1 of 1

**Deep Seismic Survey Extending from
Western Washington to Mist Gas Field, Oregon**

Final Report

D.D. Hollis

October 1992

Work Performed Under Contract No.: DE-AC21-88MC24155

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Geophysical Systems Corporation
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Abstract

Between October 1988 and September 1990, approximately 217 kilometers of vibroseis seismic reflection data was collected in Washington State. In particular, the profiles were placed to image a body of low resistivity rocks postulated to be marine sediments which were delineated by Stanley using magnetotelluric methods. The low resistivity rocks are known as the Southwestern Washington Cascade Conductor (SWCC).

The profile data was processed using standard reflection seismic methods and also state-of-the-art data enhancing and 3-D reconstruction methods. Along with the reflection data, several dynamite refraction profiles and 3 component data were collected. The reflection and refraction data has been interpreted by Lawrence Berkeley Laboratory, Morgantown Energy Technology Center and the University of West Virginia. Results of the Lawrence Berkeley and University of West Virginia work are presented in a separate reports.

This report summarizes the data acquisition and processing portions of the project.

Preface

This report describes the state of the art seismic reflection profile collected over the Southwestern Washington Cascades Conductor in Washington state. It summarizes the data collection activities of the survey. Results of the interpretation of the survey can be found in reports by Lawrence Berkeley Laboratory and Morgantown Energy Technology Center.

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Table of Contents

Abstract	
Preface	
Acknowledgments	
Table of Contents	
List of Tables	
Executive Summary	
Introduction	
Geographical Area	
Weather	
Terrain	
Logistics	
Recording	
Summary	
Recording Parameters	
Line Descriptions	
Line 1/2	
Line 3	
Line 4	
Lines 3 and 4 Data Processing	
Line 5	
Line 6	
Lines 5 and 6 Data processing	
Three Component Recording	
Three Dimensional Coverage	
Permitting and Public Relations	
Surveying	
Field Data	
References	
Appendices	
Tape Formats	

List of Tables

1. Data Acquisition Parameters
2. Summary of Lines
3. Processing Sequence for Lines 1/2, 3, and 4.
4. Processing Sequence for Line 1 West and Line 1 East
5. Processing Sequence for Lines 5, and 6.

Executive Summary

The purpose of this project was to acquire, process, and interpret seismic reflection and refraction data over the Southwestern Washington Cascade Conductor in Washington State. The project was broken up into three portions each performed by a different contractor: project management and data acquisition was performed by Geophysical Systems Corporation; data processing was performed by Golden Geophysical for Lines 1, 2, 3, and 4 and by GeoTrace Technologies for Lines 5 and 6; finally, data interpretation by Lawrence Berkeley Laboratory (LBL).

This report documents the data acquisition and data processing portions of this project. Information regarding the data interpretation portion of this project can be found in LBL's final report, "Seismic Imaging of the SWCC".

Introduction

A deep crustal seismic survey program was conducted in southwestern Washington State was carried out over three field seasons between October, 1988, and September, 1990, by Party 128 of Geophysical Systems Corporation for the United States Department of Energy, Morgantown Energy Technology Center, Morgantown, West Virginia.

Geographic Area

The study area is located in Lewis, Thurston and Pierce counties in the State of Washington.

Weather

Weather conditions ranged from fair and warm to rainy and cool. The data was collected over three field seasons during the summer or fall so as to minimize operational delays and hazards associated with wet weather.

Terrain

The survey area is located in the southern part of the Cascade range. The survey transverse was restricted to highways and logging roads for ease of operations and access. The terrain along the line ranges from flat to mountainous.

Logistics

The crew was accommodated in the city of Morton which is approximately in the center of the study area.

Line Descriptions

In all, six reflection lines were recorded. Table 2 summarizes each line.

Recording Parameters

Parameters used for the data recording are listed in Table 1.

Lines 1 and 2

Line 1 follows Highway 12 starting at Mossyrock, heads east and ends just west of Morton. Along several portions of the line vibrator sweeps were tested.

Table 1 - Data Acquisition Parameters

Recording Instrument	GEOCOR IV 1,024-channel data acquisition and field processing system with expanded memories.
Number of Active Channels	1,024
Spread Geometry	Split Spread
Offset Range	10,240 - 0 - 10,240 meters
Fold	256
Receiver Interval	30 meters (Line 1 only) 20 meters (Lines 2 thru 6)
Geophone Type	Mark Product L-21A 10Hz
Geophone Array	6 phones over the group array
Energy Source:	Vibroseis
Number of Vibrators	5
Vibrator Type	Litton Model 311 Truck-mounted units (27,000 lbs peak force)
Vibrator electronics	Pelton Advance I Model 5 with force control and RAM options
Vibrator Array	Bumper-to-Bumper, Stationary (approximately 40 meters from first pad to last pad)
Vibrator Interval	60 meters (Line 1 only) 40 meters (Lines 2 thru 6)
Sweep Type	VARISWEEP™ composed of 6 linear subsweeps as follows: 24 - 9 Hz 27 - 9 Hz 30 - 10 Hz 33 - 11 Hz 36 - 12 Hz 39 - 13 Hz
Number of Sweeps per VP	18 (3 x Subsweep Set)
Sweep Length	15 seconds
Total Listen Time	30 seconds
Correlated Output	15 seconds
Sample Interval	4 milliseconds

Table 2 - Summary of Lines

<u>Line No.</u>	<u>Station #s</u>	<u>Length(km)</u>	<u>Start Date</u>	<u>Finish Date</u>
1	101 - 851	22.500	10/20/88	10/27/88
2	2513 - 3642	22.580	10/29/88	11/13/88
3	3001 - 5236	44.700	7/25/89	8/13/89
4	4001 - 7316	66.300	8/16/89	9/09/89
5	962 - 2957	39.900	8/14/90	8/29/90
6	1001 - 3550	50.980	9/01/90	9/22/90

Line 1 used an offset range of 15,360 - 0 - 15,360 meters. Initial field data processing showed first break energy and observable reflection energy dying out around 10,000 meters. After briefly acquiring data with an reduced number of channels to limit the far offsets, a decision was made to change the receiver geometry to 10,240 - 0 - 10,240 meters by picking up and relaying the recording spread of 1,024 channels at a 20 meter group interval instead of the 30 meter group interval. The last source point on Line 1 was #851 and the active spread was from station #526 to station #1175. Using station #851 as a center point the spread was changed and station #851 then became station #2513 on Line 2. The first active channel on Line 2 for VP #2513 was #2001 which was roughly in the same location as station #509 on Line 1. The last active channel on Line 2 for VP #2513 was #3024 which was roughly in the same location as station #1192 on Line 1.

Lines 1 and 2 are described as two separate lines in the raw data set, but were processed by Golden Geophysical as one line which has been named 'Line 1/2' and data from both lines are contained some special processed versions known as 'Line 1W' and 'Line 1E'.

Line 2 continued along Highway 12 to east until the town of Randle.

Lines 1 and 2 were sent to Golden Geophysical for processing. The processing flow for these lines are shown in Table 3.

Table 3 - Processing Sequence for Line 1/2

Reformat
Crooked Line Geometry Description and Application
Refraction Statics Calculation
Refraction Statics and Normal Moveout Corrections
Shot Summing
Spherical Divergence and Inelastic Attenuation Corrections
Deconvolution
Datum Statics
CMP Sort
Data Set Merge
Velocity Analysis
Surface Consistent Residual Statics
Velocity Analysis
Surface Consistent Residual Statics
Normal Moveout Corrections
First Break Suppression
Time Variant Scaling
Datum Statics Application
CMP Stack
F-X Spatial Deconvolution
Band Pass Filter
Trace Balance
Phase Correction to Zero Phase

Although Lines 1 and 2 are identified as separate line, they, along with Line 3 which was acquired during the next field season, make up a continuous profile along Highway 12 from Mossyrock to 7 miles pass Packwood. Line 1 has a CMP interval of 15 meters and Line 2 has a CMP interval of 10 meters. To merge the two lines adjacent channels were summed with static and dynamic corrections applied resulting in a 30 meter CMP interval for both lines.

After the final sections were completed, two portions of Line 1/2 were selected for more detailed processing so as to determined procedures to improve data quality. These portions were designated as Line 1 West and Line 1 East. Table 4 shows the processing flow for these sections.

Table 4 - Processing Sequence for Line 1 West and Line 1 East

Reformat
Crooked Line Geometry Description and Application
Refraction Statics Calculation
Refraction Statics and Normal Moveout Corrections
Spherical Divergence and Inelastic Attenuation Corrections
Deconvolution
Datum Statics
CMP Sort
Velocity Analysis
Surface Consistent Residual Statics
Time and Space Variant Beam Steer in Shot Domain
Mute Analysis
Velocity Analysis
Surface Consistent Residual Statics
Trim Statics
Time Variant Scaling
Datum Statics Application
CMP Stack
F-X Spatial Deconvolution
Phase Correction to Zero Phase
Band Pass Filter
Trace Balance

Line 3

Based on the results of data processing after the first field season, the decision was made to extend Line 1/2 to the east along Highway 12. Originally, Line 1/2 terminated at the town of Randle. In order to maintain consistent fold the beginning of Line 3 was started back to the west one-half spread length or approximately 5 kilometers from the town of Randle. Line 3 continued east along Highway 12 and terminated about 7 miles east of Packwood near the junction of Highway 12 and 123.

Line 4

Line 4 started about 8 kilometers southeast of the town of Morton where the Cosmos Road terminates at the Cowlitz River. The line proceeds northwest up Cosmos Road then heads west on Highway 12. At Fern Gap the Line proceeds along Old Railroad Grade Road skirting the town of Morton to the north and then proceeds west on Highway 508 and ends near the town of Alpha.

The receiver spread at the beginning of Line 4 was also used for refraction profiles. The source for the refraction profiles was 60 to 90 pounds of dynamite in a single hole per shot ranging from 40 to 68 feet in depth.

Line 3 and 4 data processing

Both Lines 3 and 4 along with the refraction profiles on Line 4 were collected during the second field season in 1990. The reflection data was processed by Golden Geophysical using the same processing flow developed from the previous year's work. The refraction data was sent to Lawrence Berkeley Laboratory and to Dr. Tom Wilson of the University of West Virginia for analysis and interpretation.

Line 5

Line 5 starts about 10 kilometers west of the town of Morton on Highway 12. The line proceeds east then turns to the north around the western side of the town of Morton where it joins Highway 7 and heads north finally ending at the town of Elbe on the Nisqually River.

The first 10 kilometers of Line 5 coincides with Line 1. This duplicated segment allowed another look at this segment of Line 1/2 using the second set of data acquisition parameter used for Line 2. Also, this additional spread allowed fold to build so the tie points between Line 5 and Line 1/2 were at full fold.

The first 1024 stations of Line 5 were used for a refraction spread. Refraction profiles using dynamite and vibroseis sources were acquired.

Line 6

Line 6 started at the Weyerhaeuser Operations Center near the town of Rainier and proceeded east crossing the Alder Lake Dam then joined Highway 708 east through the town of Elbe where it intersected Line 5 and ended at the entrance to Mount Rainier National Park.

Lines 5 and 6 Data Processing

Line 5 and 6 were sent to GeoTrace Technologies in Denver for data processing. Based on the previous flows and testing performed on Line 5, lead to revision of the previous processing flow. This data processing flow is shown in Table 5. The refraction data was sent to Lawrence Berkeley Laboratory and to Dr. Tom Wilson of the University of West Virginia for analysis and interpretation.

Table 5 - Processing Sequence for Lines 5 and 6

Recording Gain Removal
Geometry Definition
Trace Editing
Refraction Statics
Surface Consistent Deconvolution
Automatic Gain Control
Trace Balance
Time Variant Spectral Balance
Velocity Analysis
Surface Consistent Residual Statics
Velocity Analysis
Surface Consistent Residual Statics
Normal Moveout
X-T Spatial Filter in Shot Domain
CMP Gather
Trim Statics
Normal Moveout Stretch Mute
CMP Stack
Finite Difference Wave Equation Migration
X-T Noise Reduction Filter
Bandpass Filter
Trace Balance

Lines 5 and 6 Three-Component Recording

An experiment was piggy-backed onto the reflection data recording on both Lines 5 and 6. 3-component geophones were placed every 300 channels along the recording spread. The 3-component geophone replaced three adjacent channels, each channel recording a different component. The first station on Line 5 to have a 3-component geophone was 1001. The components were placed on adjacent channels in the following order: vertical, north, then east. Because of the crooked nature of the recording spread, lateral and transverse polarizations would have been difficult, if not impossible to determine, so horizontal polarizations were aligned north-south and east-west. Therefore, station #1001 was the vertical component, station #1002 was the north-south component, and station #1003 was the east-west component, and so on.

Three Dimensional Coverage

Due to the mountainous terrain of the study area the seismic lines were placed along roads and highways. The crookedness of the seismic lines meant that source-to-receiver midpoints are scattered around the seismic line. This scattering provides three dimensional information of the subsurface. Three of the seismic lines (1/2, 4, and 5) passed through the town of Morton and coincidentally had major bends in the seismic lines as they pass through the town. This resulted in an area around Morton that contain a large amount of scattered midpoints. GeoTrace used these scattered midpoints to produce additional section reconstructions of the subsurface.

Permitting and Public Relations

All permitting was done by Jim Quintinella of Rocky Mountain Permit Service of Monument, Colorado. Public relations were good with the local residents and authorities.

Surveying

Surveying was performed using a surveyor's chain to measure and deploy the station markers. Northing, easting and elevation were measured using theodolite and EDM equipment. Raw data was recorded by hand notes and then processed on a field computer. Processed survey data is available in printout form and on 9 track tape. The data format for the 9 track tape is shown in the appendix.

Field Data

The recording system demultiplexes, correlates and composites the data before recording the data to 9 track tape. To reduce the volume of tapes for storage the data was copied from 9 track tape to 8mm tape cartridge.

References

Daly, T.M., Majer, E.L., 1992, Seismic Imaging of the SWCC, Lawrence Berkeley Laboratory Report, LBL-31982, UC-132.

Appendix

Tape Formats

GEOCOR IV
FIELD TAPE FORMAT

Field data is recorded on IBM compatible $\frac{1}{2}$ inch, 9 track tape in demultiplexed format at either 800 or 1600 bits-per-inch density. Each tape reel is divided into trace data blocks each containing a trace identification header and data values from one channel (Fig. 1). Each trace data block is separated from the next by a .6 inch interblock gap (IBG). Data values are recorded in two's complement notation with 16 bits per sample standard (recording 1 or 8 bits per sample is available as a non-standard option).

Two trace data block formats are available:

Trace Data Block - 4 word Trace Identification Header (Fig. 2)
Format #1

Trace Data Block - 32 word Trace Identification Header (Fig. 3)
Format #2

Trace data block Format #2 contains more header information and is standard.

TRACE HEADER ITEM DEFINITIONS

	<u>Format</u>	<u>Limits</u>
File number is the sequential number assigned to each record (or file) on a magnetic tape. Each line of receivers generates one record at each source point. A record may contain from one to 1024 traces. The file numbering begins at one for the first record on the first tape and continues sequentially through all the tapes for the line.	16 bit two's complement	1 to 32767
Trace Number is the sequential number, beginning at 1, assigned to each trace collected at a source point.	16 bit two's complement	1 to 1024
Source Point Number represents the actual number assigned to each source point by the surveyor.	16 bit two's complement	-32767 to 32767
Port/Channel Code is a code identifying the input port and channel used to collect each trace. The most significant 6 bits represent the port (0-15) and the least significant 10 bits represent the channel (0-1023).	6 bit/10 bit two's complement	0-15/0-1023
Source Line Name is the alphabetic or numeric identification of the line of source points.	6 ASCII characters left justified	
Receiver Line Name is the alphabetic or numeric identification of the line of receivers.	6 ASCII characters left justified	
Receiver Number represents the actual number assigned to each receiver location by the surveyor.	16 bit two's complement	-32767 to 32767

GEOCOR IV
FIELD TAPE FORMAT

FIG. 1

FIG. 3

GEOCOR IV
LOG TAPE FORMAT

All acquisition parameters and log entries recorded in the GEOCOR IV Acquisition Log may also be recorded on magnetic tape for input to subsequent data processing steps. Each line of text written in the log may be recorded as a 65-word block on tape. The format of each text block is described in Figure 2.

Information describing each source point as it is acquired is also recorded in a second format (figures 3, 4, 5). Each source point generates one block of information which contains one section describing the source location and identification and sixteen sections describing the receiver configurations. The source point blocks are 501 words long with the source section occupying words 2-101 and the receiver sections occupying words 102-501. One receiver section is filled in for each independent line of active receivers. An illustration of the total log tape is shown in figure 1.

The information is recorded on IBM compatible, $\frac{1}{4}$ inch, 9-track magnetic tape at either 800 or 1600 bits-per-inch density. Each block of information is separated from the next by a .6 inch inter-block gap (IBG). The source point blocks are written on tape in triplicate to insure that they can be read correctly. Each source point block contains a checksum word to permit detection of incorrect reads.

DEFINITIONS

	<u>Format</u>	<u>Limits</u>
Source Point Number - the number assigned to the actual ground location of each shot or vibrator point.	16 bit two's complement	-32767 to 32767
Source Line Name - the alphabetic or numeric identification of the line of source points.	6 ASCII characters left justified	
Number of Receiver Lines - the number of independent lines of receivers active during data acquisition.	16 bit two's complement	1 to 16
Checksum - the exclusive-or checksum of all the data within the block.	16 bit two's complement	-32768 to 32767
File Number - the number assigned to each group of traces generated by a line of receivers. The file numbers are sequential on tape.	16 bit two's complement	1 to 32767
Receiver Line Name - the alphabetic or numeric identification of the line of receivers.	6 ASCII characters left justified	
Reel Identification - the alphabetic or numeric identification of the magnetic tape reel.	10 ASCII characters left justified	
Number of First Active Trace - the number of the first trace containing seismic data.	16 bit two's complement	1 to 1025
Receiver Number of First Active Trace - the number assigned to the receiver location of the first active trace.	16 bit two's complement	-32767 to 32767
Number of Last Active Trace - the number of the last trace containing seismic data.	16 bit two's complement	1 to 1025
Receiver Number of Last Active Trace - the number assigned to the receiver location of the last active trace.	16 bit two's complement	-32767 to 32767
Number of Traces/File - the number of active and dummy traces within each file on tape. The number of traces/file does not change within a line.	16 bit two's complement	1 to 1025
Block Identification Code - the number which identifies the type of block. 0 = Source Point Block 1 = Text Block	16 bit two's complement	0 to 1

LOG TAPE

TEXT BLOCK

WORD	BYTE
1	1
2	2
2	3

BLOCK IDENTIFICATION
CODE (1)

128 ASCII
CHARACTERS

65 130

Fig. 2

SOURCE POINT BLOCK

Fig. 3

SOURCE SECTION
OF SOURCE POINT BLOCK

WORD	BYTE	
2	3	SOURCE POINT NUMBER
	4	
3	5	SOURCE LINE NAME
5	10	
	11	NUMBER OF RECEIVER LINES
6	12	
	13	NUMBER OF TRACES/FILE
7	14	
8	15	UNUSED
		UNUSED
100	200	BLOCK CHECKSUM
101	201	
	202	

Fig. 4

RECEIVER SECTION #1
OF SOURCE POINT BLOCK

WORD	BYTE	
102	203	FILE NUMBER
	204	
103	205	RECEIVER LINE NAME
105	210	
106	211	REEL IDENTIFICATION
110	220	
111	221	NUMBER OF FIRST ACTIVE TRACE
	222	
112	223	RECEIVER NUMBER AT FIRST ACTIVE TRACE
	224	
113	225	NUMBER OF LAST ACTIVE TRACE
	226	
114	227	RECEIVER NUMBER AT LAST ACTIVE TRACE
	228	
115	229	UNUSED
		UNUSED
126	252	

Fig. 5

GEOCOR IV

Coordinate Tape Format

The GEOCOR IV System records geophysical survey information on magnetic tape in a blocked, gapped format which is fully IBM compatible. For each source point and receiver location associated with the survey, X, Y, and Z coordinate, residual static correction, latitude and longitude information is included. This information is recorded in data blocks which are followed on the coordinate tape by edit blocks which include receiver edit information for each source point.

The tape is an IBM-compatible 9-track-magnetic tape that is recorded at either 800 or 1600 bits-per-inch (BPI). Tape codes consist of 16-bit words which include a sign bit and 15 data bits. The data bits are recorded in a straight binary code with a two's complement negative number representation. The sign bit of the least significant word of two word values is always set to zero.

The coordinate tape is written with three identical copies of each block. Each block is separated from the next block by a .6 inch interblock gap (IBG). Data blocks contain 2002 words each and edit blocks contain 1040 words each. (Fig. 1)

Each data block contains a block number (word 1), 100 20-word records (words 2-2001) and a checksum (word 2002). (Fig. 2) Each 20-word record is associated with a source point of receiver location. Latitude and longitude are expressed in hundredths of a second as 32-bit integer values. (Fig. 3)

Each edit block contains a block number (word 1), the source point number to which the edits apply (word 2), the number of receiver edits included in the block (word 3), spare words (words 4-15), receiver edits (words 16-1039) and a checksum (word 1040). (Fig. 4)

The first n blocks on the coordinate tape contain source point location data and are numbered consecutively from 1 to n. These are followed by m blocks containing receiver location data numbered from 1 to m. An all-zero record indicates the termination of data within a block, and the remainder of the records in that block will also be all-zero. These data blocks are followed by p edit blocks numbered consecutively from 1 to p. There is one 1040-word edit block for each source point described in the first n data blocks.

COORDINATE TAPE FORMAT

FIG. 1

BLOCK FORMAT

FIG. 2

Source or Receiver Line Name (6 Ascii characters left justified)	Words 1 - 3
Source or Receiver #	Word 4
2-word X coordinate	Words 5, 6
2-word Y coordinate	Words 7, 8
1-word Z coordinate	Word 9
2-word packed latitude	Words 10,11
2-word packed longitude	Words 12,13
Residual Static	Word 14
Available for additional data	Words 15 - 20

DATA RECORD FORMAT

FIG. 3

**DATE
FILMED**

1 / 3 / 94

END