UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OPEN FILE REPORT

PRELIMINARY INTERPRETATION OF A SEISMIC-REFRACTION PROFILE ACROSS THE LARGE APERTURE SEISMIC ARRAY, MONTANA*

by

C. A. Borcherdt** and J. C. Roller** (or Clayton) 1921-

This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards.

MENLO PARK, CALIFORNIA

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National Center for Earthquake Research
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* Work performed under ARPA Order No. 923

** U. S. Geological Survey, Menlo Park, California

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U. S. GEOLOGICAL SURVEY
Washington, D. C.
20242

For release MAY 27, 1968

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2. Preliminary interpretation of a seismic-refraction profile across the Large Aperture Seismic Array, Montana, by C. A. Borcherdt and J. C. Roller. 53 p., including text, 2 figs., and 26 p. tabular material.

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3. Timber Mountain Tuff, southern Nevada, and its relation to cauldron subsidence, by F. M. Byers, Jr., Paul P. Orkild, W. J. Carr, and W. D. Quinlivan. 23 p., 11 figs.

4. Silent Canyon volcanic center, Nye County, Nevada, by Donald C. Noble, K. A. Sargent, H. H. Mehnert, E. B. Ekren, and F. M. Byers, Jr. 20 p., 4 figs., 2 tables.

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ABSTRACT

A reversed seismic-refraction profile extending northeastward from Greycliff, Montana, across the Large Aperture Seismic Array (LASA) to Charleson, North Dakota, indicates that the crust of the earth consists of two layers with P-wave velocities of 6.1 km/sec and 6.7 km/sec, and that the upper-mantle velocity is 8.3 km/sec. The Mohorovicic discontinuity is 50-km deep at Charleson and remains at nearly the same depth southwestward for a distance of about 300 km, from where it slopes upward to the southwest at about 2^{o} to a depth of 41 km near Greycliff, Montana.

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INTRODUCTION

In October 1966, the U. S. Geological Survey conducted a seismic-refraction survey along a profile trending southwest through the Large Aperture Seismic Array (LASA) to determine the crustal structure and seismic-wave velocities in the crust and upper mantle in the vicinity of the array. The project was sponsored by the Advanced Research Projects Agency of the Department of Defense as part of the VELA UNIFORM Program. A reversed seismic-refraction profile 562-km long was made from Greycliff, Montana, to Charleson, North Dakota, with intermediate shot points at Billings, Angela, and Sidney, Montana (Fig. 1).

The entire profile lies within the Great Plains, with the south-western end (Greycliff) situated near the boundary of the Great Plains and the Rocky Mountains (Fenneman, 1946). The geology in Central Montana is characterized by a generally east-west assemblage of

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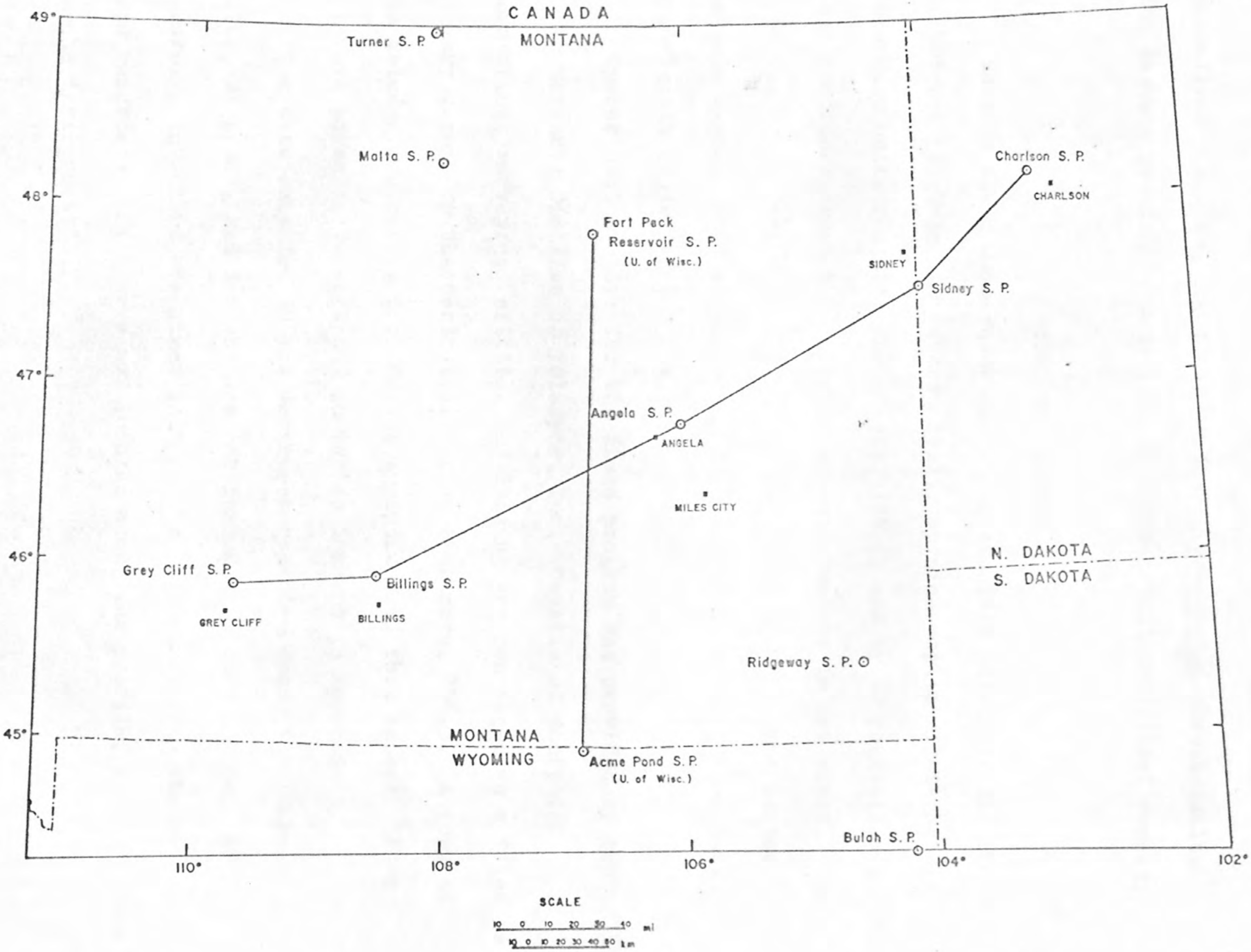

Figure 1.--Index map showing the location of the Geological Survey shot points and seismic profile, and also the University of Wisconsin profile (Steinhart and Meyer 1961).

monoclinal flexures, domes, and belts of <u>en-echelon</u> thrust faults. The eastern portion is dominated by assymetrical anticlinal ranges.

FIELD OPERATIONS

Seismic waves were recorded, using standard seismic-refraction techniques (Jackson and others, 1963), by nine mobile eight-channel recording units (Warrick and others, 1961), and by 20 portable magnetic-tape recorders connected to selected seismometers in the array. The tape recorders were used to record the high-frequency part of the seismic signals because the standard LASA telemetry equipment cuts off signals above about 5 cps.

Operational support for the field program was provided by the Earth Sciences Division of Teledyne, Inc. Details of shotpoint permitting, surveying, drilling and loading are contained in a Teledyne summary report to the Geological Survey (McLamore, 1966). A copy of the Teledyne report is included as Appendix I of this report. Shot data are given in Table 1 and in Tables 2 and 3 in Appendix I.

The data recorded on the northwest-trending crossline (Turner, Malta, Ridgeway, and Beulah) are not included in this report. All recording locations are given in Appendix II. Times from the magnetic-tape recorders, which were not located along the profile, were not used in the interpretation.

Table 1.--Shot-point data

	Shot No.	Date, Oct. 1966	Mountain Standard Time	Charge size, pounds	Charge depth, feet Top	Bottom	Latitude, N	Longitude, W	Surface elevation, feet
Greycliff	1	6	05:00:00.24	6,000	90	210	45° 53.60'	109° 41.20'	4357
	2	7	05:30:00.49	1,020	90	210			
	3	9	05:00:00.29	20,100	90	210			
Billings	1	5	05:30:00.28	4,080	75	195	45° 56.51'	108° 31.00'	3451
	2	8	05:00:00.63	19,920	75	193			
Angela	1	5	05:00:00.36	4,020	110	200	46° 48.00'	106° 02.00'	3120
	2	8	05:30:00.22	4,020	110				
Sidney	1	6	05:30:00.28	19,980	115	200	47° 39.75'	104° 02.20'	2088
	2	9	05:30:00.27	4,020	115	200			
Charleson	1	6	06:29:59.86	7,770		45	48° 07.70'	103° 03.50'	2000
(Garrison	2	7	06:30:00.75	1,020					
Reservoir)	3	8	06:00:01.10	16,230					

RESULTS

The traveltimes have been fit with the least number of straight-line segments satisfying the data (Fig. 2). This assumes plane boundaries between layers of constant velocity and increased velocity in successively deeper layers. Some aeromagnetic data suggest the presence of lateral variations in velocity due to lithologic changes (Isidore Zeitz, oral communication); however, for this preliminary interpretation all lateral velocity variations have been explained by lateral changes in structure.

Three waves are identified: (1) A direct wave (P_g) propagating with a velocity near 6.1 km/sec through an upper crustal layer, (2) a refracted wave (P*) from a lower crustal layer propagating with a velocity near 6.7 km/sec, and (3) a refracted wave (P_n) from the upper mantle propagating with a velocity near 8.3 km/sec.

The University of Wisconsin (Steinhart and Meyer, 1961) recorded a profile nearly perpendicular to the Geological Survey line and crossing it just west of the Angela shot point (Fig. 1). Steinhart and Meyer report a third layer with a velocity 7.4 to 7.7 km/sec, based on secondary arrivals propagating in the lower crust. We were not able to detect this layer. However, our station spacing may be too large to correlate secondary events unless they are very prominent, as, for example, the 6.7 km/sec events shown in Figure 2.

Greycliff--The first arrivals recorded from the Greycliff shot point define a two-segment time-distance curve. Thirteen seismograms of good quality were recorded from Greycliff to a distance of 206 km

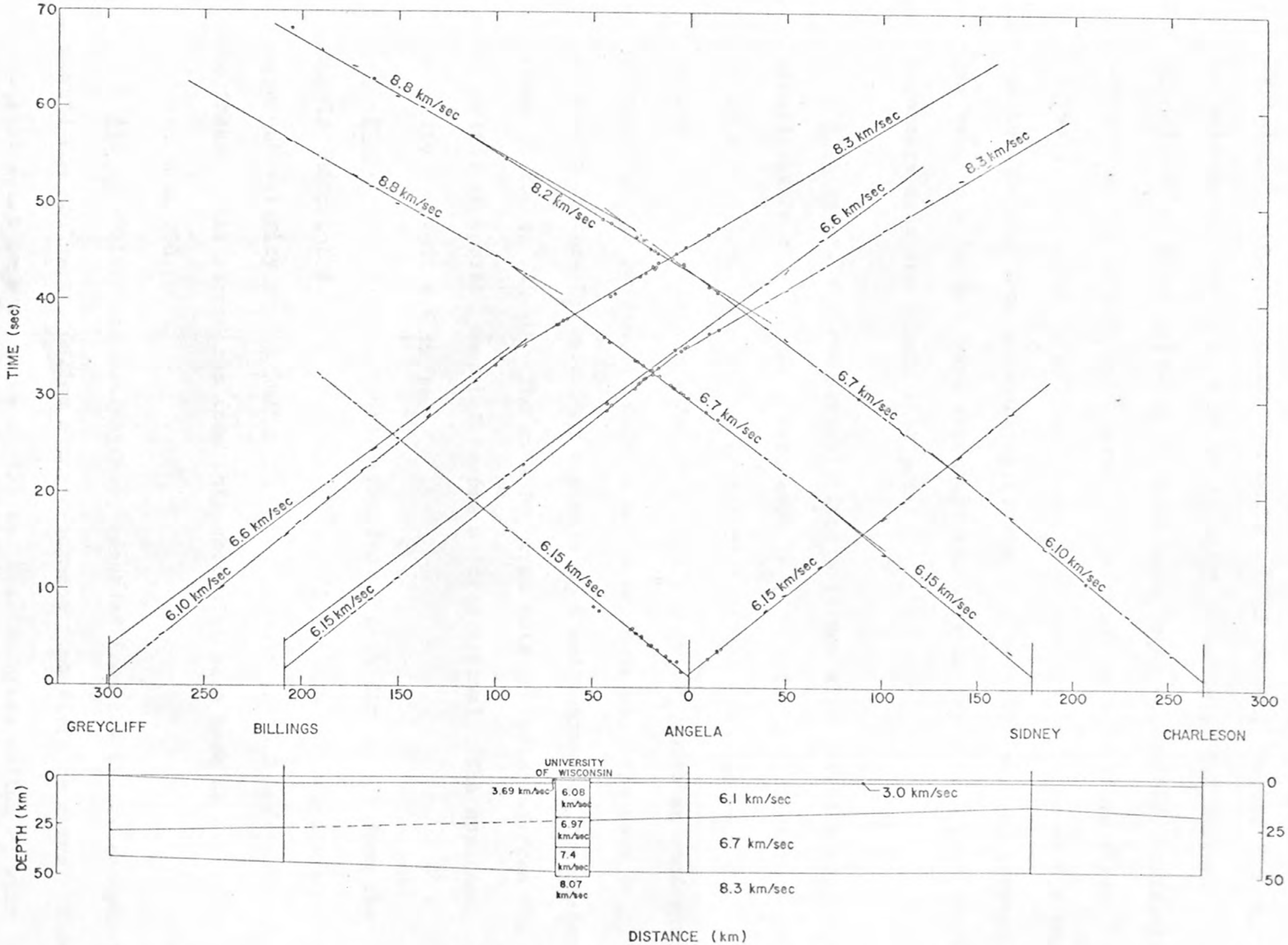

Figure 2.--Time-distance curves from Greycliff, Montana, to Charleson, South Dakota, and crustal model. The crustal model obtained by the University of Wisconsin at the intersection of their profile and the Geological Survey profile is also shown. (Steinhart and Meyer, 1961).

defining P_g with an apparent velocity of 6.1 km/sec. Beyond 206 km, 14 seismograms define P_n with an apparent velocity of 8.3 km/sec. Beyond 400 km first arrivals were too weak to be determined. Refracted waves from the intermediate layer in the crust do not become first arrivals, but a poorly defined P* with an apparent velocity of 6.6 km/sec can be obtained from secondary arrivals on 5 seismograms. No attempt has been made to determine secondary arrivals on tapes from the portable recorders near the Angela shot point.

Billings--The first arrivals from Billings also define a two-segment time-distance curve. The direct wave, P_g, is defined by first arrivals on 16 seismograms from the shotpoint to a distance of 200 km. The apparent velocity is 6.1 km/sec. Beyond 200 km, P_n, with an apparent velocity of 8.3 km/sec, is defined by 14 seismograms. The wave P*, is poorly defined by secondary arrivals on 4 seismograms in the distance range of 250 to 210 km. The wave P*, from this shotpoint as from the Greycliff shotpoint, does not become a first arrival. The apparent velocity of P* is 6.6 km/sec.

Angela--All first arrivals recorded in both directions from the Angela shotpoint fall on the direct-wave (P_g) line and indicate an apparent velocity of 6.1 km/sec to the southwest and 6.2 km/sec to the northeast. All recordings from this shotpoint were made at distances of less than 200 km.

Sidney--Thirty-one seismograms, recorded from the Sidney shotpoint toward the southwest, define a three-segment time-distance curve. From the shot point to a distance of 137 km, 8 seismograms define P_g with an apparent velocity of 6.1 km/sec. From 137 km to 225 km, 16 seismograms define P* with an apparent velocity of 6.7 km/sec. Beyond 225 km an apparent velocity for P_n of 8.8 km is defined by 7 seismograms. This is probably too high for the true P_n velocity and is probably an apparent updip velocity, although it has not yet been reversed to determine this positively. From previous work in the High Plains (Jackson and others, 1963) and past experience in most of the United States, it is believed that a P_n velocity of 8.8 km/sec is too high to be accounted for by a change in mantle composition or properties.

Charleson--Three explosions were detonated in the Garrison Reservoir, and the seismic waves generated by these explosions were recorded to a distance of 476 km to the southwest. The first arrivals define a four-segment time-distance curve. The direct wave, P_g, with an apparent velocity of 6.1 km/sec is defined by 7 seismograms from the shotpoint to a distance of 140 km. The refracted wave P* is defined by 8 seismograms from 140 km to 265 km and has an apparent velocity of 6.7 km/sec. The refracted wave P_n is best represented by two line: from 265 km to 385 km, five seismograms show an apparent velocity at 8.2 km/sec; beyond 385 km the apparent velocity increases abruptly to 8.8 km/sec, which is the same high velocity that was recorded in the same area from the Sidney shot point. Here again we consider this to be caused by an upward slope to the southwest of the M-discontinuity.

The crustal structure computed from the five shotpoints is shown in Figure 2 and tabulated in Table 2. The crustal structure computed by the University of Wisconsin at a point where their profile crosses

Table 2.--Crustal models

Greycliff			Billings			Angela			Sidney			Charleson		
Velocity, km/sec	Thickness, km	Depth to bottom of layer, km	Velocity, km/sec	Thickness, km	Depth to bottom of layer, km	Velocity, km/sec	Thickness, km	Depth to bottom of layer, km	Velocity, km/sec	Thickness, km	Depth to bottom of layer, km	Velocity, km/sec	Thickness, km	Depth to bottom of layer, km
3.0[1/]	1.2	1.2	3.0	2.9	2.9	3.0	2.3	2.3	3.0	2.4	2.4	3.0	1.5	1.5
6.10	27.4	28.6	6.15	23.8	26.7	6.15	-	-	6.15	12.2	14.6	6.1	17.8	19.3
6.7		41[3/]	6.6	18.0	44.7	[2/]	-	-	6.7			6.7	29.9	49.2
8.3	—	—	8.3	—	—	—	—	—	[4/]	?		8.2	—	—

1/ Average velocity of surface layers assumed

2/ Only Pg velocity measured

3/ Depth computed using dip of 2° from Greycliff to Billings

4/ Only an apparent updip velocity of 8.8 km/sec recorded the Geological Survey profile, is also shown (Fig. 2). The depths to the top of the intermediate layer (21 km for the Geological Survey profile and 25 km for the Wisconsin profile) and the depths to the M-discontinuity (52 km for the University of Wisconsin profile and 48 km for the Geological Survey profile) show good agreement. The main difference on the two profiles is in the velocity of the intermediate layer (P*). The Geological Survey data indicate a velocity of 6.7 km/sec for the entire intermediate layer, whereas the University of Wisconsin data indicate an upper intermediate-layer velocity which averages 6.97 km/sec (7.07 km/sec and 6.88 km/sec average) and a 7.58-km/sec velocity in the lower part of the crust. Only secondary arrivals were used to obtain the 7.58 km/sec velocity.

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Warrick, R. E., Hoover, D. B., Jackson, W. H., Pakiser, L. C., and Roller, J. C., 1961, The specification and testing of a seismic-refraction system for crustal studies: Geophysics, v. 26, no. 6, p. 820-824.

APPENDIX I

SUMMARY OF FIELD OPERATION
(EXCLUDING LINE RECORDING)
LASA CRUSTAL STUDIES PROJECT
MONTANA

CONTRACT NO. 14-08-0001-10640

Prepared for
UNITED STATES DEPARTMENT OF INTERIOR
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WASHINGTON 25, D.C.

26 OCTOBER 1966

By

EARTH SCIENCES
A TELEDYNE COMPANY

Prepared by:

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INTRODUCTION

This report summarizes the operational support provided by Earth Sciences, a Teledyne Company, to the U.S. Geological Survey, Branch of Crustal Studies, during the large Aperture Seismic Array (LASA) Crustal Studies Project, 12 August 1966 to 15 October 1966.

The work was performed under the direction of the Field Supervisor, Branch of Crustal Studies, in accordance with U.S. Department of Interior, Contract Number 14-08-0001-10640, dated 12 August 1966. The project was sponsored by the Department of Defense, Advanced Research Projects Agency, as a part of the VELA Uniform Program to calibrate ARPA's Montana LASA.

Earth Sciences was assigned responsibility for the following functions:

1. Permitting and surveying of shot points
2. Drilling and loading of shot points
3. Designing, fabricating, installing, and operating the interfacing amplifier/filter units
4. Shooting
5. Operating three USGS recording trucks
6. Assisting in maintaining the uninterrupted progress of the field program.

The LASA Crustal Study program was designed to provide precise and detailed seismic wave travel times and velocities in the crust and upper mantle of the earth in the vicinity of and surrounding the Montana LASA.

TECHNICAL DISCUSSION

PERMITTING AND SURVEYING

All permits were obtained in behalf of the U.S. Geological Survey by Earth Sciences permit agents. All shot points were located on land controlled by U.S. government agencies. In the case of the shots in Garrison Reservoir, North Dakota, permission was obtained from the North Dakota Game and Fish Department as well as the U.S. Army Corps of Engineers.

The shot points were surveyed using plane table, alidade, and stadia rod. The surveys were tied to the closest available bench mark, triangulation station, or section corner.

SHOOTING AND RECORDING

Conventional refraction-seismograph procedures were used to record a refraction profile passing from northeast to southwest through the LASA and extending outside the LASA by approximately 200 kilometers. Portable, unattended tape recorders were installed in 20 of the LASA subarrays (omitting Subarray B2) to record the output of selected LASA seismometers.

A series of four, 4000-pound shots were detonated along a line extending from the northwest to southeast through the LASA with the recording trucks distributed between Terry and Sidney, Montana on the northeast to southwest line. The line and shot-point locations are shown in Figure 1.

Earth Sciences supported the recording effort by furnishing three observers to operate three of the nine USGS recording trucks

See Figure 1, Page 3 in main body of report.

in addition to furnishing two technicians to install the portable tape recorders and interfacing filter/amplifiers. One of these technicians made periodic checks of the recording units during the recording program.

The amplifier/filter units used for interfacing between the portable tape recorders and the LASA seismometers were designed and manufactured by Earth Sciences in accordance with specifications established by the USGS.

Teledyne provided a shooter at each shot. The Earth Sciences shooter was responsible for laying out the firing line, priming the charges, and arming the blaster so that the shot could be detonated by the USGS communications engineer. He was also responsible for shot-point safety prior to and during the firing sequence.

A statistical summary of the shooting program is provided in Table 1. The charge size, date, and time of each shot are shown in Table 2.

DRILLING

Drilling was provided by the West Texas Drilling Company, a subsidiary of Teledyne, Inc. Two of the three drilling rigs provided were company-owned. The other was subcontracted from the Buell-Edlund Company, Miles City, Montana. Each drill crew consisted of a driller, helper, and explosives loader. Two of the drills were combination air/water rigs and one was capable of water drilling only.

One rig was started on 12 September 1966, approximately three weeks prior to the recording operation. The other two rigs were started two weeks later.

Nine shot points were used. Eight of these were land points and one was in water. Drilling was attempted at a total of eleven locations before the eight land-points were selected. A summary of the drilling conditions at each location is shown in Table 3.

Table 1. Statistical Summary

Number of drilled-hole shot points	8
Number of water shot points	1
Number of recording production days	6
Number of shots	16
Total footage drilled	8725
Number of holes drilled	48*
Number of rock bits used	22
Number of insert drag bits used	20
Pounds of drilling mud used	6150
Pounds of Super Tovex slurry explosives used	124,260
Number of HDP-1 boosters used	185
Number of detonators used	143
Feet of Primacord Used	28,000
Number of Earth Sciences-furnished vehicles on project**	5
Total vehicle miles (Earth Sciences-furnished vehicles)**	25,448

* Includes 4 holes at abandoned locations.

** Excluding drilling crew vehicles.

Table 2. Shot Point Locations and Shot Data

Shot Point	Location	Drilled Footage	Explosives, in pounds	Shot Time (MST) hr	min	Date of Shot
Grey Cliff	NE¼, SE¼, NE¼, Sec 26, T2N, R16E, Montana	1730	6000 1020 20,100	05 05 05	00 30 00	6 Oct 1966 7 Oct 1966 9 Oct 1966
Billings	NW¼, NW¼, NE¼, Sec 8, T2N, R26E, Montana	2182	4080 19,920	05 05	30 00	5 Oct 1966 8 Oct 1966
Angela	NW¼, NW¼, SW¼, Sec 14, T12N, R45E, Montana	800	4020 4020	05 05	00 30	5 Oct 1966 8 Oct 1966
Sidney	NE¼, SW¼, SE¼, Sec 3, T148N, R105W, North Dakota	2210	19,980 4020	05 05	30 30	6 Oct 1966 9 Oct 1966
Charlson	SW¼, SW¼, NW¼, Sec 29, T154N, R96W, North Dakota	None, Water Shots	7770 1020 16,230	06 06 06	30 30 00	6 Oct 1966 7 Oct 1966 8 Oct 1966
Turner	SW¼, SW¼, SE¼, Sec 10, T37N, R28E, Montana	400	4020	05	00	10 Oct 1966

Table 2. Shot Point Locations and Shot Data (Continued)

Shot Point	Location	Drilled Footage	Explosives, in pounds	Shot Time (MST) hr	Shot Time (MST) min	Date of Shot
Malta	NW¼, SW¼, SE¼, Sec 20, T29N, R29E, Montana	400	4020	05	30	10 Oct 1966
Ridgway	SE¼, SE¼, NW¼, Sec 34, T4S, R58E, Montana	360	4020	04	30	9 Oct 1966
Beulah	NE¼, NE¼, NE¼, Sec 32, T51N, R61W, Wyoming	315	4020	04	30	10 Oct 1966

NOTE: A total of 328 feet were drilled at the Red Lodge, Absarokee, and Turner locations. These holes were abandoned because of geologic conditions.

Table 3. Summary of Drilling Conditions (Continued)

Shot Point	Air or Water Drilling Used	Water Table, Feet	Immediate Loading Required	Remarks	Typical Log
Beulah	W	50	YES	Lost Circulation at 30 ft	0 to 55 ft Gravel and Broken Rock; 55 to 80 ft Clay and Limestone; 80 to 130 ft Limestone; 130 to 150 ft Red Clay, 150 to 165 ft Limestone
Red Lodge	W	NO	YES	Lost Circulation at 65 ft; did not shoot	0 to 50 ft Sandy Clay and Gravel; 50 to 93 ft Boulders, Gravel and Sand; 93 to 102 ft Boulders and Sandy Clay
Absarokee	W	NO	NO	Did not shoot	0 to 58 ft Gravel and Clay; 58 to 76 ft Igneous Rock
Turner	W	*	YES	Abandoned: Caving Gravels	0 to 50 ft Clay and Limestone streaks; 50 to 80 ft Gravel

* Not determined; water drilling.

Table 3. Summary of Drilling Conditions

Shot Point	Air or Water Drilling Used	Water Table, Feet	Immediate Loading Required	Remarks	Typical Log
Sidney	A	NO	NO		0 to 70 ft Sand and Clay; 70 to 210 ft Blue Shale
Angela	A	NO	YES	Caving Sand	0 to 25 ft Sand; 25 to 30 ft Lignite; 30 to 35 ft Sand; 35 to 170 Blue Clay; 170 to 200 ft Sand
Billings	A/W	140	YES	Boots at Water Table	0 to 200 ft Clay and Shale with Limestone Stringers from 105 to 200 ft
Grey Cliff	A/W	100	NO		0 to 30 ft Clay and Loose Rock;30 to 70 ft Clay and Sandstone Stringers; 70 to 210 ft Shale, Sandy Clay and Sandstone
Turner	W	*	YES	Blind	0 to 25 ft Clay and Boulders 25 to 200 ft Clay with Gravel layers
Malta	W	*	NO	Clay Boots	0 to 15 ft Clay; 15 to 35 ft Sandstone; 35 to 120 ft Clay and Shale; 120 to 128 ft Sandstone; 128 to 200 ft Shale and Clay
Ridgway	W	*	NO	Frequent Clay Boots	0 to 180 ft Clay and Shale; Limestone Stringers in last 60 ft

LOADING

Drilled Holes

Preloading was accomplished by the loader assigned to the drill crew at each shot point. Super Tovex-Gel was used for all shots. From 2000 to 3000 pounds of explosives were loaded in each hole, with Dupont HDP-1 Boosters near the bottom, middle, and top of each charge. Plastic-coated Primacord was attached to each booster so that the shooter could prime the charge with the blasting cap shortly before shot time.

Firm tamp of the holes was obtained by adding a few feet of crushed rock or cuttings on top of the charge, followed by two sacks of cement (or ready mix) and a few more feet of crushed rock. The holes were then filled to the top with cuttings. No surface cratering occurred, and the only hole-blow occurred at the Grey Cliff shot point.

Water Point

Loading at the water shot point, Garrison Reservoir, was accomplished by five personnel; three were from the USGS and two were from Earth Sciences. The boat and all equipment and supplies were furnished by the USGS. Large quantities of Super Tovex-Gel had not previously been loaded for water shots.

The first step was to locate the old river channel where the deepest water was available, and where there were no inundated trees and shrubs. This area was located with a fathometer. When the channel was located, five buoys were set out to mark it. The water was generally between 40 and 50 feet deep, which meant that the individual charges should be less than 3000 pounds and at least 80 to 100 feet apart to prevent loss of energy by venting. After some experimentation to determine optimum handling procedures, a specific routine was followed.

A loading platform consisting of two boards was laid across the boat, approximately at midship. Five, 30-pound bags of Trovex-Gel, one containing an HDP-1 Booster and Primacord Lead, were stacked on the platform and taped together with nylong-filament tape. This bundle was dumped overboard to serve as an anchor. The Primacord lead was tied to an automobile innertube which served as a buoy to mark the location. After several such anchors and buoys were set, spaced approximately 100 feet apart, each one was revisited so that six more bundles, each containing five bags of Trovex-Gel, could be lowered down the existing Primacord lead. An eighth bundle, including a booster and Primacord lead was added to the charge, providing a charge of 1200 pounds with boosters at the top and bottom. The same procedure was repeated to load an additional 1050 pounds with the new anchor-charge being dropped as near the existing charge as possible. This provided a charge of 2250 pounds at each location in the pattern.

CONCLUSIONS

The LASA Crustal study was a reasonably efficient operation, averaging some 2.6 shots per day during the recording session. This particular program was simplified by the definite assignment of charge sizes at each shot point several days prior to the start of the recording program.

Appendix II

Table 1.--Station Locations

Shots: Greycliff 2, Charles 2

Station		latitude (N)	longitude (W)	elevation (feet)
Hotel	E	45° 55.03'	109° 24.26'	4558
	W	45° 54.98'	109° 26.35'	
Juliet	E	45° 58.80'	109° 19.62'	4209
	W	45° 55.85'	109° 21.51'	
Kilo	E	45° 58.50'	109° 04.37'	4000
	W	45° 58.50'	109° 06.37'	
Lima	E	45° 54.93'	108° 55.56'	4080
	W	45° 54.93'	108° 57.32'	
Papa	E	47° 41.35'	103° 56.50'	2500
	W	47° 41.35'	103° 58.50'	
Quebec	E	45° 56.65'	108° 30.00'	3450
	W	45° 56.65'	108° 31.95'	
Romeo	E	47° 46.55'	103° 41.55'	2300
	W	47° 46.55'	103° 41.55'	
Sierra	E	47° 53.55'	103° 27.00'	
	W	47° 53.55'	103° 28.90'	
Tango	E	47° 59.10'	103° 07.50'	2000
	W	47° 59.45'	103° 09.50'	

Table 1.--(Continued)

Shots: Billings 1, Greycliff 1, Charleson 1, Angela 1, Sidney 1

Station		latitude (N)	longitude (W)	elevation (feet)
Hotel	E	45° 59.15'	108° 25.55'	3200
	W	45° 59.20'	108° 28.00'	
Juliet	E	46° 05.20'	108° 15.30'	3400
	W	46° 04.10'	108° 16.10'	
Kilo	E	46° 03.50'	107° 59.70'	3200
	W	46° 03.50'	108° 01.60'	
Lima	E	46° 09.80'	107° 56.70'	3200
	W	46° 09.80'	107° 58.70'	
Papa	E	46° 13.50'	107° 48.00'	3400
	W	46° 13.75'	107° 49.75'	
Quebec	E	46° 12.75'	107° 36.00'	3300
	W	46° 12.55'	107° 37.80'	
Romeo	E	46° 20.20'	107° 19.25'	2800
	W	46° 20.20'	107° 21.25	
Sierra	E	46° 20.30'	107° 02.50'	2700
	W	46° 19.90'	107° 04.00'	
Tango	E	46° 25.20'	107° 00.35'	2900
	W	46° 26.50	107° 00.35	

Table 1.--(Continued)

Shots: Greycliff 3, Sidney 2, Billings 2, Angela 2, Charleson 3

Station		latitude (N)	longitude (W)	elevation (feet)
Hotel	E	46° 59.10'	105° 34.60'	3000
	W	46° 57.75'	105° 35.30'	
Juliet	E	47° 07.25'	105° 33.60'	3400
	W	47° 06.25'	105° 34.62'	
Kilo	E	47° 10.85'	105° 19.00'	3000
	W	47° 10.85'	105° 21.05'	
Lima	E	47° 21.05'	104° 57.60'	2800
	W	47° 21.05'	104° 59.70'	
Papa	E	47° 20.40'	104° 47.80'	2900
	W	47° 20.40'	104° 49.75'	
Quebec	E	47° 24.70'	104° 41.05'	2700
	W	47° 24.70'	104° 42.90'	
Romeo	E	47° 30.00'	104° 28.75'	2400
	W	47° 30.00	104° 30.75'	
Sierra	E	47° 34.30'	104° 19.15'	2100
	W	47° 34.30'	104° 21.15'	
Tango	E	47° 32.70'	104° 05.60'	2400
	W	47° 31.75'	104° 07.10'	

Table 2.--Traveltimes

Station		Greycliff 1 Time, sec	Greycliff 1 Dist., km	Greycliff 2 Time, sec	Greycliff 2 Dist., km	Greycliff 3 Time, sec	Greycliff 3 Dist., km	Billings 1 Time, sec	Billings 1 Dist., km	Billings 2 Time, sec	Billings 2 Dist., km	Angela 1 Time, sec	Angela 1 Dist., km
Hotel	1	17.12	98.32	4.42	22.07	50.30	336.66			40.27	253.86		205.06
	6	16.76	95.18	4.00	19.38	50.49	338.33			39.99	251.97		207.85
Juliet	1	19.39	112.99	5.47	28.20		342.96	5.02	25.88	41.35	261.96	31.89	188.96
	6	19.43	111.62	5.12	25.80		344.85	4.74	23.83	41.04	260.34	31.99	190.05
Kilo	1	22.65	132.76	8.81	48.47		362.06	7.76	42.80	43.75	281.37	29.22	171.51
	6	22.30	129.95	8.45	45.93		364.46	7.37	40.11	43.44	279.09	29.42	173.99
Lima	1	23.41	138.15	10.33	59.08		394.13	9.11	50.63	47.80	314.11	27.89	162.97
	6	22.97	135.63	10.01	56.80		396.57	8.85	48.39	47.46	311.79	28.10	165.28
Papa	1	25.25	150.58				405.29	11.29	63.75	49.19	324.45	25.65	149.90
	6	24.96	148.50				407.58	11.06	62.03	48.90	322.70	25.77	151.73
Quebec	1	28.22	165.34	15.80	92.23		416.26			50.80	335.66		136.84
	6	27.83	163.00	15.50	89.72		418.39			50.51	333.61		139.05
Romeo	1	31.74	189.41				434.08	17.60	102.30	52.82	353.92	19.23	111.34
	6	31.54	186.92				436.40	17.24	99.98	52.70	351.70	19.63	113.61
Sierra	1	35.40	210.36					20.82	122.20	54.51	366.09	16.20	92.79
	6	35.14	208.32					20.54	120.14	54.80	368.30	16.21	94.80
Tango	1	35.83	215.19					22.16	128.39		382.09	14.95	84.47
	6	35.91	215.41					21.95	129.19		380.12	15.04	85.41

Table 2.--Traveltimes (cont'd)

Station		Angela 2 Time, sec	Angela 2 Dist., km	Sidney 1 Time, sec	Sidney 1 Dist., km	Sidney 2 Time, sec	Sidney 2 Dist., km	Charleson 1 Time, sec	Charleson 1 Dist., km	Charleson 2 Time, sec	Charleson 2 Dist., km	Charleson 3 Time, sec	Charleson 3 Dist., km
Hotel	1	8.12	40.43	56.37	383.25	23.75	138.66	68.2	472.11			37.14	228.21
	6	7.86	38.43	56.68	385.93	23.91	140.79					37.43	230.38
Juliet	1	9.69	50.26	54.61	366.55	22.09	129.83	65.85	454.96			35.95	218.87
	6	9.50	48.48	54.74	368.09	22.36	131.84	66.02	456.91			36.26	220.95
Kilo	1	12.69	69.03	52.81	350.23	19.34	110.44	64.15	441.81			32.79	199.70
	6	12.46	66.99	53.05	352.64	19.59	112.70	64.30	454.96			33.20	201.88
Lima	1	17.76	101.96	51.74	341.18	13.84	77.71	62.94	430.18			27.90	166.78
	6	17.47	99.85	51.83	342.96	13.96	80.08		432.36			28.17	169.03
Papa	1	19.49	111.48	49.94	328.06	12.48	67.56	61.06	417.05	14.44	82.13	26.36	157.11
	6	19.21	109.41	50.02	329.77	12.66	69.65	61.18	418.71	14.67	84.15	26.70	159.14
Quebec	1	21.32	122.93	48.71	315.58	10.54	56.17	59.91	404.83			24.72	145.61
	6	21.06	120.99	48.88	317.75	10.76	58.19	60.04	406.97			25.05	147.55
Romeo	1	24.25	141.25	45.81	290.01	7.78	37.88	57.10	380.98	11.01	61.48	21.92	127.72
	6	23.89	139.14	46.03	292.20	7.99	40.10	57.18	381.41	11.45	63.50	22.07	129.39
Sierra	1	26.27	153.59	43.84	271.85	5.26	23.52	54.7	361.34	7.51	39.26	19.99	114.95
	6	26.59	155.27	44.06	273.86	5.59	25.80			7.77	41.05	19.71	112.85
Tango	1	28.51	166.30	42.83	263.28	3.67	13.74			3.54	16.69	17.81	102.08
	6	28.37	168.79	42.85	264.56	4.02	16.05			3.63	17.01	17.92	103.62

Table 3.--Travel times and distances from the Angela shot point

Channel No.	Site No.	Travel time (seconds)	Distance (km)	Channel No.	Site No.	Travel time (seconds)	Distance (km)
6	B1	1.6	3.892	1	E1	8.2	41.846
7	C1	2.7	6.336	7	D3	8.4	43.473
7	B1	2.4	6.937	3	D3	8.4	43.976
4	B1	3.7	7.046	1	E2	10.8	56.930
1	B1	2.7	8.318	2	E2	11.0	58.279
3	C1	2.8	8.412	7	E2	11.2	60.332
1	D1	2.9	9.722	3	E2	11.4	61.378
2	B1	2.9	9.806	6	E2	11.5	62.827
3	B1	2.8	9.865	4	E2	11.7	63.235
1	C1	3.3	11.812	6	E4	11.4	64.597
3	D1	3.2	11.841	4	E4	11.9	65.990
7	D1	3.8	14.689	7	E4	12.2	67.867
3	C2	3.7	14.811	1	E4	12.2	69.087
3	B4	3.9	16.418	3	E4	12.4	69.204
7	C2	3.7	16.567	2	E4	12.7	71.131
1	C2	4.0	16.601	1	E3	13.5	75.249
1	B4	(3)	18.614	3	E3	13.6	75.930
7	A0	4.3	19.023	7	E3	13.9	78.160
7	B4	4.4	19.414	6	F1	15.9	87.249
1	A0	4.3	20.431	7	F1	15.7	90.268
3	A0	4.4	20.944	4	F1	16.1	90.293
7	B3	5.1	23.969	3	F1	16.1	90.444
7	C4	5.3	24.104	2	F1	16.6	92.932
1	B3	5.5	26.425	1	F1	16.7	93.311
3	B3	5.6	26.745	3	F4	(3)	96.889
3	C4	5.9	26.990	7	F4	(3)	97.275
7	C3	5.6	27.254	1	F4	(3)	100.102
7	D4	5.8	27.539	1	F2	19.5	106.058
1	C4	6.1	29.184	6	F2	19.6	106.215
1	D4	6.2	29.218	7	F2	19.7	107.611
1	C3	6.1	30.014	2	F2	19.9	109.291
3	C3	6.1	30.069	4	F2	20.0	109.425
3	D4	6.4	30.995	3	F2	20.3	110.605
1	D2	(1)	31.340	4	F3	(3)	119.380
3	D2	(1)	32.561	6	F3	(3)	119.914
7	D2	(1)	34.564	3	F3	(3)	121.320
7	E1	7.6	38.580	7	F3	(3)	122.315
3	E1	8.0	40.353	2	F3	(3)	124.372
1	D3	7.9	41.225	1	F3	(3)	125.718

Table 3.--Travel times and distances from the Sidney shot point

Channel No.	Site No.	Travel time (seconds)	Distance (km)	Channel No.	Site No.	Travel time (seconds)	Distance (km)
2	F1	16.1	89.562	3	A0	32.9	199.427
1	F1	16.2	90.561	1	A0	33.0	199.477
3	F1	16.3	91.139	7	D2	(1)	200.661
4	F1	16.5	92.550	7	C4	(3)	201.918
7	F1	16.8	93.852	7	B3	33.4	203.015
6	F1	17.1	96.033	7	C3	33.5	203.587
1	E1	26.8	159.242	3	C4	(3)	204.917
7	E1	27.0	160.024	1	B3	33.8	205.388
6	E2	27.0	160.079	3	B3	33.8	205.768
3	E1	26.9	162.178	1	C4	(3)	206.405
1	E2	27.3	162.335	3	C3	33.9	206.985
7	E2	27.3	162.816	1	C3	34.1	207.968
4	E2	27.4	163.271	1	D3	35.9	220.163
7	D1	27.8	164.483	3	F4	(3)	220.634
2	E2	27.6	165.170	6	F2	36.4	221.125
3	E2	27.8	166.075	7	D3	36.3	222.512
3	D1	28.1	167.444	3	D3	36.3	222.832
1	D1	28.6	169.322	4	F2	36.7	222.849
7	C1	30.0	179.586	7	F4	(3)	223.220
6	B1	30.6	182.216	1	F4	(3)	223.725
3	C1	30.6	182.828	7	F2	36.8	224.105
1	C1	30.7	183.511	1	F2	36.9	225.162
4	B1	(3)	184.366	3	F2	37.1	226.040
7	C2	30.9	184.881	2	F2	37.3	227.538
7	B1	30.9	185.693	6	E4	(2)	237.283
3	C2	31.0	186.604	4	E4	38.3	237.413
1B	B1	31.2	187.300	7	E4	38.4	240.192
1	B1	31.2	187.653	3	E4	(2)	240.620
2	B1	31.4	188.688	1	E4	(2)	242.412
1	C2	31.4	188.729	3	E3	39.2	242.769
1	D4	(2)	191.702	2	E4	(1)	243.419
1	D4	(2)	193.201	1	E3	39.3	243.714
3	B4	32.3	194.517	7	E3	39.5	245.671
3	D4	(2)	194.717	4	F3	(2)	295.790
1	B4	32.5	195.437	6	F3	(2)	296.819
3	D2	(1)	197.393	3	F3	(2)	297.261
7	B4	33.0	197.398	7	F3	(2)	298.801
7	A0	32.6	197.923	2	F3	(2)	300.482
1	D2	(1)	198.916	1	F3	(2)	302.289

Table 3.--Travel times and distances from the Billings shot point

Channel No.	Site No.	Travel time (seconds)	Distance (km)	Channel No.	Site No.	Travel time (seconds)	Distance (km)
1	F3	(3)	108.433	7	F4	(3)	199.960
6	F3	(3)	111.098	7	D2	33.3	200.236
7	F3	(3)	111.301	1	D2	33.3	200.722
2	F3	(3)	111.586	1	D4	(2)	201.024
4	F3	(3)	113.806	1	F4	(3)	201.893
3	F3	(3)	114.497	3	F4	(3)	202.884
2	E4	(3)	150.109	3	D2	33.2	203.278
1	E4	(2)	150.551	2	B1	34.5	204.274
7	E4	25.6	153.144	1	B1	34.3	205.246
3	E4	(2)	153.202	3	B1	34.6	205.824
6	E4	(2)	155.747	1	C2	34.6	206.806
4	E4	26.0	156.205	7	B1	34.4	207.266
1	E3	(1)	167.706	1	C1	34.9	208.288
3	E3	(1)	170.494	3	C2	34.8	208.669
7	D3	29.6	170.738	4	B1	(3)	209.026
3	D3	29.3	171.102	3	C1	34.9	209.100
1	D3	(2)	173.473	6	B1	35.2	210.748
1	C4	31.1	185.446	7	C2	35.0	211.122
1	C3	31.1	186.599	7	C1	35.4	212.405
3	C4	31.3	187.066	1	D1	36.7	223.203
1	B3	(2)	187.169	3	D1	37.0	225.383
3	B3	31.5	187.291	7	D1	37.2	228.255
3	C3	31.2	188.395	1	F2	36.5	232.154
7	B3	32.0	189.829	3	E1	38.3	232.466
7	C4	31.7	190.061	2	F2	36.7	233.053
7	C3	32.1	191.908	7	E1	38.4	233.942
1	A0	32.5	193.313	7	F2	36.6	235.142
3	A0	32.5	194.236	1	E1	38.5	235.440
7	B4	32.8	194.658	3	F2	36.8	236.327
7	A0	32.7	195.247	6	F2	37.1	236.973
1	B4	32.8	196.453	4	F2	(3)	238.622
3	B4	33.1	197.596	2	E2	(2)	248.298
3	D4	33.0	198.068	1	E2	(2)	249.546
7	D4	33.4	199.174	3	E2	(2)	249.576
				7	E2	39.4	251.298

Table 3.--Travel times and distances from the Charleson shot point

Channel No.	Site No.	Travel time (seconds)	Distance (km)	Channel No.	Site No.	Travel time (seconds)	Distance (km)
2	F1	29.6	177.588	1	D2	45.6	288.461
1	F1	29.7	178.132	1	A0	(2)	288.973
3	F1	29.8	179.512	3	A0	45.4	289.015
4	F1	30.0	180.511	7	D2	45.7	290.149
7	F1	30.1	181.420	7	C4	45.1	291.191
6	F1	30.5	183.918	7	B3	46.4	292.513
1	E1	39.7	246.497	7	C3	46.5	293.235
6	E2	39.8	247.386	3	C4	(2)	294.188
7	E1	39.8	247.597	3	B3	46.7	295.289
3	E1	40.2	249.471	1	C4	45.8	295.583
1	E2	40.2	250.172	3	C3	47.0	296.631
7	E2	40.3	250.329	1	C3	(2)	297.593
4	E2	40.4	250.489	3	F4	(2)	301.925
2	E2	40.6	252.847	7	F4	(2)	304.707
3	E2	40.7	253.450	1	F4	(2)	304.740
7	D1	41.0	254.028	6	F2	(2)	305.045
3	D1	41.3	256.998	4	F2	(2)	306.422
1	D1	41.5	258.824	7	F2	47.7	308.066
7	C1	43.4	268.902	1	F2	47.9	309.447
6	B1	43.6	271.764	3	F2	48.4	309.712
3	C1	43.8	272.101	1	D3	48.1	309.718
1	C1	43.9	272.646	2	F2	(2)	311.547
4	B1	(3)	273.954	7	D3	(2)	312.026
7	C2	(2)	274.523	3	D3	48.5	312.406
7	B1	44.0	275.235	4	E4	(2)	325.497
3	C2	44.3	276.252	6	E4	(2)	325.557
1	B1	44.4	276.774	7	E4	(2)	328.375
3	B1	44.7	277.243	3	E4	(2)	328.658
2	B1	44.6	278.225	1	E4	(2)	330.725
1	C2	44.5	278.377	2	E4	(2)	331.555
1	D4	43.9	279.973	3	E3	(2)	331.885
7	D4	44.0	281.659	1	E3	(2)	332.940
3	D4	44.0	282.967	7	E3	(2)	334.813
3	B4	45.0	283.862	4	F3	(2)	385.400
1	B4	45.3	284.663	6	F3	(2)	386.454
7	B4	45.3	286.715	3	F3	(2)	386.842
3	D2	45.1	286.879	7	F3	(2)	388.414
7	A0	45.2	287.470	2	F3	(2)	390.071
				1	F3	(2)	391.905

Table 3.--Travel times and distances from the Greycliff shot point

Channel No.	Site No.	Travel time (seconds)	Distance (km)	Channel No.	Site No.	Travel time (seconds)	Distance (km)
1	F3	33.3	199.339	7	D2	44.4	288.855
6	F3	34.0	202.018	1	D2	44.6	289.056
7	F3	33.7	202.227	2	B1	(2)	289.902
2	F3	33.6	202.478	1	B1	(2)	290.478
4	F3	34.1	204.735	3	D2	44.7	291.783
3	F3	34.0	205.410	3	B1	45.0	291.798
2	E4	37.5	230.721	1	C1	45.0	292.076
1	E4	37.6	231.869	7	B1	(2)	292.840
3	E4	38.2	233.475	3	C1	45.1	293.359
7	E4	38.0	233.971	1	C2	45.3	293.785
4	E4	38.2	236.696	4	B1	(2)	294.885
6	E4	38.1	236.945	3	C2	45.7	295.504
7	D3	40.5	257.233	6	B1	45.7	296.265
3	D3	40.5	258.054	7	C1	45.1	296.763
1	E3	(1)	258.279	7	C2	(2)	298.187
7	E3	(1)	258.410	1	D1	47.0	308.130
1	D3	40.8	260.187	3	D1	47.3	310.545
3	E3	(1)	261.142	3	E1	47.7	312.272
7	F4	(3)	266.347	7	D1	(2)	313.297
1	F4	(3)	267.507	7	E1	(2)	314.230
3	F4	(3)	269.357	1	E1	(2)	315.242
1	C4	(3)	269.795	1	F2	(2)	323.012
3	C4	(3)	271.774	2	F2	(2)	323.864
1	B3	42.6	272.724	7	F2	(2)	325.995
3	B3	42.6	273.308	3	F4	(2)	327.139
1	C3	(2)	273.570	6	F2	(2)	327.854
7	C4	(3)	274.714	4	F2	(2)	329.470
7	B3	43.0	275.617	2	E2	(2)	337.576
3	C3	42.8	275.697	1	E2	(2)	338.637
1	A0	43.2	278.989	3	E2	(2)	339.027
7	C3	43.4	279.182	7	E2	(2)	340.571
7	B4	43.8	279.399	4	E2	(2)	342.244
3	D4	43.7	279.413	6	E2	(2)	344.080
3	A0	43.4	280.549	6	F1	(2)	378.178
1	B4	43.9	280.780	7	F1	(2)	380.527
7	D4	43.9	281.064	4	F1	(2)	381.639
7	A0	43.6	281.202	3	F1	(2)	382.956
3	B4	44.1	282.391	1	F1	(2)	383.826
1	D4	44.2	282.433	2	F1	(2)	384.610

Table 4.--Location of LASA seismometers

Site A0

Channel No.	Hole No.	Coordinates: Latitude (N)	Coordinates: Longitude (W)	Elevation (feet)
1	76	46° 42'01"	106° 15'28"	2801.1
2	85	46° 40'15"	106° 15'37"	2766.8
3	74	46° 39'42"	106° 13'10"	2691.4
4	83	46° 40'30'	106° 10'51"	2598.6
6	72	46° 42'14"	106° 11'23"	2644.9
7	10	46° 41'19"	106° 13'20"	2442.4

Site B1

Channel No.	Hole No.	Coordinates: Latitude (N)	Coordinates: Longitude (W)	Elevation (feet)
1	86	46° 46'05"	106° 07'53"	2739.1
2	75	46° 44' 20"	106° 07'33"	2719.9
3	84	46° 43'15"	106° 05'30"	2729.9
4	73	46° 44'20"	106° 03'27"	2718.2
6	82	46° 46'05"	106° 03'06"	2804.7
7	10	46° 45'08"	106° 05'30"	2475.2

Table 4.--Location of LASA seismometers

Site B3

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 41'14"	106° 20'16"	2813.6
3	10	46° 39'33"	106° 19'01"	2370.5
7	71	46° 40'54"	106° 17'44"	2841.7

Site B4

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 47'23"	106° 16'36"	2686.1
3	10	46° 46'05"	106° 14'35"	2351.2
7	75	46° 45'37"	106° 16'51"	2708.2

Table 4.--Location of LASA seismometers

Site C1

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 51'47"	106° 09'29"	2722.4
3	10	46° 50'22"	106° 07'39"	2355.6
7	82	46° 50'44"	106° 05'00"	2740.7

Site C2

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	75	46°39'05"	106° 02'06"	2736.7
3	25	46°40'02"	106° 01'06"	2768.1
7	73	46°39'22"	105° 58'39"	2686.3

Table 4.--Location of LASA seismometers

Site C3

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 35'36"	106° 17'09"	2552.8
3	10	46° 34'27"	106° 14'59"	2238.8
7	82	46° 35'10"	106° 12'26"	2619.6

Site C4

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	76	46° 44'55"	106° 24'29"	2848.7
3	10	46° 44'07"	106° 22'26"	2506.7
7	72	46° 44'56"	106° 20'24"	2734.0

Table 4.--Location of LASA seismometers

Site D1

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	76	46° 50'53"	105° 55'37"	2846.8
3	10	46° 50'23"	105° 53'22"	2488.9
7	72	46° 51'27"	105° 51'36"	2961.2

Site D2

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 31'06"	106° 03'03"	2517.7
3	21	46° 30'27"	106° 00'40"	2449.1
7	75	46° 29'21"	106° 02'40"	2446.6

Table 4.--Location of LASA seismometers

Site D3

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	72	46° 34'20"	106° 27'31"	2781.1
3	10	46° 32'59"	106° 28'49"	2626.3
7	81	46° 34'40"	106° 30'03"	2828.3

Site D4

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	72	46° 57'06"	106° 20'47"	2675.4
3	10	46° 56'31"	106° 23'00"	2341.2
7	83	46° 55'20"	106° 20'51"	2720.8

Table 4.--Location of LASA seismometers

Site E1

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	72	47° 10'35"	106° 01'18"	2441.6
3	10	47° 09'46"	106° 03'22"	2248.9
7	83	47° 08'49"	106° 00'58"	2572.8

Site E2

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	46° 32'08"	105° 23'47"	2424.0
2	75	46° 30'23"	105° 24'10"	2419.7
3	84	46° 28'57"	105° 22'39"	2350.5
4	73	46° 29'36"	105° 20'16"	2268.4
6	82	46° 31'13"	105° 19'13"	2178.9
7	10	46° 30'46"	105° 21'53"	2000.5

Table 4.--Location of LASA seismometers

Site E3

Channel No.	Hole No.	Coordinates Latitude (N)	Coordinates Longitude (W)	Elevation (feet)
1	86	46° 09'55"	106° 22'25"	2849.6
3	10	46° 08'58"	106° 20'03"	2497.8
7	75	46° 08'10"	106° 22'05"	2850.5

Site E4

Channel No.	Hole No.	Coordinates Latitude (N)	Coordinates Longitude (W)	Elevation (feet)
1	74	46° 44'11"	106° 55'59"	2833.6
2	85	46° 45'28"	106° 57'45"	2819.9
3	76	46° 46'58"	106° 56'22"	2874.3
4	81	46° 47'22"	106° 53'51"	2789.8
6	72	46° 45'48"	106° 52'39"	2774.7
7	26	46° 45'52"	106° 55'14"	2903.6

Table 4.--Location of LASA seismometers

Site F1

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	81	47° 24'05"	105° 10'33"	2689.6
2	72	47° 22'41"	105° 08'57"	2573.6
3	83	47° 20'56"	105° 09'16"	2647.0
4	10	47° 22'15"	105° 11'15"	2428.0
6	85	47° 21'45"	105° 13'56"	3014.7
7	76	47° 23'23"	105° 12'58"	2868.9

Site F2

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	76	45° 54'49"	105° 31'26"	2917.1
2	85	45° 53'06"	105° 30'50"	2852.8
3	74	45° 53'03"	105° 28'18"	2904.0
4	83	45° 54'17"	105° 26'27"	2923.0
6	72	45° 55'50"	105° 27'40"	2717.5
7	10	45° 54'34"	105° 29'08"	2474.7

Table 4.--Location of LASA seismometers

Site F3

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	85	45° 57'16"	107° 07'06"	3022.1
2	74	45° 56'46"	107° 04'40"	3189.9
3	83	45° 57'36"	107° 02'25"	3106.7
4	72	45° 59'19"	107° 03'00"	3010.5
6	81	46° 00'15"	107° 05'10"	2950.1
7	10	45° 58'22"	107° 04'54"	2747.0

Site F4

Channel No.	Hole No.	Coordinates Latitude (N)	Longitude (W)	Elevation (feet)
1	86	47° 25'19"	106° 59'14"	2626.9
3	10	47° 24'40"	106° 56'37"	2320.9
7	75	47° 23'38"	106° 58'28"	2583.3