# KEYSTONE MINING LTD.

# SEISMIC REFLECTION SURVEY OF THE DUNCAN CREEK PROPERTY, MAYO AREA, YUKON TERRITORY

Mike Power, M.Sc., P.Geoph.

PLACER CLAIMS

| | |
|---|---|
| BON 1-11 | P2663-P2673 |
| 1st Tier Bench 1-16 | P16758-P16771, P16773 |
| TAYLOR 1-4 | P3676-P3680 |
| TRIPLE 1-13 | P2722-P2734 |

Location: 63° 47' N 135° 30' W
NTS: 105 M 13/14
Mining District: Mayo
Date: January 20, 2004

## SUMMARY

The Duncan Creek Placer Property consists of 45 Placer Claims on the lower end of Duncan Creek, approximately 30 km northeast of Mayo, YT. The property covers a 4 km (north-south) by 1 km (east-west) area centred on the Mayo Lake - Duncan Creek Road junction, immediately west of Duncan Creek.

In the property area, the Duncan Creek valley is underlain by Hyland Group schists and phyllites and covered by a thick succession of overburden. Auriferous placer deposits occur in pre-Reid, Late Reid, Koy-Yukon and Holocene age gravels at different levels in the overburden succession. The most significant production to date has been won from Holocene placers on Upper Duncan Creek and its tributaries, and from Late Reid gravels on the lower end of Duncan Creek. These latter deposits are preserved beneath McConnell glacial and periglacial sediments deposited by an ice lobe which moved part way up the Duncan Creek valley. The target of the exploration program described in this report is Late Reid gravel in a buried channel presumed to lie beneath a large plateau west of the present Duncan Creek flood basin.

Prior to the seismic survey, 5.1 line-km of seismic line was cut to cover the entire area where the deposit is presumed to occur. The seismic grid consisted of a central 2.1 km north-south base line and 5 orthogonal survey lines extending from the creek 300 to 500 m west to cover the plateau. The base line runs along the presumed axis of the buried channel and is roughly coincident with the Duncan Creek road north of the Mayo Lake Road turnoff. Line ends were surveyed with differential GPS to accurately record their location, and elevations and station locations along the survey lines were surveyed with a total station transit / EDM. During this survey, bedrock exposures near the seismic survey grid were surveyed in as well to provide subsurface control.

The reflection seismic survey was conducted with a 48 channel engineering seismograph using an ATV mounted accelerated weight drop source, supplemented by a 50 lb sledge hammer for inaccessible areas on the steep portions of the seismic lines. A 2 m phone spacing and 4 m source spacing provided 24-fold coverage with reflection points spaced at 1 m along the survey lines. Full 2D reflection data processing incorporating surgical noise-cone mutes of individual shots, refraction statics and semblance velocity analysis was conducted after the survey.

The final depth sections demonstrate that the bedrock surface beneath the Duncan Creek valley in the survey area is generally flat area and that bedrock is covered by 50 to 60 m of overburden beneath the plateau west of Duncan Creek. Within the overburden section, reflection-bounded units can be discriminated. These include steep sided, basal units with complex internal reflections inferred to be Late Reid gravel deposits from their stratigraphic position and morphology. These are overlain by silts and capped by very thin gravel units not imaged by the seismic survey. The survey results suggest that a thick succession of Late Reid gravels may lie beneath

the western plateau. In particular there appears to be a discrete gravel at the eastern edge of the plateau characterized by steep sides, steeply dipping internal reflections and a lenticular shape. This target is imaged on Lines 03-3 to 03-5. Drill testing of this target is recommended.

## TABLE OF CONTENTS

# LIST OF FIGURES

## 1.0 INTRODUCTION

Aurora Geosciences Ltd. was retained by Keystone Mining Ltd. to conduct seismic reflection surveys on placer claims located on Duncan Creek near Mayo, YT. A total of 2.77 line-km were surveyed on 6 lines between September 2 and 11, 2003. The surveys were conducted to map bedrock and overburden topography in order to locate potential placer deposits. This report describes the seismic surveys and results.

## 2.0 LOCATION AND ACCESS

The Duncan Creek Property is centred at 63$^0$ 47' N 135$^0$ 30' W, about 30 km northeast of Mayo, Yukon. The property is located approximately 340 km northeast of Whitehorse (Figure 1). It is accessible by road from Mayo according to the following route:

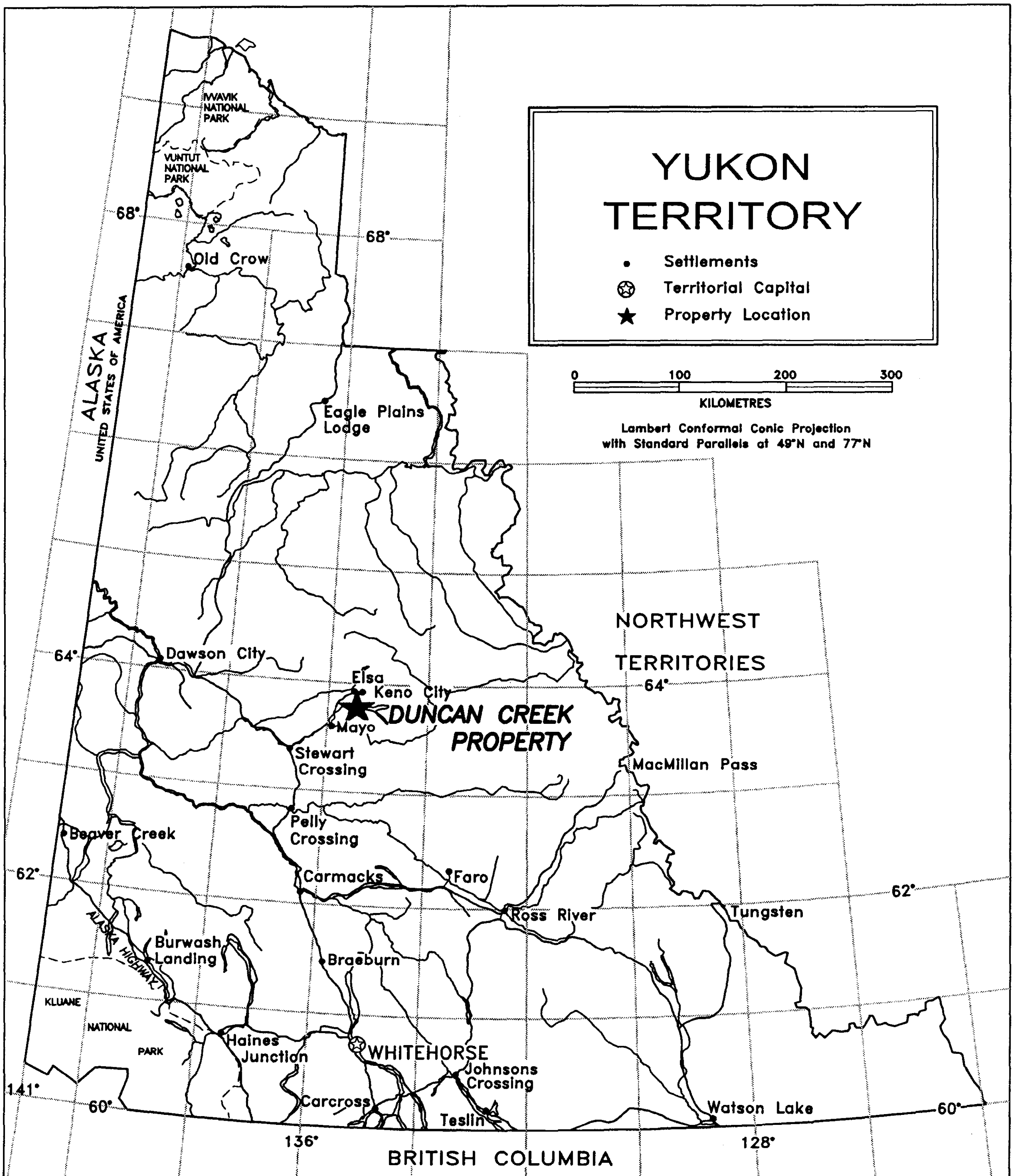
| Leg | Distance (km) |
|---|---|
| Mayo - Duncan Creek Road | 18 |
| Duncan Creek Road - Mayo Lake turnoff | 21 |
| Mayo Lake turnoff - camp (via Duncan Creek Road) | 2 |

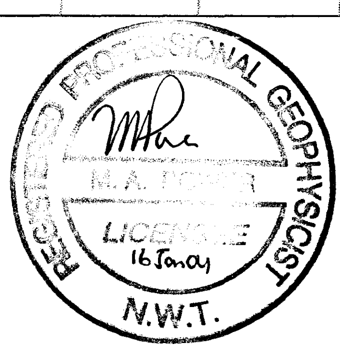
## 3.0 PROPERTY

The Duncan Creek Property consists of 45 un-surveyed placer claims staked under the Yukon Placer Mining Act in the Mayo Mining District. Claim locations are shown in Figure 2 and claim information, provided to the author by the Mayo Mining Recorder on January 12, 2004 is summarized below:

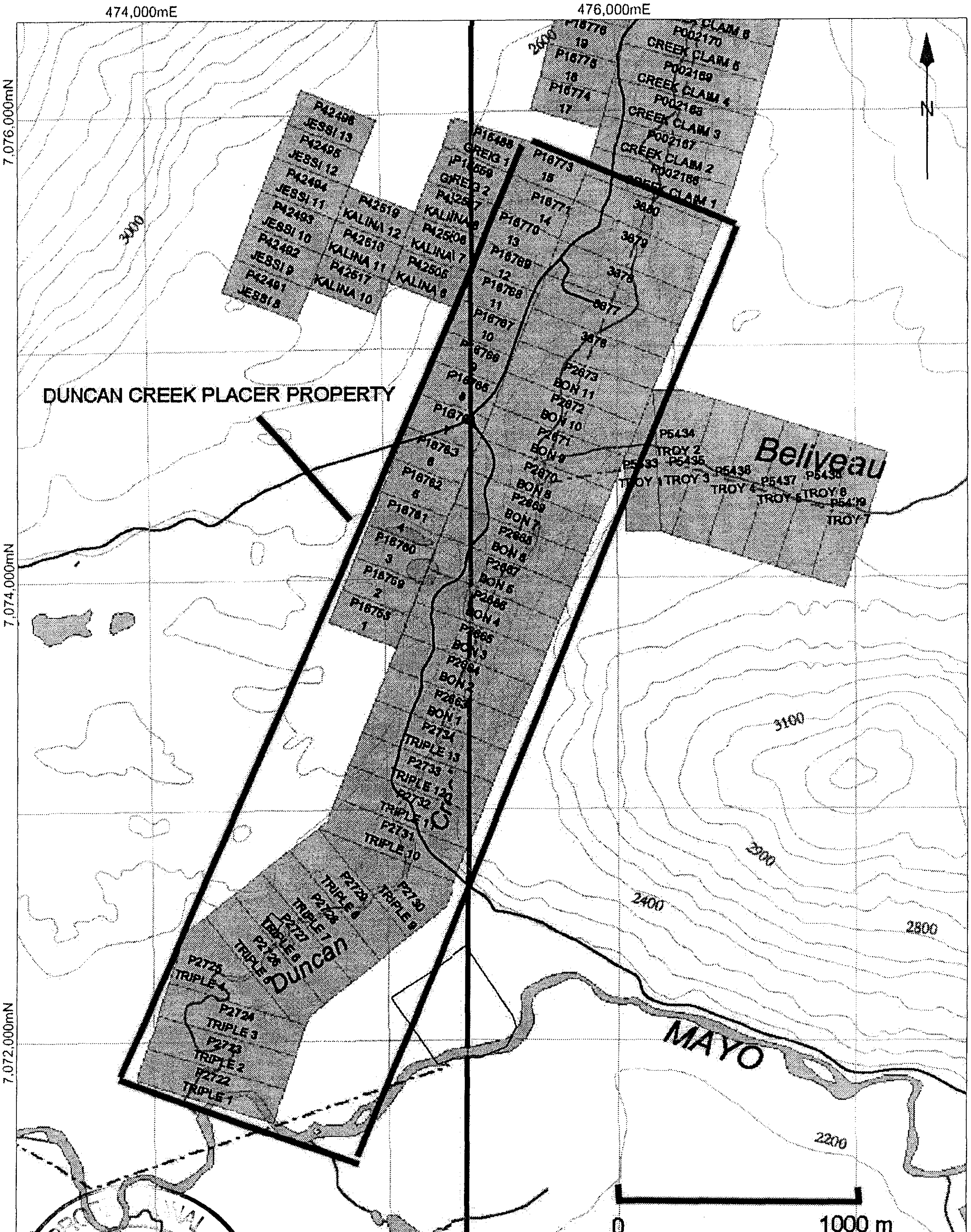
| Claim | Record Number | Expiry Date |
|---|---|---|
| BON 1-11 | P2663-P2673 | December 28, 2004 |
| 1$^{st}$ Tier Bench 1-16 | P16758-P16771, P16773 | December 28, 2004 |
| TAYLOR 1-4 | P3676-P3680 | December 28, 2004 |
| TRIPLE 1-13 | P2722-P2734 | December 28, 2004 |

The claims are 100% owned by Duncan Creek Golddusters Ltd. and are being explored under option by Keystone Mining Ltd.




| | |
|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY |
| SEISMIC REFLECTION SURVEY PROPERTY LOCATION | MINING DISTRICT: MAYO |
| | SCALE 1: 6,000,000 \| NTS: N/A |
| | DATUM: N/A \| DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 \| FIGURE: 1 |




| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
|---|---|---|
| SEISMIC REFLECTION SURVEY CLAIM LOCATION | MINING DISTRICT: MAYO | |
| | SCALE 1: 25,000 | NTS: 105 M13/14 |
| | DATUM: NAD 83 | DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 | FIGURE: 2 |

REGISTERED PROFESSIONAL GEOPHYSICIST
LICENSEE
16 Jan 04
N.W.T.

## 4.0 PHYSIOLOGY AND PLACER GEOLOGY

The physiology and placer geology of the property area has been described by LeBarge *et.al.* (2002); bedrock geology is described by Roots and Murphy (1992).

Lower Duncan Creek is underlain by Upper Proterozoic Hyland Group rocks and by a small window of underlying Keno Hill Quartzite, exposed in the footwall of the Robert Service Thrust, 4 km WNW of the Duncan Creek Property. The Hyland Group rocks are grey weathering, dark grey to grey-white schist, dark green phyllite and rare limestone. This rock unit hosts gold occurrences near the McQuesten airstrip, 13 km to the NW. Foliation and presumed foliation parallel bedding strikes WNW and dips SSW in the property area. Bedrock is exposed in sparsely distributed outcrops along Duncan Creek.

The Duncan Creek area has been affected by three glacial events separated by two periods of interglacial sedimentation. These are summarized below:

| Name (Age) | Description |
|---|---|
| Holocene (10Ka - recent) | Modern stream sedimentation and limited mass wasting on steep slopes. Reworked placer deposits in modern drainage where older deposits have been exposed by erosion. |
| McConnell glaciation (20 Ka peak) | Glaciofluvial and glaciolacustrine deposits up to 40 m thick. |
| Koy-Yukon interglacial (200 - 20 Ka) | Alluvial fans and glaciofluvial sediments (reworked Reid sediments); some placer occurrences. |
| Reid glaciation (300-200 Ka) | Extensive glacial and periglacial deposits with up-valley ice flows apparent in the Duncan Creek valley. |
| Pre-Reid glaciations (2.58Ma - 300Ka) | Erratics, glacial and interglacial deposits primarily exposed at elevations of 1200-1600 m above sediments deposited by younger glaciations. Pre-Reid sediments may occur in the Duncan Creek Valley either above 1200 m or preserved beneath Reid deposits. |

The surficial geology is illustrated in schematic cross section in Figure 3. The Duncan Creek drainage contains or is inferred to contain several placer deposit types at different stratigraphic levels. These are summarized in the table below:

| Age | Description |
|---|---|
| Holocene | Reworked placers, often containing coarse gold, formed where post-glacial down cutting has facilitated local placer generation. These deposits are most common in Upper Duncan Creek, in Lightning Creek and in the lower portions of Duncan Creek in the modern drainage. |
| Koy-Yukon | High grade placer deposits limited in size by the restricted volume of interglacial sediments in the Duncan Creek drainage. |
| Reid | Laberge *et. al.* (2002) asserts that the Late Reid outwash gravels are the most significant gold-bearing unit in the Duncan Creek valley and represent the largest potential buried placer deposit in the Mayo District. This unit is usually the lowest stratigraphic unit exposed along Duncan Creek. Auriferous gravels recently discovered west of the modern channel are presumed to be the Late Reid pay unit. |
| Pre-Reid | Interglacial placer deposits may occur beneath the Reid deposits to the west of the present Duncan Creek drainage. |

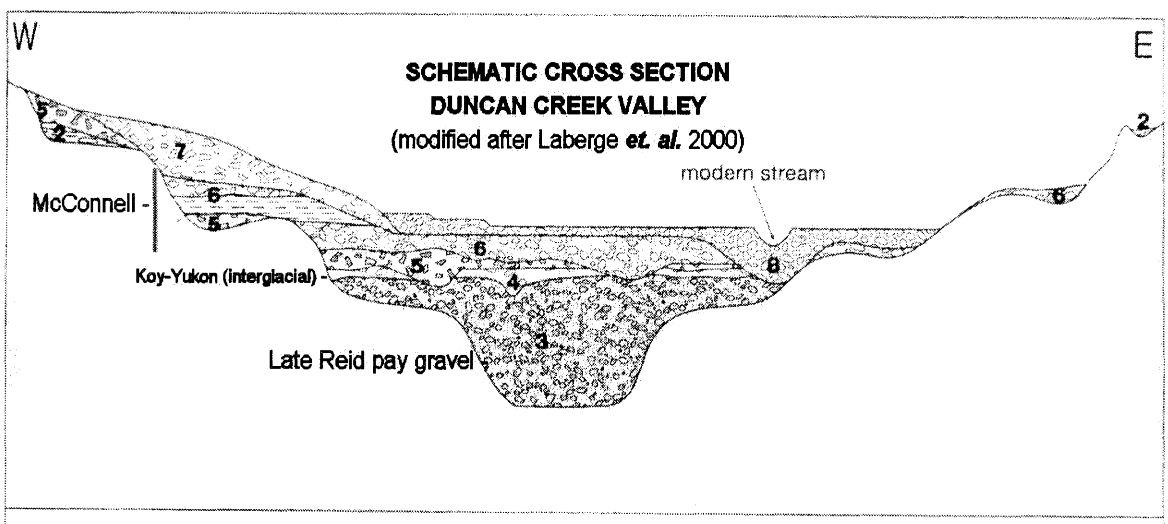



Figure 3. Stratigraphy of the lower Duncan Creek Valley after LeBarge *et. al.* (2002).

Placer mining along Duncan Creek and its subordinate creeks commenced in 1898 and has continued until the present. The bulk of past production has been from Holocene deposits in lower Duncan Creek and from the narrow west-draining tributaries east of Duncan Creek. In the late 1990's, isolated pockets of Late Reid gravels were discovered in the west side of the Duncan Creek valley and limited production occurred from these deposits. Exploration, including drilling, test pitting and seismic surveys have been conducted along the length of Duncan Creek, largely confined to the area immediately adjacent to the present drainage. Seismic survey programs and limited drilling conducted west of the present creek drainage have indicated the presence of a thick overburden section.

The following stratigraphy is based on exposures on the right limit of Duncan Creek in the area of the seismic survey as described by Troy Taylor. Units are grouped into overburden layers with differing bulk lithology. Boundaries between layers with different bulk lithology are most likely to be detected as discrete reflections in a seismic reflection survey. The interpretation in this report is also keyed to this stratigraphy:

| Unit (number) | Description |
|---|---|
| Upper gravel (5) | Holocene and Late McConnell unconsolidated boulder to cobble gravel covered by a thin soil layer |
| Middle silt (4) | Late McConnell silt |
| Middle sand (3) | Early to Middle McConnell sand with lesser pebble to locally cobble gravel. This unit thins to the south in the seismic survey area and is not inferred to be present on Line 03-2 (southern most line). |
| Pay gravel (2) | Late Reid boulder to cobble gravel. At the base of this unit is compact sand and cobble gravel (Early to Middle Reid) which may be indistinguishable from the upper unit in seismic sections. |
| Bedrock (1) | Primarily quartz-chlorite and quartz-feldspar schist. |

The seismic survey program described in this report was conducted to investigate in detail the hypothesis that a buried Late Reid gravel deposit (Unit 2) may lie west of the present drainage in an area roughly coincident with the present Duncan Creek - Keno City road. Auriferous gravels of presumed Late Reid gravels age have been exposed at several locations on the west side (right limit) of Duncan Creek above and below the area which was the focus of the seismic survey.

## 5.0 PERSONNEL AND EQUIPMENT

Line cutting and topographic surveys were conducted in June 2003 prior to the seismic survey. This work was performed by the following personnel:

| | |
|---|---|
| Mike Power | Crew chief |
| Warren Kapaniuk | Line cutter |

The seismic survey was conducted by a three man crew consisting of the following personnel:

| | |
|---|---|
| Mike Power | Geophysicist |
| Dave Hildes | Technician |
| Warren Kapaniuk | Source technician |

They were equipped with the following instruments and equipment:

| | | |
|---|---|---|
| Acquisition: | 1 - | Strataview R-48: 48 channel digital engineering seismograph. |
| | 48 - | Mark Products 100 Hz geophones |
| | 2 - | 12 channel refraction cables w/ takeouts at 5 m |
| | 1 - | 24 channel refraction cable w/ takeouts at 10 m |
| | 1 - | Trigger cable |
| Source: | 1 - | Digipulse™ impulse seismic source mounted on a Polaris 550 ATV |
| | 1 - | 50 lb sledgehammer source |
| Data processing: | 1 - | Dell 800 MHz laptop |
| | 1 - | HP340C colour printer |
| Other: | 1 - | 4-man camp (sleeper / kitchen-office tents) |
| | 1 - | Honda 440 ATV |
| | 1 - | GMC 1 Ton 4x4 |

The geophysical crew spent a total of 19 days on the property. The geophysical survey log is attached as Appendix B, a statement of project expenditures is attached in Appendix C and instrument specifications are in Appendix D.

## 6.0 SURVEY GRID

The location of the seismic survey grid is shown in Figure 4. The grid consists of a central base line, sited to follow the inferred axis of the target buried channel. Cross lines are orthogonal to the base line and commence at or near Duncan Creek, extending up a steep bank on the right limit to an elevated plateau west of the creek. The seismic lines were cut to a nominal width of about 2 m and thoroughly brushed to ground level to permit the ATV mounted source to move along them. The lines were straight chained (not slope corrected) and picketed at 48 m intervals with tagged and flagged half-length survey lathe. The north end of the base line and the eastern ends of the cross lines are the line origins and all station coordinates are relative to these points. The line name and station chainage are marked on both the pickets and the attached metal tags.

The relative elevations and horizontal locations of the station pickets were surveyed with a total station transit / EDM relative to the origins of the seismic lines. In addition, the end points of the seismic lines were located with a Geoexplorer I differential GPS receiver and the locations were corrected using data from the Whitehorse Geodetic Survey of Canada GPS base station. The absolute locations of the end points are presumed to be accurate within 1 m vertical and horizontal. All elevations in this report are expressed in metres above mean sea level. End-of-line DGPS elevation differences and end-of-line transit elevation differences agree with each other within the bounds of DGPS measurement error ($\pm$ 2 m). Digital survey data is contained in the archive on the CD-ROM appended to this report.

The coordinate system used in the seismic data processing follows conventions used in oilfield seismic reflection data processing. The first station on any line, located at the origin of the line, is designated 101 and station numbers increment sequentially (101, 102, 103...) down line (away from the origin). The straight chained coordinate of any station is x=(Processing station -101) x Station spacing.

The seismic reflection surveys did not cover all portions of the seismic lines which were cut. Figure 4 illustrates the areas covered by the seismic survey (yellow) and the full extent of the lines (black). Seismic line origins are also indicated on the diagram.

The elevation of the bedrock surface is known at two points in the immediate area of the seismic survey. In Figure 4, the extent of mine workings excavated in 2002 and 2003 are indicated in red. The base of the pay gravel is exposed at the water line in the pit at this location and has a surveyed elevation of 697 m. Troy Taylor estimates that this pit contained 3 m of water at the time of survey and consequently, bedrock probably occurs at an elevation of 694 m at this point in the pit. The second point bedrock exposure is in the vicinity of an abandoned cabin on a small knob (Chamber's Cabin) immediately south of the eastern end of Line 03-5. The elevation of the origin of this line is 706 m but bedrock obviously lies several metres beneath this point at the edge of the creek.

## 7.0 SURVEY SPECIFICATIONS

The reflection seismic survey were conducted according to the following specifications:

| | | |
|---|---|---|
| Channels: | 48 | |
| Receiver station spacing: | 2 m | |
| Receivers: | single phone | |
| Minimum offset: | 2 m | |
| Maximum offset: | 96 m | |
| Source spacing: | 4 m | |
| Nominal maximum fold: | 24 | (with local exceptions along the base line and line 03-2) |
| Record length: | 512 ms | |
| Sampling: | 0.500 ms | |
| Analog input filter: | 500 Hz high cut | |
| Source effort: | Digipulse: 4 blows<br>Hammer: 10 blows | |

Exceptions or deviations from these specifications are described in the description of operations along each line. With these survey parameters, nominal subsurface coverage consisted of reflection points spaced 1 m apart along the survey lines.

## 8.0 SEISMIC THEORY AND DESCRIPTION OF DATA PROCESSING

The theory behind the seismic reflection method is summarized in Sheriff and Geldart (1995). Yilgaz (1990) contains a comprehensive description of seismic reflection data processing. This section summarizes a few elements of the basic theory underlying the seismic reflection method as applied in high resolution, shallow seismic surveys. It also describes the methods used to process and interpret the data.

### 8.1 Basic theory

Seismic waves are mechanical perturbations, transmitted by compressing or shearing a medium as the wave passes through it. The elastic strain response of a solid body to stress is governed by Lame's Constants $\lambda$ and $\mu$. $\lambda$ is the strain response perpendicular to applied compressional force and is termed the *fluid incompressibility.* In effect it is the amount of elastic "lateral bulge" per unit volume when a mass is compressed. $\mu$ is the *shear modulus* or resistance to shearing that the medium possess. Any solid or semi-solid has a measurable shear modulus; a liquid does not as it cannot store elastic energy when sheared. The shear modulus of a rigid rock would be high whereas that of compacted clay would be less.

Seismic wave propagate through a medium in one of two ways, shown in Figure SR-1 (a). Straightforward compression of the medium, similar to the generation of a sound wave, is termed a P-wave because it is the primary or first arrival in an earthquake record. The velocity of the P-wave is governed by:

$$V_p = \sqrt{\frac{\lambda + 2\mu}{\rho}} \qquad (1)$$

where $\rho$ is the density of the rock and the other variables are defined as above.In water or air, the P-wave velocity reduces to:

$$V_p = \sqrt{\frac{\lambda}{\rho}} \qquad (2)$$

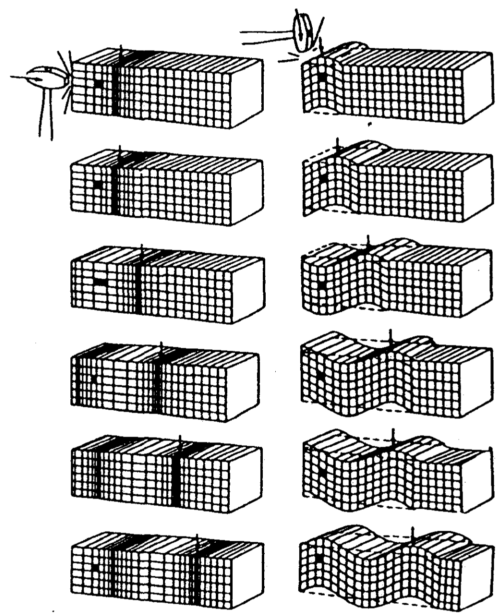
A second wave type is generated in response to stress transverse to the propagation direction of the seismic wave; this is similar to the wave on a string and is termed the S-wave as it is the secondary arrival in the seismic wave train recorded in an earthquake record The S-wave velocity is:

$$V_s = \sqrt{\frac{\mu}{\rho}} \qquad (3)$$

In nature, $\lambda$ and $\mu$ increases rapidly with density and consequently seismic velocity actually tends to increase with rock density. The range of P-wave velocities commonly encountered in shallow reflection seismic work is summarized in Table SR-1 below. P-waves are the fastest and strongest waves measured by conventional seismic instruments and the remainder of this discussion will focus exclusively on their properties.

Seismic waves radiate away from a point source in all directions creating spherical wave fronts traveling through the surrounding media. Huygen's Principle states that any point on a wave front is a point source for succeeding waves. The interference of these waves at any later time defines the new position of the moving wave front. It is useful to simplify a consideration of seismic wave motion by examining a ray path rather than the whole wave. Both the ray and wave obey the same physical laws but wave motion is easier to visualize if the raypath is considered first. The

(a) P-wave and S-wave motion (Press & Siever 1974)



(b) Seismic ray reflection and refraction

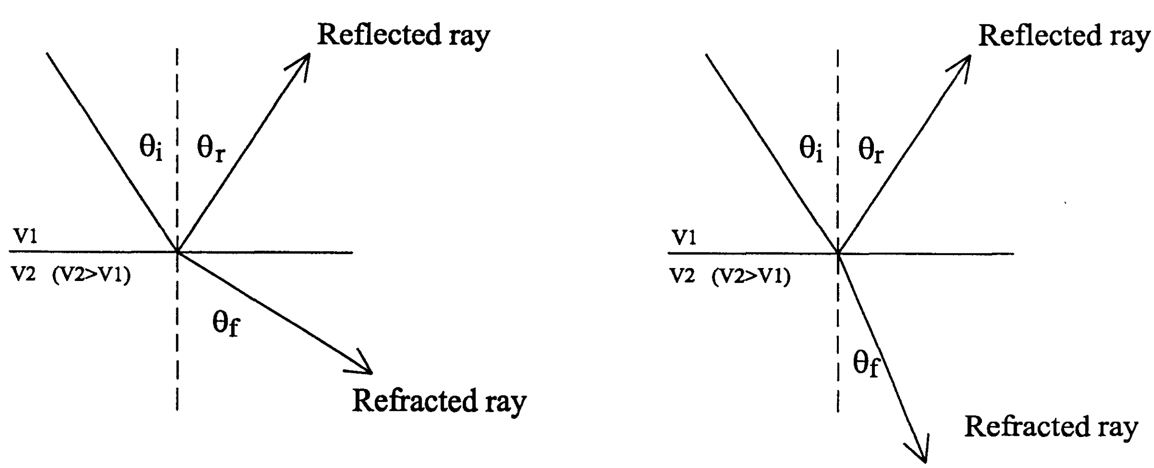



Figure SR-1. Seismic wave motion and behaviour at boundaries.

wave front is nothing more than the sum of the possible ray paths.

**Table SR-1. P-wave velocities of common rocks and sediments**
(after Sheriff and Geldart (1995))

| Material | P-wave velocity (m/s) |
|---|---|
| Air | 330 |
| Water | 1550 |
| Gravel or sand (water saturated) | 1500 - 1900 |
| Gravel or sand (dry) | 500 - 1500 |
| Ice or permafrost | 3500 |
| Granite | 4000 - 5500 |
| Gabbro | 5000 - 7000 |
| Shale or schist | 2000 - 5000 |

Seismic waves are both reflected and refracted at the boundary between media with different seismic velocities. As shown in Figure SR-1(b), a portion of the seismic energy will reflect back towards the source and the residual energy will be transmitted through the boundary and be refracted upon entry into the second medium. For reflection, the angle of incidence - the angle between the incident ray and a normal to the reflecting surface - equals the angle of reflection. Refraction is governed by Snell's Law:

$$\frac{\sin\theta_i}{v_i} = \frac{\sin\theta_f}{v_f} \qquad (4)$$

If the velocity in the lower medium is slower than that of the upper medium $\theta_f < \theta_i$ and the ray will bend away from the velocity boundary. If the velocity in the lower medium is faster than that of the upper medium $\theta_f > \theta_i$ and the ray will bend towards the velocity boundary. In this situation, at a distance from the shot termed the *critical distance*, the wave will be bent so as to travel along the layer boundary, generating returning rays which will travel back to the surface at an angle equal to the *critical angle of incidence*. At shot to geophone separations greater than a *cross-over distance*, the first energy to arrive at the geophone will not be the direct wave traveling parallel to the surface, but a refracted arrival traveling down to, along and upwards from the faster layer beneath.

Seismic energy will reflect at the boundary between materials with different seismic impedances. The seismic impedance (Z) is defined as:

$$Z = \rho V_p \qquad (5)$$

where $\rho$ is the bulk density and $V_p$ is the compressional wave velocity. The strength of the reflection (R) at the boundary between two materials with differing seismic impedances for the most simple case of vertical incidence is:

$$R = \frac{(Z_2 - Z_1)}{(Z_2 + Z_1)} \qquad (6)$$

where $Z_1$ and $Z_2$ are the seismic impedances of the overlying and underlying layers respectively. The greater the contrast in density and / or velocity, the stronger the reflection coefficient. Similarly the sign of the reflection coefficient (and the polarity of the signal) will be reversed if low density or low velocity material forms the underlying layer. To a first approximation, seismic velocity exerts the strongest control on seismic impedance and reflection coefficients in surficial materials.

## 8.2 Seismic reflection - general notes

Seismic reflection survey methods involve placing vertical component microphones (geophones) with centre frequencies in the order of 10 Hz to 100 Hz in the ground and recording the arrivals of seismic waves after applying a shock to the ground using an energy source. For placer work, energy sources consist of small explosive charges at surface, 12 gauge shotgun slugs, rifle bullets, dropped weights or sledge hammer blows. The geophones are uniformly spaced at from 2 to 5 m apart depending upon the resolution required and are strung in-line down the seismic survey line. A trigger is connected from the energy source or its initiator back to the seismograph to start the seismograph when the energy is released. The trigger can be a switch which is momentarily opened and closed (hammer switch), a pulse from a blasting box or the simple breaking of a circuit if a wire is wrapped around explosives. The seismograph records the vertical vibrations at each geophone from the instant at which the recording is triggered at the source for a period of time (record length) ranging from 0.5 seconds to several seconds.

Figure SRL-2 illustrates the distribution of seismic energy in the earth from a surface shot together with the pattern of recorded energy in a simplified shot record. The shot energy creates three different seismic waves which travel at different speeds along different paths. As a consequence, they arrive at different times in the shot records creating a characteristic pattern which can be exploited in subsequent data processing to yield subsurface information. Near the shot, the direct wave (DW in Figure SRL-2(a)) travels horizontally beneath the receiver array at a low velocity. On the seismic shot record (Figure SRL-2(b)), it forms a straight line with a slope which is the inverse of the velocity of the near surface material. At the cross-over distance from the shot, the first energy to arrive is refracted along the first higher velocity layer beneath the surface (R1). The inverse slope of this line is the velocity of this underlying layer. This *refracted arrival* may in turn be supplanted by refractions from

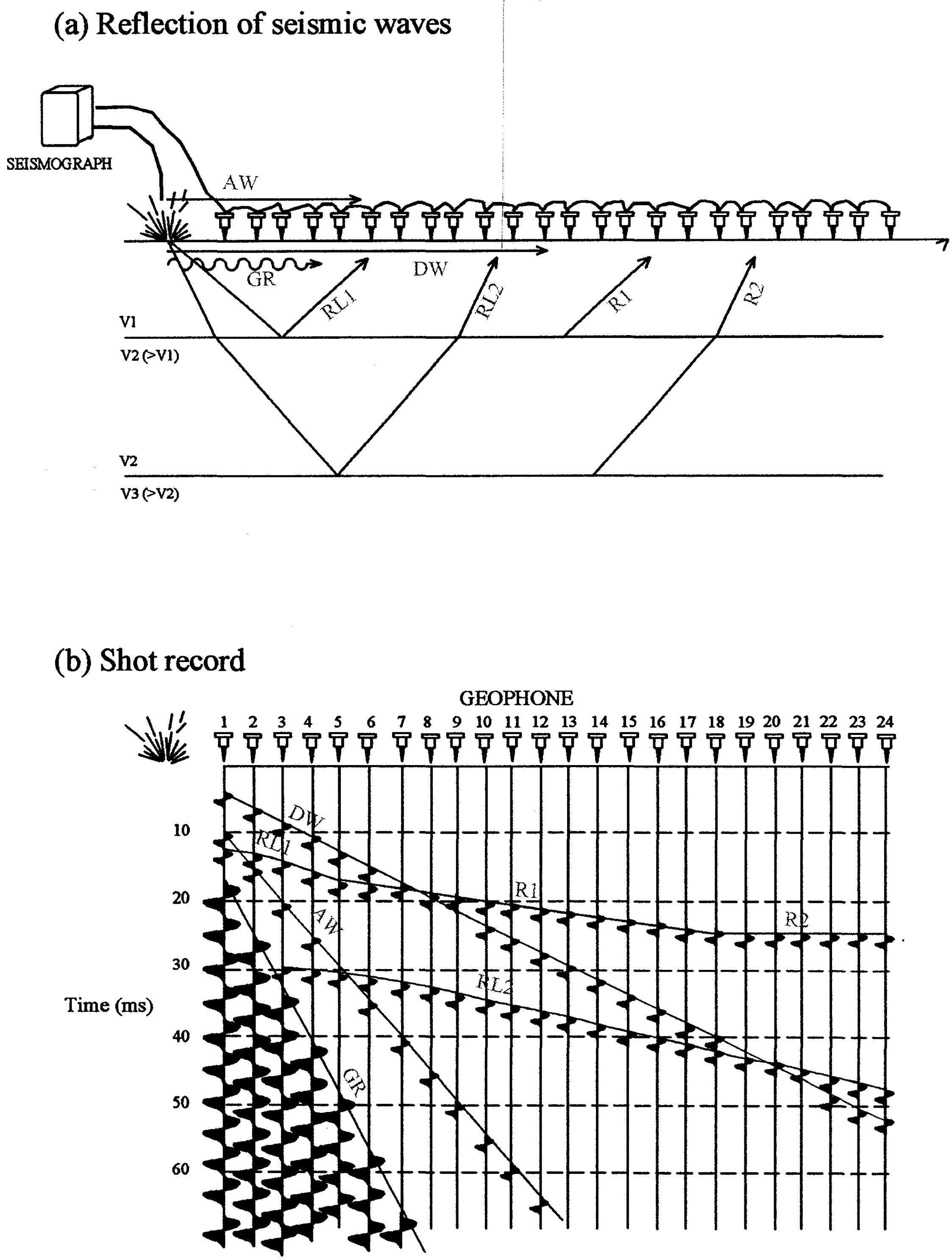



Figure SRL-2. Seismic reflection method.

deeper, faster layers at greater distances from the shot point (eg. R2). The direct wave and, at greater offsets, the refracted arrivals, are collectively termed *first arrivals* - the first seismic energy to be received from the shot at the geophones.

Following the first arrivals are one or more reflections from underlying layers ( in this case - two reflections from two layer boundaries (RL1 & RL2)). This energy is of variable intensity and forms a hyperbolic pattern in the shot record (*normal move out* or *NMO)*. Reflections can be discriminated from other seismic events using this property. At large offsets reflections die out and are supplanted by refractions; for example reflection RL1 is observed near the shot but at greater distances, the energy reaching the first reflector returns as refraction R1.

The third type of energy present in the section is the *air wave* and associated *ground roll* - low velocity surface waves traveling essentially parallel to the direct wave. Both waves travel at essentially the same speed. The airwave has a high frequency and travels at 330 m/s away from the shot. Ground roll has a much lower frequency, a long wave train (ie. is persistent) and, in shallow reflection surveys, tends to swamp the weaker high frequency reflection energy arriving after the passage of the ground roll.

Seismic reflection acquisition and processing is designed to enhance the reflected energy while suppressing or eliminating the first arrivals and the ground roll. This can be achieved by recognizing that the three different types of energy appear at different locations in a shot record and that they have different frequency spectra. Surgical muting (cutting away sections of a shot record dominated by ground roll or refractions) and band-pass filtering (allowing only high frequency reflections to remain in a shot record) are two examples of processing procedures designed to exploit these characteristics.

## 8.3 Common mid-point method

The common mid-point (CMP) method (also termed the common depth point or CDP method) was developed in the early 1960's as a method of enhancing reflections by suppressing coherent noise using the normal moveout of the reflected arrivals. The essence of the method is displayed in Figure SRL-3. Four 7-channel shot records are shown in Figure SRL-3(a). The highlighted traces have one feature in common: They all reflect at a common mid-point labeled P.

In Figure SRL-3(b), the four traces which reflected at point P (traces a through d) are shown in a CMP or CDP *gather* consisting of all traces in the seismic data set which reflected at the same common midpoint. This point is commonly indexed with a CDP bin number during data processing and any references to a station in a stacked (ie. final) seismic section refer to the CDP bin number. Only reflections in a CDP gather have normal moveout; all other events follow different curves. A unique property of a CDP gather is that the moveout is not asymmetric even if the reflecting horizon is dipping - unlike a shot record. The fact that reflections always exhibit NMO can be exploited if an accurate velocity versus travel time function is defined.

In Figure SRL-3(b)(2), the normal moveout has been removed from the CDP gather by performing a NMO correction using an accurate velocity function. The reflection from point P is now a horizontal arrival while the direct wave and any other events are transformed into curved arrivals. In Figure SRL-3(b)(3), all the traces in the gather have been added together (CDP *stack*) and the gather is replaced by a single trace. The reflections add constructively and are enhanced while other arrivals tend to cancel one another or, at least, not add constructively. The constructive addition of NMO corrected reflections and suppression of other arrivals results in a dramatic improvement in the reflection signal to noise ratio. The signal to noise ratio will improve by $n^{1/2}$ where n is the number of traces in the CMP gather. The nominal number of traces in a CMP or CDP gather is termed the fold of coverage. The fold of coverage is also expressed as a percentage of single fold (n=1) coverage. Thus, in a seismic section with a nominal 12 traces in each CDP / CMP gather, the fold of coverage would be 12 or 1200%.

In conventional oil field seismic surveys, CMP acquisition is performed using seismic cables which can be interconnected and which are capable of transmitting data from a large number of channels on adjacent interconnected cables. For example, a seismic cable may have 6 take-outs (connectors) but be capable of handling an additional 114 channels of data from adjacent cables. If the junction between two such cables in a string is broken, the seismograph could record signals from 120 channels in either direction from the break. Commonly, multichannel cables are connected to the seismograph via a *roll along switch* which takes multi-channel cable data as input and which outputs a user-selected subset of these available channels to the seismograph for a given shot record. For example, a seismograph capable of recording 120 channels may be connected to a roll along switch which takes 120 channels from each of two sides. If the data is being recorded using a split spread (shot in the centre of the receiving array), such a configuration would permit the recording of 120 - 120 channel records before the seismograph would have to be moved. This method of acquiring CMP seismic data is very efficient but requires a large number of heavy multi-channel cables and additional hardware to conduct the survey.

Small shallow seismic survey programs rarely justify the expense of using multichannel cables to acquire CMP data. Fortunately, there is an alternative method of acquiring CMP data using conventional engineering seismographs and non-interconnected refraction cables. The acquisition method is described in Figure SRL-4. An array of 12 phones is set up in a fixed position and the seismic source is moved along the line, firing shots at the prescribed source interval (every other station in this case). The subsurface coverage obtained from each shot along this single receiver array set-up is shown in Figure SRL-4(a). The fold of coverage increases to a maximum in the centre of the array and decreases to 1 at either end. The maximum fold possible using this array occurs when shots are fired at every receiver and this maximum is equal to the number of receivers in the array. A plot of maximum fold versus CDP bin number for the array in this single setup is a triangular region.

Upon completion, the receiver array is moved up by half its length to overlap the previous section and the same shooting pattern is repeated. For example, a 12 channel receiver array would be moved from the origin at Station 101 up one half the array length to Station 107: Phones 1 to 6 will now cover a section of the line shot during the preceding setup while Phones 7 to 12 will be in new locations at Station 113 to 118. The fold plot for this setup will also be a triangular region but half of it will overlap with the triangular region covered by the array in the previous move. During the CDP stacking, traces in the same CDP bin collected in each of the two arrays will be combined. The sum of the overlapping triangular fold coverage patterns in the final CDP coverage plot is a trapezoidal region with constant nominal maximum fold in the centre of the line and two zones of reduced coverage tapering to single fold coverage at the ends of the line (Figure SRL-4(b)).

This method is most efficiently performed with 3 double-ended refraction cables, each equal to half the available seismograph channels and with 150% of the required geophones. With this equipment, some of the crew can be setting up the next spread as the remainder of the crew is firing the preceding spread. The only inherent inefficiency in this method is that the source is required to fire 2 to 3 times as often as would be required in a conventional CMP survey achieving the same coverage. The advantages are the economies in time and cost achieved by avoiding the cost and delays associated with handling numerous cumbersome CMP cables.

### 8.4 Static corrections.

Seismic reflections can be seriously distorted by arrival time variations originating within a layer of very low velocity immediately beneath receiver and shot stations. For shallow reflection surveys, the low velocity layer (LVL) is the uppermost region in the earth where seismic velocities are near the speed of sound (330 m/s). The velocity of the layer immediately beneath the LVL (the replacement velocity) is often twice the LVL velocity. Both the LVL and replacement velocities may vary significantly along a seismic line. Variations in arrival time caused by seismic waves passing through variable thicknesses of very low velocity material tend to shift adjacent shot record seismic traces up or down section. This makes it difficult to recognize seismic events on a shot record, degrades the accuracy of velocity analyses upon which proper CDP corrections depend, and degrades the effectiveness of data processing algorithms. In extreme cases, they can introduce artifacts into the final stacked section which resemble legitimate reflections.

Static corrections to remove distortion originating in the LVL are applied by (1) mapping the thickness of the LVL using refraction analysis of selected shot records and (2) removing the effect of the LVL by subtracting the time delay resulting from the seismic waves passing through the LVL.

The thickness of the LVL may be derived from delay time refraction analysis based on interpretation of the first break times. The first break is the first coherent deflection on a seismic trace attributable to the source. Shots at the start, end and mid-point of each receiver array setup (ie. each setup as shown in Figure SRL-4 (a)) are used in this analysis, together with the geometric coordinates of the station

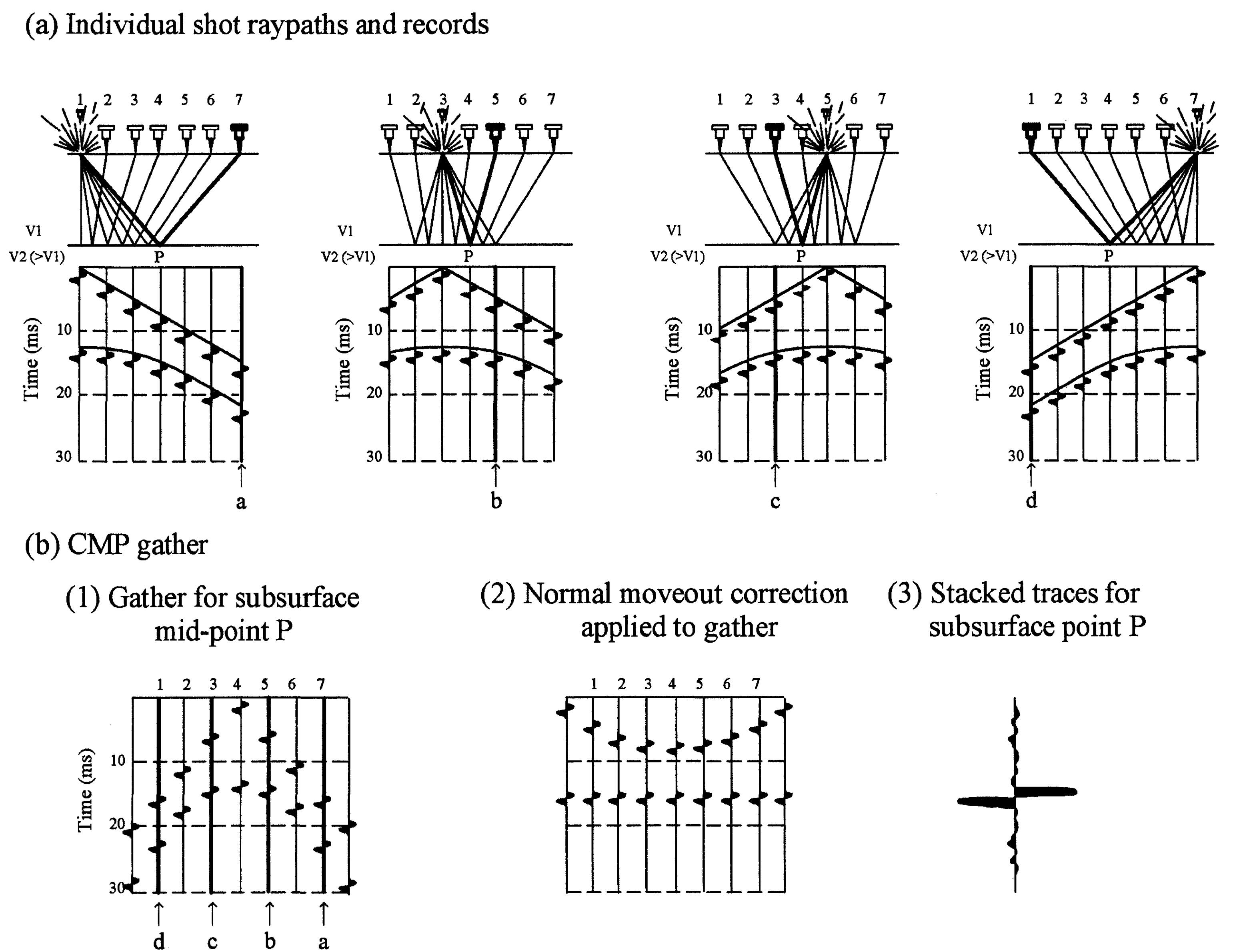



Figure SRL-3. Common mid-point method

locations. The refraction interpretation is focused on mapping the irregular boundary between the LVL (the first layer in the model) and the underlying higher velocity layer. First break arrival times are plotted in T-X plots and assigned to either the LVL or to underlying layers based on slope of the travel time curves. The section of each travel time curve nearest the shot with a uniform slope and velocity less than 800 m/s is assigned to the LVL and all arrivals at greater distances from the shot point are assigned to the underlying layers. The thickness of the LVL can then be calculated using delay time refraction interpretation methods.

The static correction involves calculating the vertical travel time from the shot or receiver to the base of the LVL twice: First using the LVL velocity followed by a second calculation using the replacement velocity (the higher velocity of the underlying material). The difference between the two travel times is the static correction - the extra time required to traverse the LVL because the low velocity material is present. The shot static correction is the correction associated with the vertical section of LVL beneath the shot while the receiver static correction is the correction associated with the vertical section of the LVL beneath the receiver. The total static correction is the sum of the shot and receiver static corrections. After static corrections, all time to depth conversions are performed using the replacement layer velocity or using velocities derived from semblance analysis; the LVL and its effects have been effectively removed from the model.

### 8.5 Data processing

This section describes in simplified form the data processing procedures applied to seismic data to derive the final depth section. A comprehensive description of seismic reflection data processing may be found in Yilmaz (1987). All data described in this report was processed using the SIS Vista (Version 7.0) package. This software was designed for processing oilfield 2D seismic reflection data. Refraction statics analysis was performed with Rimrock Geophysics SIP Version 4.0 software. This package incorporates a delay time method to perform seismic refraction analysis (Scott 1973).

The seismic data processing procedures applied to each section vary somewhat, reflecting the different source parameters, ground conditions and geology found in the survey area. This section describes the general features, parameters and common outcomes of the data processing steps normally employed in shallow seismic reflection data processing. Detailed descriptions of the data processing parameters applied to each line are discussed in the subsequent section. The following description follows the flow chart outlined in Figure SRL-5.

*1. Topographic survey data processing.* The topographic survey data is first processed to yield the inline and offset horizontal coordinates and elevation of each shot and receiver station. Horizontal coordinates are calculated in metres from the start of the line and offset, left (-) or right (+), of the nominal centre line. Elevations are reduced to metres above mean sea level. Station designations for seismic data processing follow the protocol outlined in Section 6. The first station on the line is numbered 101 and receiver / shot stations increment up from this number.

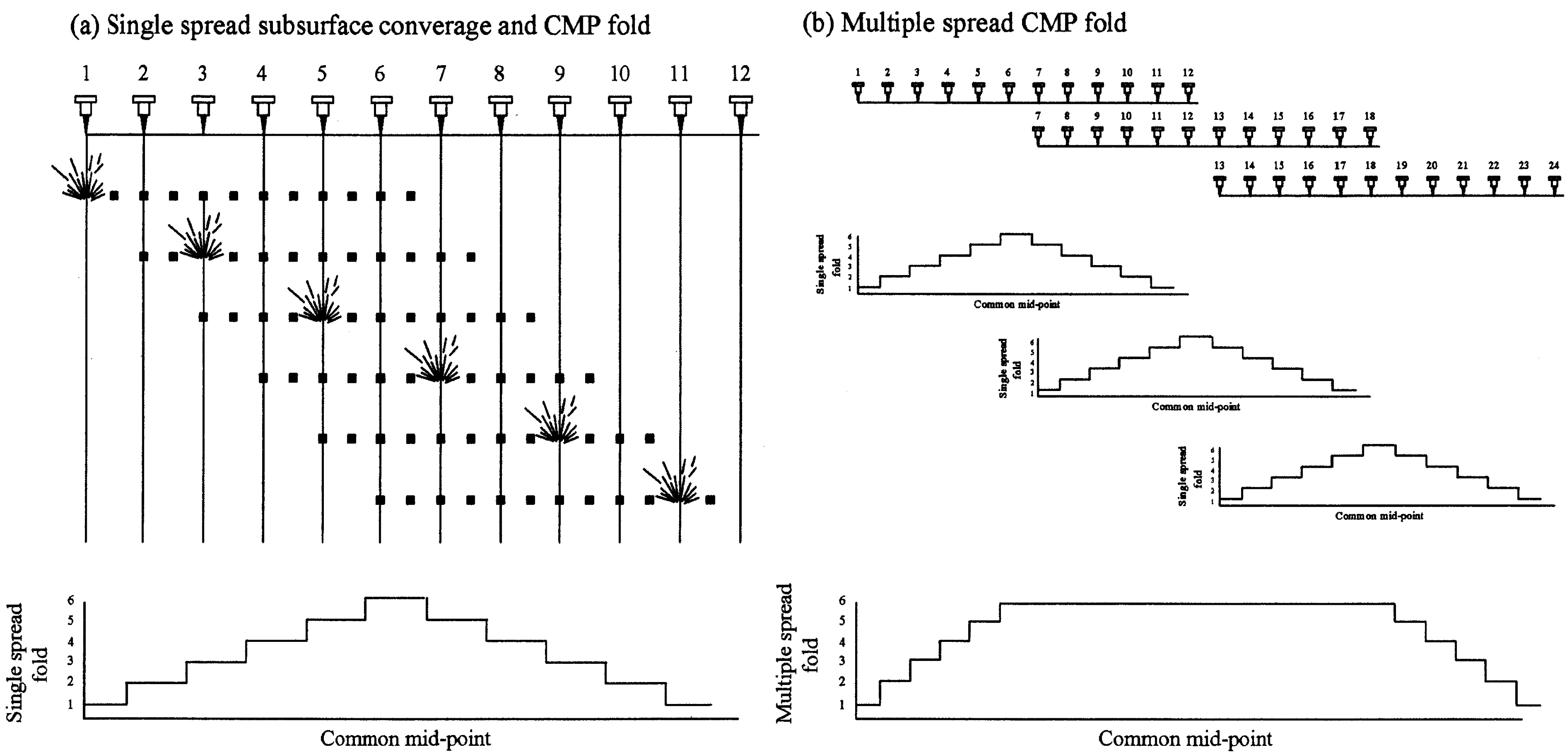



Figure SRL-4. Modified CMP survey procedure

*2. Refraction analysis to determine thickness of LVL.* Refraction analysis involves the extraction of 3 shots per spread setup - the two end shots and one shot in the middle of the spread. The first breaks on these shots are then timed and entered into the interpretation package together with the phone and shot geometries (horizontal coordinates and elevations). The first breaks are then plotted in a T-X diagram showing shot location on the x-axis and first break time on the vertical axis. The steep straight line portion of the T-X curve nearest the shot is the direct wave through the LVL. Each first break is assigned to a layer from which it is interpreted to originate. For the purposes of static corrections, only the uppermost boundary between the first and second layer is of interest; nonetheless, refraction interpretation will involve a model with as many layers as seem present in the data set to avoid distortion in the upper layer boundary. After layers are assigned, forward modeling is performed to determine the layer boundary depths and, critically, to observe the scatter of depth points used to map each layer boundary. Some arrivals may have to be re-assigned and some first breaks omitted from the refraction analysis to ensure that a plausible solution with minimum depth point scatter is achieved. This is an iterative process requiring repeated examination and editing of the layer assignments and geophone data. When an acceptable final model has been achieved, the elevation of the base of the LVL, together with the LVL velocity and the velocity of the underlying layer (replacement velocity). This information is then formatted for input to the headers of the shot record files for use in subsequent static corrections.

*3. Data import.* The field data is collected in SEG2 format and must be transformed to SEGY format for processing. Files are batch converted to SEGY floating point format and final records (depth sections & stacked sections) are in this format as well.

*4. Trace kills.* Some recording channels are dead because of wiring faults or dead phones. Other channels contain highly distorted data, resulting from poor clip connections or ground conditions. Each shot recorded must be edited and traces which are obviously dead or highly distorted killed (removed from the shot record).

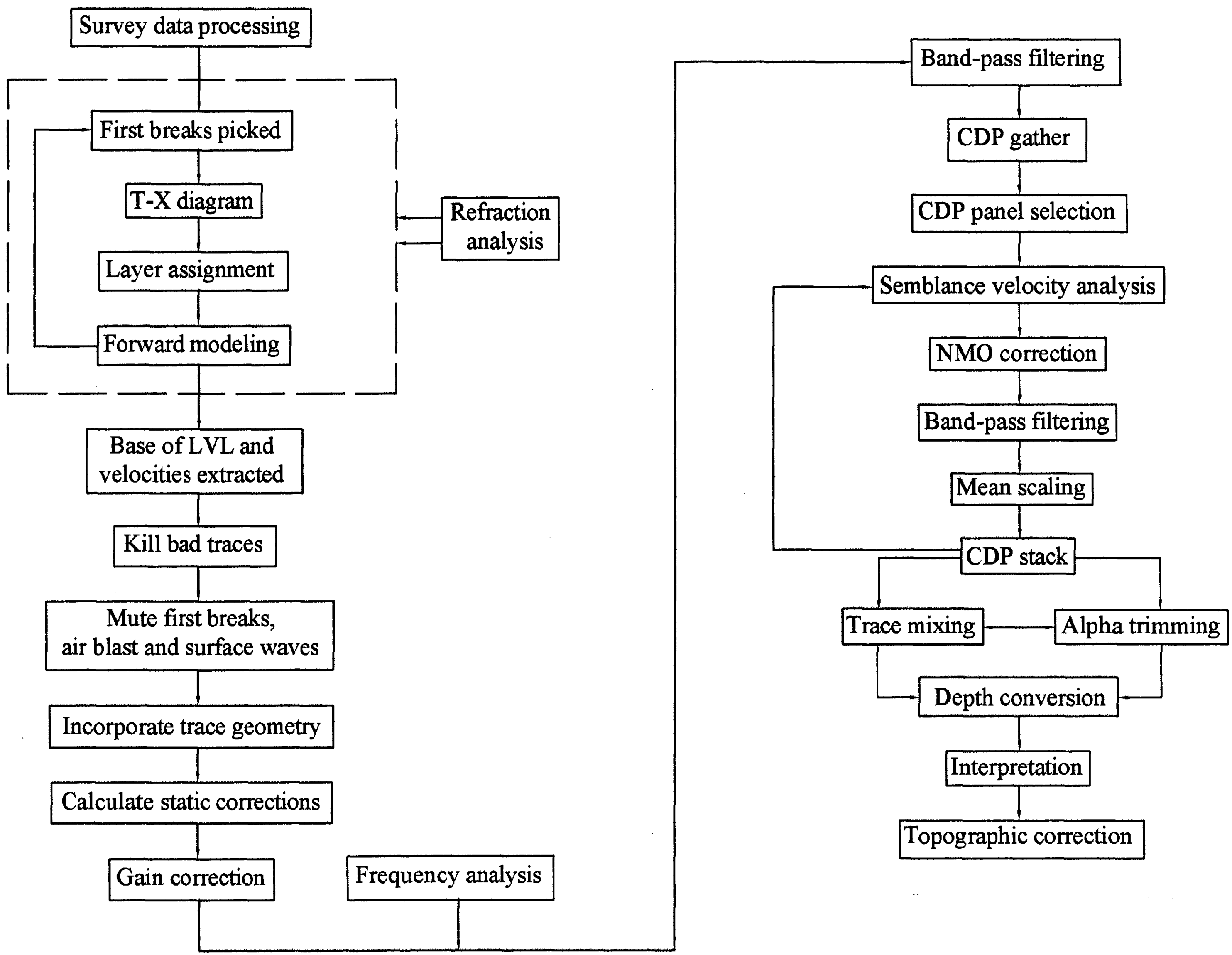



Figure SRL-5. Typical data processing flow-chart

5. *Surgical muting.* Surgical muting involves the removal of portions of a shot record dominated by unwanted noise. First arrivals (direct wave and refractions) can stack into the final sections as either a flat single reflection or as a complex series of dipping (shingled) reflections which on the whole form a flat event in the stacked section. Consequently, these events are normally removed during surgical muting. The air blast from the source and the surface waves which immediately follow are another source of noise. The air blast is a high frequency event with an apparent horizontal velocity of 330 m/s while surface waves are much lower frequency and have even lower apparent horizontal velocities. In a shot record, they form a cone

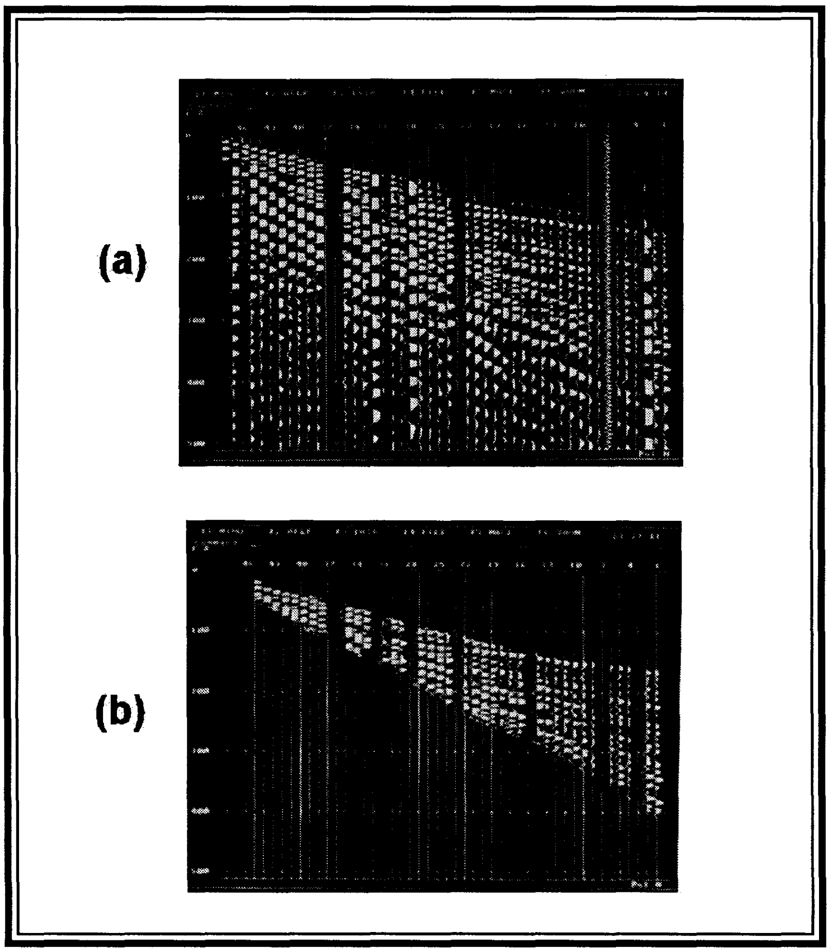



Figure SRL-6 Kills & surgical mutes. (a) Raw shot record. (b) Dead traces in raw shot record have been killed and the first arrivals and noise cone (airwave & ground roll) have been surgically muted. Reflections and some guided waves remain.

extending away from the shot location at an apparent horizontal velocity of 330 m/s or thereabouts. This region is also removed during the surgical muting. Surgical muting and trace kills are very time consuming as they were performed on each shot record prior to subsequent data processing.

6. *Trace combination.* All shot records are amalgamated into a single data file (data

stack) for subsequent data processing. The files are added in a strict order based on ascending receiver array spread number and ascending station number.

7. *Incorporation of trace geometry.* The geometry of the seismic array consisting of the shots and receivers is critical in performing all subsequent data processing. In particular the shot to geophone offset is necessary to remove the effect of normal moveout. The three dimensional location, thickness of the low velocity layer (LVL) and the velocities of the LVL and underlying layer must be also be known for each station to remove static effects. These parameters are entered into a spread sheet, converted to an ASCII input file format and assigned to trace headers for each trace in each shot record.

8. *Static corrections.* Conventional bulk static corrections are applied using the elevation of the LVL and velocities derived from the refraction analysis using the method described in the previous section. The information required to perform this correction is assigned to each trace in the previous data processing step.

9. *Frequency analysis.* Prior to conducting any filtering, the frequency spectrum of the data is examined. The amplitude spectrum of each trace is calculated by Fourier analysis and the amplitude spectrum (amplitude versus frequency graph) of selected traces is inspected to determine the peak frequency response and the upper frequency limit. This is typically performed on every 500$^{th}$ trace in the data set.

10. *Spherical and exponential gain correction.* Seismic energy per unit area of wave-front decreases as $1/r^2$ where r is the distance from the shot to the receiver point. A second source of attenuation are losses through non-elastic displacements and heat generation in the medium through which the wave is traveling. A correction factor for the combined losses (inverse of the amplitude function ) is:

$$C = \frac{4\pi r^2}{e^{-\alpha r}} \qquad (7)$$

where $\alpha$ is the attenuation constant of the medium and r is the distance from the source to the receiver. Since r is unknown, it can only be estimated using the layer velocity (replacement velocity) and the travel time. The only quantity that is specified for this correction is the attenuation constant (8.0 is an average value).

11. *Band-pass filtering.* A Butterworth filter is applied to the data prior to CDP sorting to enhance the reflection signal strength. This consists of a trapezoidal pass region defined by:

a. Low frequency truncation - all frequencies below this frequency are completely attenuated.

b. Low frequency cut - frequencies between the low cut and low truncation are passed with attenuation inversely proportional to the frequency above the truncation.

c. Pass region - Frequencies higher than the low cut and lower than the high cut are passed without attenuation.

d. High frequency cut - frequencies between the high cut and the high truncation are passed with attenuation proportional to the frequency above the high cut.

e. High frequency truncation - all frequencies above the high truncation are completely attenuated.

Frequency filtering parameters in the rest of this report are listed as follows: Low truncation / low cut / high cut / high truncation (eg. 30 / 60 / 200 / 300). In general, a a larger taper (greater frequency range) is used on the high end of the filter than on the low end to avoid ringing in the filtered sections.

*12. CDP sorting.* The seismic traces are sorted into CDP bins ordered in ascending CDP number. The traces in each bin / gather have a common mid-point between the shot and receiver and consequently contain data from numerous shots. The nominal number of traces in each gather is the nominal CDP fold at that station, per the stacking chart.

*13. CDP panel selection.* The CDP sorted data stack is next examined to identify 5 to 15 representative, high quality gathers equally distributed along the survey line. These gathers were then individually copied from the CDP sorted data stack to separate smaller gather files for subsequent velocity analysis.

*14. Semblance velocity analysis.* A full description of semblance analysis is beyond the scope of this report but an excellent description is contained in Yilmaz (1987). Semblance plots are created by applying a normal moveout correction using a trial velocity to each time sample in a trace and stacking the traces in the gather. If the correct velocity has been chosen for a given event, it will stack constructively, creating a high amplitude sample. This process is repeated for all trial stacking velocities in a specified velocity interval and the results are plotted in a semblance plot. This plot shows travel time in the vertical dimension and velocity in the horizontal dimension. Within this space, the contoured semblance values (stacked trace sample values) are contoured. High amplitude regions in the semblance plot indicate possible stacking velocities. The semblance plot is supplemented by a display of the original CDP gather together with a NMO hyperbola which indicates the arrival time pattern in the time section for a corresponding velocity / travel time point in the semblance plot. The interpreter interactively selects best fit normal moveout velocities for different time intervals by comparing the fit of the hyperbola to the arrival time pattern, with due reference to the corresponding semblance plot.

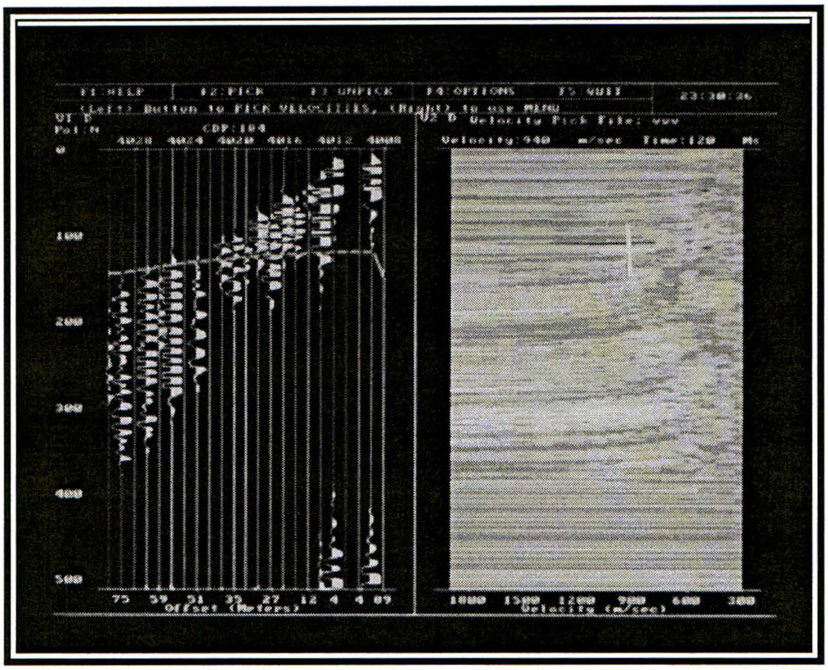


Figure SRL-7. Interactive CDP stack velocity picking using semblance analysis (right side) and NMO hyperbola (left side)

The final result of the semblance analysis for a single gather is a vertical velocity profile showing NMO stacking velocity as a function of arrival time. This result is written to a velocity file. When velocity analysis for all CDP gathers is complete, the velocity file defines a velocity function which is dependent upon CDP bin number and arrival time. This velocity function is then used in the subsequent NMO correction.

*15. NMO correction.* The normal moveout correction consists of removing the normal moveout associated with each trace using the velocity function described in the previous section and the offset distance between the shot and receiver recorded in the trace header during step 7.

*16. Band-pass filtering.* The normal moveout correction tends to stretch the traces at large offsets, introducing low frequency components into the signal. This effect is partially mitigated by an NMO mute which blanks out sections of traces which have been stretched by more than 17%. Band-pass filtering using a Butterworth (Trapezoidal) filter and the same frequencies as were used in the initial filtering is often performed after NMO correction to mitigate the effect of NMO stretch.

*17. Mean scaling.* Amplitudes of adjacent traces may vary considerably due to ground conditions or distance from the shot. Prior to stacking, traces are balanced using mean scaling. Each sample is normalized by the mean amplitude of each trace within a window specified by the interpreter and then scaled to a nominal peak amplitude value. The principal effect of this is to boost the amplitude of reflections from distant shots in the data stack. The window selected normally is restricted to the region containing the reflections in the surgically muted data stack.

*18. F-k filtering.* In some instances, NMO corrected data stacks contained steeply dipping arrivals which stack into the final section, producing noise or in some cases, coherent arrivals. These events can be attenuated in the data stack by F-k filtering (Yilmaz, 1987). Rejection regions are normally defined by specifying small polygonal regions with large (negative or positive) wave numbers (k). The define the steeply dipping events in the seismic record. In rare instances, pie-shaped rejection regions originating at the origin are defined to reject specific dipping events. Rejection regions are usually kept small and are tapered into the surrounding F-k domain to avoid generating ringing effects or dipping artifacts in the filtered data. F-k filtering is rarely used and only as a last resort in filtering the data prior to stacking.

*19. CDP stack.* CDP gathers (traces with common depth points) are summed together to produce a single trace at each CDP bin (station location). This has the effect of enhancing the horizontal reflections in the NMO corrected CDP gathers at the expense of all other events. The single summed CDP traces are then assembled in the stacked section (*brute stack*).

*20. RMS scaling.* Each sample in the brute stack was normalized by the root-mean-square (RMS) value of all samples in its corresponding trace and then scaled to a nominal peak amplitude value specified by the interpreter. The effect of this scaling is to boost the amplitude of regions with low trace amplitudes. This scaling was performed using the whole trace and thus was not effective in balancing trace amplitudes for sections where patchy sections had low amplitudes.

*21. Trace mixing.* Trace mixing and / or alpha-trimming was applied to the brute stack after RMS scaling. Trace mixing involves replacing each sample by a weighted average of samples from adjacent traces. The net effect is to suppress dipping arrivals or isolated events in the brute stack. This filter is commonly applied by mixing 5 traces together with the centre weighted as 40, the adjacent traces as 20 and the end traces as 10.

*22. Alpha trimming.* Alpha trimming is similar to trace mixing except that filter can be adjusted to (1) replace the centre trace by the mean of all traces in the filter, (2) replace the centre trace by the mode of all traces in the filter or (3) replace the centre trace by an average of some subset of all traces in the filter, rejecting values which are higher or lower than the values closer to the mean. The net effect of this filter is very similar to trace mixing but tends to accentuate horizontal arrivals at the expense of dipping arrivals.

*23. Band-pass filtering.* Additional band-pass filtering may be performed using the same parameters described in the previous two applications to accentuate events with the same frequency spectra as the reflections in the raw data.

*24. Depth conversion.* The time section is transformed to a depth section using the velocity-time function defined in the prior semblance analysis.

*25. Interpretation.* Significant reflections are identified in the depth sections and highlighted in the interpretation sections. To facilitate comparison, the interpretation sections are plotted with the depth sections in the final plots.

*26. Topographic correction.* The depth sections show the depths of reflection events - not their elevations. To display the true elevation of significant reflections in the interpreted time sections, these events are digitized, corrected for topography and plotted in profile format showing the elevation of surface topography, the base of the LVL and reflections of interest.

Portions of the data processing were commonly performed in iterative loops. In particular, velocity analysis had to be checked and revised repeatedly to improve the quality of the brute stack.

# 9.0 RESULTS

The final depth sections are in Appendix E. Each plot shows the raw depth section and the interpreted depth section beneath to facilitate comparison. The depth sections show horizontal distance from the origin in metres along the x-axis and depth in metres along the vertical axis. Appendix F contains elevation profiles showing the cross sections of the topography, the base of the LVL and all reflections. The vertical axis in these profiles is elevation in metres above mean sea level. All references to line coordinates in this and subsequent sections are expressed in distances east or south from the origins in the depth sections or elevation sections. The digital archive (CD-ROM) contains station topography, final depth sections(SEGY format), digital images of the final depth and interpretation sections (JPEG format), and elevation profiles (AutoCAD .DWG format).

The remainder of this section describes the results of the seismic survey by line including a description of the data, processing parameters, final sections and interpretation.

## 9.1 Base line

*Acquisition*

The base line was surveyed on September 9-11, 2003 and the survey covered 763 m of the base line from Station 726 to 1109. The line was surveyed from south to north and the survey was hampered by intermittent light rain which produced noise on some shot records. Three to 8 channels were dead on most spreads and these have been killed in the data processing. The Digipulse source was used for all shots on the base line. From Station 726 to 940 (0 to 426 m in the depth section), the nominal fold of coverage was only 12-fold while from Station 941 to 1109 (427 to 763 m in the depth section), nominal 24-fold coverage was maintained. The fold of coverage was reduced to permit the crew to finish the base line in the time available.

*Data processing*

Data processing on the base line consisted of the following steps and procedures:

1. *Topographic data processing.* Some complications were encountered here because the line was chained and topographically surveyed from north to south but was shot from south to north. Base line coordinates commence at Station 101 (at the north end of the line / 0 m S) and end at Station 1109 (at the south end / 2016 m S).

2. *Refraction processing to determine the LVL.* The data set was split into two parts for processing because of the spread limitation in the refraction interpretation software. The northern section included Stations 726 to 917 ( 0 to 382 m S in the depth section). LVL velocities in this area ranged from 250 m/s to 620 m/s and averaged 457 m/s. The underlying replacement (Layer 2) velocity ranged from 555 to 752 m/s and averaged 631 m/s. Average LVL and replacement velocity values were used in the LVL depth determinations. The southern section of the line included Stations 727 to 1109 (384 to 763 m S in the depth section). LVL velocities in this section ranged from 309 m/s to 694 m/s and averaged 458 m/s. The underlying replacement (Layer 2) velocity ranged from 588 to 1197 m/s and averaged 783 m/s. The average LVL velocity and constrained replacement velocities determined for each spread (650 to 1080 m/s) were used in the LVL depth determinations.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination*. Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL and both LVL and replacement velocities.

8. *Statics.* Correction performed using LVL elevation and layer velocities determined from seismic refraction processing.

9. *Frequency analysis.* Dominant frequency from 50 to 100 Hz, depending upon quality of record. Low frequency rumble (< 50 Hz). Most high frequency signal is instrument noise.

10. *Band-pass filtering.* 30 Hz / 50 Hz / 200 Hz / 300 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 9 gathers were extracted

for analysis.

*14. Semblance analysis.*

*15. NMO.* Results of semblance analysis used as the initial velocity model. Results were not satisfactory and a simplified model using the replacement velocities from the refraction results was used.

*16. Band-pass filtering.* 30 Hz / 60 Hz / 200 Hz / 300 Hz

*17. CDP stack.*

*18. RMS Scaling.* Full trace to nominal amplitude 100.

*19. Alpha trim.* 5 traces using average of 3 middle traces.

*20. Band-pass filtering.* 30 Hz / 50 Hz / 200 Hz / 300 Hz

*21. Time to depth conversion.* Performed using same velocity model as was used for the NMO correction.

*22. Interpretation.* Identification of key reflections followed by digitizing.

*23. Depth section preparation.*

*Interpretation*

Moderate amplitude, flat to shallow dipping reflections are abundant in the depth section. The reflection shown in green at a depth of about 50 m runs the length of the seismic section, has a relatively strong amplitude and truncates other reflections. These properties suggest that this may be the bedrock reflection.

The topography of the reflector shown in green is similar to that expected of bedrock in the survey area. In the Duncan Creek flood plain, bedrock exposures and excavations indicate that the bedrock surface dips gently downstream. North of the survey area, drilling beneath the western plateau near the edge of the flood basin (Figure 4) also indicates that the bedrock surface does not rise significantly west of Duncan Creek, at least near the edge of the plateau. Consequently, the flat dip of the interpreted bedrock reflector agrees with the available geological information.

The depth of the interpreted bedrock reflection is also consistent with the available geological information. Bedrock was exposed in recent mine workings at an elevation of 694 m, 140 m east of the base line and 100 m south of the intersection between the base line and Line 03-4. The elevation of the bedrock reflection on the base line 100 m south of the intersection with Line 03-4 is approximately 695 m. This observation supports the interpretation that the reflector identified in green in the base line depth section is the bedrock reflection.

In the overburden section, the reflection pattern suggests that up to three units are present. Immediately overlying the bedrock reflection is a continuous layer running the length of the base line. This unit is approximately 20 m thick, contains strong flat (?bedded) reflections on the south and north ends and has an upper boundary which truncates internal reflections. The unit is notably thicker near 300 S and thins considerably near 400 S at the northern edge of the overlying unit. This basal unit is interpreted to be Unit 2 pay gravel based on its stratigraphic position. On the southern and northern ends of the base line, the basal unit is apparently overlain by a 10 to 25 m thick unit characterized by fewer internal reflections and irregular upper and lower boundaries. Near 400 S, this unit appears to be fill overlying an eroded section of the basal unit. This middle unit is interpreted to be either a separate gravel layer in Unit 2 Pay Gravel or to be overlapping Unit 3 Middle Sand. The uppermost unit is a zone of strong, flat lying high frequency reflections interpreted to belong to Unit 4 Middle Silt. The boundary between this unit and any overlying coarse gravels may be visible near 500 S but in general the top of this unit is not visible.

### 9.2 Line 03-1

*Acquisition*

Line 03-1 was surveyed on September 3 - 4, 2003 and the survey covered 470 m (Stations 101 to 340; 0 to 480 m W in the sections). The survey was hampered by showers on September 3. From 3 to 8 channels were dead on most spreads and these have been killed in the data processing. The sledge hammer was used as the energy source in the interval from 0 to 210 m W and the Digipulse source was used for all shots thereafter on the flat terrain to the west. Nominal 24-fold coverage was maintained on all the line except for the interval between 48 -112 W where the fold was reduced to 12. Data quality was poor on the steep slopes in the eastern portion of the line where the sledge hammer was required.

*Data processing*

Data processing on Line 03-1 consisted of the following steps and procedures:

1. *Topographic data processing.*

2. *Refraction processing to determine the LVL.* LVL velocities ranged from 263 m/s to 420 m/s, averaging 328 m/s. The underlying replacement (Layer 2) velocity ranged from 613 to 2114 m/s and averaged 1040 m/s. The average values were used in the depth calculations for all spreads.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination.* Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL and both LVL and replacement velocities.

8. *Statics.* Bulk statics performed using LVL elevation and layer velocities determined from seismic refraction processing.

9. *Frequency analysis.* Dominant frequency was around 100 Hz on the west end of the line and closer to 50 Hz on the eastern end of the line. Most high frequency signal is instrument noise.

10. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 9 gathers were extracted for analysis.

14. *Semblance analysis.*

15. *NMO.* Results of semblance analysis used as the initial velocity model. Results were not satisfactory, largely because of noise in the eastern portion of the line. The average of all semblance analysis velocities - 1360 m/s - was used in the NMO correction for the final run.

16. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

17. *CDP stack.*

18. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

19. *Trace mix* 5 traces using weights (first to last sample) of 10 / 20 / 50 / 20 /10 respectively.

20. *Mean amplitude trace scaling.* Samples were normalized by the mean amplitude of each trace in the window from 80 to 200 ms and scaled to a nominal amplitude of 100.

21. *Trace mix* 3 traces using weights (first to last sample) of 10 / 30 /10 respectively

22. *RMS scaling.* Samples were normalized by the RMS amplitude for the

entire trace and scaled to a nominal maximum amplitude of 100.

23. *Time to depth conversion.* Performed using same velocity model as was used for the NMO correction.

24. *Interpretation.* Identification of key reflections followed by digitizing.

25. *Depth section preparation.*

*Interpretation*

Line 03-1 commenced beside Duncan Creek at a location where bedrock is known to be very shallow from nearby excavation work. Steep topography occurs between 30 W and 200 W as the line heads up the west side of the modern Duncan Creek valley and the line intersects the base line at 284 W on Line 03-1 and at 601 S on the base line. The interpreted depth to bedrock on the base line at the intersection point with Line 03-1 is about 56 m.

The reflection identified in green is interpreted to be the top of bedrock in the depth section. This reflection is strongest near 250 W and at the west end of the survey line. It is too shallow to see clearly at the east end of the survey line and was lost or severely attenuated in processing. The bedrock reflection in the depth section inversely reflects the surface topography. In the elevation section, bedrock dips to the west and is overlain by a very thick succession of overburden. The bedrock reflection at the intersection point with the base line is at a depth of 48 m. Errors in the velocity models could account for this discrepancy.

West of 160 W in the depth section, a seismic unit characterized by strong dipping internal reflections overlies the bedrock reflection. The top of this unit is irregular and locally steeply dipping. This unit is interpreted to be Pay Gravel (Unit 2). The overlying material is interpreted to be Unit 4 Middle Silt.

### 9.3 Line 03-2

*Acquisition*

Line 03-2 was surveyed on September 1-2, 2003 and the survey covered 466 m (Stations 101 to 340; 0 to 480 m W). The survey was hampered by very heavy rain on September 2 and by intermittent showers September 3; some records contain significant rain noise. From 3 to 8 channels were dead on most spreads and these have been killed in the data processing. The sledge hammer was used as the energy source in the interval from Station 101 to 166 (0 to 132 W) and the Digipulse source was used for all shots thereafter on the flat terrain to the west. Nominal 24-fold coverage was maintained on the lengths of the line, except for the end of line tapers. Data quality was poor on the steep slopes in the eastern portion of the line where the sledge hammer was required and where rain hampered the survey most significantly.

## Data processing

Data processing on Line 03-2 consisted of the following steps and procedures:

1. *Topographic data processing.*

2. *Refraction processing to determine the LVL.* LVL velocities ranged from 219 to 338 m/s, averaging 303 m/s. The underlying replacement (Layer 2) velocity ranged from 628 to 808 m/s and averaged 724 m/s. The LVL velocity was constrained to 350 m/s and 724 m/s was used as the replacement velocity in the refraction analysis and in subsequent static corrections.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination.* Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL and both LVL and replacement velocities.

8. *Statics.* Bulk statics performed using LVL elevation and velocities determined from seismic refraction processing.

9. *Frequency analysis.* The centre frequency of the reflection response was approximately 75 Hz for most of the line.

10. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 11 gathers were extracted for analysis.

14. *Semblance analysis.*

15. *NMO.* Results of semblance analysis used as the initial velocity model. Results were not satisfactory because of noise in the eastern portion of the line. The average of all semblance analysis velocities in three windows ( 0 - 65 ms: 1128 m/s / 65-130 ms: 1275 m/s / 130+ ms: 1200 m/s) was used in the NMO correction for the final run.

16. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

17. *CDP stack.*

18. *F-k filtering.* F-k filtering performed to remove steeply dipping noise in the section.

19. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

20. *Trace mix* 5 traces using weights (first to last sample) of 10 / 20 / 40 / 20 /10 respectively.

21. *Mean amplitude trace scaling.* Samples were normalized by the mean amplitude of each trace in the window from 30 to 150 ms and scaled to a nominal amplitude of 100.

22. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

23. *Time to depth conversion.* Performed using the NMO correction velocity model.

24. *Interpretation.* Identification of key reflections followed by digitizing.

25. *Depth section preparation.*

*Interpretation*

Line 03-2 is the southernmost line surveyed and commenced on the mine access road immediately west of Duncan Creek. Bedrock is presumed to be shallow at this location but there are no nearby bedrock exposures, drill holes or excavations to confirm this. Steep topography occurs from 20 m W to 105 m W as the line heads up the west side of the modern Duncan Creek valley. Line 03-2 intersects the base line at 292 m W; on the base line, Line 03-3 crosses at 751 m S.

The reflection identified in green is interpreted to be the top of bedrock in the depth section. This reflection is strongest and most apparent on the eastern end of the line between 0 W and 140 W. Bedrock is undulating between 0 to150 m W and rises steadily to the west at a gentle slope thereafter. On the base line, the interpreted bedrock reflection is lost at the intersection with Line 03-2 and the nearest strong bedrock reflection, 30 m to the north, is at a depth of 55 m. At the same point on Line 03-1, the depth to the interpreted bedrock reflector is 61 m.

A number of prominent reflections occur above the bedrock reflection. In aggregate, they appear to divide the overburden stratigraphy into two units. The lowermost unit is characterized by strong hummocky reflections which locally truncate each other. This unit is interpreted to be Unit 2 Pay Gravel and it appears to thicken dramatically in the eastern portion of the line. There appears to be a discrete unit within the interpreted Pay Gravel from 20 to 180 W which may be a separate gravel accumulation. It is defined by a steeply west dipping boundary and by an attenuated eastern boundary. The centre of this unit is roughly at the eastern edge of the plateau west of Duncan Creek (120 m W). The seismic sequence overlying the interpreted Unit 2 Pay Gravel is interpreted to be Unit 3 Middle Silt.

### 9.4 Line 03-3

*Acquisition*

Line 03-3 was surveyed on September 5-6, 2003 and the survey covered 372 m (Stations 101 to 292; 0 to 384 m W). From 3 to 8 channels were dead on most spreads and these have been killed in the data processing. The sledge hammer was used as the energy source in the interval from Station 101 to 143 (0 to 86 W) and the Digipulse source was used for all shots thereafter on the flat terrain to the west. Nominal 24-fold coverage was maintained along the line, except for the end of line tapers. Data quality was poor on the steep slope (0-86 m W) where the sledge hammer was required.

*Data processing*

Data processing on Line 03-3 consisted of the following steps and procedures:

1. *Topographic data processing.*

2. *Refraction processing to determine the LVL.* LVL velocities ranged from 273 to 386 m/s, averaging 329 m/s. The underlying replacement (Layer 2) velocity ranged from 619 to 1006 m/s and averaged 753 m/s. Average LVL and replacement velocities were used in the refraction analysis and in subsequent static corrections. Patches of high velocity attributed to permafrost were noted on the steep slopes of the hill at the eastern end of the line; these high velocity intervals were ignored in the determination of the LVL as they did not appear to be very thick.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination.* Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL, LVL velocity and replacement velocity.

8. *Statics.* Bulk statics performed using LVL elevation and velocities determined from seismic refraction processing.

9. *Frequency analysis.* The centre frequency of the reflection response was approximately 75 to 100 Hz for most of the line.

10. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 9 gathers were extracted for analysis.

14. *Semblance analysis.*

15. *NMO.* Results of semblance analysis used as the initial velocity model. Results were not satisfactory because of noise in the eastern portion of the line. A single average CDP velocity was used in the NMO correction for the final run.

16. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

17. *CDP stack.*

18. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

19. *Trace mix* 5 traces using weights (first to last sample) of 10 / 20 / 60 / 20 /10 respectively.

20. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

21. *Time to depth conversion.* Performed using the same velocity model used in the NMO correction.

24. *Interpretation.* Identification of key reflections followed by digitizing.

25. *Depth section preparation.*

## *Interpretation*

Line 03-3 commences on the mine access road, approximately one third the way up the steep western slope bordering the modern Duncan Creek drainage. The steepest topography is from the eastern end of the line to approximately 75 W in which interval the elevation changes by 30 m. Line 03-3 intersects the base line at 179 W. The base line intersects Line 03-3 at 453 S.

The reflection identified in green is interpreted to be the top of bedrock in the depth section. This reflection is strongest and most apparent from 190 W to 260 W where the reflection flattens. The bedrock reflection on Line 03-3 at the intersection point with the base line occurs at a depth of 58 m. On the base line, the interpreted depth to bedrock at the intersection with Line 03-3 is 50 m. The discrepancy between the interpreted bedrock reflection depths may reflect errors in the velocity model for this line or may be caused by a shift in reflection point, not compensated for in the non-migrated depth sections. The interpreted bedrock reflection is rising at the intersection point and it is therefore possible that the bedrock reflection on the base line is not located directly beneath the intersection point. The bedrock reflection inversely reflects the surface topography in the area where the ground rises from the valley bottom to the edge of the western plateau but continues to dip to the west after the topography has flattened over the plateau. West of 140 m W, bedrock appears to be flat.

The pattern of reflections in the overlying overburden are chaotic. A weak, generally continuous reflection at a depth of about 25 m appears from 60 W until the western end of the line. There are prominent east dipping reflections on the eastern end of this reflection which appear to mark the eastern boundary of the unit. This unit is interpreted to be Unit 2 Pay Gravel, the eastern edge of which is roughly coincident with the edge of the western plateau.. The thickest Unit 2 accumulation would appear to be near the intersection with the base line at 190W where, coincidently , bedrock is deepest. This point appears to mark the location of a possible paleochannel defined by bedrock scour and a thick accumulation of gravel. The overlying material is assumed to be Unit 4 Middle Silt.

## 9.5 Line 03-4

*Acquisition*

Line 03-4 was surveyed on September 7-8, 2003 and the survey covered 374 m (Stations 101 to 292; 0 to 384 m W). From 3 to 8 channels were dead on most spreads and these have been killed in the data processing. The sledge hammer was used as the energy source in the interval from Station 164 to 193 (128 to 186 W) and the Digipulse source was used for all other shots on the line. Nominal 24-fold coverage was maintained on the lengths of the line, except for the end of line tapers. Data quality was poor on the steep slope (128 to 186 m W) where the sledge hammer was required.

*Data processing*

Data processing on Line 03-4 consisted of the following steps and procedures:

1. *Topographic data processing.*

2. *Refraction processing to determine the LVL.* LVL velocities ranged from 250 to 460 m/s, averaging 362 m/s. The underlying replacement (Layer 2) velocity ranged from 572 to 1412 m/s and averaged 705 m/s. Average LVL and replacement velocities were used in the refraction analysis and in subsequent static corrections.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination.* Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL, LVL velocity and replacement velocity.

8. *Statics.* Bulk statics performed using LVL elevation and velocities determined from seismic refraction processing.

9. *Frequency analysis.* The centre frequency of the reflection response was between 50 and 100 Hz, and commonly about 60 Hz.

10. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 8 gathers were extracted for analysis.

14. *Semblance analysis.*

15. *NMO.* Results of semblance analysis used as the initial velocity model. Results were not satisfactory and an average CDP velocity profile was used for this correction.

16. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

17. *CDP stack.*

18. *Surgical mute.* That portion of the seismic section below the base of usable signal (about 200 ms) was surgically muted to suppress noise generated from the band-pass filtering.

19. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

20. *Alpha trim:* 5 traces used as input, centred on the filtered trace. The data sample was replaced by the median of the 5 filter samples at the same arrival time.

21. *Trace mix* 5 traces using weights (first to last sample) of 10 / 20 / 40 / 20 /10 respectively.

20. *RMS Scaling.* Samples were normalized by the RMS amplitude for the entire trace and scaled to a nominal maximum amplitude of 100.

23. *Additional spherical and exponential gain correction.* Implemented to boost deeper amplitudes; exponent 8.0 used.

24. *Mean amplitude trace scaling.* Samples were normalized by the mean amplitude of each trace in the window from 20 to 200 ms and scaled to a nominal amplitude of 100.

25. *Band-pass filtering.* 20 Hz / 60 Hz / 150 Hz / 280 Hz

26. *Time to depth conversion.* Performed using 700 m/s because of disagreement between stacking and replacement velocities; the latter was used.

27. *Interpretation.* Identification of key reflections followed by digitizing.

28. *Depth section preparation.*

<u>*Interpretation*</u>

Line 03-4 commences in a flat, stripped area within a few metres of Duncan Creek. From the origin to 130 W, the line rises gently (10 m) and then steepens dramatically from 130 W to 190 W, rising 28 m in this interval. The remainder of the line lies on the western plateau and topography is essentially flat. Line 03-4 intersects the base line at 213 W and the base line intersects L03-4 at 154 S.

The reflection identified in green is interpreted to be the top of bedrock in the depth section. This reflection is strongest and most apparent from 200 W to 340 W. On the whole, the bedrock reflection slopes gently to the east along the line. The deepest point appears to be very close to the base line intersection. At the intersection point between the base line and Line 03-4, the depth to bedrock along the base line is 52 m while along Line 03-3, the depth to bedrock is 54 m. The difference is negligible.

Reflections in the overburden section overlying the interpreted bedrock reflection are moderately strong and continuous. Two units are identified in the interpretation section. The lower unit, interpreted to be Unit 2 Pay Gravel is characterized by steeply dipping internal reflections which are truncated at the bedrock reflection and at the upper bounding reflection. The upper boundary is generally continuous, commences near 30 W and rising to the west end of the line. The unit thickens dramatically from 140 W until the western end of the line. Within the interpreted Unit 2 Pay Gravel is a lozenge-shaped zone from 160W to 290W located in a small bedrock depression.. This may be a separate gravel accumulation in a paleochannel defined by bedrock scour. Above the interpreted Unit 2 Pay Gravel, low amplitude reflections are interpreted to originate in Unit 4 Middle Silt.

## 9.6 Line 03-5

### *Acquisition*

Line 03-5 was surveyed on September 6 and 7, 2003 and the survey covered 325 m (Stations 101 to 268; 0 to 334 m W). From 3 to 8 channels were dead on most spreads and these have been killed in the data processing. The sledge hammer was used as the energy source from Station 101 to 174 (0 to 146 W) and the Digipulse source was used for all other shots on the line. Nominal 24-fold coverage was maintained on the lengths of the line, except for the end of line tapers. Data quality was poor on the steep slope (0 to 146 m W) and on selected shots elsewhere in the eastern portion of the line. This was caused by intermittent shot generated noise traced to an electrical grounding fault.

### *Data processing*

Data processing on Line 03-5 consisted of the following steps and procedures:

1. *Topographic data processing.*

2. *Refraction processing to determine the LVL.* LVL velocities ranged from 167 to 630 m/s, averaging 376 m/s. The underlying replacement (Layer 2) velocity ranged from 546 to 1272 m/s and averaged 833 m/s. Average LVL and replacement velocities were used in the refraction analysis and in subsequent static corrections.

3. *Data import*

4. *Trace kills* - typically 4 to 6 traces killed per shot record due to dead phones

5. *Surgical mutes*

6. *Trace combination.* Create data stack.

7. *Trace geometry.* Trace geometry incorporated survey geometry, elevations above mean sea level, elevation of LVL, LVL velocity and replacement velocity.

8. *Statics.* Bulk statics performed using LVL elevation and velocities determined from seismic refraction processing.

9. *Frequency analysis.* The centre frequency of the reflection response was between 50 and 100 Hz.

10. *Band-pass filtering.* 30 Hz / 60 Hz / 200 Hz / 300 Hz

11. *Spherical and exponential gain.* Exponent 8.0 used.

12. *CDP sort.*

13. *Extraction of CDP gathers for velocity analysis.* 6 gathers were extracted for analysis.

14. *Semblance analysis.*

15. *NMO.* Results of semblance analysis used for this correction.

16. *Band-pass filtering.* 30 Hz / 60 Hz / 180 Hz / 240 Hz

17. *CDP stack.*

18. *Alpha trim:* 5 trace input replacing centre trace with the median of the 5 traces.

19. *Trace mix* 5 traces using weights (first to last sample) of 10 - 20 - 50 - 20 -10 respectively.

26. *Time to depth conversion.* Performed using 1100 m/s (average of CDP velocities).

27. *Interpretation.* Identification of key reflections followed by digitizing.

28. *Depth section preparation.*

*Interpretation*

Line 03-5 commences on the west side of Duncan Creek immediately north of a small knob containing an abandoned cabin (Chambers Cabin). Bedrock outcrops near the creek below the cabin. From the origin of the line to 146 W, the line rises 45 m to the eastern edge of the western plateau. Thereafter, topography is flat until the western end of the line. Line 03-5 intersects the base line at 190 W and the base line intersects L03-5 at 37 S.

The reflection identified in green is interpreted to be the top of bedrock in the depth section. This reflection is strongest and most apparent from 50 m W to 100 m W. The bedrock reflection dips gently east. The bedrock reflection on Line 03-5 at the intersection point with the base line is at a depth of 52 m. On the base line, the interpreted depth to bedrock at the intersection with Line 03-5 is 54 m. At the intersection point between the base line and Line 03-5, the depth to bedrock along the base line is 52 m while along Line 03-3, the depth to bedrock is 58 m. On the whole, the depths to bedrock are anomalously deep and the interpreted bedrock elevations somewhat lower than would be anticipated in this area. This may indicate an error in the velocity model for this line.

Reflections in the overburden section overlying the interpreted bedrock reflection are discontinuous and chaotic. Several weak high frequency reflections are visible and these suggest that three units may be present in the overburden. The lowermost unit extending from 70 W until the end of the line appears has steeply dipping internal reflections which are truncated at the bedrock reflection and forms several hummock-shaped or lenticular subunits. This unit is interpreted to be Unit 2 Pay Gravel. Overlying this unit from 0 W to 270 W is a unit containing few and weaker reflections. This unit is interpreted to be the Unit 3 Middle Sand which was encountered in test pits near the line (Troy Taylor, 2003, *pers. comm.*). Overlapping both of these units is a third seismic unit interpreted to be Unit 4 Middle Silt.

## 10.0 DISCUSSION

The general quality of the seismic data was poor despite a very considerable acquisition effort. The essential problem is that there does not appear to be a strong impedance contrast between the overburden layers. This may be compounded by lateral variations in velocity along the seismic lines. Despite these limitations, coherent reflections were recorded which appear to relate to known stratigraphic units and they corroborate and extend the limited geological information in the survey area.

It appears that the top of bedrock is relatively flat in the survey area and that the area west of Duncan Creek is overlain by 50 to 60 m of overburden. The topography of the bedrock surface indicated by the seismic reflection survey agrees with the available geological information from drill holes and excavations. Bedrock depths and elevations in the Duncan Creek flood plain appear anomalously deep on Line 03-5 relative to depths and elevations on adjacent lines and relative to the elevation of bedrock in outcrop immediately south of the start of the line.

On all cross lines, the lowermost seismic unit is characterized by dipping internal reflections and is bounded on the east side by dipping reflections near the edge of the western plateau. This seismic unit, interpreted to be Unit 2 Pay Gravel, appears to underlie the entire western plateau. Further, the eastern edge of this unit appears to be nearly coincident with the edge of the plateau in all cases. Where Unit 2 Pay Gravel reflections appear east of the plateau edge, they are notably thinner and have flatter dips.

The seismic survey results and geological data suggest that the western plateau is an alluvial terrace underlain predominantly by Late Reid gravel and capped by sands and silts. The present flood plain may be a post-Late Reid event / pre-McConnell event. The elevation change between the flood basin and the plateau is defined primarily by the change in thickness of the Late Reid gravels. The overlying McConnell silts and sands appear to drape rather than fill the margins of the flood basin. Consequently, the present Duncan Creek flood basin in the survey area may have been created by a high energy erosional event prior to the McConnell glaciation. The silts and sands which overlie the Late Reid deposits may have been deposited in a lacustrine or lower energy fluvial environment, perhaps associated with ice-lobe damming of the Duncan Creek valley. This event would have raised the mean water level above the top of the alluvial terrace. In such an environment, sands and silts would tend to drape over valley floor depressions rather than fill them. This could account for the observed pattern of reflections in the overburden succession.

Unit 3 Middle Sand is known to be present on Line 03-5 in test excavations near the lower access road (around 120 W). Three reflection bounded layers are present in the Line 03-5 depth section; the middle layer in this succession has been interpreted to be Unit 3 Middle Sand. On the base line, there are two areas which appear to be overlain by three overburden units. At the south and north ends of the base line, two lenticular reflection bounded sequences characterized by lower amplitude internal reflections overlie the basal Unit 2. Both of these units pinch out in the centre of the base line depth section. The northernmost unit is interpreted to be Unit 3 Middle Sand based on the presence of this unit on Line 03-5. The southern lens has been assigned to Unit 2 Pay Gravels because three separate units are not readily apparent in any of the other seismic sections. If Unit 3 Middle Sand is present south of Line 03-5, it is likely thin and it is entirely possible that it has been grouped into the Unit 2 Pay Gravels.

The most prospective exploration target identified by the seismic survey is a lenticular body of gravel on Lines 03-3 to 03-5 characterized by steeply dipping internal reflections, by east and west dipping boundaries and by its location in a local bedrock depression near the base line. On Lines 03-3 and 03-4, this unit appears to be a separate sequence enclosed within the larger Unit 2. This sequence may be a gravel accumulation in a paleochannel preserved beneath McConnell sands and silts. Despite its depth, this unit is thick and occurs near the edge of the plateau in a setting which may permit open-pit mining.

## 11.0 CONCLUSIONS

The results of the seismic reflection survey conducted on the Duncan Creek Property support the following conclusions:

a. The top of bedrock is flat to very gently dipping throughout the area covered by the seismic survey.

b. The plateau west of Duncan Creek in the area of the Mayo Lake Road turnoff is covered by 50 to 60 m of overburden.

c. The overburden west of Duncan Creek appears to contain laterally varying thicknesses of inferred Late Reid pay gravels. The boundaries of these bodies can be steeply dipping. In general, these units appear to thicken west of the present drainage in Duncan Creek.

d. There appears to be a paleochannel beneath the seismic survey grid between Lines 03-3 and 03-5. The clearest evidence of this channel is on the seismic section from Line 03-4. A local bedrock depression on lines 03-3 and 03-4 appears to be centred just east of the cross cutting base line. Overlying this depression is a lenticular body, up to 20 m thick and bounded by steeply east and west dipping reflections. This body has a shape and position relative to the bedrock depression which suggests that it is a gravel accumulation.

## 12.0 RECOMMENDATIONS

The following recommendations are made based on the conclusions of this work:

a. The area between Lines 03-03 and Line 03-04 should be tested by drilling, preferably on Line 03-4 where the clearest reflections are recorded. The hole should be drilled at the intersection of Line 03-04 and the base line, should extend to bedrock and should be properly logged and sampled.

Respectfully submitted,
**AURORA GEOSCIENCES LTD.**

M.A. POWER
16 Jan 04
LICENSEE
N.W.T.

Michael A. Power, M.Sc. P.Geo.
Geophysicist

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# APPENDIX A. CERTIFICATE

I, Michael Allan Power, with residence and business address in Whitehorse, Yukon Territory do hereby certify that:

1. I hold a B.Sc. (Honours) in Geology granted in 1986 and M.Sc. in Geophysics granted in 1988, both from the University of Alberta.

2. I have been actively involved in mineral exploration in the northern Cordillera and in the Northwest Territories since 1988. I am a professional geoscientist registered with the Association of Professional Engineers and Geoscientists of British Columbia (Registration number 21131) and a professional geophysicist registered by the Northwest Territories and Nunavut Association of Professional Engineers, Geologists and Geophysicists (licensee L942).

3. I conducted the geophysical surveys described in this report, interpreted the data collected and prepared this report.

4. I have no interest, direct or indirect, nor do I hope to receive any interest, direct or indirect, in the property of Keystone Mining Ltd.

Dated this 20th day of January 2004 in Whitehorse, Yukon Territory.

Michael A. Power, M.Sc. P.Geo.
Geophysicist

# APPENDIX B. SURVEY LOG

# AURORA GEOSCIENCES LTD.

## SURVEY LOG
## JOB KML-03-001-YT
## KEYSTONE MINING LTD.
## DUNCAN CREEK SEISMIC SURVEY

Period: June 12th, 2003 - September 12th, 2003

Personnel:
Mike Power (MP) - Crew chief
Warran Kapaniuk (WK) - Line cutter / Source technician
Dave Hildes (DH) - Technician

### LINE CUTTING AND TOPOGRAPHIC SURVEY

Wed 12 June 03
Mobe to Duncan Creek. Running around in AM, left at 12PM and had to return for pickets and maps from Carmacks. Reached Duncan Creek about 8PM. Set up camp.

Thu 13 June 03
Started cutting base line. Wx: Sunny and warm
Production: 700 m

Fri 14 June 03
Finished base line, deviating along road. Wx: Sunny and warm.
Production: 1320 m

Sat 15 June 03
Cut Line 03-01 (528m) and started 03-02 (192 m). Run into Halfway Lakes Lodge in PM. Wx: showery and cloudy.
Production: 720 m

Sun 16 June 03
Cut Line 03-03 (528m) and worked on 03-02 (200) Wx: partly cloudy and warm.
Production: 720 m

Mon 17 June 03
Cut Line 03-04 (528 m) and finished 03-02 (176 m). Run into Mayo for survey gear: Bob Adair not there. Wx: warm and sunny.
Production: 705 m

Tue 18 June 03
Cut Line 03-05 (480 m) and picked up survey instrument in Mayo. Wx: sunny and hot, clouding over late in day.
Production: 480 m

| | |
|---|---|
| Wed 19 June 03 | Surveyed base line and started L03-01 to L03-03 on the steep east ends. Wx: cloudy with rain starting in afternoon. Production: 2.6 line-km. |
| Thu 20 June 03 | Completed survey of lines; surveyed pit and picked up drill holes. Wx: rain in early morning, cloudy and cool all day. Production: 2.5 line-km and pit. |
| Fri 21 June 03 | Demobe to Finlayson Lake (Job SJV-03-001YT). |

**REFLECTION SEISMIC SURVEY**

| | |
|---|---|
| Mon 01 Sep 03 | Left Whitehorse at 1100 hrs. Arrived Duncan Creek at 1700 hrs. Set up camp. |
| Tues 02 Sep 03 | Standby day. Set up line L03-02 and began work at east end. Very heavy rain. Survey suspended twice. Broke rubber band on Digipulse; put on spare. Broke trigger switch; rigged up geophone to act as trigger. Wx: very heavy rain showers with some breaks; drizzle. |
| Wed 03 Sep 03 | Survey day. Completed L03-02 and did one spread on L03-01. DH-Observer, WK – source, MP-jug. Wx: showers, cloudy, improving as the day went on. |
| Thurs 04 Sep 03 | Survey day. Completed L03-01. Worked 0830 hrs to 2130 hrs. Flat on quad fixed with puncture seal. Broke trigger again. Wx: partly cloudy, cooling off. |
| Fri 05 Sep 03 | Survey day. Surveyed on L03-03, completing 5 spreads including the hill. Wx: partly cloudy. Production: 5 spreads. |
| Sat 06 Sep 03 | Survey day. Completed 2 spreads on L03-03 across the road to finish. Moved to L03-05 and did the eastern (lower) section with the sledge hammer. Finished 4 spreads. Ordered food and gear from Holly; taken up by Kel in the evening. Wx: fair. Production: 6 spreads |
| Sun 07 Sep 03 | Survey day. Discovered that the wear on the hammer prevented us from using it. Took it down to the service truck and WK welded repairs. Began surveying L03-05 again but the records on the first spread were very noisy. Switched triggering mechanism from contact at plate (with grounding error) back to geophone. Progress was slower with this method. Completed 2 spreads on L03-05 and did one spread on L03-04 at east end on the mud flats. Wx: Drizzle and rain, breaking by mid-day and very heavy showers after dark. Production: 3 spreads. |
| Mon 08 Sep 03 | Survey day. Completed Line 03-4, tore down equipment and moved gear to the southern end of the base line. Wx: more rain. |
| Tue 09 Sep 03 | Survey day. Set up and surveyed the base line from 2016S to |

| | |
|---|---|
| | 1728S. Wx: partly cloudy, some late showers |
| Wed 10 Sep 03 | Survey day. Surveyed the base line from 1728S to 1250S to complete. Conducted a three spread walkaway at the northern end of the base line. Had dinner with the Taylors that evening. |
| Thu 11 Sep 03 | Demobe to Whitehorse. Tore down camp, packed up, left Duncan Creek at 1130 hrs. MP dropped off in Mayo for a visit to the Pike Property; remainder of crew drove to Whitehorse. |

**Summary:**

| | |
|---|---|
| Line cutting & topographic survey: | 5.1 line-km |
| Seismic reflection survey: | 2.8 line-km |

| | |
|---|---|
| Line cutting & topographic survey:: | 8.0 days |
| Seismic reflection survey: | 8.0 days |
| Seismic survey standby: | 1.0 days |

**Personnel:**

| | |
|---|---|
| Mike Power | 1 Bates Crescent<br>Whitehorse Yukon Y1A 5T8 |
| Warren Kapaniuk | 12 Cloverleaf Drive<br>Watson Lake, YT Y0B 1B0 |
| Dave Hildes | 25 Cloudberry Lane<br>Whitehorse, YT Y1A 1B0 |

# APPENDIX C. STATEMENT OF EXPENDITURES

| | |
|---|---|
| <u>Line cutting and topographic survey</u> | |
| Mobe / demobe | $1,855 |
| Line cutting: 6.0 days @ 870 (includes crew, camp, truck, ATV, groceries and incidental expenses) | $5,220 |
| Topographic survey: 2.0 days @ 870 | $1,740 |
| <u>Seismic reflection survey</u> | |
| Mobe / demobe | $3,100 |
| Survey: 8.0 days @ $1,940 (includes crew, seismic system & source, ATV, truck, camp, groceries & incidentals) | $15,520 |
| Standby: 1.0 days @ $1400 | $1,400 |
| <u>Data processing & report</u> | |
| Data processing: 192 hrs @ $35 | $6,720 |
| Report preparation & drafting | $2,100 |
| *Subtotal* | *$37,655* |
| *GST* | *$2,636* |
| ***Total charges*** | ***$40,291*** |

I certify that these expenses are correct to the best of my knowledge.

PROFESSIONAL GEOPHYSICIST
M. A. POWER
16 Jun 04
LICENSEE
N.W.T.

Michael A. Power, M.Sc., P.Geo., P.Geoph.
Geophysicist

# APPENDIX D. INSTRUMENT SPECIFICATIONS

GEOMETRICS

# StrataView RX Specifications

Home
What's New
About Us
Employment
Products
Downloads
Literature
Applications
Lease/Rentals
Contact Us
Links
Y2k

SmartSeis | StrataView RX | StrataVisor NZ | StrataVisor NX | Geode | McSEIS 3 | Seismic CD

Features | Specifications | Configurations



## R Series Specifications

| | |
|---|---|
| A/D Conversion: | 24 bit A/D process using 32 kHz over sampling, digital anti-alias and decimation to users selected sample rate |
| Dynamic Range: | 135 dB theoretical, 113 dB measured @ 2 ms, 3 to 150 Hz |
| Distortion: | 0.005% @ 2 ms, 3 to 150 Hz |
| Bandwidth: | 3.0 to 14 kHz, |
| Common Mode Rejection: | > -90 dB @ |
| Crosstalk: | -85 dB @ 24 Hz |
| Noise Floor: | 0.25 uV, RFI @ 2 ms, 3 to 150 Hz |
| Trigger Accuracy: | 1 microsecond |
| Maximum Input Signal: | 300 mV, P-P |
| Preamplifier Gains: | 36 dB, followed by 24 dB floating point amplifier |
| Anti-alias Filters: | Digital, automatically selected to correspond to sample rate. -3 dB corner frequency, down 80 dB at Nyquist, except -74 dB when sampling at 16 kHz and none at 32 kHz. |
| Sample Interval: | 0.032, 0.064, 0.128, 0.25, 0.5, 1.0, 2.0 ms |

| | |
|---|---|
| Record Lengths: | 24,000 samples per channel for 12 or 24 channels, 12,000 for 36 channels or more |
| Line Testing: | Real-time full wave form noise monitor. |
| Power Consumption: | 30 W plus 1.0 W per channel |
| Data Formats | SEG-2, SEG-Y, real-time to disk, off-line to tape. |

| | |
|---|---|
| Pretrigger Data: | Up to 4096 samples. |
| Stacker: | Full 32-bit |
| Acquisition and Display Filters: | Low cut: out, 10, 15, 25, 35, 50, 70, 100, 140, 200, 280, 400 Hz, 24 or 48 dB / Octave, Butterworth. Display filters do not affect data. |
| Correlator: | Hardware full precision correlator. Operates either before or after stack. |
| Automatic Gain Control: | Digital AGC with user adjustable window. Display only - does not affect raw data. |
| Number of channels: | 12 to 72 channels per 12V portable module. 12 to 132 channels per rack mount module (NX series only). Modules stackable to form systems up to 600 channels, controlled internally from one keypad or externally by a PC based computer (discuss detailed configurations with the Geometrics' sales department). |

# APPENDIX E. DEPTH SECTIONS

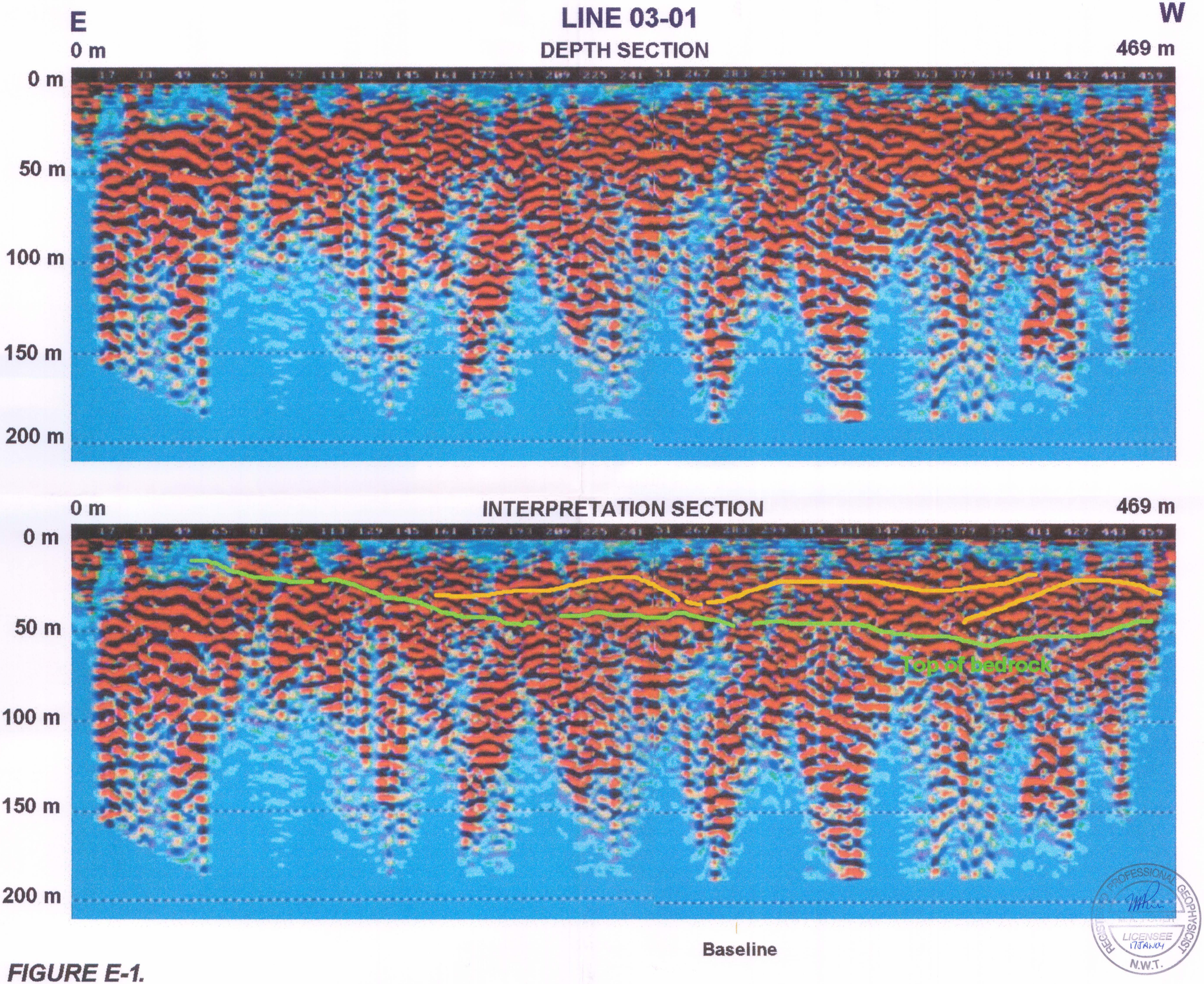
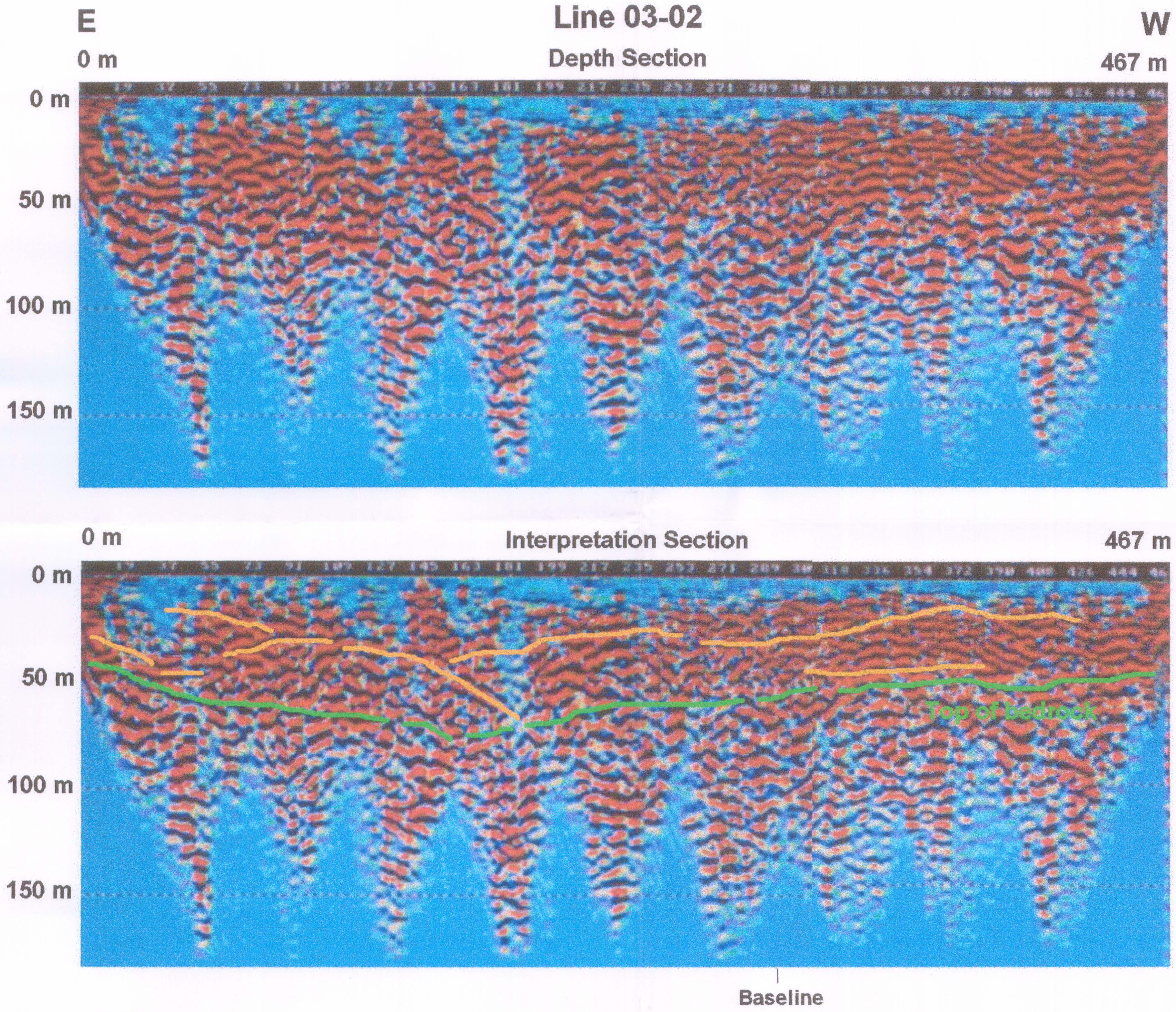

E
LINE 03-01
W
0 m
DEPTH SECTION
469 m
0 m
50 m
100 m
150 m
200 m
0 m
INTERPRETATION SECTION
469 m
0 m
50 m
100 m
150 m
200 m
Top of bedrock
Baseline

FIGURE E-1.

# Line 03-02



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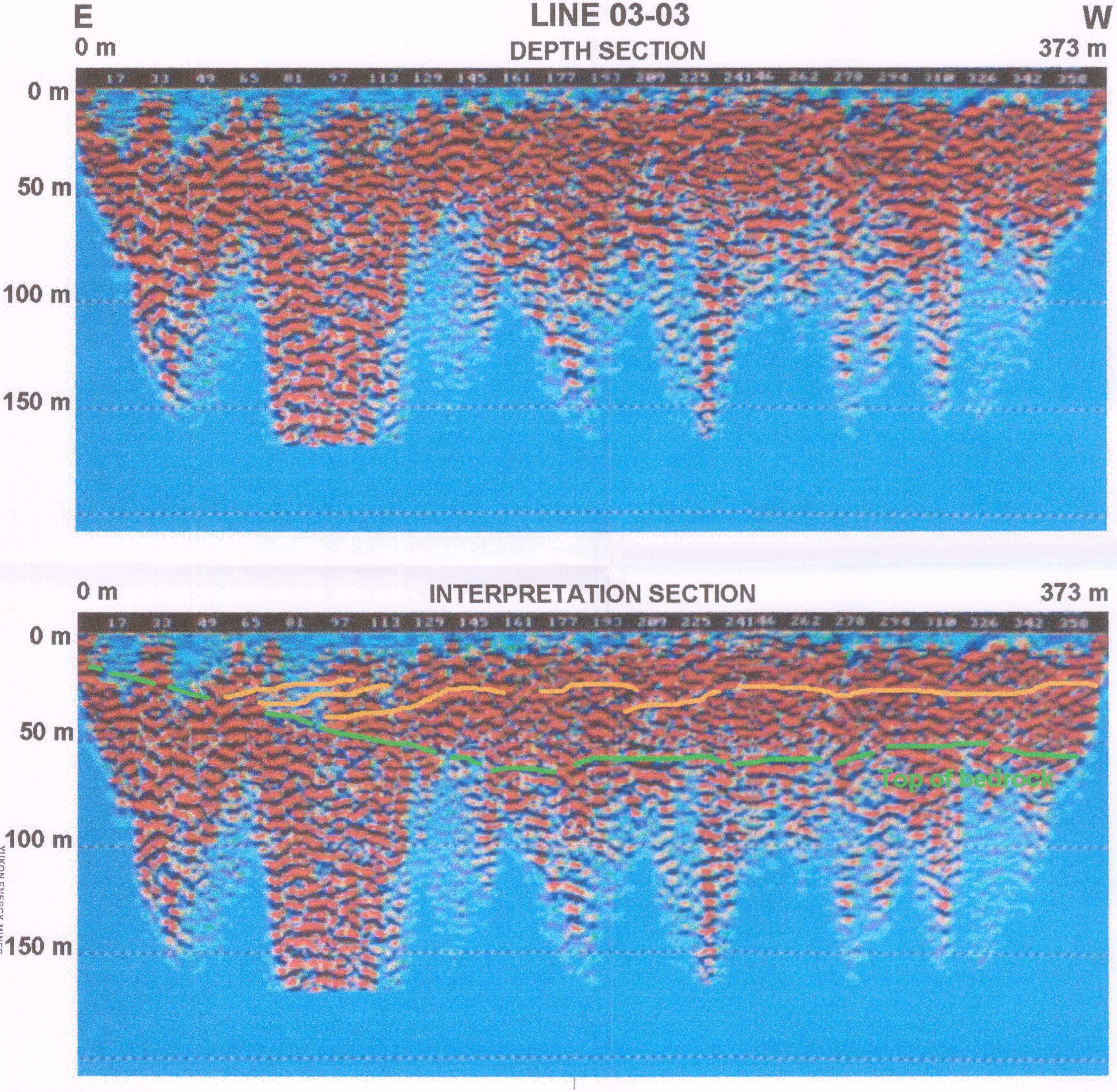
M.A. POWER
LICENSEE
17 Jan 04
N.W.T.

*FIGURE E-2.*




Baseline



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17 Jan04
N.W.T.

*FIGURE E-3.*

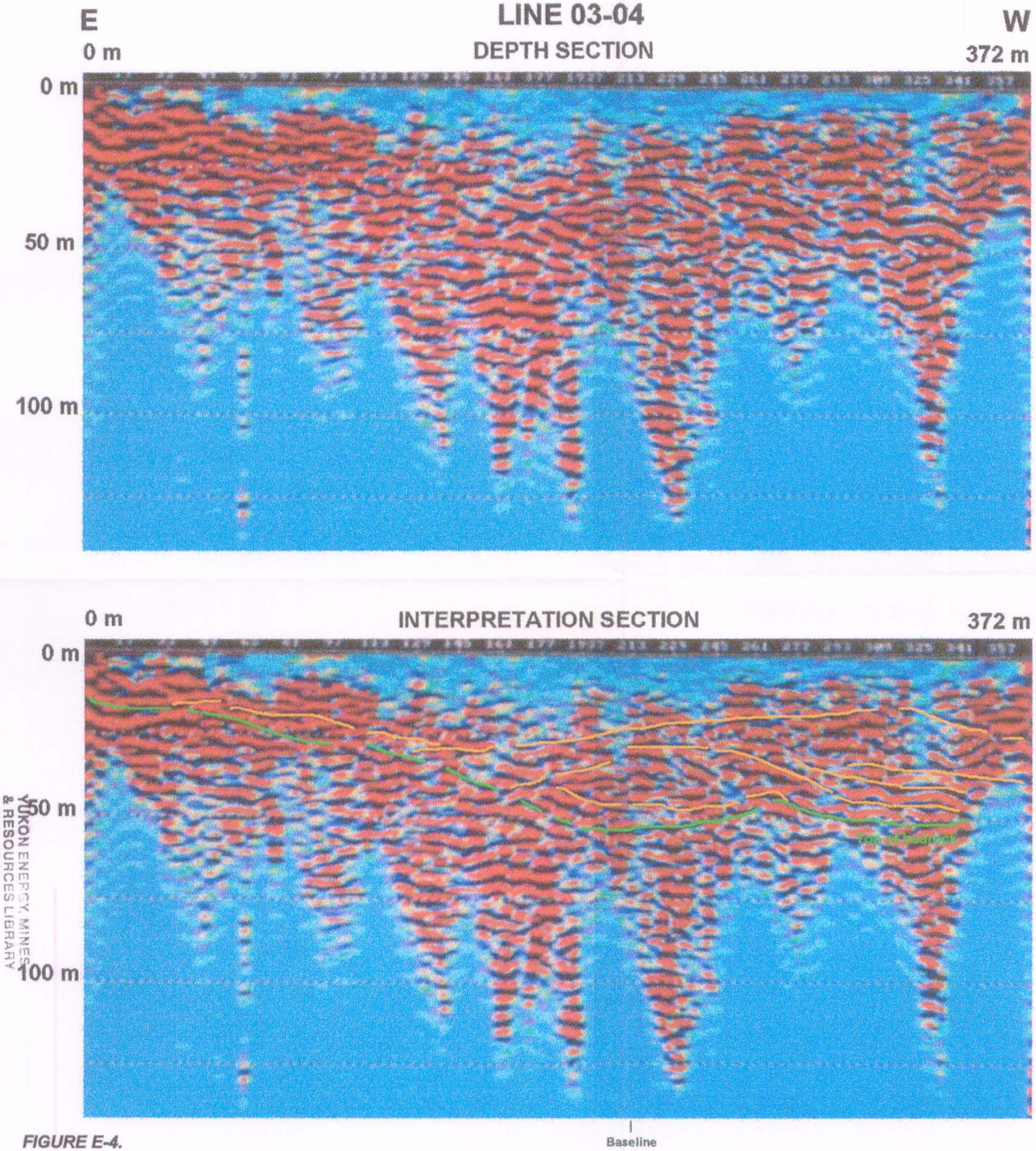

E
LINE 03-04
W
0 m
DEPTH SECTION
372 m
0 m
50 m
100 m
0 m
INTERPRETATION SECTION
372 m
0 m
50 m
100 m
Top of bedrock
Baseline

*FIGURE E-4.*

# LINE 03-05

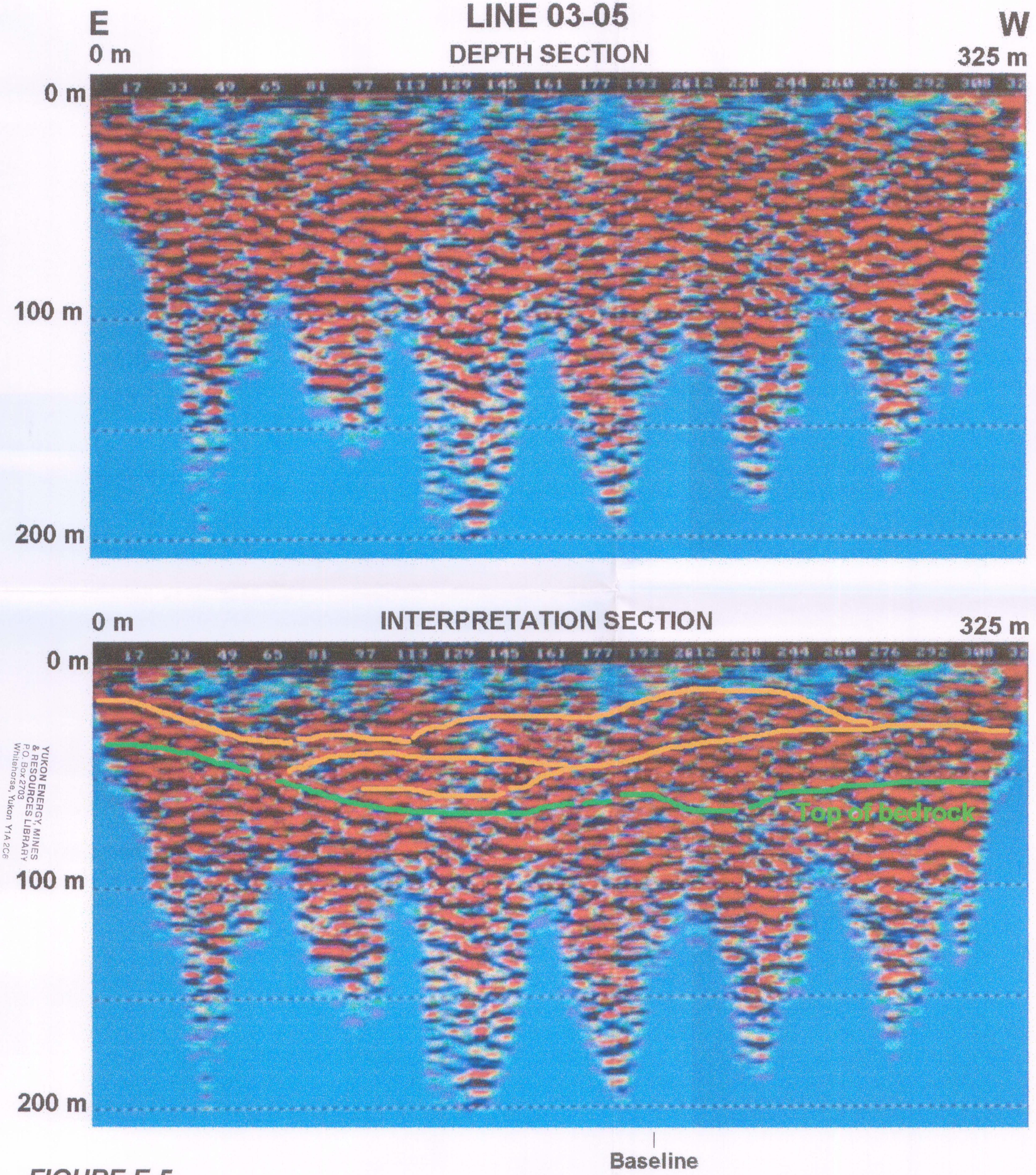
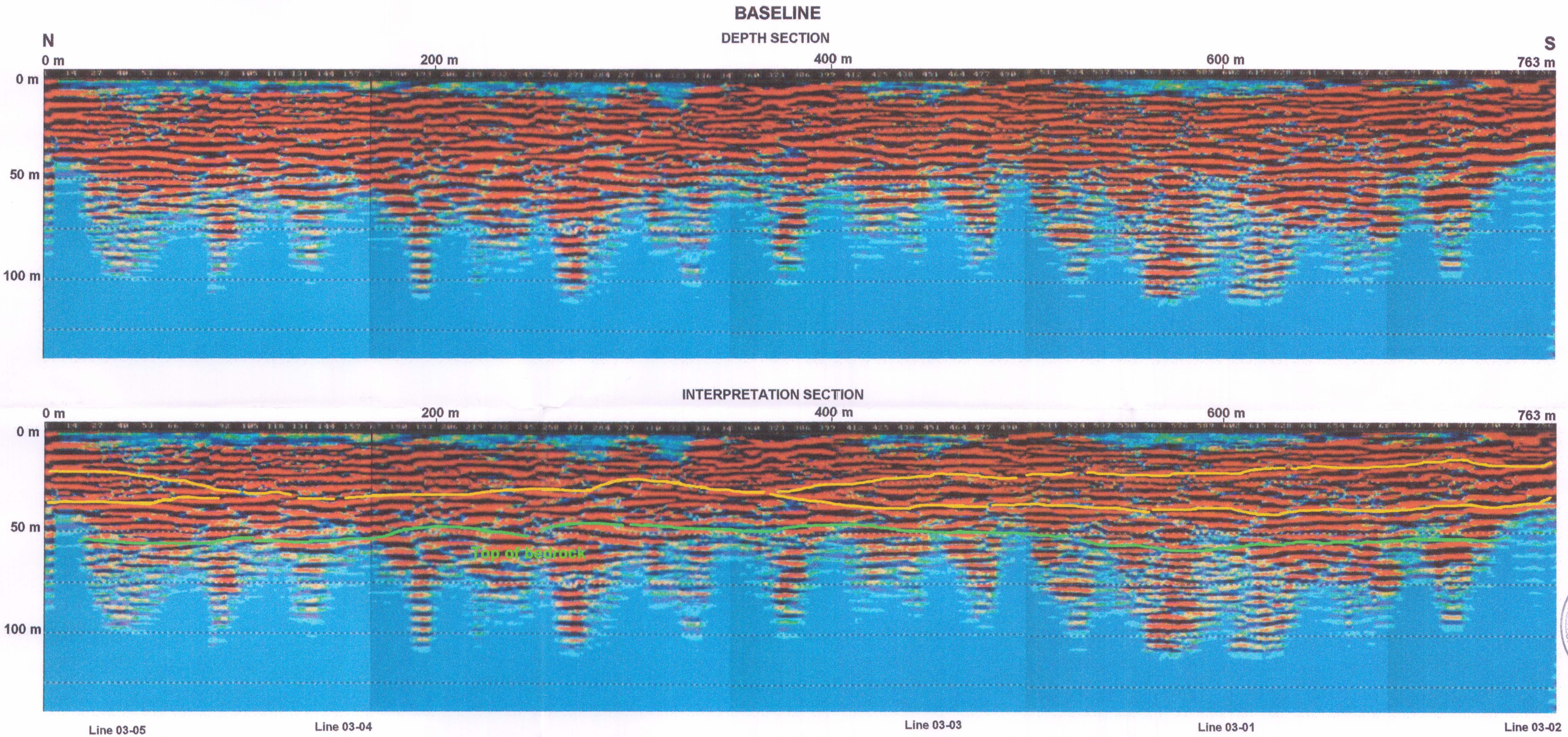



*FIGURE E-5.*

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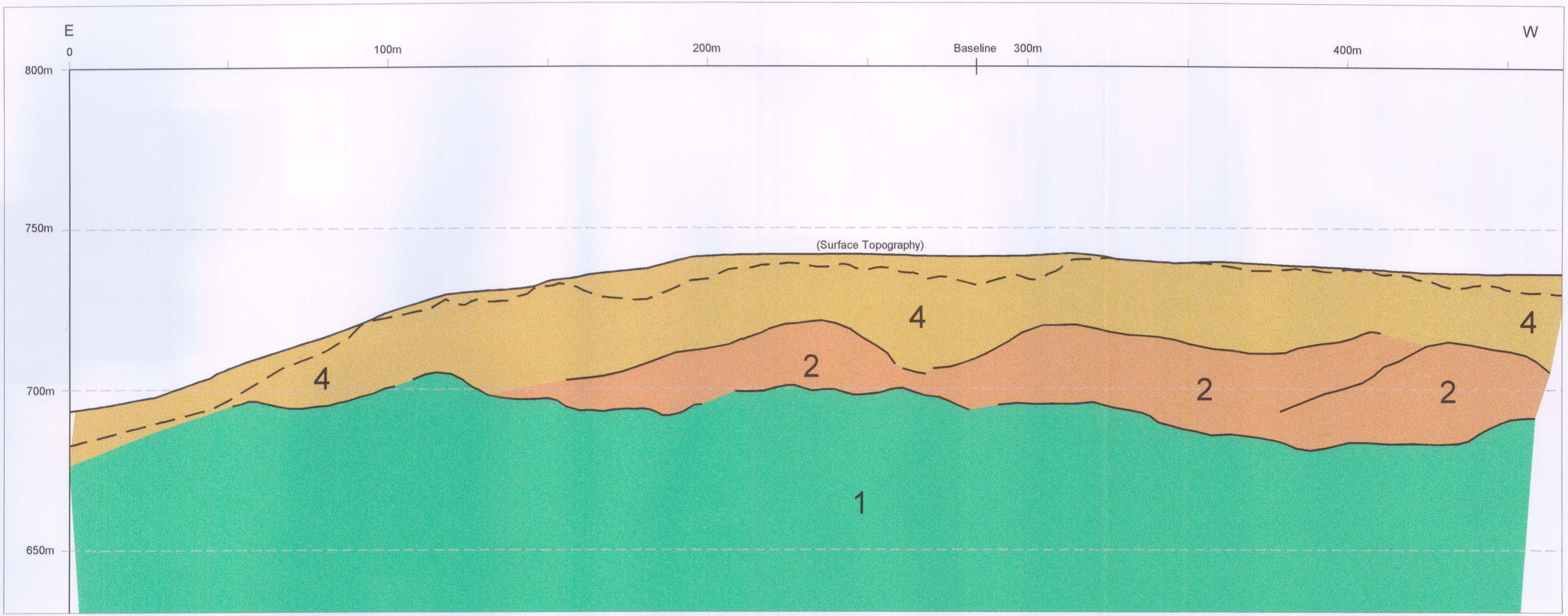
17 JAN 04
N.W.T.

*FIGURE E-6*

# APPENDIX F. ELEVATION SECTIONS




## LEGEND

| | |
|---|---|
| 5 | Holocene and Late McConnell unconsolidaited boulder to cobble gravel |
| 4 | Late McConnell silt |
| 3 | Early to Middle McConnell sand with lesser pebble to locally cobble gravel |
| 2 | Late Reid boulder to cobble gravel (Pay Gravel) |
| 1 | Quartz chlorite schist, phyllite, quartzite |

— — — Base of low velocity layer

0 25m 50m
metres
Scale: 1:1000
Elevations in metres above mean sea level

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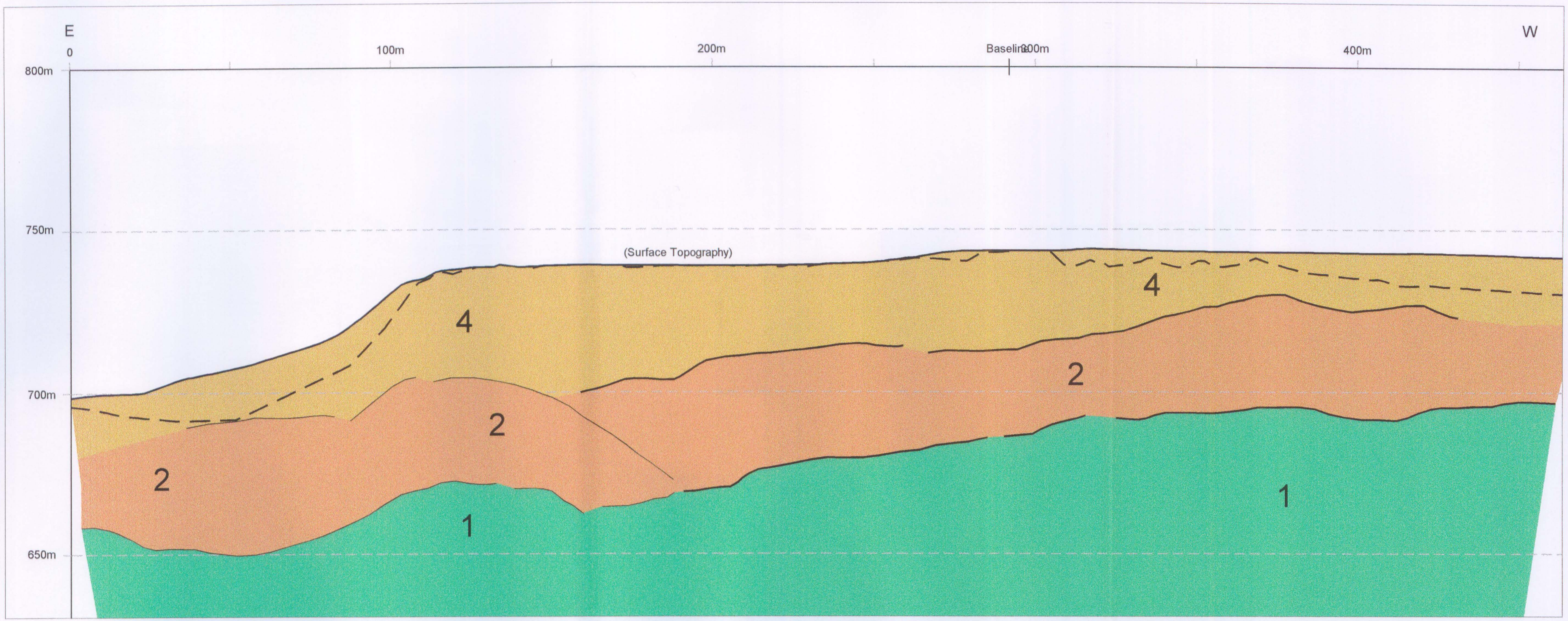
M. A. POWER
LICENSEE
16 Jan 04
N.W.T.

| | | |
|---|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
| SEISMIC REFLECTION SURVEY ELEVATION SECTION LINE 03-1 | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| AURORA GEOSCIENCES LTD. | DATE: 15 January 04 | DRAWING F-1 |




## LEGEND

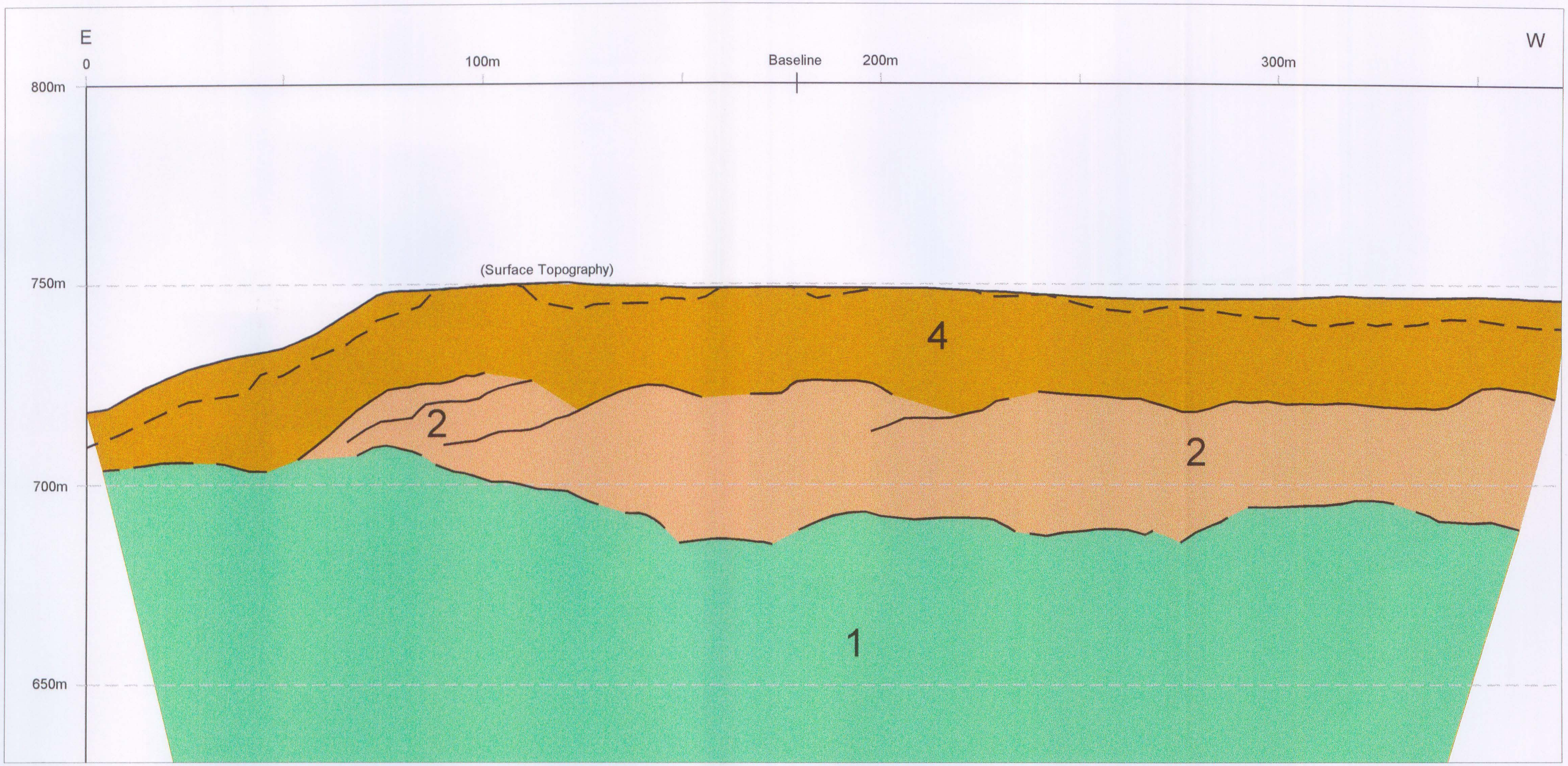
| | |
|---|---|
| 5 | Holocene and Late McConnell unconsolidated bouldeir to cobble gravel |
| 4 | Late McConnell silt |
| 3 | Early to Middle McConnell sand with lesser pebble to locally cobble gravel |
| 2 | Late Reid boulder to cobble gravel (Pay Gravel) |
| 1 | Quartz chlorite schist, phyllite, quartzite |

— — — Base of low velocity layer

0 25m 50m
metres
Scale: 1:1000
Elevations in metres above mean sea level

REGISTERED PROFESSIONAL GEOPHYSICIST
M. A. POWER
LICENSEE
16 Jan 04
N.W.T.

| | | |
|---|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
| SEISMIC REFLECTION SURVEY<br>ELEVATION SECTION<br>LINE 03-2 | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 | DRAWING F-2 |




## LEGEND

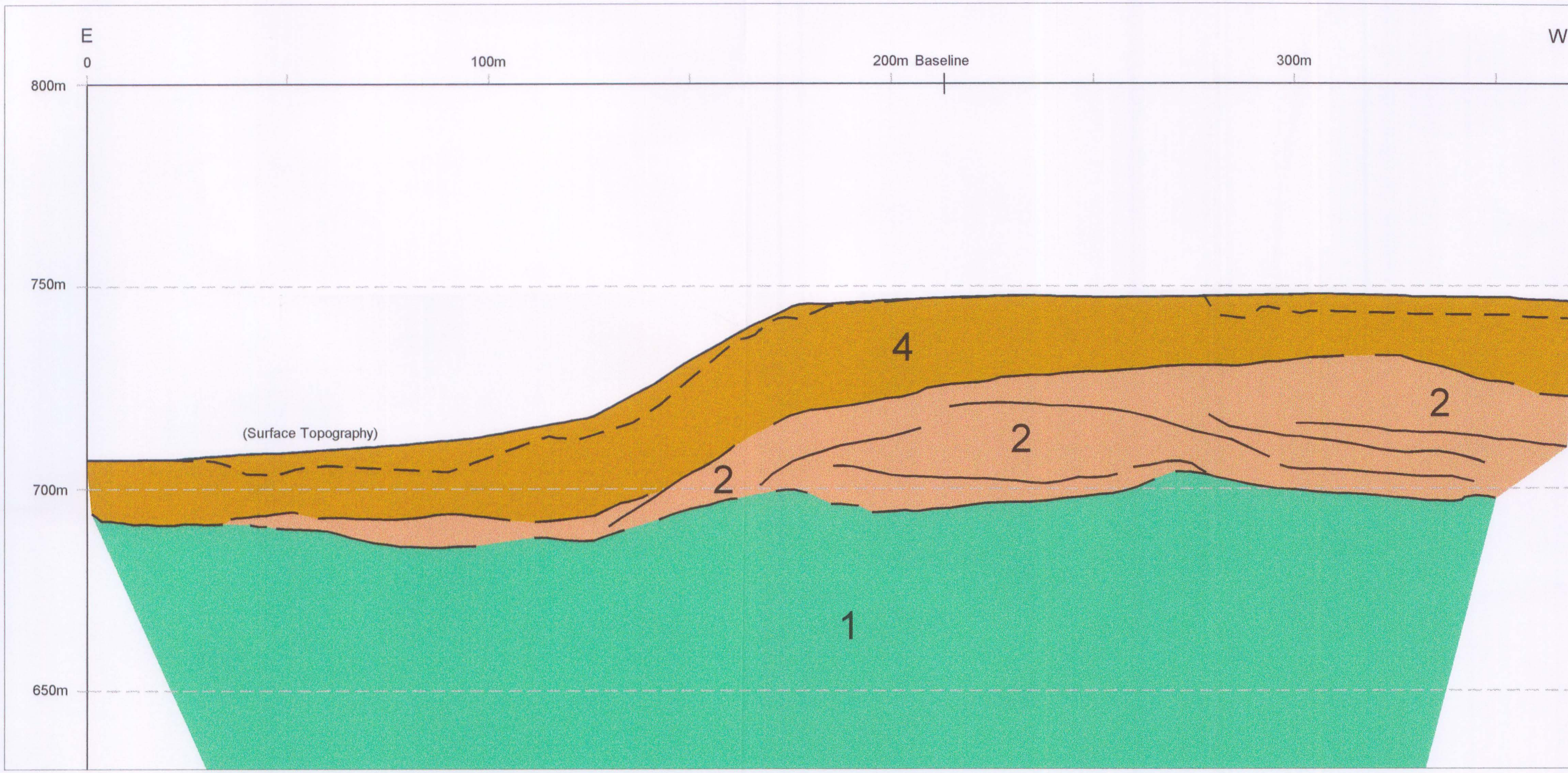
| | |
|---|---|
| 5 | Holocene and Late McConnell unconsolidated boulder to cobble gravel |
| 4 | Late McConnell silt |
| 3 | Early to Middle McConnell sand with lesser pebble to locally cobble gravel |
| 2 | Late Reid boulder to cobble gravel (Pay Gravel) |
| 1 | Quartz chlorite schist, phyllite, quartzite |

— — — Base of low velocity layer

0 25m 50m
metres
Scale: 1:1000
Elevations in metres above mean sea level

REGISTERED PROFESSIONAL GEOPHYSICIST
M. A. POWER
LICENSEE
N.W.T.

| | | |
|---|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
| SEISMIC REFLECTION SURVEY<br>ELEVATION SECTION<br>LINE 03-3 | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 | DRAWING F-3 |




## LEGEND

- 5 Holocene and Late McConnell unconsolidated boulder to cobble gravel
- 4 Late McConnell silt
- 3 Early to Middle McConnell sand with lesser pebble to locally cobble gravel
- 2 Late Reid boulder to cobble gravel (Pay Gravel)
- 1 Quartz chlorite schist, phyllite, quartzite

— — — Base of low velocity layer

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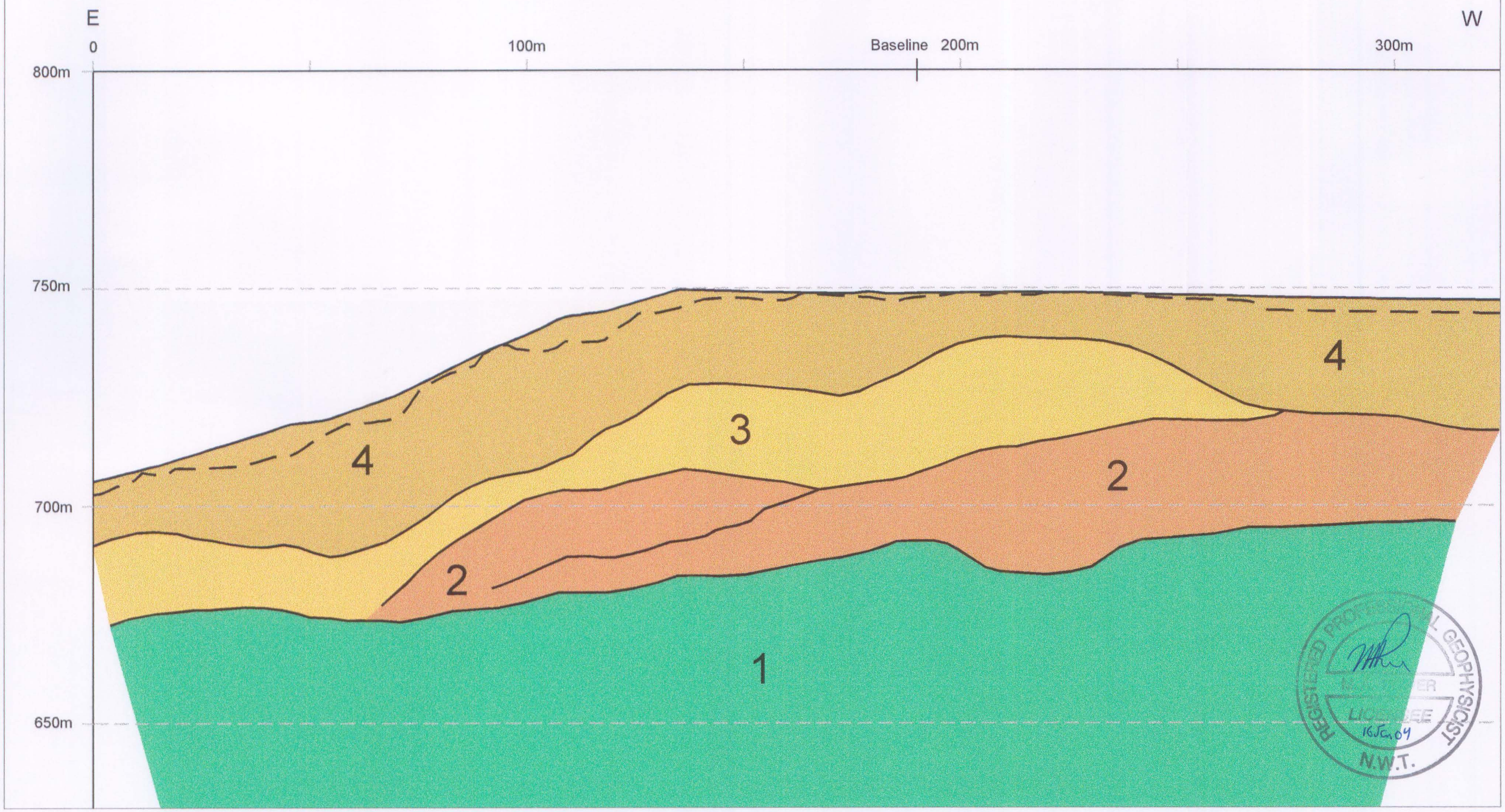
M. A. POWER
LICENSEE
16 Jan 04
N.W.T.

0 25m 50m
metres
Scale: 1:1000
Elevations in metres above mean sea level

| | | |
|---|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
| SEISMIC REFLECTION SURVEY ELEVATION SECTION LINE 03-4 | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 | DRAWING F-4 |




## LEGEND

| | |
|---|---|
| 5 | Holocene and Late McConnell unconsolidated boulder to cobble gravel |
| 4 | Late McConnell silt |
| 3 | Early to Middle McConnell sand with lesser pebble to locally cobble gravel |
| 2 | Late Reid boulder to cobble gravel (Pay Gravel) |
| 1 | Quartz chlorite schist, phyllite, quartzite |

— — — Base of low velocity layer

0 25m 50m
metres
Scale: 1:1000

Elevations in metres above mean sea level

| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
|---|---|---|
| SEISMIC REFLECTION SURVEY<br>ELEVATION SECTION<br>LINE 03-5 | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| *AURORA GEOSCIENCES LTD.* | DATE: 15 January 04 | DRAWING F-5 |


## LEGEND

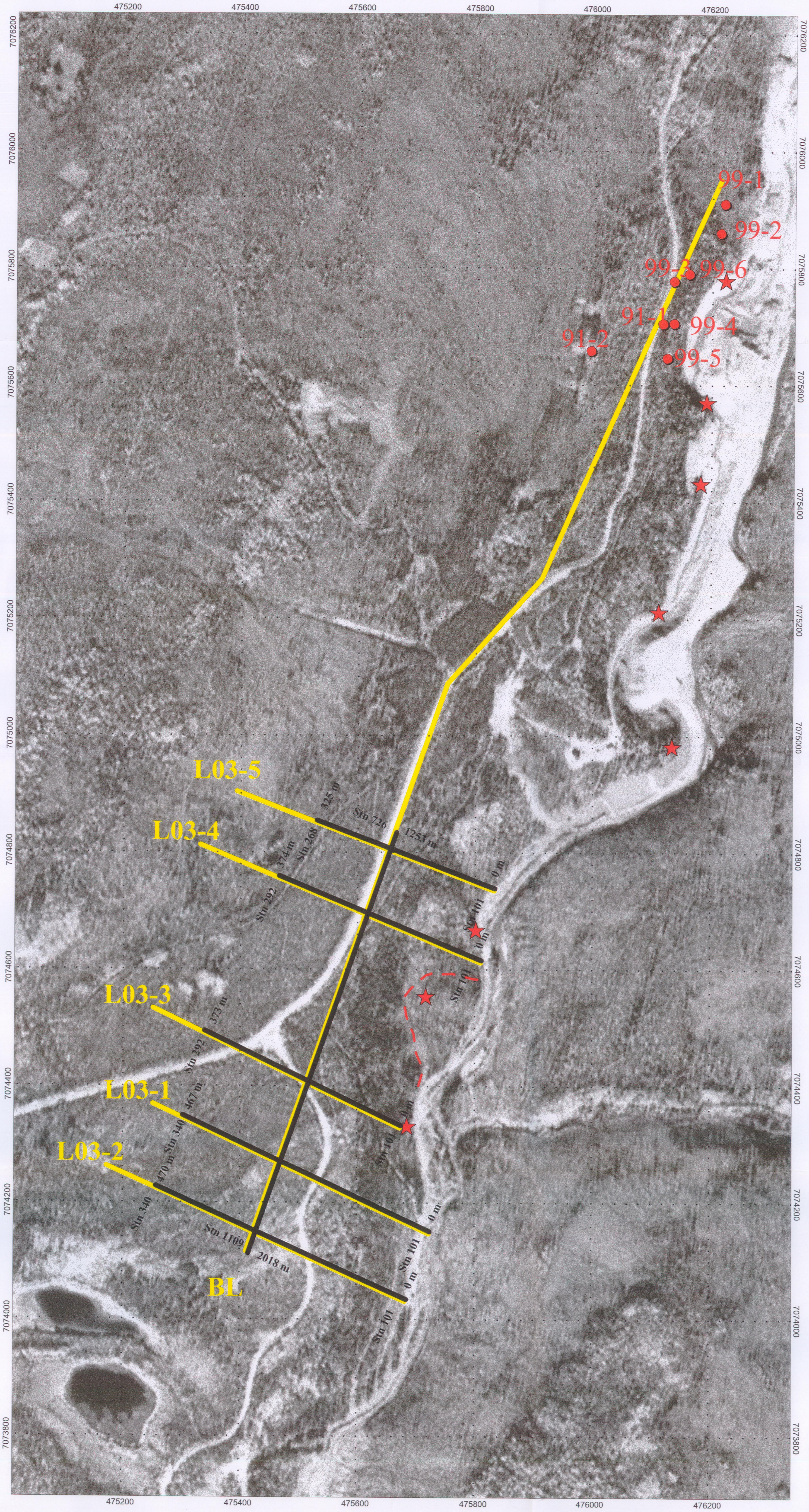
| | |
|---|---|
| 5 | Holocene and Late McConnell unconsolidated boulder to cobble gravel |
| 4 | Late McConnell silt |
| 3 | Early to Middle McConnell sand with lesser pebble to locally cobble gravel |
| 2 | Late Reid boulder to cobble gravel (Pay Gravel) |
| 1 | Quartz chlorite schist, phyllite, quartzite |

— — — Base of low velocity layer

0 25m 50m
metres
Scale: 1:1000
Elevations in metres above mean sea level

REGISTERED PROFESSIONAL GEOPHYSICIST
M.P. POWER
LICENSEE
16 Jan 04
N.W.T.

| | | |
|---|---|---|
| KEYSTONE MINING LIMITED | DUNCAN CREEK PROPERTY | |
| SEISMIC REFLECTION SURVEY ELEVATION SECTION BASELINE | MINING DISTRICT: MAYO | |
| | JOB: KML-03-001-YT | NTS: 105 M13/14 |
| | DATUM: N/A | DRAWN BY: HDS |
| AURORA GEOSCIENCES LTD. | DATE: 15 January 04 | DRAWING F-6 |




# LEGEND

| | |
|---|---|
| ★ | Bedrock Exposure |
| ● | Drill hole |
| - - - | Present quarry |
| — (yellow) | Cut line |
| — (black) | Seismic survey |

REGISTERED PROFESSIONAL GEOPHYSICIST
LICENSEE
16 Jan 04
N.W.T.

Scale 1:4000

50 0 50 100 150 200 250 300
metres

NAD27 / "Transverse Mercator (-135,0,0.9996,500000,0)



Keystone Mining Ltd.

**Duncan Creek Property**
**Reflection Seismic Survey**
**Line Plan**

Figure 4

| | |
|---|---|
| Datum: NAD1927 | NTS: 105 M13/14 |
| Proj: UTM Zone 8 | Mining District: MAYO |
| Job: KML-03-001-YT | Date: 15-01-2004 |

*Aurora Geosciences Ltd.*