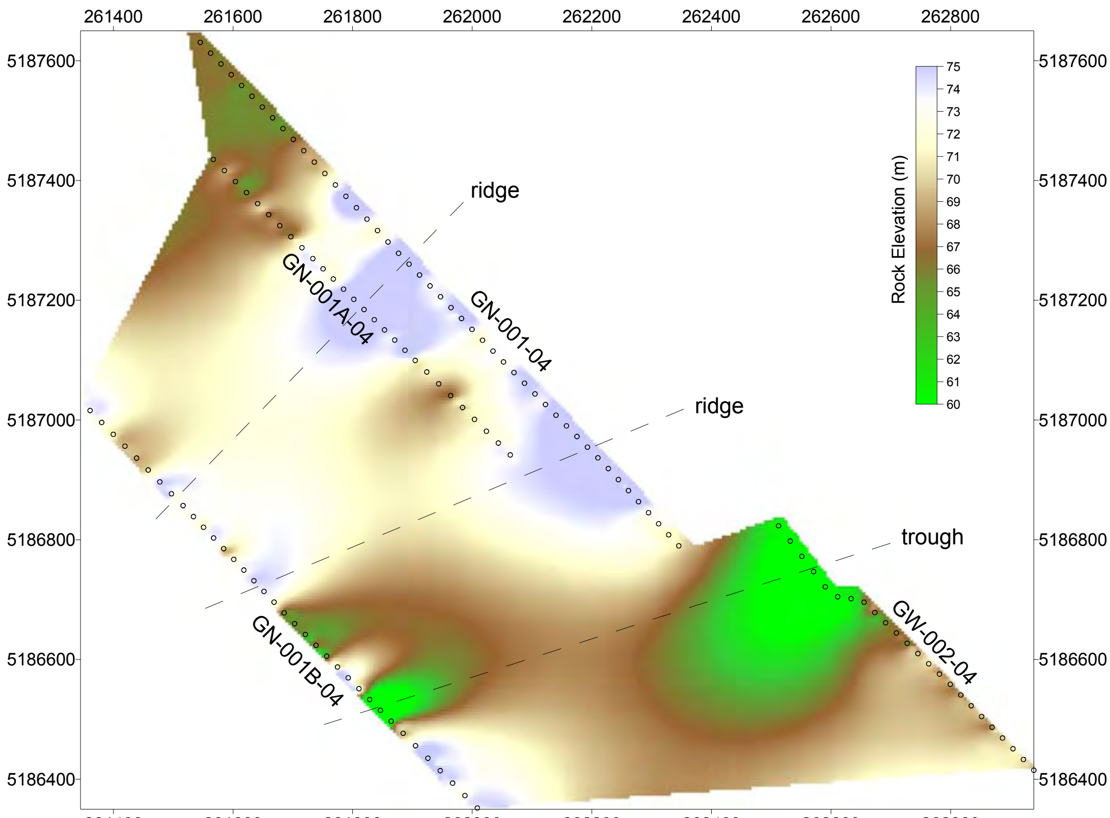


Figure 6: Possible general trends in the rock topography

The seismic resonance surveys confirmed the South-East dip trend of the low seismic velocities measured at the rock surface. Some intermediate seismic velocities also correspond with SE dipping reflectors, and they could also be associated with shear and/or fault zones. The presence of resonant reflectors within the first metres of the rock surface, and without deeper extension, suggests that such sectors could probably be related with surface weathering instead of shear and/or fault zones (ex.: GN-001A-04, 3200 m/s from 0+157 to 0+178).

7. CONCLUSION AND RECOMMENDATIONS

A seismic refraction survey was undertaken as a part of a feasibility study by Terratech for the Rabaska Project. The surveyed site was located at the North-East extremity of Lévis (Qc, Can.). The seismic investigations were composed of four seismic refraction profiles (33 spreads), and among these, two profiles (14 spreads) were also surveyed by seismic resonance.

The quality of the seismic data gathered throughout this campaign varied from good to excellent. The data processing indicated high seismic velocities for the rock, for the major part of the lines, except for GN-001B-04 who shown 50% of rock seismic velocities inferior to 3900 m/s.

However, the seismic lines surveyed shown some low and intermediary seismic velocity zones. The intermediate to low rock seismic velocities are usually related to highly weathered, fractured, faulted or sheared zones (see appendix B-2). They can also indicate the presence of a different rock type, mechanically less competent. In both cases, the rock competency being possibly lowered, significantly. Further geotechnical investigations are recommended to be carried out on these targeted zones

We would like to thank the Terratech representatives for their esteemed collaboration.

This report has been written by Jean-Luc Arsenault, Eng., geoph., and approved by Réjean Paul, Eng., geoph.

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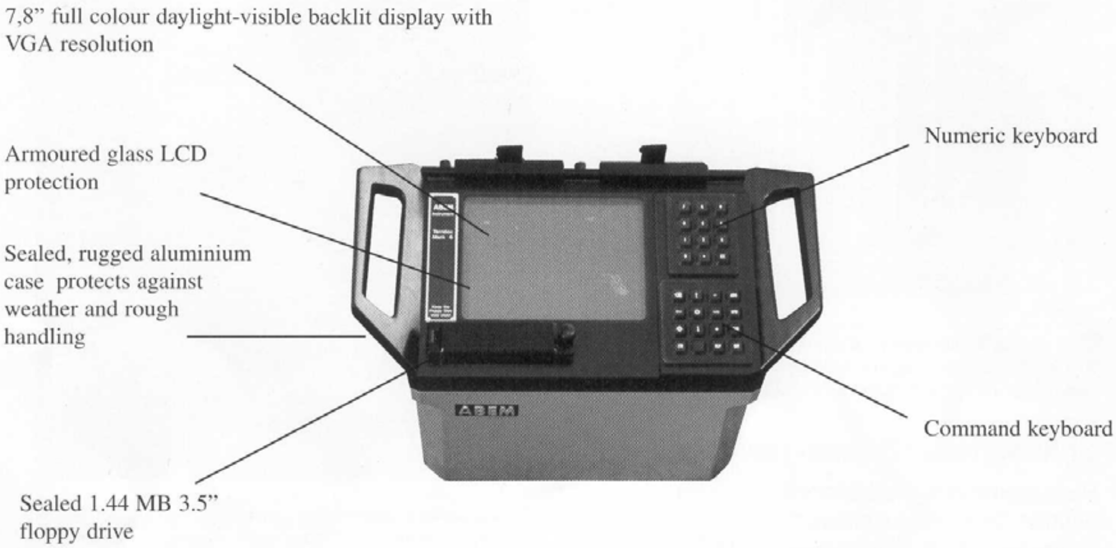
APPENDIX A

Equipment Fact Sheets

GREAT FEATURES IN A SMALL SEISMOGRAPH

The Terraloc Mark 6 is a high resolution multi-channel seismograph with an 18-bit A/D converter and 3-bit instantaneous floating point (IFP) amplifier. Overall resolution is thus 21 bits. Its dynamic range, 126 dB, eliminates all gain setting hassles and satisfies the most stringent shallow reflection requirements.



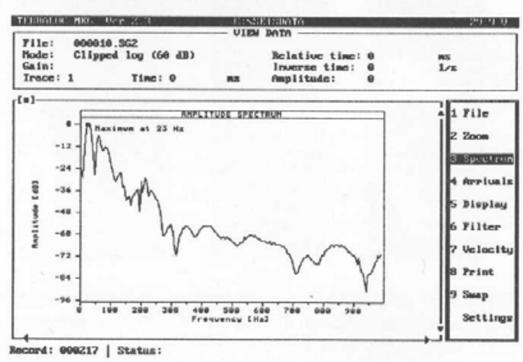
Added Terraloc advantages:

- **Great for tomography thanks to high sampling rates starting at 25 µs.**
- **Usable with various energy sources (even mini-vibrators) thanks to long record lengths, auxiliary source signature channel input and built-in correlation software.**
- **Provides sophisticated automation. A versatile digital (TTL) interface (trigger IN/OUT, arming IN/OUT signals) makes it easy to connect several Terralocs and supports handshaking with vibrators and marine seismic energy sources.**
- **Ideal for refraction as well as shallow reflection seismics thanks to built-in roll-along function and a broad spectrum of analog and digital filters.**
- **In-field quality control. On-site geophone testing, cable testing and noise monitoring. Wide choice of multi- or single-trace view modes and frequency spectrum analysis (FFT).**

Powerful computer

Fully compatible with your office computer thanks to MS-DOS 6.0 or higher, an internal hard disk, a built- in 1.44 MB floppy drive, and compliance with the international SEG-2 format for storing of seismic traces and header information.

Interpretation software (such as the packages listed on the back page) can be installed and run right in your Terraloc field unit.



Spectrum analysis helps you select the right filter, and it can also reveal soil properties.

Technical specifications

Number of channels (smaller unit)	4-24 in steps of 4
Number of channels (larger unit)	4-48 in steps of 4
Additional channels	Easily obtained by linking two or more units together
Up-hole channel	Yes
Sampling rate (selectable)	25, 50, 100, 200, 500, 1000 & 2000 μs
Record length (selectable)	128, 256, 512, 1024, 2048 4096, 8192 or 16384 samples per trace equivalent to: 3.2 ms - 32.7 s
Pre-trig record (selectable)	0-100 % of record length
Pre stack correlation	Yes, cross correlation with reference or any other channel
Delay time	Related to sampling rate May be set (for example) from: 0-0.8 s at 25 μs sampling rate 0-131 s at 2 ms sampling rate
Stacking	32 bits, up to 999 impacts
Unstack	Remove last shot from stack
First-arrivals picking	Automatic or manual. Times can be saved with record
Trigger inputs	Trigger coil, make/brake, geophone, TTL
A/D converter resolution	21 bits (18 bits plus 3-bit IFP)
Dynamic range (theoretical/measured)	126 / 114 dB
Max input signal	500 mV p-p
Frequency range	1 - 4000 Hz (at 25 μs sampling rate)
Total harmonic distortion	- 80 dB
Crosstalk	- 86 dB
Input impedance	3 kΩ
Noise monitor	Amplitude or full waveform display available on-line

Processor, RAM memory and hard disk size

Processor	5x86 / 133 Mhz
Internal memory	16 MB
Hard disk space	at least 2,1 GB
Post recording features	FFT Analysis auto correlation cross correlation first-arrival picking refractor velocity analysis
Floppy Drive	1.44 MB 3.5"
Display	7,8" FULL COLOUR LCD, daylight visible
Digital I/O ports	Parallel and serial (PC/AT compatible) SCSI interface
Power	10 - 30 V DC external battery
Power consumption	36 W (24-ch) or 60 W (48-ch)
Ambient temp (operating 24-ch)	0 to +50 °C
Ambient temp (operating 48-ch)	0 to +45 °C
Ambient temp (storage)	- 40 to + 80 °C
Casing	Rugged cast aluminium
Weight, 24 channel unit	16 kg
Weight, 48 channel unit	23 kg
Dimensions, 24 channel unit	480 x 260 x 330 mm
Dimensions, 48 channel unit	480 x 260 x 470 mm

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MS-DOS is a registrered trade mark of Microsoft Corp.
All other trade marks belong to their respective holders.

Analog filters

- Low cut (selectable)	12 or 24 dB/octave 16 steps from 12 to 240 Hz
- Notch	50 or 60 Hz specify when ordering
- Anti-aliasing	set automatically based on sampling rate

Digital filters

Bandpass, low-cut, high-cut, bandreject, alpha-beta and remove DC offset

Spectrum analysis — Any single trace

To order, please specify

MARK 6, 12 CHANNEL SYSTEM	33 0011 02
MARK 6, 24 CHANNEL SYSTEM	33 0011 03
MARK 6, 48 CHANNEL SYSTEM	33 0010 80

Each system includes:
Operatorsmanual, Referencemanual (incl. servicemanual), DOS manual & program, SEG-2 format description, Trigger cable 250 m on reel, Trigger coil, Accessories & Tools kit, Mk6 Program and sample records.

External monitor, keyboard and mouse are optional extras

Field Accessories

Seismic cables 12 take-outs at 12.5 m (other cable configurations also available)	36 0001 29
Extension cable, 60 m	36 0001 59
Extension cable, 160 m	36 0001 60
Portable reel	38 3001 52
10 Hz vertical geophone	39 1000 62
10 Hz horizontal geophone	39 1000 93
4.5 Hz vertical geophone	39 1000 63
4.5 Hz horizontal geophone	39 1000 64
4.5 Hz 3-D geophone	39 1000 85
100 Hz vertical geophone (land)	39 1000 77
100 Hz vertical geophone (marsh)	39 1000 78
Shock plate	33 0010 18
Hi-voltage CB 20 VA shotbox	39 9000 17
Backpack carrying frame	33 0001 98
Extra spares kit for remote locations	33 0011 61

INTERPRETATION SOFTWARE

First-arrival picking	FIRSTPIX
Refraction data interpretation (GRM)	GREMIX VIEWSEIS
Reflection data interpretation	SEISTRIX

Alternative software packages, see page 7

Printers

Any EPSON/IBM compatible office printer will work with your Terraloc Mark 6. There are also several battery operated printers that can be used in the field.

ABEM products undergo continuous development.
Please fax, phone or write today for the latest technical information and prices.

ABEM Instrument AB

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Sweden

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+46-8-28 11 09

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gprmtl@citenet.net

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APPENDIX B-1

Seismic Refraction Method

THE SEISMIC REFRACTION METHOD

The seismic refraction survey is used to infer subsurface conditions on the basis of contrasting seismic wave velocities. The primary goal of the seismic survey is to rapidly and efficiently obtain subsurface information, thereby reducing direct investment costs, such as drilling. Geological information typically obtained from a well-planned and executed seismic refraction survey will include: depth and shape of bedrock surface, nature and competency of bedrock, such as degree of fracturing and alteration, whether it is faulted or sheared, nature of overburden and depth to the water table. Modern portable equipment makes the method accessible to remote and rough regions. A review of the seismic refraction theory, field methods and interpretational procedures can be found in Dobrin (1976) and Telford et al (1990).

INSTRUMENTATION

The instrumentation involved in a seismic refraction survey consists of an energy source to generate seismic waves (typically explosives), a line of geophones to detect the seismic energy and a seismograph which is essentially a highly accurate stopwatch. By measuring the arrival times of the first seismic waves at various distances from the energy source, or shotpoints, depths to interfaces and seismic velocities can be determined. Seismographs are usually 12 or 24-channel, in they can simultaneously record the vibrations at 12 or 24 geophones. The record of these vibrations is a seismogram. Digital seismographs (e.g. ABEM Terraloc MK6, EG&G SMARTSEIS S-24) acquire data with a built-in computer, whereas analog seismographs (e.g ABEM Trio) output the data to photographic paper as it is acquired. The energy source must be coupled to the seismograph so that the instant of detonation or impact can be recorded. A recording time step of 50 μs was used to permit very accurate estimates of arrival times.

FUNDAMENTAL PRINCIPLES

The seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the shotpoint to each geophone. The fastest seismic waves are the compressional (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival, such as reflected waves or transverse (S) waves, is not considered under routine seismic refraction interpretation.

Figure C-1 shows a simple geological structure, where a layer with a velocity of V_1 overlies a second layer with a higher velocity, V_2. At one end of the spread, a shotpoint is detonated and the vibrations at each geophone are recorded. Seismic waves will travel via the direct path from the source to each of the geophones. Waves may also be refracted at some critical angle along the interface and travel at the higher velocity V_2. Energy is continually leaked back to the surface as it travels along the interface. A time-distance graph may be constructed, plotting the first arrival transit times as a function of position along the seismic line.

The first arrival at the closest geophones is the direct wave. However, at the critical or crossover distance (Xc) the refracted wave which travels along the higher velocity layer overtakes the direct arrival. The inverse slope of a straight line segment of the time-distance curve is equal to the velocity in that layer. The crossover distance is directly proportional to the depth of the interface.

INTERPRETATION

The simplest methods of interpretation are illustrated in figure B-1. Having determined the velocity of compressional waves through each layer, one may calculate the depths according to crossover distance or the intercept time formulas. The case of a horizontal interface, illustrated in figure B-1, becomes slightly more complicated if the planar interface is dipping. The general case of an irregular interface can be handled by more complex interpretational schemes, including various delay-time methods, the reciprocal and generalized reciprocal methods and ray tracing. One method may be better suited than another to a particular geological environment.

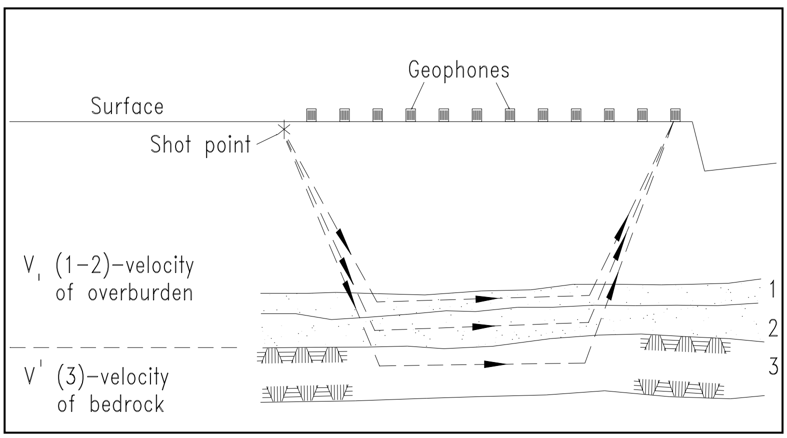


FIGURE B-1

PRINCIPLES OF SEISMIC REFRACTION

APPENDIX B-2

Seismic Velocities versus Geological Materials
(“Vp” from compressional seismic waves)

SEISMIC VELOCITIES VERSUS GEOLOGICAL MATERIALS

The seismic refraction differentiates the overburden layers from the bedrock. In general, a layer of overburden material, with associated velocities of 300 - 500 m/sec is seen followed by a second layer under the water table with a velocity corresponding to an impermeable material 1400 - 1600 m/sec.

In some cases, certain limitations may arise, such as differentiation between two different layers having approximately the same velocity. As an example:

- a contact within sand under the water table
- a contact between till and sand, under the water table (both at 1500 m/sec)

As a guideline, the following figure shows a classification of geological material by seismic velocities.

Seismic velocities in the overburden

Variations in the overburden layer can vary over a wide range as a function of its age, its depth of burial, differences in the granular state, degree of porosity, and whether water or air fills the voids (Telford 1976).

Seismic velocities in bedrock

A significant variation in seismic velocities for a particular rock mass may be caused by several factors. These factors include a change in the rock quality when the rock is weathered, sheared, faulted or fractured, a radical topographic change or a rock type change. Other features, such as the distribution of rock types, mineral content, the bonding of the minerals, joints opening, rock pressure, saturation and chemical composition of the minerals may all affect the velocities to some degree, explaining the differences of velocities in sound rock.

Rock type or change in bedrock quality

A rock type change will generally result in a different velocity because of differences in crystallization, mineralization or other physiochemical properties.

In the same way, a change in rock quality such as the presence of large open joints or several small open joints will undoubtedly bring about a velocity change for the same type of rock. Features such as a weathered, sheared, fractured or faulted rock will cause a drop in the velocity.

Faults, deep valleys

A radical topographic change in the bedrock profile may also cause a drop in the measured velocity. The cause of this is geometric and the use of specialized interpretative methods permits an estimation of the true depth of bedrock. A fault will also cause a similar velocity anomaly in the bedrock.

These anomalies may be due to either a deep valley or a cavity like feature (which may be water or sediment filled), or a physical feature in the rock such as a fault or open joints. Since the analysis of the time distance curve does not allow the differentiation of the anomalies, the two possible interpretations are presented on the drawings. In such a case, borehole data gives the best information to assess the true nature of the anomaly.

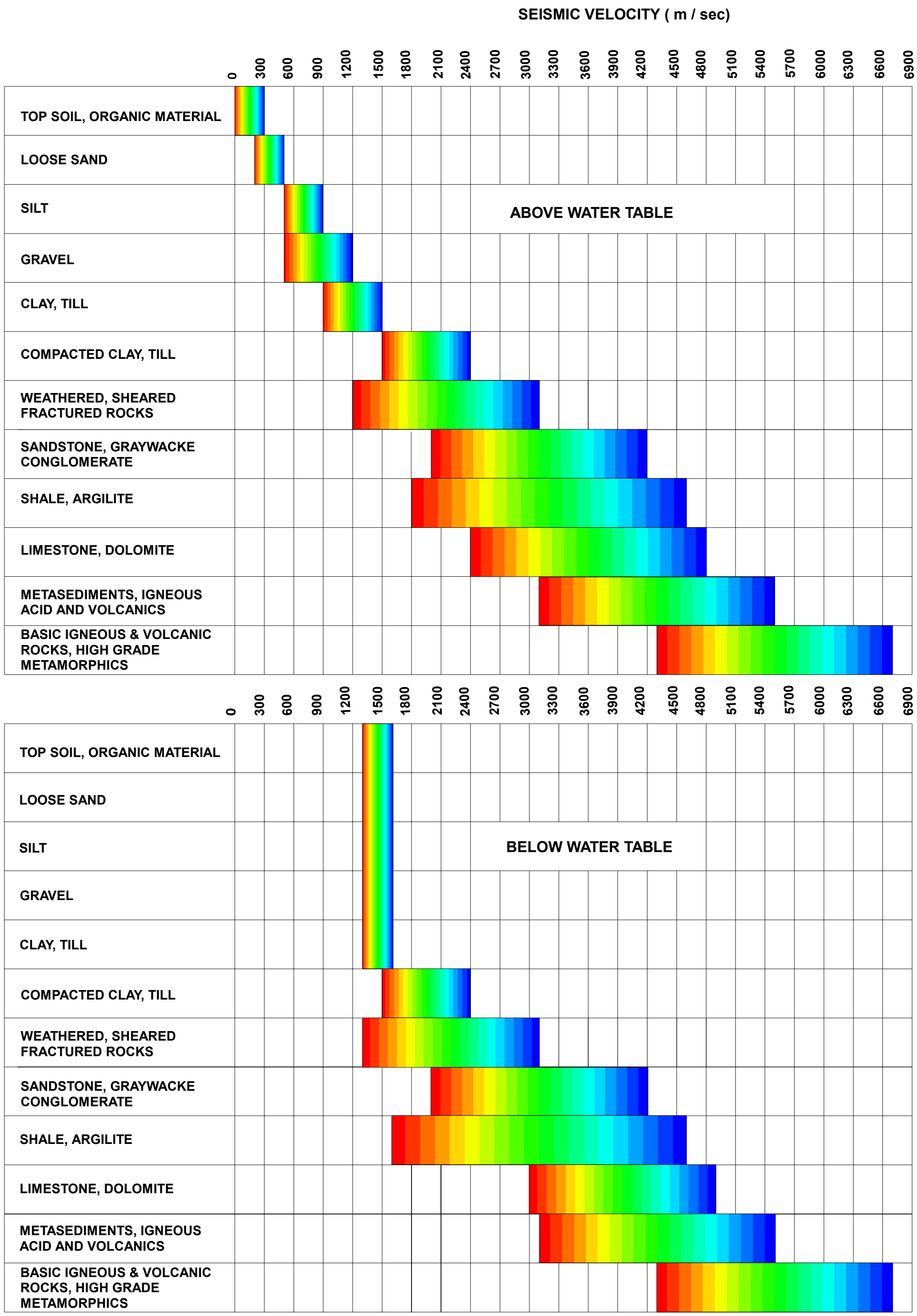


FIGURE B-2

CLASSIFICATION OF GEOLOGICAL MATERIALS BY SEISMIC VELOCITIES

CAUSES OF LATERAL VELOCITY ANOMALIES IN BEDROCK

Velocity changes in rock may represent a change in rock quality, a radical topographic effect or a rock type change. We will discuss each possibility in turn using figure B-3 as a reference.

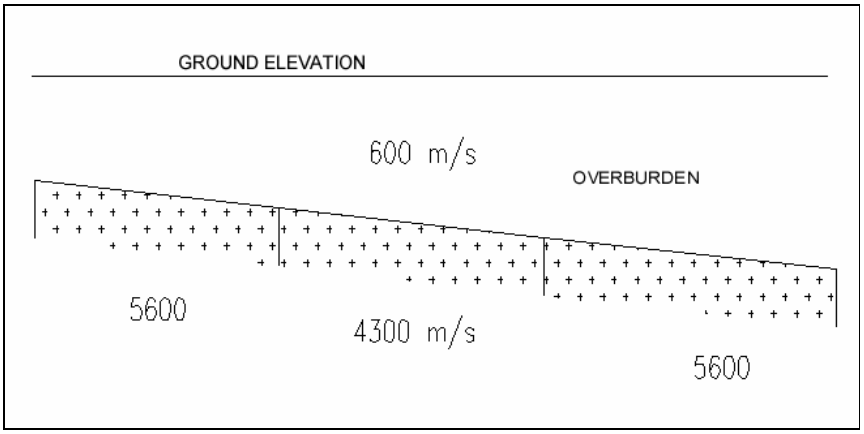


Figure B-3

In the above case, a survey was done using a geophone spacing of 7,5 metres. A zone whose velocity is 4 300 m/sec was measured between the two zones of sound bedrock with a seismic velocity of 5 600 m/sec.

Case 1 – Rock Type Change

A rock type change will result in a velocity change. For example, a sandstone resting on a gneissic rock may bring about the case shown in figure B-4. In this case, the rock may be of good quality, however, the lower velocity represents a physiochemical difference.

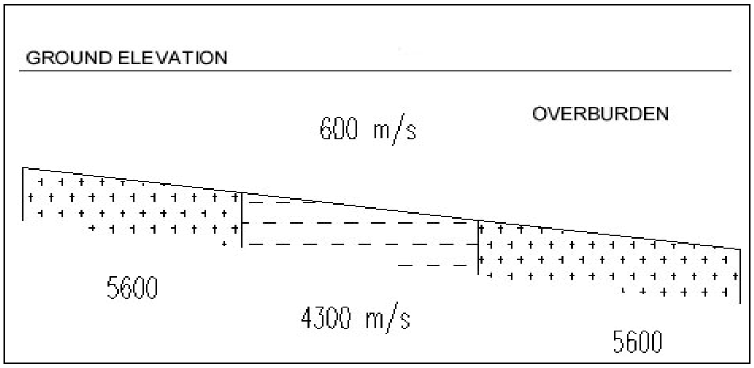
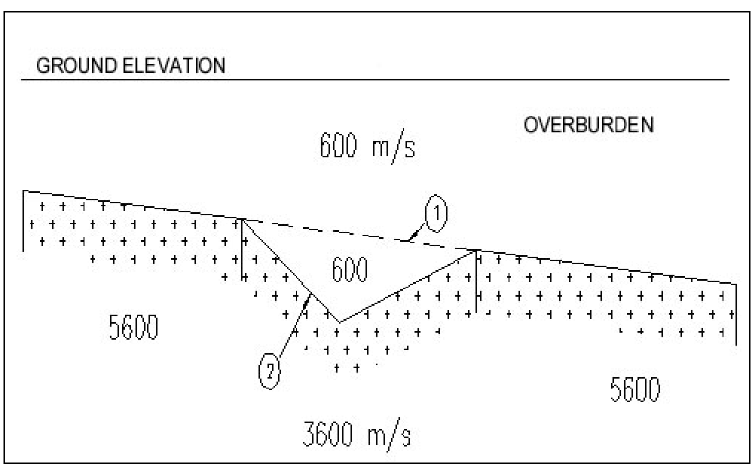


Figure B-4

Case 2 – Topographic effects

A radical topographic change in the bedrock profile, such as a fault with a vertical displacement or a buried valley may bring about a velocity change. The cause of this is geometric and the use of specialized interpretative methods will permit the determination of the true velocity, as seen in figure B-5.



(1) Topography before correction
(2) Topography after correction

Figure B-5

Case 3 – Rock quality change

A change in rock quality will also bring about a velocity change as illustrated in the following cases:

a) Open joint
The presence of a large open joint will bring about a velocity change. Using a 7,5 metres geophone spacing, the zone may appear to be 15 metres large, (as shown). However, in reality, the joint is 4,7 metres large with a velocity of 2 500 m/sec (Figure B-6).

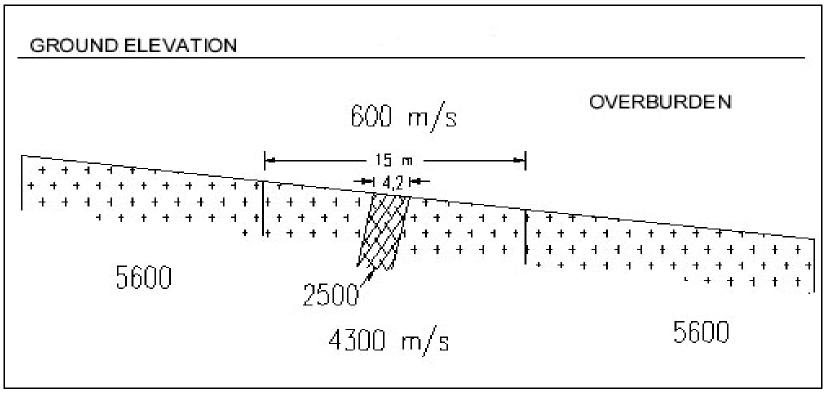


Figure B-6

b) Several small open joints
An important number (6) of small joints, 0,7 metres in width, having a velocity of 2 500 m/sec will cause the velocity to drop as seen in figure B-7.

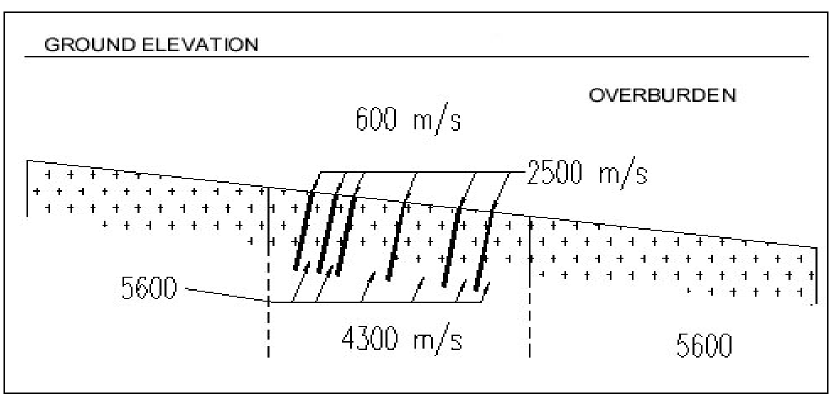


Figure B-7

c) Healed Faults

A healed fault of a zone of filled fractures will also show the same aspect, figure B-8.

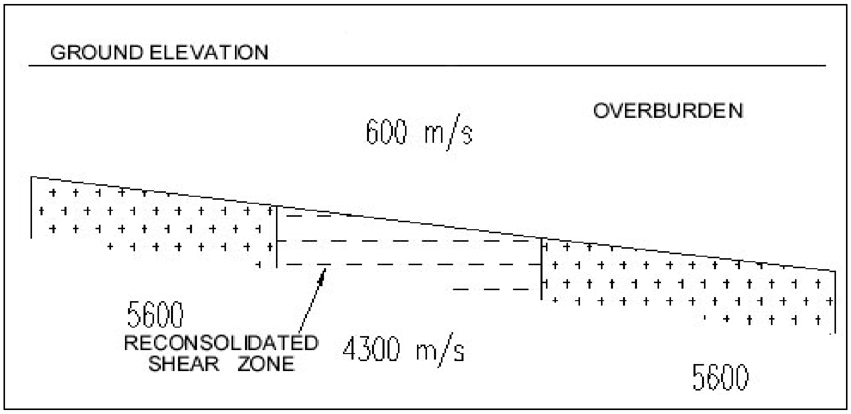


Figure B-8

More important weathered zone

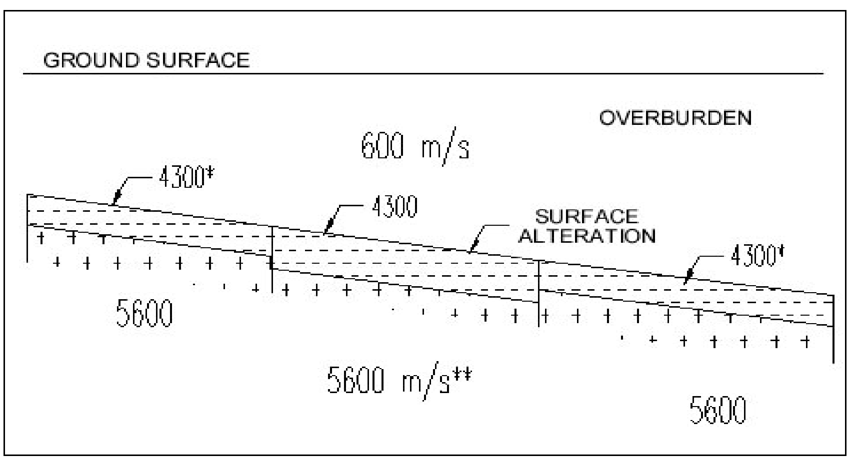


Figure B-9

* These rock weathered zones are not to be identified if too thin

** The 5 600 m/s seismic velocity is not measured if the width of the zone is too small

APPENDIX B-3

Descriptive Classification of Bedrock Seismic Velocities with RQD Values

DESCRIPTIVE CLASSIFICATION OF BEDROCK SEISMIC VELOCITIES WITH MRQD VALUES

Seismic velocities depend on a wide variety of parameters and it is always difficult to relate them to borehole logging. However, there is a way which involves measuring compressional wave velocities in the field and in the laboratory.

The field and laboratory velocities are different. The field velocity is measured on a large scale and depends on the bedrock type and its fracturation degree. The laboratory velocity is measured on a small core sample and depends more on the microscopic features of the bedrock. From these velocities, one can define the velocity index.

The classification of Coon and Merritt is based upon the velocity index property of in-situ rock which is a measure of the discontinuities in the rock mass. According to Coon and Merritt, the velocity index is defined as the square of the ratio of seismic field velocity to laboratory compressional wave velocities, measured on a core sample, representative of a sound rock. The field seismic velocities are normalized by the laboratory results in order to minimize the influence of lithology. Hence as the number of joints decreases, the ratio of the velocities will approach 1. This ratio is then squared to make the velocity index equivalent to the ratio of dynamic moduli.

The following table is extracted from a study by Coon and Merritt (ASTM STP 477) and illustrates the relationship of the velocity index versus the MRQD values (Rock Quality Designation).

We must keep in mind that the seismic refraction usually measures the velocity of the bedrock as is shallow (0 - 100 metres in depth).

TABLE C-1

ENGINEERING CLASSIFICATION FOR IN SITU ROCK (1)			
MRQD (%)	VELOCITY INDEX	DESCRIPTION	SEISMIC DESCRIPTION
0 - 25	0.00 - 0.20	Very poor	Low velocity
25 - 50	0.20 - 0.40	Poor	Low velocity
50 - 75	0.40 - 0.60	Fair	Intermediate
75 - 90	0.60 - 0.80	Good	Sound rock
90 - 100	0.80 - 1.00	Excellent	Sound rock

(1) Taken and adapted from: Coon,R.F. and Merritt,A.H.,**Predicting in-situ Modulus of Deformation using Rock Quality Indexes**, Determination of the in-situ modulus of deformation of rock, ASTM STP 477, American Society for testing and materials 1970, pp. 154-173.

It is important to note that the RQD can be affected by the drilling, whereas the velocity measurements are not. The relation between the RQD values and the seismic velocities have always been a concern of geologists and geophysicists. This empirical relation could, thus, be useful. The only additional data needed to compute the velocity index, would be the core laboratory seismic velocity.

Without laboratory calibration, we used one of the highest seismic velocity measured over the tunnel axis as reference (4800 m/s), which lead to :

for a geophysical (seismic) appreciation :

$Vp \geq 3700$ m/s → Sound rock
$3100 \leq Vp < 3700$ m/s → Intermediate
$Vp < 3100$ m/s → Low velocity

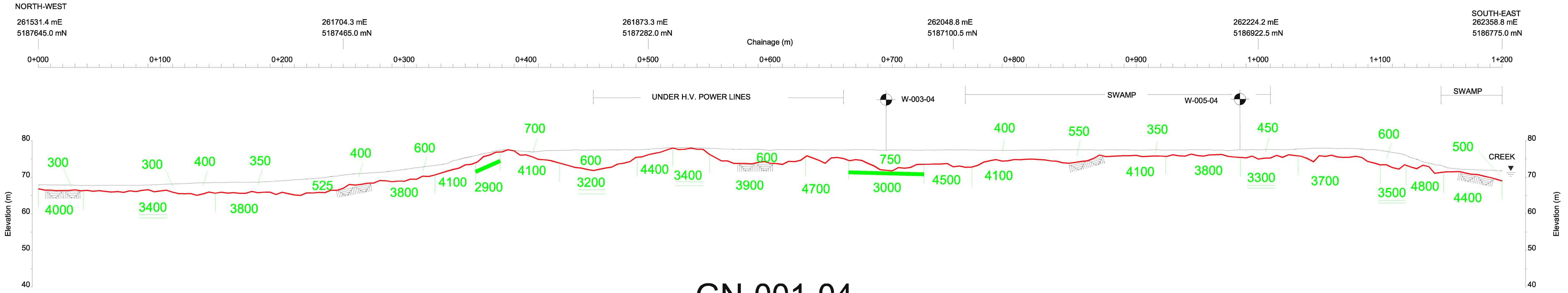
or, for an equivalent geotechnical classification:

$Vp \geq 4300$ m/s → Excellent
$3700 \leq Vp < 4300$ m/s → Good
$3100 \leq Vp < 3700$ m/s → Fair
$2200 \leq Vp < 3100$ m/s → Poor
$Vp < 2200$ m/s → Very poor

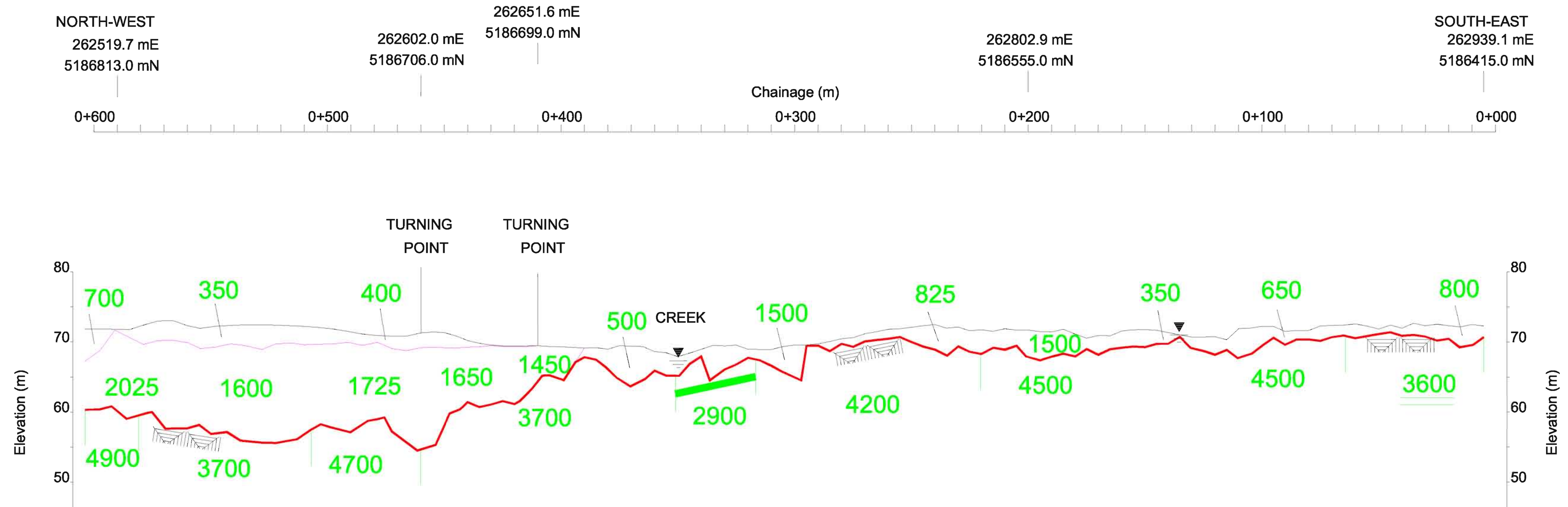
APPENDIX C

Seismic Refraction Profiles

Drawing No: 04-11-822-00



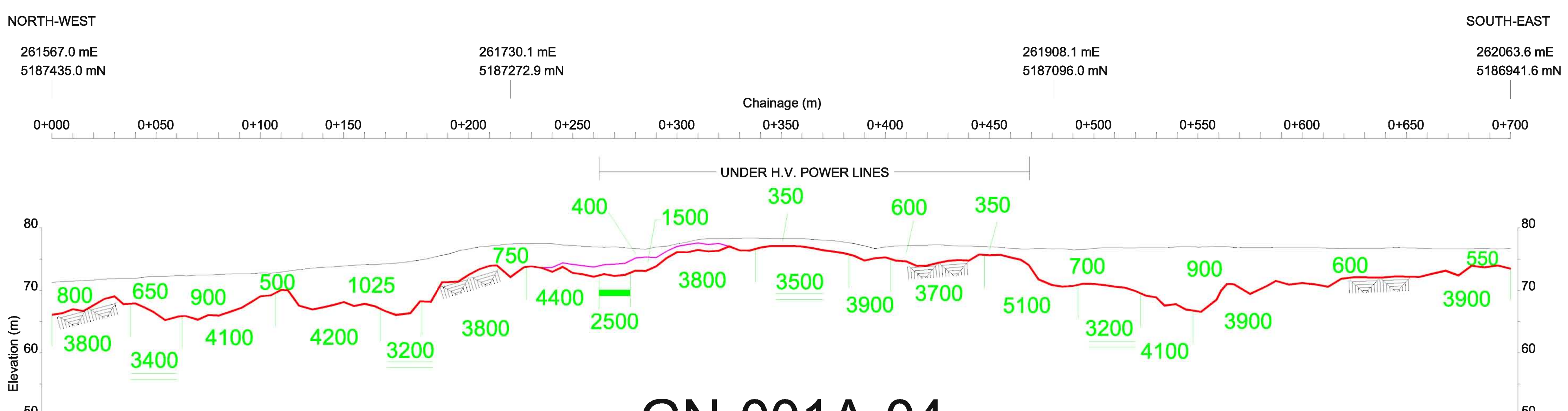
GN-001-04



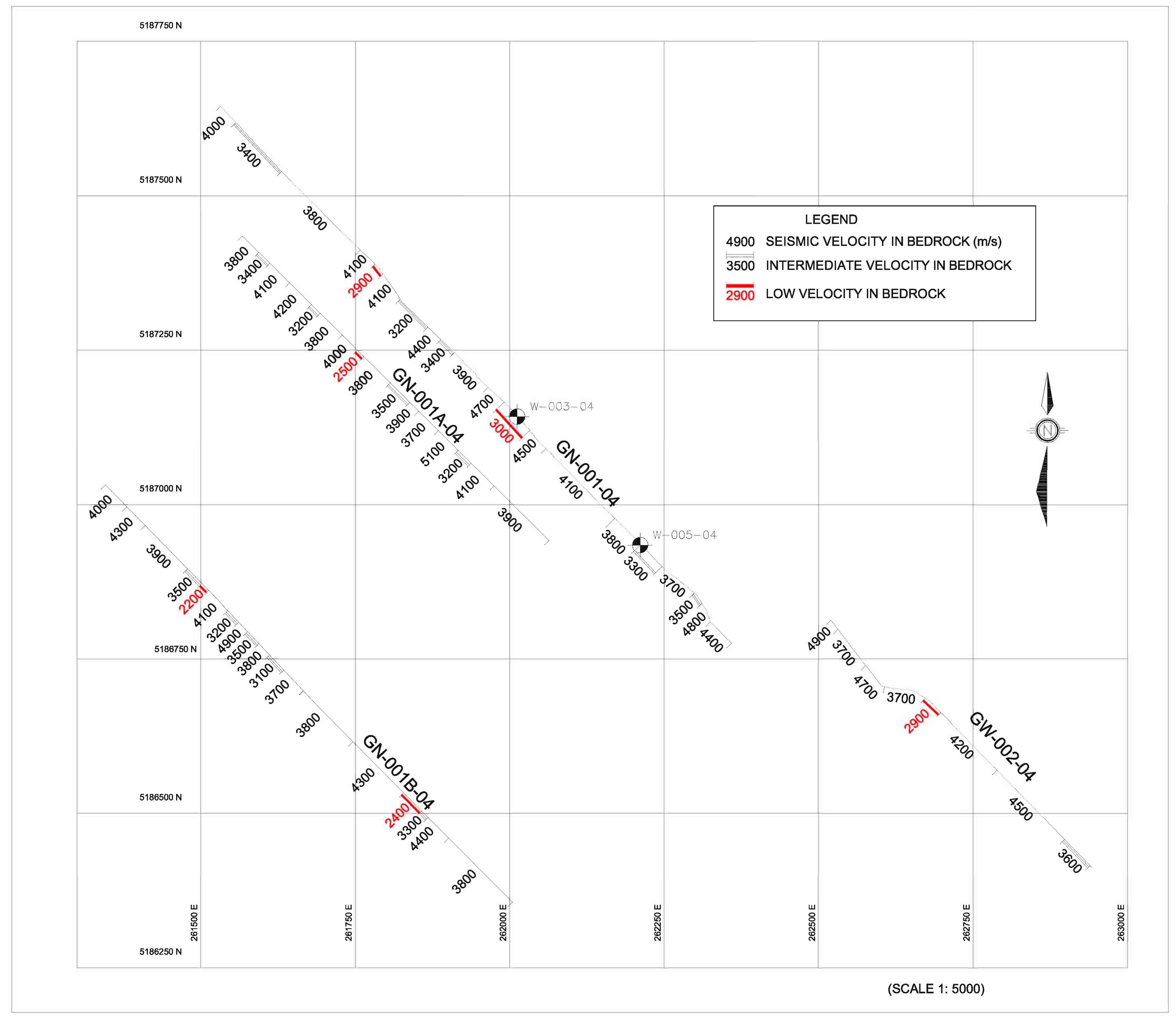
GW-002-04

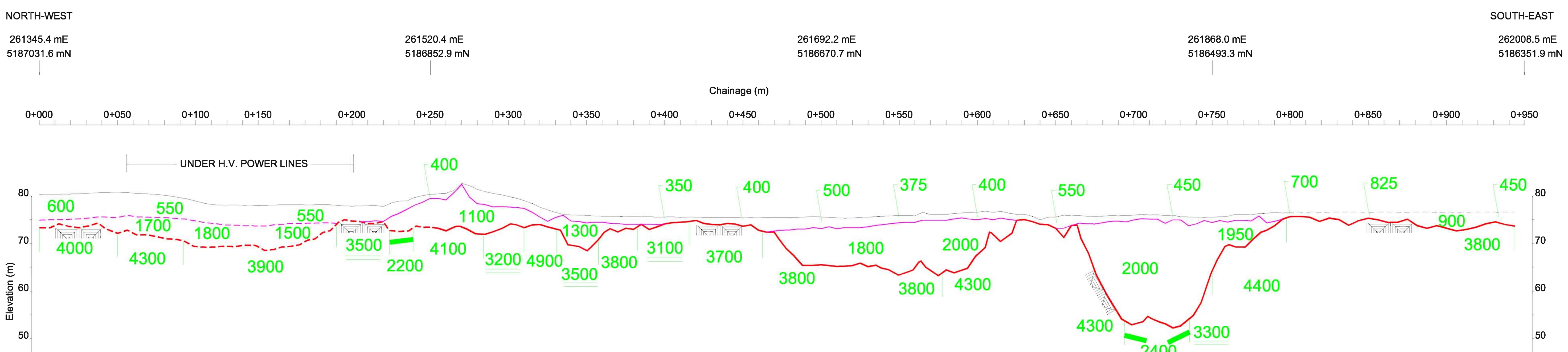
LEGEND

- SURFACE TOPOGRAPHY
- EXTRAPOLATED SURFACE TOPOGRAPHY
- 500 SEISMIC VELOCITY (m/s)
- REFRACTOR PROFILE
- ROCK PROFILE
- PROBABLE REFRACTOR PROFILE
- PROBABLE ROCK PROFILE
- LATERAL CONTACT OR LIMIT
- 3300 INTERMEDIATE VELOCITY IN BEDROCK
- 2900 LOW VELOCITY IN BEDROCK
- BOREHOLE



GN-001A-04





GN-001B-04

No.	NOTES
1	THE SEISMIC REFRACTION PROFILES WERE SURVEYED BY GEOPHYSICS GPR INTERNATIONAL INC. THE 4TH AND FROM THE 18TH TO 21ST OCTOBER (GN-001-04 AND GW-002-04), AND THE 11TH TO 15TH NOVEMBER, 2004 (GN-001A-04 AND GN-001B-04).
2	THE COORDINATE SYSTEM IS MTM (SCoPQ), NAD 83, ZONE 8.
3	THE ELEVATIONS ARE RELATIVE TO THE M.S.L.
4	THE PROFILE COORDINATES AND TOPOGRAPHIC DATA WERE PROVIDE BY TERRATECH.

No	DESSINS DE REFERENCE DRAWINGS

No	DATE	MODIFICATIONS	GPR APP.

SCEAU PROFESSIONNEL / PROFESSIONAL SEAL

GEOPHYSICS GPR INTERNATIONAL INC

DESSINÉ PAR / DRAWN BY	A. Beaudoin, tech.
VERIFIÉ PAR / CHECKED BY	J.L. Arsenault, Eng.
APPROUVÉ PAR / APPROVED BY	R. Paul, Eng.
# CONTRAT / CONTRACT #	M-04958
DATE	24 november 2004
ÉCHELLE / SCALE	hor.: 1 : 1500 vert. 1: 500
# DESSIN / DRAWING #	04-11-822-00

CLIENT: TERRATECH

PROJET / PROJECT: RABASKA PROJECT - LÉVIS

TITRE / TITLE: SEISMIC REFRACTION SURVEYS