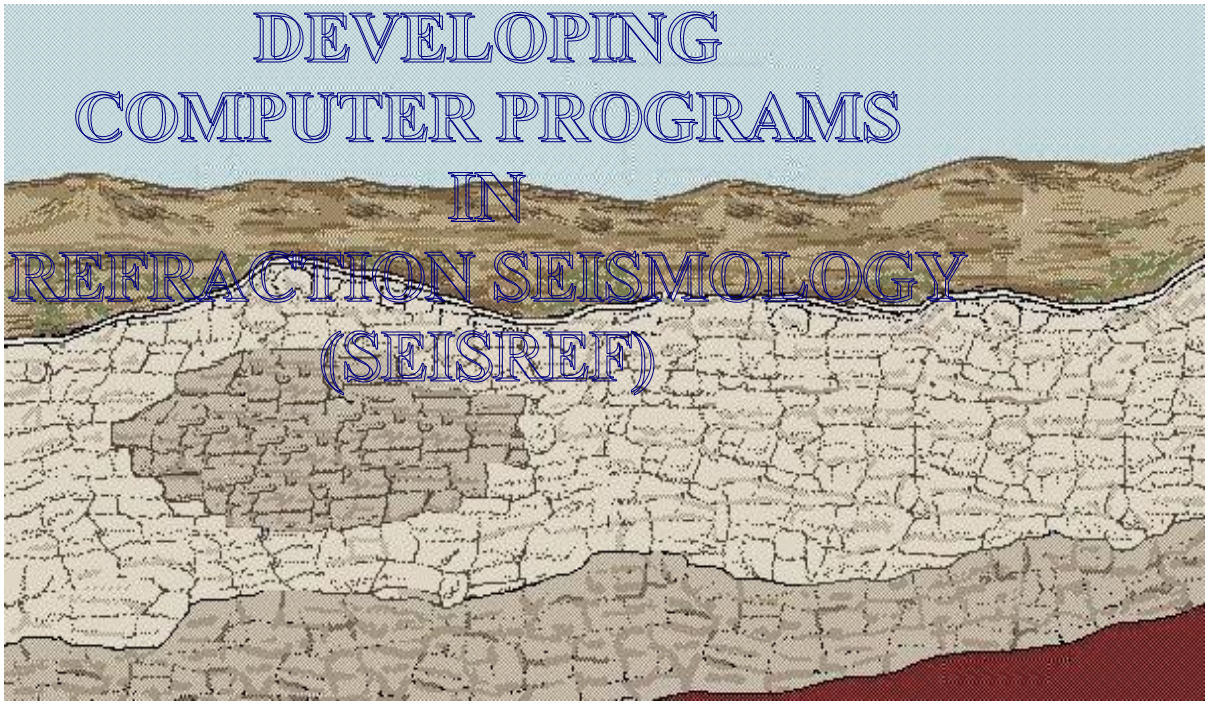
ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
FACULTY OF SCIENCE
DEPARTMENT OF EARTH SCIENCE



A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES OF ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN GEOPHYSICS

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Dedicated

To

My grand mother Imuhay Azanash Haile

***For your concern and sacrifices through out my education and life*.**

TABLE OF CONTENTS

ACKNOWLEDGMENT.....I

TABLE OF CONTENTS.....IV

LIST OF FIGURES.....V

ABSTRACT.....1

1. INTRODUCTION.....2

1.1 PREVIOUS WORKS.....3
1.2 AIM OF THE PRESENT STUDY.....3
1.3 METHODOLOGY.....3
2. BASICS OF THE METHODS USED IN THIS WORK.....4

2.1 SEISMIC WAVES.....4
2.1.1 BASIC PROPERTIES OF SEISMIC WAVES PROPAGATION.....4
2.1.2 THE LAW AND PRINCIPLES OF SEISMIC WAVES.....5
2.2 THE GENERALIZED RECIPROCAL METHOD (GRM).....7
2.3 INTERPRETATION BY GENERALIZED RECIPROCAL METHOD.....8
2.3.1 OPTIMUM XY VALUE.....9
2.3.2 THE VELOCITY ANALYSIS FUNCTION (TV).....11
2.3.3 THE TIME-DEPTH ANALYSIS FUNCTION (TG).....13
3. VISUAL BASIC (VB).....15

3.1 HISTORICAL BACKGROUND OF VISUAL BASIC PROGRAMMING LANGUAGE 15
3.2 SIGNIFICANT LANGUAGE FEATURES.....17
3.3 AREAS OF APPLICATION.....17
3.4 WHERE VISUAL BASIC CAN BE USED.....18
3.5 FEATURES OF VISUAL BASIC.....19
4. SEISMIC REFRACTION SOFTWARE (SEISREF).....20

4.1 INTRODUCTION.....20
4.2 SYNTHETIC AND REAL DATA.....20
4.2.1 FAULT MODEL.....21
4.2.2 IRREGULAR REFRACTOR MODEL.....25
4.2.3 REAL DATA.....30
5. RESULTS.....37

6. CONCLUSIONS.....38

REFERENCES.....39

APPENDICES.....40

LIST OF FIGURES

FIGURE 1: DIAGRAM SHOWING HOW SEISMIC WAVES REFRACT AT INTERFACE..... 5
FIGURE 2: CRITICALLY REFRACTED WAVE ON HORIZONTAL SMOOTH REFRACTOR..... 6
FIGURE 3: DIAGRAM SHOWING PARAMETERS USED IN GRM.....9
FIGURE 4: FAULT MODEL..... 21
FIGURE 5: IRREGULAR REFRACTOR MODEL.....25

ABSTRACT

Refraction seismic presents an integrated and practical approach which unifies interpretation theory which is suitable for the development of modern exploration technique. The generalized reciprocal method (GRM), one of the seismic refraction methods, provides a technique to accommodate irregular refractor.

Seismic refraction software is developed using Visual Basic (VB) which is one of the user friendly programming languages. That is consistent user friendly interface and the fastest and the easiest way to create applications for Microsoft windows®.

The developed software (SEISREF) aims on implementing the features of the generalized reciprocal method (GRM) and was tested using both synthetic and real data and it proved to be very good and functional.

1. INTRODUCTION

Refraction seismic presents an integrated and practical approach which unifies interpretation theory which is suitable for the development of modern exploration technique. Particularly it is valuable for reconnaissance in areas with practically unknown subsurface geology.

The generalized reciprocal method (GRM), one of the refraction seismic methods, is a technique for delineating undulating refractors at any depth from in-line seismic refraction data consisting of forward and reverse travel-times. The travel-times at two geophones, separated by a variable distance *XY*, are used in refractor velocity analysis and time-depth computations.

Visual basic (VB) is one of the user friendly programming languages and an event deriving. It is the fastest and easiest way to create applications for Microsoft windows®. Windows based application has a consistent user interface, which helps the user to simply “point and click”. This means that all windows application provides a picture, an “icon” or a button for a function. The user will point at the picture with a mouse and click. The computer simply jump up to perform (or some time declines) the task.

In this work the seismic refraction software (SEISREF) is developed using visual basic (VB) on one of the high level programming language based on the generalized reciprocal method (GRM).

The SEISREF targeted on implementing the features of the generalized reciprocal method (GRM), was tested by implementing two synthetic and one additional real data and it proved to be very good and functional.

1.1 PREVIOUS WORKS

To the outers knowledge no previous work has been done by the department or any organization with in the country. However lots of seismic refraction software has been developed outside Ethiopia and are available in the market. For example, GREMIX from Interpex limited.

1.2 AIM OF THE PRESENT STUDY

The major objectives of this work includes:-

1. To develop software on the generalized reciprocal method of refraction seismology. Examine its functionality using synthetic and real data. The developed software can be used by local exploration companies that cannot afford to buy from the market at an expensive price. The software can also be used as a teaching aid in the department of earth science.

1.3 METHODOLOGY

Using a higher programming language, Visual basic serves as the tool for writing the codes and developing the software.

The SEISREF goes through testing all the application and features of the generalized reciprocal method by applying synthetic and real data. In addition to that, the total procedure of the software well explained on the User's manual.

2. BASICS OF THE METHODS USED IN THIS WORK

2.1 SEISMIC WAVES

Seismic waves are messengers that convoy information about the earth's interior. Basically, these waves test the extent to which earth materials can be stretched or squeezed some what as you can squeeze a sponge. They cause the particles of the material to vibrate, which means that these particles temporarily stretched out of position as they move back and forth. The capacity of material to be temporarily deformed by passing seismic waves can be described by its property of elasticity. These physical properties can be used to distinguish different materials. They influence the speed of the seismic waves through those materials.

Seismic sources may be natural, for example earthquake, or artificial, for example explosives. The seismic waves generated travel down into the earth and are reflected and refracted back to the surface from geological interfaces in the earth. The seismic instruments record the resulting seismic waves as they reach the surface of the earth.

2.1.1 BASIC PROPERTIES OF SEISMIC WAVES PROPAGATION

Depending on their depth of propagation seismic waves is divided as body waves and surface waves. As their name implies, the former one can travel directly through a mass of some substance in any direction, and the latter can travel only near the surface of such a mass, or close to the border between two different substances. Body waves are further subdivided into two namely P and S waves while surface waves are divided into Raleigh and Love waves.

Seismic elastic wave is a form of energy, which travels through a medium depending on its elastic property. It is by vibrating the particle of the medium that seismic waves travel inside the earth. Energy could be released from a controlled source which could be a mere smite of the surface by hammer or through the detonation of explosives inside borehole.

P (primary)-waves, which are the most important waves in exploration seismology, also known as compression/longitudinal waves; travel by vibrating the particles of the medium in the direction of their propagation. Their names are typical of their behavior for the particles are vibrated in a continuous rarefaction and compression and they are the first arrival on the seismographs.

S (secondary)-waves are also named as shear/transversal waves; travel by vibrating particles of the medium in the direction that is perpendicular, or transverse, to their direction of propagation. As their name implies S-waves arrive on the receivers after P-waves.

2.1.2 THE LAW AND PRINCIPLES OF SEISMIC WAVES

While they travel through the earth seismic waves follow the following natural laws.
Snell's law states, "The direction of the reflected and refracted waves traveling away from a boundary depends on the direction of the incident wave and the speed of the waves". It governs the direction of reflected and refracted waves produced by an incident waves.

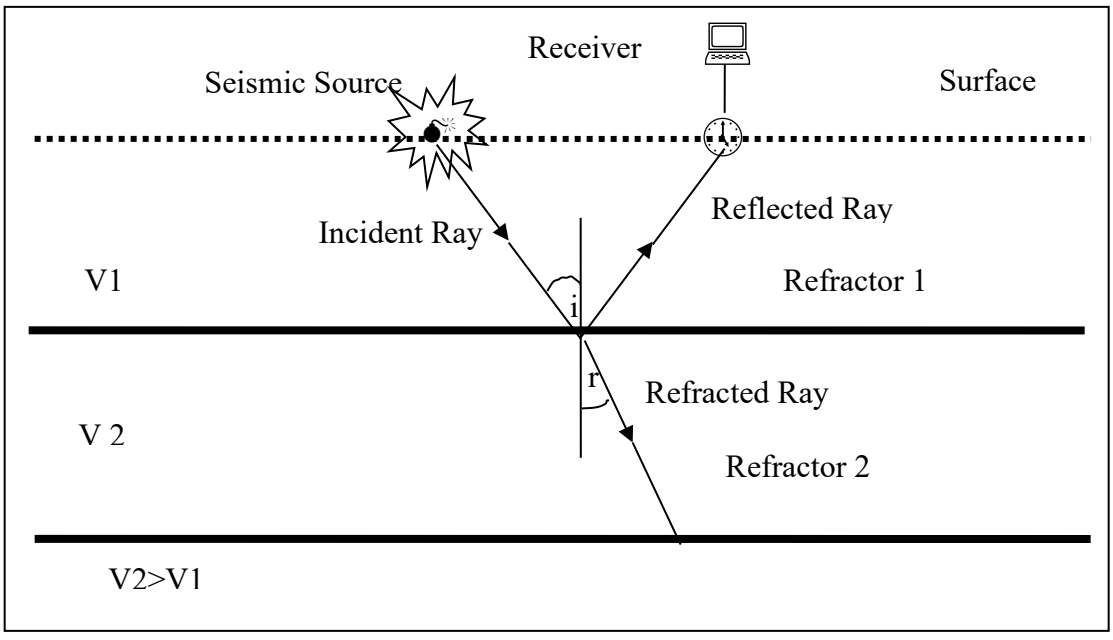

Figure 1: Diagram showing how seismic waves refract at interface

$V_1/V_2 = \sin i / \sin r$.....1

Where, V_1 is the speed of the wave in the first medium; and

V_2 is the speed of the wave in the second medium

Equation 1 is known as the Snell's law

When the angle of incidence reaches a particular value, known as the critical angle the angle of refraction becomes 90^0. The refracted wave travels along the boundary of the lower medium, whose speed of propagation is greater than that of the over lying medium, (i.e. $V_2 > V_1$). The material at the interface is subjected to an oscillating stress from the passage of the refracted wave, which in turn generates the upward moving waves, known as head waves, which may eventually reaches the surface.

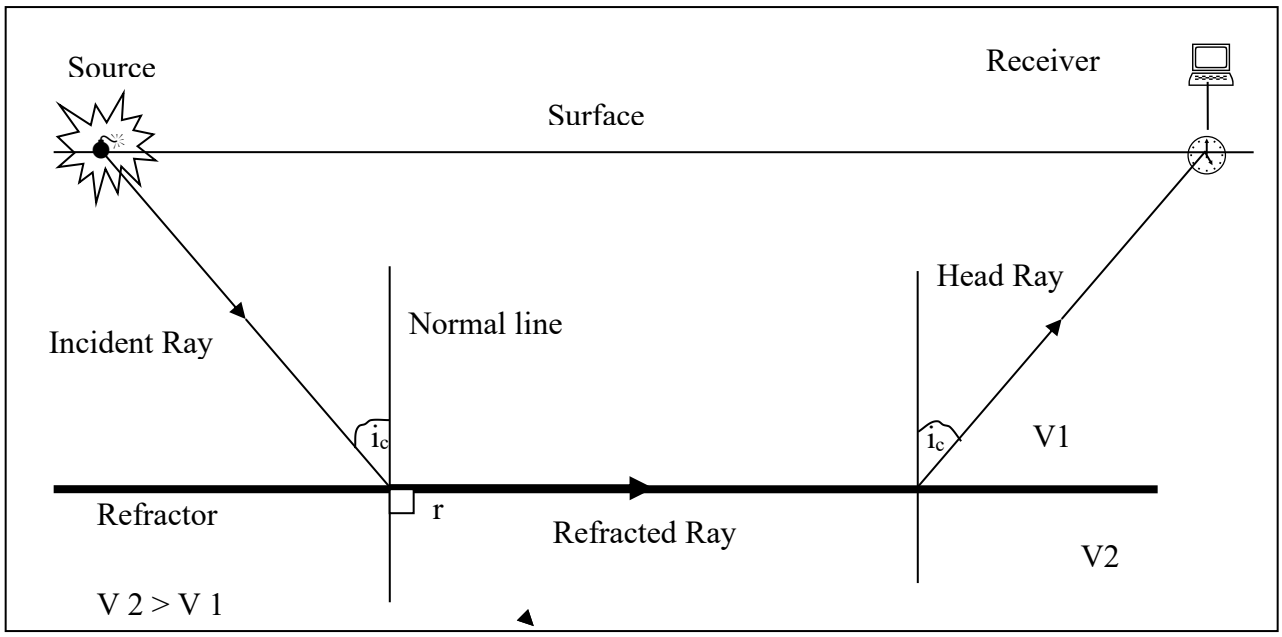

Figure 2: critically refracted wave on horizontal smooth refractor

Fig. 2 shows that at critical angle of incidence, the wave is "critically refracted". Hence Snell's law becomes:

$\sin i_c = V_1 / V_2$.....2

It is worth nothing from equation 1 the following three points

a) If $V_1 = V_2 \rightarrow i = r$, then there is no refraction.
b) If $V_1 > V_2 \rightarrow i > r$, then there is no way one can record the refracted waves.
c) If $V_1 < V_2 \rightarrow i < r$, then the refracted waves go up to the surface.

Huygens's principle states "every point in the wave front is a source of new waves that travel away from it in all direction". That is critically refracted waves is made of infinite amount of point explosions, which simulate infinite amount of explosions inside the earth. Hence energy from within the earth is again released and reaches the surface to be recorded.

2.2 THE GENERALIZED RECIPROCAL METHOD (GRM)

The generalized reciprocal method (GRM) is a technique for delineating undulating refractors at any depth from in-line seismic refraction data consisting of forward and reverse travel-times. The travel-times at two geophones, separated by a variable distance *XY*, are used in refractor velocity analysis and time-depth calculations. At the optimum *XY* spacing, the upward traveling segments of the rays to each geophone emerge from near the same point on the refractor. This results in the refractor velocity analysis being the simplest and the time-depths showing the most detail. In contrast, the conventional reciprocal method which has *XY* equal to zero is especially prone to produce numerous fictitious refractor velocity changes, as well as producing gross smoothing of irregular refractor topography. The depth conversion factor is relatively insensitive to dip angles up to about 20 degrees, because both forward and reverse data are used. As a result, depth calculations to an undulating refractor are particularly convenient even when the overlying strata have velocity gradients. The GRM provides a means of recognizing and accommodating undetected layers, provided an optimum *XY* value can be recovered from the travel-time data, the refractor velocity analysis, and/or the time-depths. The presence of undetected layers can be inferred when the observed

optimum *XY* value differs from the *XY* value calculated from the computed depth section. The undetected layers can be accommodated by using an average velocity based on the optimum *XY* value. This average velocity permits accurate depth calculations with commonly encountered velocity contrasts (Palmer 1980).

A principal difference of the GRM compared with the plus-minus or ABC method is that the critically refracted rays emerge at or very near the same point on the refractor, thereby removing the smoothing problem. They arrive at two different geophone locations separated by a distance *XY.*

Two functions are computed within the generalized reciprocal method: the velocity analysis function (t_V) and the time-depth function (t_G). The latter is determined with respect to a position “G” at the mid point between the points of emergence at the surface of forward and reverse rays at X and Y, respectively. Both functions are expressed in units of time.

2.3 INTERPRETATION BY GENERALIZED RECIPROCAL METHOD

The generalized reciprocal method (GRM) developed by Palmer (1980, 1981) is a flexible and powerful method of seismic refraction interpretation that is well-suited to irregular refractor configuration and lateral changes in refractor velocity. The GRM centers on the key aspect that a geophone spacing, termed the XY spacing, can be found whereby up going rays from forward and reverse shot depart from the same point on a refractor. Once this spacing is found, it is theoretically possible to map refracting surfaces accurately and to determine an average velocity for the layers overlaying the refractor. The average velocity allows depth to the refractor to be calculated; irrespective of whether undefined velocity inversion or hidden layers are present.

General criteria for selecting the GRM technique are

1. Only a few targets at shallow depth (<50m) are of interest
2. Lateral velocity and dip changes are expected or they are the object of interest.

The method essentially uses a pair of detector position on the survey line where the forward and reverse rays leaving the refractor at approximately the same point (D. in fig.3) arrive at the detector positions, such as X and Y.

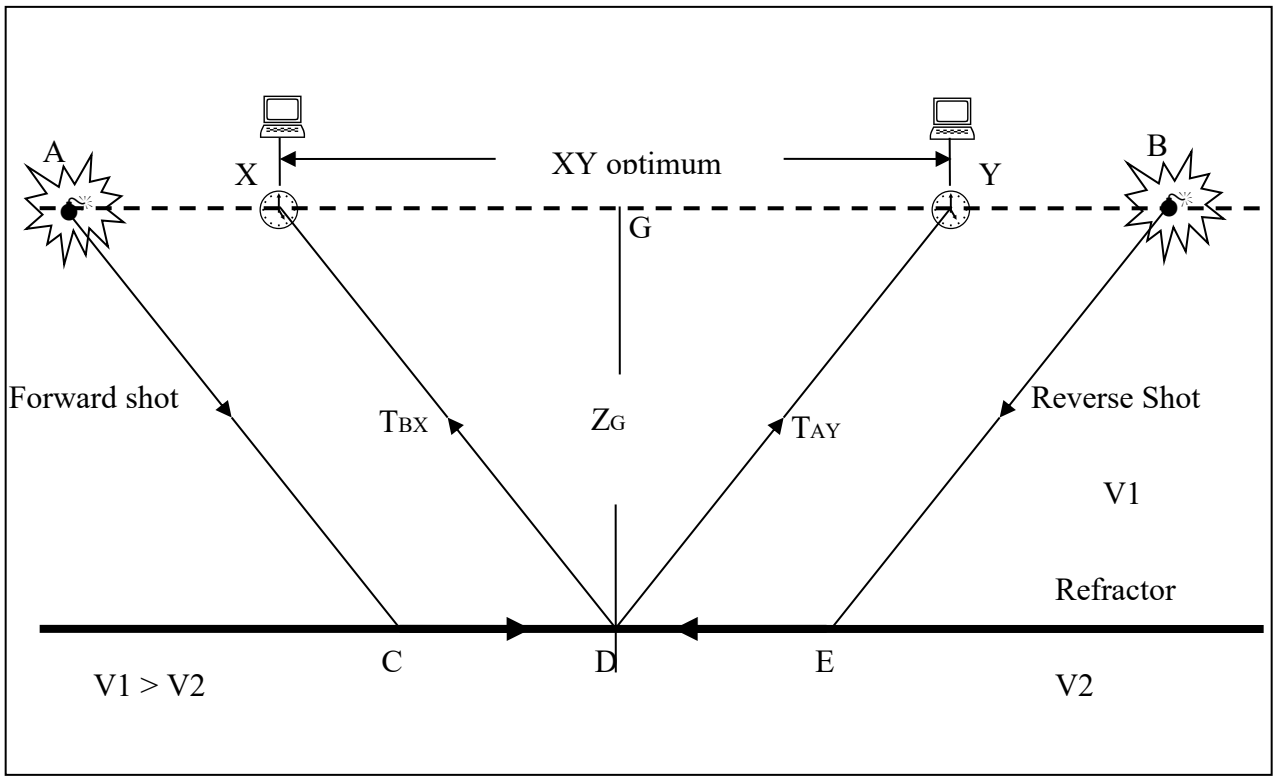

Figure 3: Diagram showing parameters used in GRM

The GRM provides a means of recognizing and accommodating undetected layers through the two basic approaches of computing and observing the optimum XY values. There are two distinct approaches for the determination of the optimum XY value, which is probably the most difficult, and the most important aspect of the GRM.

a) Direct calculation of XY values
b) Observation of XY values

2.3.1 OPTIMUM XY VALUE

The optimum *XY* value distance is defined (palmers, 1980) as the separation between a geophone in a forward-direction experiment and a geophone in a reverse-direction experiment such that the same point on the refractor.

The correct value for *XY* distance is necessary for props time- to- depth migration of the data. The optimum *XY* parameter can be obtained and monitored as it changed along a survey line through two more or less independent methods, i.e. evaluation of the velocity-analysis function and the time-depth function on *XY* is varied.

Analysis of the optimum *XY* value by using the above method is a quality-control feature of the GRM that has no analog in other refraction interpretation schemes. As palmers (1980) states “If the *XY* values agree, ever though the thicknesses and velocities of intermediate layers may be in error”

If the interpreter works from the surface downward and if the optimum *XY* analysis is favorable for each layer, the conclusion is that every layer has in fact been detected is valid.

If the optimum *XY* values do not agree, a hidden layer is probably present. However, in addition to indicating that a hidden-layer problem has been encountered, the comparison of the optimum *XY* values allows the nature of the hidden-layer problem to be exposed. The example above shows the case in which the calculated optimum *XY* is greater than the observed value, a situation which always occurs in the velocity-inversion case. Knowing that the hidden layer is caused by a velocity inversion, the interpreter knows that the correct depth to the refractor is less than the calculated.

On the other hand, if the calculated optimum *XY* is less than the observed optimum *XY*, the hidden layer is known to be too thin to give to first arrivals (thin layer problems). In this case, the calculated depth is too small.

In addition to its strength in quantifying lateral changes in depth to and velocity along refractors in non-hidden-layer cases, the GRM’s ability to indicate that a hidden layer has been encountered and the probable nature of that hidden layer invites its routine use in shallow- target studies. However, the GRM is also able to go beyond a qualitative assessment of the nature of hidden layer and to give the correct depth to horizons

below the hidden layer if good control on optimum *XY* value for the target refractor is available.

The optimum *XY* parameter in the generalized reciprocal method (GRM) of processing refraction seismic data is sufficient as a quality control factor in refraction data interpretation.

2.3.1.1 XY-VALUE: - DIRECT CALCULATION

We can directly calculate the optimum XY from the seismic velocities and thickness of the layers using the formula

$$XY_{optimum} = 2\sum_{j=1}^{n-1} Z_{jG} \tan i_{jn}$$

Where, $i_{jn} = \sin^{-1}(V_j/V_n)$

n = the total number of layers

Hence an optimum XY value can be calculated for any seismic velocity versus depth section.

2.3.1.2 XY-VALUE: - OBSERVATION

We can directly selecting the optimum XY by observing from the Velocity Analysis Function curves and Time-Depth curves.

2.3.2 THE VELOCITY ANALYSIS FUNCTION (Tv)

Following Palmer (1980) the velocity analysis function, T_V, used in GRM in interpretation is calculated through the equation

$$T_V(_{AG}, _{XY}) = (T_{AY} - T_{BX} + T_{AB})/ 2 \quad \text{.....3}$$

Where the terms on the right - hand side are travel – times along the path of critical refraction from one point to another as indicated by the subscripts. The time T_{AB} (or T_{BA}) is refracted to as the reciprocal time between the pair of shots at A and B.

Although the application of equation (1) is quite straight forward, the determination of the refractor velocity(s) with equation (4) the reciprocal of the slope is subject to considerable personal judgment.
The seismic velocity in the refractor Vn, is the reciprocal of the gradient, as equation (4)

$dt(V) / dx = 1 / Vn = Slope$ 4

If the distance *XY* is optimum, C and D coincide with E. (fig.3). Each Tv value is referred to the G position, midway between x and y.

A velocity analysis curve is generated from equation (3) by selecting an *XY* values and varying AG to give a set of Tv values. Additional curves are made for other *XY* values. The proper curve to use is the one that is smoothest with the least amount of irregularity.

The slope of the velocity analysis curve for any position along the line is approximately equal to the reciprocal of the refractor velocity, V_2, at that position. Thus, the velocity of the refractor can be determined continuously along the line and lateral velocity changes can be readily identified.

Once the optimum *XY* distance for a target refractor is chosen, an average velocity from the surface to the refractor may be calculated from Palmer's (1981) equation.

$$V_{average} = [V'^2_2 \, XY / (XY + 2T_G \, V')]^{1/2} \quad \text{.....5}$$

2.3.3 THE TIME-DEPTH ANALYSIS FUNCTION (TG)

The generalized time-depth function is given by

$T_G\ (_{AG},\ _{XY}) = [T_{AY}+T_{Bx} - (T_{AB} + XY/V')] / 2$……6

Where V' is the apparent velocity in the refractor determined at each G position during the velocity analysis stage.

In a multilayer case (total numbers n>2), the depth (h_{rf}). To the principal refractor can be calculated using the average velocity with out defining every layer about the refractor (h_1, h_2… h_{n-1}).

a) Two Layer Case

$Z_1 = (0.5)\ t_{G1}$ DCF ……7

Where: - Z_1 is the depth to the second layer

DCF is the depth conversion factor and

$DCF = V_2\ V_1 / (V_2^2 – V_1^2)^{1/2}$

Where: - t_{G1} = is the optimum value for second layer

V_1 = the velocity of the first layer

V_2 = the velocity of the second layer

$Z_1 = (0.5)\ t_{G1}\ V_2V_1 / (V2^2 – V1^2)^{1/2}$……..8

b) Three Layer Case

$Z_2 = (0.5)\ t_{G2}$ DCF……9

DCF is the depth conversion factor and for three layers case will be

$$Z_2 = (0.5)\, t_{G2}\, V_2V_3 / 2(V3^2 - V2^2)^{1/2} - Z_1V_2\, (V_3^2 - V_1^2)^{1/2} / V_1\, (V_3^2 - V_2^2)^{1/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots 10$$

Where: - Z_2 = is the depth of the third layer

t_{G2} = is the optimum value of the third layer

V_1 = the velocity of the first layer

V_2 = the velocity of the second layer

V_3 = the velocity of the third layer

The construction of t_G curves is useful to confirm the optimum *XY* value (*XY* opt); Palmer's criterion is that the curve defining *XY* opt is the one that shows the maximum detail (opposite to the minimum detail criterion used in the velocity analysis case).

The t_G curve gives the shape of the refracting horizon in time. The optimum *XY* and reciprocal time are crucial parameters interpretation process. The geophone spacing must be as short as possible to give the greater resolution of *XY*. A palmer recommends a geophone spacing approximately one-third of the optimum *XY* value.

GRM field surveys are typically run using five shots per spread: one center shot, one shot at each end of the spread, and one shot offset well beyond the end of each spread.

3. VISUAL BASIC (VB)

3.1 HISTORICAL BACKGROUND OF VISUAL BASIC PROGRAMMING LANGUAGE

Microsoft released Visual Basic in 1987. It was the first visual development tool from Microsoft, and it was to compete with C, C++, Pascal and other well-known programming languages. From the start, Visual Basic wasn't a hit. It wasn't until release 2.0 in 1991 that people really discovered the potential of the language, and with release 3.0 it had become the fastest-growing programming language on the market.

Visual Basic is an event driven programming language. The “Visual” part refers to the method used to create the graphical user interface (GUI). Rather than writing numerous lines of code to describe the appearance and location of interface elements, you simply drag and drop pre-built objects into place on the screen.

The advantage of such an approach was that there were fewer bugs and lesser surprises. Building prototypes became very easy. Once the interface was developed, the programmers had to fill in the relevant functions, and collect the check. (It’s almost as simple as that.)

It is considered “the fastest and easiest way to create applications for Microsoft Windows (r)”. Whether you are an experienced professional or brand new to Windows programming, Visual Basic (VB) provides you with a complete set of tools to simplify rapid application development (RAD).

Windows based application has a consistent user interface, which helps the user to simply ‘Point and Click’. Like a kid in a candy store who does not know the name of the toffee. He merely points it and the parent will buy it for him. This means that all Windows application provides a picture (or an ‘icon’ as the jargon goes) or a button for a function. The user will point at that picture with a mouse and click. And Lo behold! The computer simply jumps up to perform (or sometime declines) the task.

Visual Basic is an ideal medium for developing Windows based application. Before the advent of Visual Basic, programmers grappled with “c” code and tons of documentation to come up with a good interface. You could spot a Windows programmer just by looking at the lost expressions of his face and a receding hairline.

The “Basic” part refers to the BASIC language, a language used by more programmers than and other language in the history of computing. Visual Basic has evolved from the original BASIC language and now contains several hundred statements, functions, and keywords, many of which relate directly to the Windows GUI*. Visual Basic allows professionals to accomplish anything that can be accomplished using and other Windows programming language.

Note: The Visual Basic programming language is to Visual Basic. The Visual Basic programming system, Applications Edition included in Microsoft Excel, Microsoft Access, and many other Windows applications uses the same language. The Visual Basic programming system, Scripting Edition (VBScript) for Internet programming is a subset of the Visual Basic language. The investment you make in learning Visual Basic will carry over to these other areas

Programmers have undergone a major change in many years of programming various machines. For example what could be created in minutes with Visual Basic could take days in other languages such: as "C" or "Pascal". Visual Basic provides many interesting sets of tools to aid you in building exciting applications. Visual Basic provides these tools to make your life far easier because all the real hard code is already written for you.

With controls you can create many applications which use certain parts of windows. With this sort of operation in mind, simple programs would take very little code. Why does it like the poor old "C" programmer who would have to write code to even display a window on the screen, when Visual Basic already has this part written for you?

Even though people tend to say Visual Basic's compiler is far behind the compilers of Pascal and C, it has earned itself the status of a professional programming language,

and has almost freed BASIC of the reputation of a children's language. Overall, you would class Visual Basic as a Graphics User Interface (GUI). As you draw, you write for the program. This must always be remembered in any kind of creation of a Visual Basic program. All in all, VB is the preferred language of many future programmers. If you want to start programming Windows, and don't know *how* to start, give Visual Basic a shot.

3.2 Significant Language Features

Visual Basic is not only a programming language, but also a complete graphical development environment. This environment allows users with little programming experience to quickly develop useful Microsoft Windows applications which have the ability to use OLE (Object Linking and Embedding) objects, such as an Excel spreadsheet. Visual Basic also has the ability to develop programs that can be used as a front end application to a database system, serving as the user interface which collects user input and displays formatted output in a more appealing and useful form than many SQL versions are capable of.

Visual Basic's main selling point is the ease with which it allows the user to create nice looking, graphical programs with little coding by the programmer, unlike many other languages that may take hundreds of lines of programmer keyed code. As the programmer works in the graphical environment, much of the program code is automatically generated by the Visual Basic program.

3.3 Areas of Application

The term "*Personal Programming*" refers to the idea that, wherever you work, whatever you do, you can expand your computer's usefulness by writing applications to use in your own job. Personal Programming is what Visual Basic is all about.

Using Visual Basic's tools, you quickly translate an abstract idea into a program design you can actually see on the screen. VB encourages you to experiment, revise, correct,

and network your design until the new project meets your requirements. However, most of all, it inspires your imagination and creativity.

Visual Basic is ideal for developing applications that run in the new Windows 95 operating system. VB presents a 3-step approach for creating programs:

1. Design the appearance of your application.
2. Assign property settings to the objects of your program.
3. Write the code to direct specific tasks at runtime.

Visual Basic can be used in a number of different areas, for example:

- Education
- Research
- Medicine
- Business
- Commerce
- Marketing and Sales
- Accounting
- Consulting
- Law
- Science

3.4 Where Visual Basic can be used

1. To create a small utility for yourself,
2. An application for a department, work group, a large enterprise-wide system,
3. Distributed applications spanning the globe via the Internet.

Visual Basic has all the tools you need. Beside there are a number of third party developers who offer utilities for almost any thing under the sun. Buy these utilize and use them in your program.

3.5 Features of Visual Basic

Data access features allow you to create databases and front-end applications for most popular database formats, including Microsoft SQL Server and other enterprise-level database.

Active X(TM) technologies allow you to use the functionality provided by other applications, such as Microsoft Word, Microsoft Excel spreadsheet, and other Windows applications. You can even automate application and objects created using the professional or Enterprise editions of Visual Basic.

Internet capabilities make it easy to provide access to documents and applications across the Internet from within your application. (Active X Documents).

Your finished application is a true .exe file that uses a run-time dynamic-link library (DLL) that you can freely distribute. (Application Setup Wizard)

The Visual Basic Philosophy

Windows became popular because of its easy and intuitive GUI or Graphical User Interface. Visual Basic helps create application that will have the same GUI as Windows. This makes it very easy for users to learn how to use the software. The Windows GUI is event driven. You have seen that unless the user initiates an action nothing happens. You have to click a button for something to happen.

4. SEISMIC REFRACTION SOFTWARE (SEISREF)

4.1 INTRODUCTION

The seismic refraction software (SEISREF) developed using the visual basic (VB) programming languages and it is based on the generalized reciprocal method (GRM). Its functionality was tested using two synthetic and one real data. And all the obtained results and the data are given in the appendices and this part.

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4.2 SYNTHETIC AND REAL DATA

The main objectives of this work are developing the software and showing its functionality. SEISREF tested using two synthetic and one real data. The models used to produce the synthetic data are:-

a. Fault model

b. Irregular refractor model

For each model the following out puts are produced:

- Travel-time curves
- Velocity analysis function data / curves
- Time-depth function data / curves
- Interpreted depth section data / curves

4.2.1 FAULT MODEL

1. The model is given below:

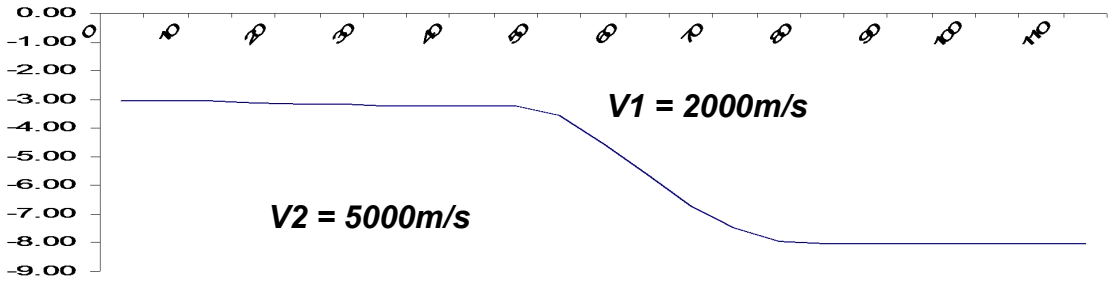

Figure 4: Fault model

The travel time data computed from the model is given in the appendices (refer Project IdNo: Synthetic 2). All the results of the SEISREF based on this data are attached with.

4.2.2 IRREGULAR REFRACTOR MODEL

The irregular refractor model is:-

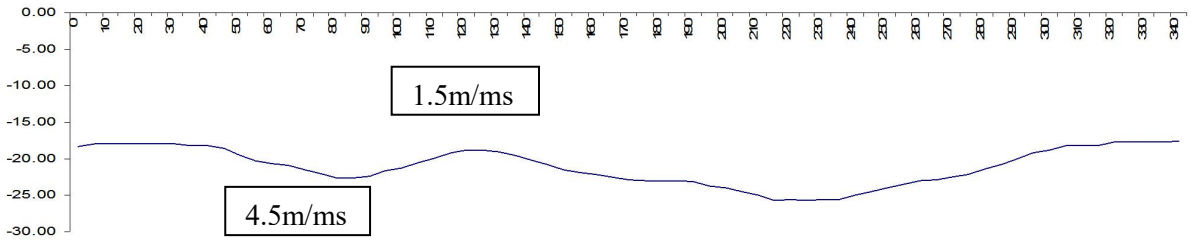

Figure 5: Irregular refractor model

The travel-time computed from the model is given in the appendices (refer Project IdNo: Synthetic 1). All the results of the SEISREF based on this data are attached with.

4.2.3 REAL DATA

The travel time data from all shots listed in appendices (refer Project Id No: Real Data). All the results of the SEISREF based on this data are attached with.

5. RESULTS

The SEISREF software tested out using two synthetic and one real data for both two and three layers. It is found out that

1. The Database sheets have been found storing and executing the collected data efficiently.
2. Every command buttons, option boxes and Text boxes are functional.
3. The Travel-Time curves, the phantomed or extrapolated curves, the Velocity analysis function curves and Time-Depth function curves are plotted correctly. Moreover, their color arrangements are easily identifiable.
4. The technique of extrapolating and assigning of the layers are functional with out any problem.
5. The graphs color and value are given adjacently.
6. The print and print preview capabilities are very clear, easy, attractive and functional with the suitable color arrangements.
7. The 2D Interpreted Depth section is accurate, very clear and readable.
8. All types of buttons are easily understandable and functional according to their sequence of execution.
9. In general the results obtained by the software using the synthetic data are of good accuracy.
10. All the steps and results are easily manageable and understandable with the aid of user's manual.

6. CONCLUSIONS

Had there been more time, the general picture of the study and its final out come could have been all the more gratifying.

Nonetheless, it should also be understood that many of the actual situations and problems discovered in this study are relevant to any types of refractor and depth. Hence, the following conclusions could be drawn based on insights and information obtained from the results of the SEISREF software.

1. The developed software performs more or less the expected duties and functions of the generalized reciprocal method.
2. The developed software can serve as a teaching aid to the Exploration Geophysics graduate students particularly on generalized reciprocal method.

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APPENDICES