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REPORT ON
A SEISMIC TEST
IN THE VANGORDA DISTRICT
OF THE CENTRAL YUKON

FOR

ANVIL MINING CORPORATION LIMITED

BY

HUNTEC LIMITED

TORONTO, CANADA

OCTOBER, 1967

bedrock velocity
Fm #1 9000'/s o/b 3900-6600
Fm #2 7500'/s
SEA : lower M, higher ρ?
↳ gravy anom ≠ comp. loc?
where is mnlzn

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I. INTRODUCTION

Between August 12th and August 27th, 1967, a seismic depth to bedrock test was carried out by Huntec Limited for Anvil Mining Corporation Limited in the Vangorda District of the Central Yukon.

Purpose of the Seismic Test

The test was planned to permit the geophysicist to acquaint himself with the physical conditions and problems of the area, and then, to test the interpretability of the results under these conditions. The test was aimed also at determining the depth to bedrock along picket lines on which anomalous gravity data were recorded. Thus, the geological conditions of the area demanded that the seismic method detect bedrock at both small and large depths.

In addition, a seismic investigation was carried out across the ~~Ross River~~ Rose Creek valley to supply information which might be helpful in determining the location of a diversion dam in this area.

Report of the Seismic Test

This formal report deals with the results of the seismic test and seismic investigation of the valley. Preliminary reports were presented verbally to the parties involved in the field as the test progressed.

Chapter II of this report is devoted to a brief discussion of the seismic method. It is included here due to the introductory nature of the present test.

Location

The location of the investigated areas are presented with their relative cross-section profiles in the Appendix of the report. Two lines over drill hole Section No.'s 6 and 7 are located in the Faro No. 1 Zone (Plate I). A line over Section No. 93 is located in the Faro No. 2 Zone (Plate II). Line 96 + 00W is located on gravity Anomaly G, west of the Faro No. 1 Zone (Plate II). Lines 8 + 00E and Line 16 + 00E are located in the Sea Grid in the Swim Lakes Area (Plate III). The Valley Profile is located about a half a mile north-east of Faro Camp across the valley and ~~Ross River~~ Rose Creek (Plate IV).

Personnel

Anvil Mining Corporation Limited provided M. Lowey as a field assistant throughout the test period.

Huntec Limited provided the services of E.L. Gregotski, Mr. Gregotski was in charge of the field operations, the actual operating of the equipment and interpretation.

Acknowledgements

Such a test can be carried out successfully only with the fullest co-operation of all the parties involved. Such co-operation was present throughout the test period and is most gratefully acknowledged here.

In particular, our gratitude is offered for help, support, geological advice and hospitality so graciously proferred by Mr. M. Hampton of Anvil Mining Corporation Limited.

II. THE THEORY OF SEISMICITY

Introduction

The seismic method depends fundamentally on the propagation of seismic waves in elastic media. The basic principles governing the propagation of seismic waves in such a media are similar to those that govern the propagation of light waves. Hence, the laws of reflection used in optical theory are also applicable to seismic studies.

Reflection occurs whenever a wave encounters a discontinuity where there is a change in the acoustic properties of the medium and part of its energy is returned back, much in the same way as a reflection from a mirror. Refraction, or a change in direction of propagation occurs whenever a wave crosses a boundary between wave-transmitting media of different acoustic properties. No change in direction is suffered when the wave path is normal to the boundary.

In the refraction method, travel time data are obtained for the elastic waves which have been refracted at boundaries separating media of different elastic constants and/or density and have travelled along the refracting boundaries. Beyond the critical distance, the refracted wave is always the fastest travelling wave, hence, first arriving waves are of main interest.

Refraction Method

The quantity that is observed in the refraction method of seismic investigation is the time between the initiation of a seismic wave at the shot point by hammer blow or explosion and its first arrival at the detector placed at a measured distance from the shot or impact point. As the first arrivals only are considered in the analysis, the wave arriving at the detector must be the one that has travelled the minimum time path between shot point and detector. Thus, by observing first arrivals for different separations of source and receiver, a time distance curve can be constructed representing variations of minimum time path with distance, (in the FS-3 this curve is plotted automatically by the instrument). From these variations, the nature and depth of the elastic discontinuities can be deduced.

The seismic waves travel through earth materials as through air, with a definite velocity and along a definite path. The velocity depends particularly upon the degree of consolidation. The path of seismic waves, like the path of light waves, follows whatever course which will require the least time between source and receiver.

The seismic paths for minimum travel time can be traced out by a simple relationship from a familiar law of optics known as Snell's law. A seismic ray will tavel in a straight line through any material which has a constant velocity but it will be bent if it passes through a discontinuity where there is an abrupt change in elastic properties.

For seismic refraction work, we are interested only in the rays which go down at the critical angle, i.e., become refracted parallel to the boundary, and are refracted back to the surface at the critical angle. The phenomenon forms the basis of the refraction method in seismic surveying and is therefore of primary importance.

The assumption that the geological structure of the survey area and the seismic fundamentals are in conformity forms the basis of seismogeological exploration.

The geological conditions for attaining correct results in the case of stratified media can thus be defined. The structural prerequisites for seismic equipment recording only first arrivals are included in the following six points:

1. Each layer or, more generally speaking geologically uniform zone, must be elastically isotropic. Its seismic velocity must have a definite and known constant value.

2. In each layer, the depth of which is intended to be determined, the velocity must be higher than in the layer above.

3. At every interface, or geological discontinuity boundary to be determined, the speed must change abruptly.

4. The speed differences between the layers must be such that each layer is represented in the time distance graph by first arrivals. If the speed differences are small, the layer thicknesses must be correspondingly larger.

5. The boundary interfaces of the layers within the survey area must be parallel planes.

6. The transmission of energy in the separate layers must be sufficient that the first arrivals become clearly detectable with the energy source in use.

The geological structure of the area can only approximate these prerequisites, consequently, the survey results are also of an approximate nature. However, it has been possible to develop calculation and interpretation methods for various types of geological structures. The source and magnitude of errors have thus been considerably reduced. The required accuracy for most practical purposes is nowadays attained under nearly all conditions.

The Reflection Method

In the reflection method the depths are determined by measuring the travel times of elastic waves generated at the surface and reflected back to the surface from the formations below.

The seismic reflection technique has many commendable features over the refraction technique. The length of the refraction spread must be many times longer than the depth to the deepest refractor, usually 4 to 6 times, whereas the reflection method is not encumbered by such a requirement.

Because of the inviolable rule that velocities must increase in each subjacent layer if a refracted wave is to return from it to the surface, the seismic refraction technique is gratly curtailed in northern countries during winter time, when the upper layer of ground freezes and masks arrivals to a distance which is many tens of times the thickness of the frozen layer. Even in temperate climates, velocity reversals are not infrequent, causing serious errors in depth to each marker horizon below the velocity reversal. The problem of velocity reversal does not seriously influence the interpretation of reflection data.

Lastly, the refraction phenomenon is a second order event compared with the reflection phenomenon. That is, the amount of energy returned to the surface by the refraction process is infinitesimal compared with the emitted source energy, and small compared with the energy reflected from those self-same horizons.

Although the basic principle of the reflection method is quite simple, technical difficulty arises in the application of the principle to underground investigation. This is due to the complex nature of the wave transmitting medium and the difficulty of recognizing a true reflection among the complex motions of the ground surface following the initiation of elastic waves.

III. FIELD EQUIPMENT AND PROCEDURES

Description of Instrument

The FS-3 consists of a recording console with self-contained power source, two geophones, a sledge hammer with steel plate, and a battery driven detonator. The FS-3 produces a permanent record on electro-sensitive paper of the elapsed time between initiation of an elastic shock on the surface of the ground and the arrival of the resulting wave at another position on the surface of the ground. Briefly, the seismic impulse transmission takes place in the following way: The shock is created by means of a sledge hammer striking a steel plate resting on the ground or by means of an electrically detonated explosive charge. In the former case, an inertia switch fitted to the sledge hammer completes a circuit at the instant of impact and a stylus starts moving over the electro-sensitive paper. The ground motion is detected by means of a velocity sensitive geophone which converts a vertical displacement into an electrical voltage which is fed to the stylus through a filter, a preamplifier, a gain control, an amplifier, a pulse former and a printing amplifier. Not only does the first seismic pulse, but also subsequent cycles of later arrivals, appear as black marks on the paper. This paper is marked by time lines every two milliseconds, the total range of the paper being 180 milli seconds. Thus, there are recorded on this paper all the seismic impulses between 3 and 180 milliseconds and also all impulses between 160 and 340 milliseconds provided the 160 millisecond delay unit is employed.

To reduce microseismic random noise, two geophones can be used.

The pulses from both geophones are thus fed through a correlator to the stylus. Recordings then result only from seismic impulses which are in phase. In the double channel or correllating mode it is possible to achieve better discrimination against sources of noise co-linear with the geophone spread.

Procedures

Refraction Survey

The setting up of the seismic equipment in the field is as follows:

The location is picked for the geophones which are firmly placed in the ground in a vertical position about 10 to 15 feet apart, with their connecting line perpendicular and symmetric to the projected hammer line. The hammer line or blasting line is measured with fabric or nylon tape, readings are generally taken at 10 foot intervals up to 50 feet and 20 foot intervals thereafter. More detail may be desired in the vicinity of "breaks in the curve" — this is accomplished by calling for additional hammer blows at shorter station separation. A time distance graph, with one or several breaks, is directly obtained when the line has been completed. This means that a preliminary examination of the results can be made in the field.

Seismic refraction investigations can be divided into three categories: single spot determinations, double spot determination

Procedures - (cont'd)

and profiling. In single spot determinations, for each seismic station one hammer line only is run, the receiving stations being successively moved in the direction of the investigation profile. This method gives information only at the seismic station or receiving station. In double spot determinations, hammer lines are run in opposite directions from the same geophone position. This means that a more detailed picture of subsurface layers and bedrock topography about that point is acquired. In profiling, the hammer line is run in one direction and on completion of the line the receiver station is placed at the end point of the hammer line; the second hammer line is run in the opposite direction to its end point which was the previous receiving position. With this technique depth determination along any hammer point between the two end points of a profile which has been shot back and forth (reversed shooting) can be calculated. This means that more detail of the bedrock topography can be acquired.

All three refraction techniques were used during the test employing either hammer sources or dynamite sources when required.

Reflection Survey

For reflection surveys the FS-3 used had been modified to possess a variable gate correlator. The variable gate-correlator is essentially a device for discriminating against non-coherent signals received at the two geophones. If the phase shift of the positive signal in either of them, relative to the other, is greater than an arbitrary time value manually set by the operator, the signals are rejected and not printed on the record paper. The variable gate correlator can then be used for recording waves which are characterized by an essentially vertical ray path in the following way:

The two single geophones are placed in line with the hammer line separated by a distance of 10 to 25 feet. The distance of the hammer point from the closest geophone depends upon the depth being investigated. Thirty feet is a typical figure. Since the two geophones are in line with the hammer point but a different distances from it, any noise coming from the general direction of the hammer point or from the opposite direction reaches the two geophones at different times and is supressed by the correlator. The same holds true for any direct arrivals resulting from the hammer blow. The reflected signals on the other hand, if the depth is much greater than the separation of geophones and hammer, arrive in phase at the two geophones and are therefore recorded.

Reflections are positively identifiable by virtue of their hyperbolic concavity when an expanding reflection spread is carried out. This useful criterion is then the basis of the field technique. This technique is limited for exploration targets at depths of 50 to 400 feet. The field procedure requires that the hammer man move out from the centre of the two collinear geophones, at 20 or 30 foot increments, impacting the ground two or three times at each hammer station, to a distance of 300 to 400 feet. If the geophone spacing and/or variable aperature correlator setting are correctly adjusted, hardly anything other than reflections are seen on the record. This technique extends the depth of investigation of hammer seismography to several hundred feet and can potentially overcome problems associated with hidden layers and frozen ground conditions.

IV. RESULTS OF TEST

Presentation

The results of the seismic test are presented in the form of profiles at the end of this report. The seismic profiles of Sections No. 6 and No. 7 in Faro No. 1 Zone (Plate I) and Section No. 93 in Faro No. 2 Zone (Plate II), have a horizontal and vertical scale of 1 inch to 100 feet. Since the above mentioned profiles were used to acquaint the geophysicist with the conditions and problems of the area, the diamond drill hole depths are also presented on the profiles for comparison with the seismic depth determinations.

The seismic profile of Line 96 + 00W (Plate I) has a horizontal and vertical scale of 1 inch to 50 feet. The seismic profiles of Line 8 + 00E and Line 16 + 00E of the Sea Grid have a horizontal and vertical scale of 1 inch to 100 feet (Plate III). The seismic profile across the valley has a horizontal and vertical scale of 1 inch to 50 feet (Plate IV).

In addition to seismic data, other available geophysical data, such as Gravity and Induced Polarization results, are presented on the seismic profiles. Additional geophysical data has been presented with all profiles except for the Valley Profile.

Location maps showing the locations of the seismic profiles at a scale of 1 inch to 400 feet are presented with the respective profiles.

The results of the seismic test are also presented in the form of tables contained in the Appendix of the report. The tables contain the following information: location of seismic profiles, seismic method used, location of the depth determinations (station). For the refraction method the velocity and thickness of the various seismic layers (V_1, V_2, V_3, V_4 and d_1, d_2, d_3), velocity of bedrock (V_R), total thickness of overburden (D_t), bedrock surface where known and record quality are given.

The quality of the field record is controlled by the surface topography, by the topography of the seismic velocity discontinuities, and conditions of the surface material.

In general, the record quality is determined by the amount of scattering. The record quality is noted in the accompanying tables by the letters E, G, F, P and ?.

A determination is marked "E" when the velocities are clearly defined in the record.

A determination is marked "G" when the velocities are well defined but some scattering of points is present.

A determination is marked "F" when it is obtained from a record where the velocities are not clearly defined and the points are scattered.

A determination is marked "P" when it is obtained from a record where velocities are not clearly defined and clouded by the scattering of points due to surface noise and other overburden irregularities such as permafrost.

A determination is graded "?" when there is some uncertainty about the velocities due to inhomogeneity in overburden or irregular bedrock.

For the reflection method the following information is given: events which correspond to the bedrock horizon (R_1, R_2 or R_3), the average velocity to the reflecting horizon, the depth to the reflecting horizon

(Z) and record quality.

In all tables the last column presents remarks salient to the depth investigation.

Performance

The number of depth determinations varied from place to place and depend upon the depths which are under investigation. On the basis of the test carried out it is estimated that a crew of two men would be able to undertake about 12 shallow reversed profiles or 24 graphs per 8 hour day. However, for long spreads required in profiling, such as the Valley Profile, progress was delayed by the need to dig the holes for the charges. This delay could be overcome with the addition of another crew member who would be employed for the purpose of pre-digging the holes in order to prevent any operational delays.

V. INTERPRETATION

Velocity and Thickness Computation

The actual field record, or time distance plot derived from the field record, serves as the basis for layer velocity and layer thickness computations. Under ordinary conditions, the points which represent first arrivals will not fall exactly on one or more straight lines, but will be slightly scattered, partially because of topography or bedrock surface irregularity and partially because of ambient noise at the site of investigation.

In the interpretation of the refraction results the "Critical Distance" method is used to determine depth at the geophone position. The critical distance is the distance from the geophone at which two straight line segments, representing different velocities, intersect. Its significance is that the refracted ray with a higher velocity from a deeper layer arrives at the same time as the refracted ray with a lower velocity from the immediately higher layer. The algebraic relationship between the critcal distance and the velocities of the intersecting line segments which determine the position of the critical distance yields the thickness of the layer of lower velocity.

It will be noted that the interpretation procedure gives data on velocities. These velocities are an important tool for identifying the subsurface materials.

First arrivals that do not fall along straight lines but appear scattered may be due to any of the following: inhomogeneity of near surface material, surface topography, bedrock topography, noise or absence of first arrivals. These irregularities can only be interpreted on a qualatative basis.

To obtain quantitative information about bedrock topography, a simple rapid technique for depth determination at any point between two end points of a profile which was shot back and forth (Reverse Shooting) has been described by P. Taanila, (Ref. 1) and others. Since depth to the refractor is a function of the effective vertical velocity, Taanila has presented the equations required for the calculation of effective vertical velocity and depth to the refractor for all points between the end points of the profile.

The depth to a reflecting horizon can be obtained by calculating the average velocity of the overlying material.

Faro No. 2 Area

Depth determinations were carried out at seismic stations that were coincident with the diamond drill holes on Section No. 93. The sites where the seismic work was carried out are on ground sloping approximately 18^{o} to the south. The material overlying the bedrock is mainly glacial material composed of loose sands and gravels and compacted clay. Between DDH 67-18 and DDH 67-19, the surface is covered by muskeg swamp. For the rest of the section the subsoil is covered by a shallow humus layer, the

Ref. 1.:

Taanila, T (1963): A profile calculation method in seismic refraction surveys based on the use of the vertical velocity. Geoexploration, Number 1, pp. 36-49.

topmost layer being a few inches of thick moss.

In this connection it may be mentioned that the geophones were placed at a depth below the topmost layer of moss, and at hammer points the moss and organic humus layer was removed. The interpretation of the refraction data indicates an average thickness of overburden of 20 feet with a minimum thickness at DDH 67-23 of 14.8 feet and a maximum thickness of 23 feet at DDH 67-16. The apparent low bedrock velocity indicates strongly weathered metamorphic formations. The interpreted seismic depths at stations which have double depth determinations agree to within ± 1.2 feet of the diamond drill hole depths to bedrock. The greatest discrepancy of + 2.8 feet at DDH 67-23, was for a single determination and thus could be due to a slightly sloping bedrock surface. This section was investigated in order to obtain correlation between the seismic velocities and the known geological section, and to obtain a comparison between the interpretation of shallow seismic refraction data and drilled depths to bedrock.

Faro No. 1 Area

Seismic depth determinations were carried out at diamond drill hole sites on Section No. 6 and No. 7. The sites along Section No. 6 are on ground that has an irregular topography. The subsurface materials inferred by the seismic refraction method vary from one end of the section to the other. The interpretation of the seismic data was further complicated by the irregularities in the bedrock surface. The combined effects of thick overburden, irregular surface and bedrock topography resulted in large discrepancies between the interpreted seismic depths and the drill hole depths. However, the errors were with ± 15%; this is acceptable in seismic work.

The higher bedrock refraction velocity of about 9000 ft/sec. in this area as compared to the lower bedrock velocity of about 7500 ft/sec in the preceding area may possibly be due to a lesser degree of weathering on the bedrock surface and the presence of a larger amount of siliceous minerals in the bedrock.

Between DDH 66-8 and DDH 66-18 the material overlying the bedrock exhibits a velocity of 3900 to 6800 ft/sec; this may indicate the presence of water saturated material.

Reflection data were obtained for stations with an indicated overburden thickness greater than 50 feet. Although relfection data gives very little information relating to intermediate layers in the overburden, it does give a rapid check of the depth to the reflecting bedrock. The reflection technique eliminates the use of dynamite for depths greater than 80 feet.

The reflection data obtained corresponded with the DDH depths within allowable error of 10% in all but one case.

DDH 66-35 records a depth of overburden of 46 feet. The refraction technique yielded a total depth of 53.7 feet, and the reflection method yielded a depth of 73 feet. Both discrepancies are due to the abrupt downward slope ot the bedrock surface along the hammer line. The result of such a condition produces a refraction depth interpretation which will be greater than the actual depth at the geophone location. The actual slope of the bedrock with respect to the ground surface would have to be known in order to offset the interpreted depth the proper distance from the geophone position. The required information could have been obtained by a reverse spread. However, due to the nature of the test the reflection technique was employed in place of reversed refraction shooting to show the effect of steeply dipping bedrock on both methods. The reflection method yielded a depth of 73 feet which is much greater than the DDH depth. The depth so obtained always refers to the depth at a point midway between the shot point and the detector position. This would place the interpreted depth at a position 70 feet from DDH 66-35 towards DDH 66-18. Assuming a uniformly sloping bedrock surface between DDH 66-35 to DDH 66-18, the bedrock depth inferred at the offset distance is 78 feet as compared with the seismic depth for that position of 73 feet. In reflection surveys in areas with uniform parallel conditions the interpreted depth usually corresponds to the seismic station. This is illustrated by the reflection spread shot between DDH 66-18 to 65-13. At DDH 66-18 the refraction spread was limited in length by the creek and loss of energy from the hammer source at that distance. The seismic results of this spread also indicated the presence of permafrost at depth. The maximum depth of overburden that could be penetrated from the limited spread length used was 70.2 feet. The reflection method was used to penetrate the suspected permafrost zone. The spread was shot perpendicular to the refraction spread at station DDH 66-18 along the contour of the surface in order to eliminate any irregularities due to surface topography. The results of the reflection method indicated three reflecting horizons. The depth of the upper horizon was interpreted as 72 feet, corresponding to the refractor at 70 feet which is considered to be a permafrost zone. The second reflecting horizon at a depth of 106 feet corresponds to the DDH depth of 112 feet. The third pronounced reflecting horizon at a depth of 170 feet corresponds with the top of the ore zone, this is in agreement with the DDH results. The reflection technique was used to obtain a depth determination at DDH 65-13 because of the increased thickness of overburden and the increased complexity due to the presence of permafrost and the nearness of a noisy creek. The results of this spread yielded only one interpretable horizon. The depth determination for this horizon is 110 feet which corresponds to the depth of overburden of 106 feet recorded by the drill hole. No shallower or deeper event was recorded, which may indicate the absence of any appreciable ore within a depth of 250 feet of the seismic station. Also the absence of any shallower event suggests that the permafrost is not continuous throughout the area.

The seismic stations along Section No. 7 are on ground which slopes irregularly to the south. The irregularity of the surface topography along the section required that all but one seismic station spread be directed at various angles to the section line. The seismic results indicate irregular thicknesses of overburden ranging from 22.4 feet to 75.2 feet. A comparison with the DDH logs indicates that both refraction and reflection results are within 10% of the depths obtained in drilling.

Line 96 + 00W

The seismic stations along this line coincide with gravity stations on ground which slopes irregularly to the south at an average slope of 9 degrees 30 minutes. The gravity survey indicated a weak residual anomaly between stations 6 + 00N and 16 + 00N only on this line. This line was surveyed with the seismic method to determine a possible cause of this weak anomaly. Drilling in the area was not able to attribute the anomaly to a change in mass distribution of the underlying rock in the presence of massive sulphides.

The irregular topographic surface and nature of the survey required that double determination be taken at each station over the anomaly.

The seismic results indicate that the bedrock surface appears to be shallowest about station 10 + 00N at a depth of 21.5 feet. The overburden then appears to generally increase toward the north baseline to a thickness of about 50 feet. South of station 10 +00N the overburden gradually thickens to about 30 feet at station 4 + 00N. Thus, the bedrock cover appears to gently decrease in thickness from the baseline to station 10 + 00N then becomes relatively thicker towards the north baseline. Drill hole information about 300 to 400 feet west of the line indicates in excess of

50 feet of overburden. The combination of the seismic results and adjacent drilling suggests that the bedrock surface forms a spur or dome on the sloping hillside.

A study of the bedrock velocities indicate an average refracting velocity of 10,500 ft/sec. corresponding to velocities recorded in metamorphic formations. Velocities below 10,000 ft/sec. are suggestive of weathered, sheared fractured rocks.

Sea Grid

Lines 8 + 00E and 16 + 00E were surveyed with the seismic method over a broad Bouguer anomaly in the Swim Lakes Area. The seismic stations were positioned on the gravity stations on these lines. The ground surface of the lines slopes gently to the north with gentle undulations. The interpretation of the seismic results was hindered by the presence of frozen layers of overburden and slight changes in velocities between the layers. The material overlying the bedrock is mainly glacial till. There is no swamp in the area and the subsoil is covered by a shallow layer of frozen sand and silt, the topmost layer being composed of moss and humus. The average bedrock velocity was determined as 13,000 ft/sec. This velocity is indicative of metamorphic sedimentary rocks.

The overburden thickness along Line 8 + 00E appears relatively uniform varying between 46 feet at station 2 + 00N to a maximum of 58 feet at 10 + 00N. The calibration test carried out at a drill hole approximately 140 feet east of line 8 + 00E served as an important guide in classifying the material overlying the bedrock as glacial till as opposed to a weathered bedrock. The velocities recorded in the Faro Areas indicate weathered bedrock; they are similar to those ascribed to the glacial till in this area. The bedrock velocity of 14,000 ft/sec obtained on this spread was used as a guide in the interpretation of refraction data obtained in this area.

The thickness of overburden along Line 16 + 00E is thicker than along Line 8 + 00E. The thickness varied between 72 ft and 111 feet. The overburden appears to increase in thickness from station 14 + 00N to 4 + 00N.

The reflection method was used at station 4 + 00N due to the increase in thickness of overburden in that area and the presence of frozen layers in the overburden. The reflection method was also used with the refraction method at station 8 + 00N as a check on the refraction interpretation and to determine the feasibility of using the reflection method on this line.

Both the gravity data and I.P. data have been plotted with respect to the seismic profile in order to get a direct comparison of the effect of the thickness of overburden on the gravitational, apparent chargeability and apparent resistivity responses.

Line 16 + 00E indicates that the Bouguer gravity and apparent chargeability are reduced as the overburden increases in thickness to the south. However the resistivity values tend to increase with the increased thickness of overburden indicating that the overburden is electrically more resistant than the bedrock material.

Valley Profile

A series of three seismic profiles in line make up the Valley Profile across the Ross River. This area was surveyed to supply continuous information about the character of the overburden material and bedrock topography for the location and installation of a diversion dam. The areas between Sections A-B and C-D and E-F were not surveyed due to the presence of excessive glacial detrital material producing an increase in the overburden thickness and irregular topography. In order to give continuous coverage the bedrock has been interpolated between the sections. As the stations were shot back and forth, depth to the refracting bedrock for all points between the end points of each sections were determined using the equations and calculations described by Taanila, (See Chapter V).

Station A of Section A-B is located near Water Well No. 1 (WW No. 1). Section A-B extends across a wet marsh to the base of the esker at Station B. The depth to bedrock determined at Station A of 77.8 feet appears to be 12% in error compared to the recorded depth of 89 feet produced by drilling. Station B indicates the bedrock is dipping away from Station A to an interpreted depth of 117.5 feet at Station B. The overburden velocities indicates that the bedrock is overlain by glacial clay. There is as an actual swamp or marsh area between the two stations. The character of the bedrock topography is quantitatively defined by the intermediate points between Stations A and B.

Station C of Section C-D is located on the other side of the esker at its base and is located about 200 feet east of WW No. 2 and WW No. 3. The spot determination at Station C indicates the bedrock at a depth of 136 feet. This depth appears to be in the proper order as the depth to bedrock recorded at WW No. 2 and WW No. 3 is in the order of 142 feet. The profile of Section C-D extends across the Ross River and terminates at the base of a moraine deposit at Station D. The interpreted depth to bedrock at Station D of 53.3 feet indicates that the bedrock surface rises abruptly from Station C to Station D. The profiling method indicates the irregular character of the bedrock surface between Stations C and D. The bedrock appears to be overlain by a compact glacial clay. There is no actual swamp in the area and the subsoil is covered with a layer of partially frozen material. The top soil varies from a few inches of moss and humus at Station C to loose bouldery glacial material at Station D.

Station E of Section E-F was offset up the hill to avoid the loose glacial material and irregular topography created by the adjacent glacial material. The depth determination of bedrock at Station E of 69.3 feet indicates that the bedrock still rises as the profile continues up the side of the valley. The closest comparison to this depth determination is at WW No. 4 about 400 feet west of Station E. The depth to bedrock at WW No. 4 was recorded as 48 feet. The profile of Section E--F continues up the gently sloping valley side to Station F. The depth determination of bedrock of 6.0 feet at Station F indicates that the bedrock continues to rise towards the surface on the valley wall. Considerable near surface permafrost was detected throughout the section and appeared to extend to the bedrock surface from Station F to about the midway point of the section. From the midway point to Station F the permafrost layer overlies a glacial clay which covers the bedrock surface in this area. The top layer of thick moss covers the subsoil along this section.

VI. CONCLUSIONS AND RECOMMENDATIONS

The seismic results obtained in Faro No. 1 and Faro No. 2 areas when compared with the drill hole results were on the whole satisfactory. At shallow depths, say less than 30 feet, the results were of the correct order. At depths up to say 100 feet the errors were reasonably small, and perhaps caused by the weathered zone which overlies the solid and homogeneous rock, by irregularities in the overburden material, by irregularities in the bedrock topography or a combination of these factors.

The results obtained on Line 96 + 00W over the unexplained gravity anomaly tend to infer that the slope of the limbs of the residual G-Anomaly possibly reflect the relative changes in the thickness of the overburden. Thus the G-Anomaly appears to be influenced by the thickness of overburden rather than mass distribution in the rock proper.

The seismic results obtained on Lines 8 + 00E and 16 + 00E on Sea Grid indicates that the overburden appears thicker on Line 16 + 00E than on Line 8 + 00E, however the intensities of the Bouguer gravity readings as a whole appear uneffected by the changes in overburden thickness.

The degree of variation in the interpretation of a gravity survey depends upon the extent to which the gravitational picture is clouded by shallow or deep disturbing effects. The assumptions made to limit the inherent ambiguity in the determination of the mass distribution to account for a given gravity anomaly are justified if premises, other than the gravity data, on which such calculations are based, are well formed. Any further limitations must come from drilling, from other geophysical data such as seismic or in the absence of other control, from general considerations of geologic reasonableness.

The seismic method may also be used in removing ambiguities resulting from overburden in evaluation of magnetic anomalies.

A natural solution to the presence or actual lack of geochemical anomalies could also be found by using the seismic method.

Due to the changes in physical conditions from one area to the other, it is recommended that wherever possible seismic determinations should be compared to known drill results in order to familiarize the interpreter with the conditions in the area.

The field operations and their results during the course of the present seismic test, clearly established, it is believed, the practicability, the applicability, the interpretability and the limitations of the seismic method as applied to the problems in the mineral exploration of the Anvil Mining Area.

It is hoped that the execution of the test, the personal discussions during the field work, and the presentation of the interpretation in the report, will have fulfilled the purpose of the test. The rather lengthy discussion and description ot the theory, equipment and procedures in Chapter II and III of this report are presented in the hope that they may serve as a handy reference on the seismic method.

HUNTEC LIMITED

E. L. Gregotski
Geophysicist

APPENDIX

1. INSTRUMENT:

The geophysical instrument used was the FS-3 portable Seismograph manufactured by Hunted Limited, Toronto, Ontario, Canada.

2. PERFORMANCE:

Due to the nature of the test the line mileage total is not a valid method to measure production. A more true indication may be arrived by the number of determinations or graphs obtained.

Line Mileage	No. of Graphs
1.82 miles	81

3.

Assessment Work	8 Hour Man Days
Field Work	28
Calculations and Drafting	7
Interpretation and Report Writing	12
Office typing and supervision	2

4. Personnel Employed on Survey:

Name	Occupation	Address	Date
E.L. Gregotski	Geophysicist	1450 O'Connor Dr., Toronto, Ontario	Aug. 13 to Aug. 26 Sept. 1 to Oct. 15/
M. Lowey	Helper	P.O. Box 2470 Whitehorse, Y.T.	Aug. 12 to Aug. 27 1967
Jean Wilson	Drafting	1450 O'Connor Dr., Toronto, Ontario	Sept. 27, 28th Oct. 3,6,11,12,17
Dawn Howard	Typing	1450 O'Connor Dr., Toronto, Ontario	Oct. 23, 31/67

Faro No. 2 Zone Section No. 93

TABLE I

Refraction

Station	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_4 ft/sec.	V_R ft/sec.	d_1(ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Bedrock	Record Quality
DDH 67-23 Shot Direction 67-23 to 67-21	900	1700			7200	3.2	11.6		14.8	Diorite	G
	DDH depth 12.0 ft. Seismic depth 14.8 ft. Shot only one way.										
DDH 67-21 Shot Direction 67-21 to 67-23	1020	2400			8000	5.8	16.8		22.6	Sericite Meta-phyllite	E
DDH 67-16 Shot Direction 67-16 to 67-21	1200	2230			7000	8.0	15.8		23.8		E
	DDH depth 24.0 ft. Average seismic depth 23.2 ft.										
DDH 67-16 Shot Direction 67-16 to 67-21	1280	2300			8300	6.0	12.2		18.2	Sericite Shist	E
Shot Direction 67-16 to 67-18	1300	3300			7500	5.8	15.5		21.3		E
	DDH depth 21.0 ft. Average seismic depth 19.8 ft.										
DDH 67-18 Shot Direction 67-18 to 67-16	1250	4100			10,000	6.0	12.3		18.3	Quart-zite Sericite Shist	E
Shot Direction 67-18 to 67-19	1500	3800			7100	7.5	12.5		20.0		E
	DDH depth 18.0 ft. Average seismic depth 19.2 ft.										

TABLE I - (cont'd)

Station	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_4 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft)	D_t (ft.)	Bedrock	Record Quality
DDH 67-19 Shot Direction 67-19 to 67-18	1400	4400			6500	11.0	9.6		20.6	Quart-zite, Meta-phyllite	E
	DDH Depth 21.0 ft. Seismic depth 20.6 ft. Shot only one way.										
Velocity Test	850				9000						E
	Outcrop area - Gabbro grading into Chlorite shist.										

Faro No. 1 Zone Section No. 6

TABLE II

Station	Refraction V1 ft/sec.	V2 ft/sec.	V3 ft/sec.	VR ft/sec.	d_1(ft.)	d_2 (ft.)	d_3(ft.)	D_t(ft.)	Bedrock Surface	Record Quality	Reflection Event	Average Velocity	Z (ft.)	Record Quality
DDH 66-54														
Shot Direction 66-54 to 66-26	850	2100	4000	9000	3.8	4.3	19.9	26.8	Quart-zite	G				
	DDH depth = 21'. Seismic depth 26.8'. Portion of error may be due to build up of debris at drill site.													
DDH 66-26														
A. Shot Direction 66-26 to 66-54	1280	2150		9100	6.8	19.0		25.8	Quart-zite	E-G				
									phylite					
B. Shot Direction 66-26 to 65-8	1170	2200		9000	7.0	23.1		30.1		G-F				
	DDH depth 24'. Seismic depth (Avg.) 27.9'.													
DDH 65-8														
A. Shot Direction 65-8 south along road	1280	2800		8000	7.8	15.3		21.1	Horn-fels	G				
B. Shot Direction 65-8 north along road	1120			7500	15.8			15.8		G				
	DDH depth 15'. Seismic depth average 18.5'. Bedrock appears to dip north from DDH 65-8.													
DDH 66-8			V_3/V_4				d_3/d_4							
Shot Direction Downslope	1200	2300	4000/ 5200	9500	8.5	12.8	14.3/ 42.6	78.2	Meta-phylite	G	R1	2750	75.6	F-G
	DDH depth 86'. Seismic depth 78.2'. Bedrock slopes up from DDH 66-8.													
DDH 66-4														
Shot along base of trench	1300	2300	3900	9200	9.0	9.3	29.9	48.2	Hornfels	F				
	DDH depth 46'. Seismic depth 48.2'.													
DDH 66-35														
Shot Direction 66-35 to 66-18	1300	2200	6000	9800	8.3	21.3	24.1	53.7	Quartz-diorite	G	R1	2800	73	G
	Offset distance for reflection depth of 73 ft. is 70 ft. toward DDH 66-18, DDH depth 46'. Bedrock dips abruptly down from station 66-75 to 66-18.													

Faro No. 1 Zone Section No. 6

TABLE II - (cont'd)

Station	Refraction V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2(ft.)	d_3(ft.)	D_t(ft.)	Bedrock Surface	Record Quality	Event	Average Velocity	Z (ft.)	Record Quality
DDH 66-18 Shot Direction 66-18 to 66-35	1100	4800	6800	11,000	17.2	16.0	37.0	70.2	Quartz-shist	G	R1	3600	72	F
											R2	3300	106	F
											R3	4400	170	G
	DDH depth 112'. Bedrock dips abruptly up from station 66-18 to 66-18. Reflection shot west perpindicular to line. R_1 - possibly due to permafrost layer. R_2 - possible bedrock surface. R_3 - corresponds with top of ore zone.													
DDH 65-13 Shot Direction 65-13 to 66-14									Sericite shist		R1	2950	110	G
	DDH depth 106'. Reflection only.													

Faro No. 1 Zone Section No. 7

TABLE III

Station	Refraction: V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_4 ft/sec.	V_R ft/sec.	d_1(ft.)	d_2(ft.)	d_3 (ft.)	d_4(ft.)	D_t(ft.)	Bedrock Surface	Record Quality	Reflection: Event	Average Velocity	Z ft.	Record Quality
DDH 66-29 Shot Direction North of 66-29	1050	2500			9,000	7.2	15.2			22.4	Quart-zite Shist	F				
	DDH depth 18'. Seismic depth 22.4'. Considerable build up about drill site.															
DDH 66-23 Shot Along Cat Trail 20 ft. from Brook	1150	3000	5600		12,000	15.5	17.1	40.7		73.3	Graphitic Phylite	G-F	R1	2850	78.5	P
	DDH depth 78'. Seismic depth 73.3'. High V_R indicates shooting up dip supported by neg. slope by reflector.															
DDH 65-5A Shot N. Along Cat Road	1620	2600	4500		9,800	9.8	11.1	20.2		41.1	Hornfels	E				
	DDH depth 42'. Seismic depth 41.1.															
DDH 66-14 Shot E. Along Edge of Pit	1280	2350	4500	6500	12,000	9.0	11.8	17.3	37.1	75.2	Sericite Shist	F	R	2700	81.1	P
	DDH depth 82.0'. Seismic depth 75.2'. Determined from 2nd arrival interpret at 10N. Reflection interpretation strained.															
DDH 66-39 66-39 to 6614	1100	2300	4100	6200	10,500	6.1	9.6	12.6	27.3	54.6	?	E-G				
	DDH depth 58'. Seismic depth 54.6'.															
DDH 65-15 Shot W. Along Cat Road	1280	2230			8,700	8.6	36.3			44.9	Sericite Shist	G				
	DDH depth 45'. Seismic depth 44.9.															
Velocity Test Pit between Sec. 6 & Sec. 7	11,500	4000			9,000	4.0	14.5					G				
	1150 ft/sec. - top soil 4000 ft/sec. - corr. to highly weathered rock in pit. V_R - 9000 ft/sec. firm bedrock.															

Faro Area - G Anomaly
Line 96 + 00W
Refraction

TABLE IV

Station	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality
2+00N Shot Direction 2N to B_L	1050	3500		11,000	11.2	16.7		27.9	F
Shot Direction 2N to 4N	1250	3700		11,000	11.8	16.1		27.9	F
	Noise level high due to heavy equipment. Average Depth 27.9 ft.								
4+00N Shot Direction 4N to 2N	1050	3600		12,000	10.8	21.2		32.0	G
Shot Direction 4N to 6N	1250	3200		11,000	8.1	21.9		30.0	G
	Loose Rocks Near Surface. Average Depth 31.0 ft.								
6+00N Shot Direction 6N to 4N	1250	3700		9,500	8.8	20.4		29.2	F
Shot Direction 6N to 8N	1180	3600		11,000	6.0	22.0		28.0	G
	Average Depth 28.6 ft.								
8+00N Shot Direction 8N to 6N	1080	3500		11,000	8.0	20.0		28.0	G
Shot Direction 8N to 10N	1300	3200		11,000	8.5	18.3		26.8	F
	Average Depth 27.4 ft.								

Faro Area - G Anomaly
Line 96 + 00W
Refraction

TABLE IV - (cont'd)

Station	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality
10+00N Shot Direction 10N to 8N	1600	2700		11,000	3.0	17.0		20.0	F
Shot Direction 10N to 12N	1100	2500		10,000	3.0	20.0		23.0	G
	Average Depth 21.5 ft.								
12+00N Shot Direction 12N to 10N	1100	2700		10,000	6.5	20.0		26.5	G
Shot Direction 12N to 14N	1100	2900		9,000	9.0	21.8		30.8	F
	Average Depth 28.7 ft.								
14+00N Shot Direction 14N to 12N	1100	2400	3600	10,000	3.0	4.0	30.5	37.0	G
Shot Direction 14N to 16N	1100	2200	3500	10,000	7.5	9.0	24.4	40.9	G
	Average Depth 38.9 ft.								
16+00N Shot Direction 16N to 14N	1300	2400	4500	11,000	2.0	9.6	28.0	39.6	G
Shot Direction 16N to 18N	1000	2600	4400	10,000	2.8	9.5	23.3	35.6	G
	Average Depth 37.6 ft.								

Faro Area - G Anomaly
Line 96 + 00W
Refraction

TABLE IV - (cont'd)

Station	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality
18+00N									
Shot Direction 18N to 16N	1000	2800	4500	9,000	5.2	13.2	31.4	49.8	D
Shot Direction 18N to 20N	1080	2400	4200	10,500	4.2	12.5	29.8	46.5	G

Average Depth 48.2 ft.

Sea Grid L- 8 + 00E

TABLE V

Station	Refraction V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality	Reflection Event	Average Velocity	Z ft.	Record Quality
2 + 00N Shot Direction 2N to BL	980	3700	8300	14,000	7.0	16.6	22.5	46.1	G				
	Shot only one way.												
4 + 00N Shot Direction 4N to 2N	1070	3500	8000	13,500	10.0	23.3	23.4	56.7	G				
6 + 00N Shot Direction 6N to 4N	980	3900	8500	13,000	5.0	22.6	28.8	56.4	F				
Shot Direction 6N to 8N	1080	3700	8000	13,000	3.0	13.6	36.6	53.2	F				
	Average seismic depth 54.8 ft.												
8 + 00N Shot Direction 8N to 6N	1200	3700	8000	13,000	7.0	19.1	25.1	51.2	F-P	R1	3800	53.2	F
Shot Direction 8N to 10N	1050	3500	8000	14,000	6.8	17.0	30.7	54.5	F-P				
	Average seismic depth 52.7 ft.												
10 + 00N Shot Direction 10N to 8N	1180	4300	7000	12,000	10.0	18.1	28.0	56.7	P				
Shot Direction 10N to 12N	1200	4600	8000	14,000	12.0	22.5	24.7	58.2	F				
	2nd arrival interpretation for 10N to 8N. Average seismic depth 57.5 ft.												
12 + 00N Shot Direction 12N to 10N	1140	4500	8000	14,000	7.0	25.0	26.3	58.3	F				
Shot Direction 12N to 14N	1020	3800	8500	13,500	7.0	23.3	23.0	53.3	F-G				
	Average seismic depth 55.8 ft. 2nd arrival interpretation for 12N to 10N.												

Sea Grid L-8 + 00E

TABLE V - (cont'd)

Station	Refraction V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality	Event	Average Velocity	Z ft.	Record Quality
14 + 00N													
Shot Direction 14N to 12N	1180	3500	7800	13,000	5.8	22.8	27.8	56.4	F				
Shot Direction 14N to 16N	1280	3500	8000	14,000	6.2	20.9	27.9	55.0	G				
	Average seismic depth 55.7 ft.												
DDH Calibrate													
16N													
140' E of station 9 + 40W	1100	3700	8000	14,000	10	11.8	36.2	58	G	R1	3300	61	G
Line 8 + 00E	DH did not reach bedrock total length approximately 48.0'.												
Velocity Test													
0 + 00 Line 59 + 00E				13,000					P				
	VR of 13,000 ft/sec. used as guide for determining bedrock arrivals.												

Seagrid L-16 + 00E

TABLE VI

Station	Refraction V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality	Reflection Event	Average Velocity	Z (ft.)	Record Quality
4 + 00N Shot Direction 4N to 1N	1230	3500	8000	-	4.5	20.0			G-P	R2	3100	111	F
	Used reflection method as energy from hammer was not sufficient past 160 ft.												
6 + 00N Shot Direction 6N to 3N	1120	5500	8000	14,000	6.0	31.7	57.8	95.5	G				
	Seismic Depth 95.5 ft.												
8 + 00N Shot Direction 8N to 5N	1160	3600	7000	13,000	6.3	27.7	56.7	90.7	G-F				
Shot Direction 8N to 11N	1380	4100	7700	13,500	7.0	31.9	44.0	82.9	F	R1	2550	82.6	G
	Average seismic depth 86.8 ft. Evidence of Interference due to permafrost.												
10 + 00N Shot Direction 10N to 13N	1350	3500	8000	13,000	11.1	22.8	38.5	72.4	G				
	Seismic depth 72.4 ft. Interference due to permafrost present.												
12 + 00N Shot Direction 12N to 15N	1350	4000	7000	13,000	5.3	24.9	54.4	84.6	G				
	Seismic depth 84.6 ft.												
14 + 00N Shot Direction 14N to 17N	1140	4000	7000	13,000	3.2	14.0	56.5	73.7	G				
	Seismic depth 73.7 ft.												

Valley Profile

TABLE VII

Refraction

Section	V_1 ft/sec.	V_2 ft/sec.	V_3 ft/sec.	V_R ft/sec.	d_1 (ft.)	d_2 (ft.)	d_3 (ft.)	D_t (ft.)	Record Quality
A - B Shot Direction	2500	4400	6500	10,500	19.0	16.1	42.7	77.8	F
Shot Direction B to A	2300	4500	6500	12,500	4.0	40.9	72.6	117.5	F
	Station A near water well (W.W.) No. 1								
C - D Shot Direction C to D	970	5000	6500	14,000	2.0	31.5	92.5	136	F-G
Shot Direction D to C	1880	3600	6500	9,500	8.0	12.8	32.5	53.3	F-G
	Station C near water well No. 2 and No. 3. See location map.								
E-F Shot Direction E to F	3200	5500		14,000	17.0	52.3		69.3	G
Shot Direction F to E	3300			16,000	6.0			6.0	F
	Station E near water well No. 4, see location map. Permafrost evident near surface.								