ISGS Contract/Grant Report: 1989-2

Geophysical Exploration for Potential Groundwater Resources Near Bloomington, Illinois

Timothy H. Larson and Vickie L. Poole

Technical Completion Report
to the
City of Bloomington

Department of Energy and Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY
1989

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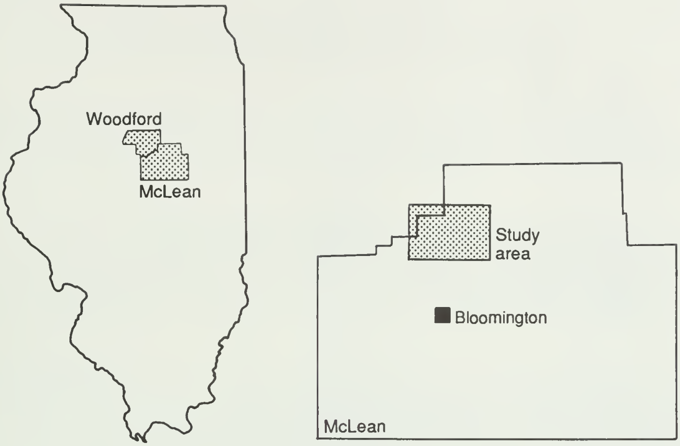


Figure 1 Study area in central Illinois.

Abstract
The 1988-90 drought in central Illinois resulted in alarmingly low water levels in reservoirs supplying water to the City of Bloomington. At the request of the city, the Illinois State Geological Survey conducted geophysical investigations to locate potential groundwater resources in the vicinity of the Lake Bloomington and Evergreen Lake reservoirs. An electrical earth resistivity survey was conducted in the Mackinaw River Valley to delineate a possible sand and gravel aquifer within the alluvium. Resistivity data indicate that some sand and gravel is present, but it is limited in extent and probably contains a significant amount of fine-grained material. A seismic refraction survey was conducted to delineate the geometry of the Danvers Bedrock Valley known to be present at depths of 200 to 400 feet beneath the ground surface. Refraction data successfully located the buried bedrock valley and revealed the presence of either a bedrock knob or island lying approximately beneath Lake Evergreen. This bedrock high separates the valley into northern and southern channels. The western extent of the northern channel is not known.

Introduction
Bloomington (population 44,200) obtains its water supply from the Lake Bloomington and Evergreen Lake Reservoirs (fig 1). The adjacent city of Normal obtains its supply from shallow wells drilled in surficial and shallow sand and gravel deposits within the Sugar Creek Valley and basal deposits within the Mackinaw Bedrock Valley near the McLean-Tazewell county line. A severe drought led to a drop in the water levels at Lake Bloomington and Evergreen Lake, causing water shortage and restrictions in the summers of 1988 and 1989. Bloomington needs a temporary, emergency supplement and a long-term supplement to the current supply of reservoir water. The city contracted with the Illinois State Geological Survey to provide geophysical assistance in the effort to locate a long-term supplemental municipal groundwater supply. The Survey's responsibility has been to investigate the shallow alluvial sand and gravel aquifer and the basal sand and gravel aquifer within the region.

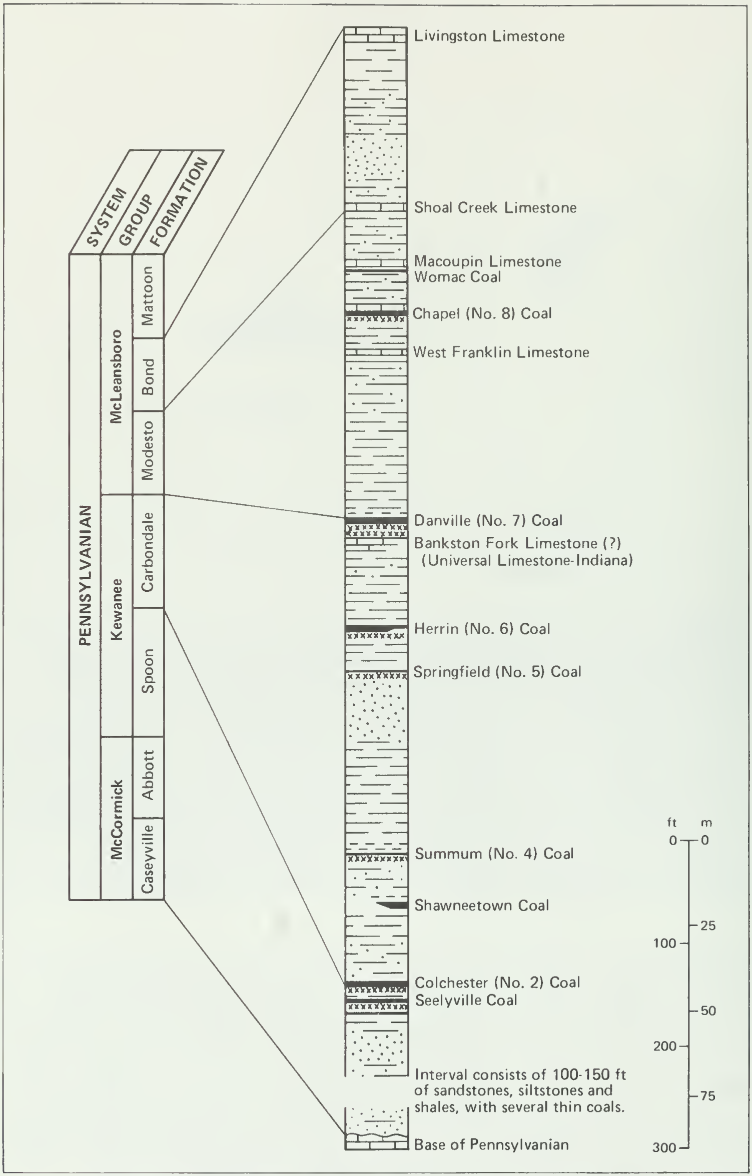


Figure 2a Stratigraphic section showing relationships among shallow bedrock units encountered in the study area.

Two regional aquifers that may yield adequate water occur in the vicinity of Lake Bloomington and Evergreen Lake. Alluvium in the Mackinaw River Valley, located north of Bloomington, may contain extensive deposits of water-bearing sand and gravel. The Danvers Bedrock Valley, which lies 200 to 400 feet below land surface, may contain sufficient basal sand and gravel deposits to yield adequate water for the city's needs.

Electrical earth resistivity profiling was conducted in section 6 of Hudson Township within the Mackinaw River Valley to map possible deposits of alluvial sand and gravel. Seismic refraction profiling was conducted in the northern half of Hudson Township (T25N, R2E, McLean County) between Lake Bloomington and Evergreen Lake to delineate the geometry of the Danvers Bedrock Valley.

The geophysical investigations conducted by the Survey are part of a more extensive study being conducted by Bloomington. The results of the geophysical investigations provide background information to that larger study. Further geological work required to confirm the geophysical results may be conducted by the City of Bloomington within the larger framework of their study.

Geologic Setting

Bedrock surface in this region is composed of sedimentary rock of Pennsylvanian age (fig. 2a). In Hudson Township, the younger Modesto Formation has been partly eroded so that rocks of the underlying Carbondale Formation are at the bedrock surface throughout much of the region. In this area, the rocks of these two formations are quite similar, primarily shales with thin layers of sandstone, coal, and limestone. The most striking feature of the bedrock surface is the buried bedrock valley, known as the Danvers Bedrock Valley, which was established sometime before Pleistocene glaciation. The exact configuration of the valley is not certain. However, it appears to enter Hudson Township from the northeast in sections 1, 2, and 3 and continue beneath the northern half of the township, before leaving somewhere in sections 18, 19 or 30. The town of Hudson lies over the southern rim of the valley, and Lake Bloomington appears to be over the eastern margin.

Between the land surface and bedrock is 200 to 400 feet of unconsolidated glacial and alluvial sediments (fig 2b). Deposits associated with the most recent glaciation, the Wisconsinan, form a thin veneer, 20 to 50 feet thick over most of the region. Only within the modern stream valleys, Six Mile Creek, Money Creek, and the Mackinaw River, are there significant nonglacial, alluvial deposits. Most of the glacial deposits are clayey sediments called till. Some coarser deposits of glacial outwash are also known to be present at several locations in the area. It is not known if these outwash deposits are continuous. At the base of the glacial deposits is an unknown thickness of outwash and alluvium, some of which may be preglacial in origin.

Hydrogeologic Setting

The Pennsylvanian bedrock is not considered an aquifer in this region. The shales and limestones encountered within 100 ft of the bedrock surface do not produce appreciable amounts of water. The State Geological Survey has no records of wells finished in the Pennsylvanian bedrock within this area.

Three aquifers occur within the unconsolidated deposits above the bedrock surface. Two aquifers are potentially suitable for development of large groundwater supplies, the third aquifer is not likely to yield large amounts of water.

The basal deposits within the Danvers Bedrock Valley could potentially yield large amounts of water. Unfortunately, the character and thickness of these deposits is unknown. Similar bedrock valleys in central Illinois do yield large amounts of water from basal sand and gravel

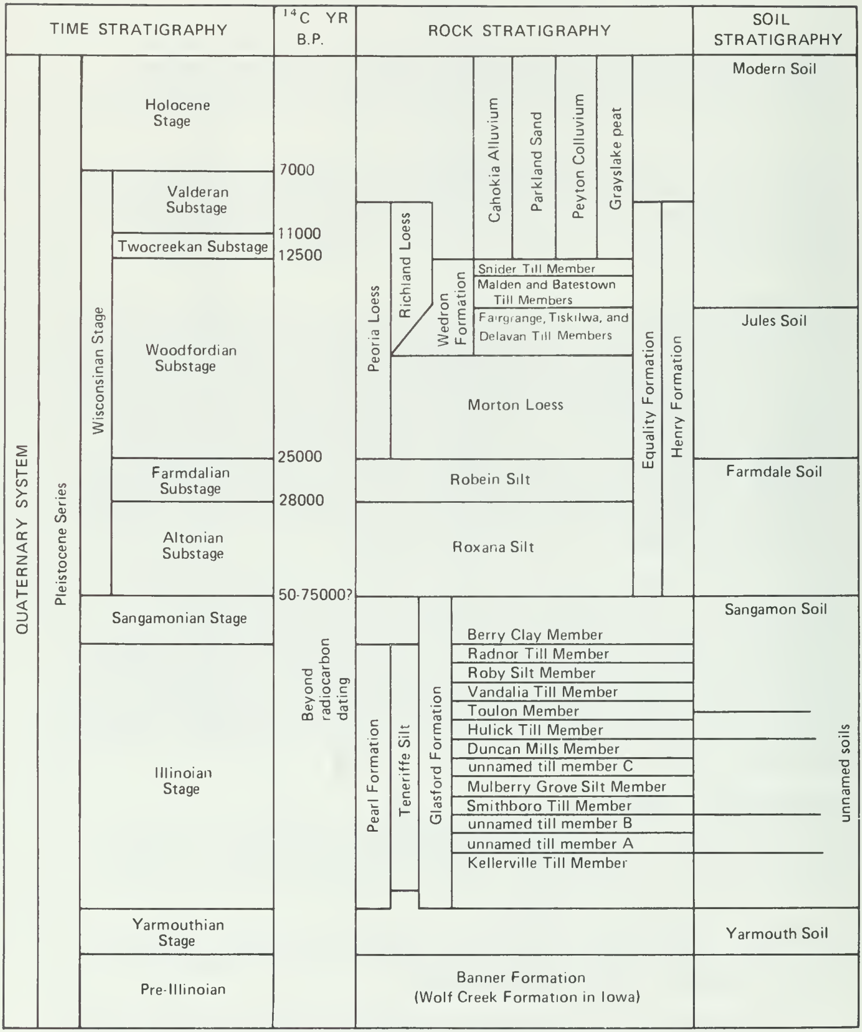


Figure 2b Stratigraphic section showing relationships among glacial sediments encountered in the study area.

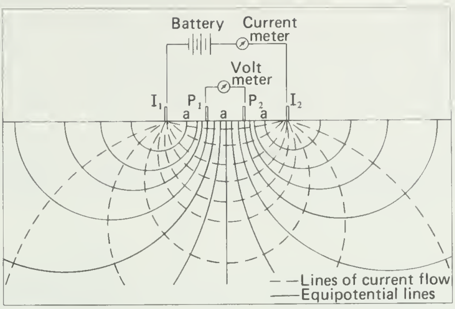


Figure 3 Schematic diagram of electrical earth resistivity method.

deposits; however, other bedrock valleys contain fine-grained basal deposits that do not yield large amounts of water. The water-bearing potential of the basal deposits of the Danvers Bedrock Valley can only be determined from test drilling. Alluvium within the Mackinaw River Valley may contain large deposits of sand and gravel; sand deposits have been quarried in the vicinity. However, the character and extent of alluvial sand in the Mackinaw Valley along the north end of Hudson Township are unknown. If present, alluvial sands and gravels could yield substantial amounts of water, sufficient for large groundwater supplies.

Outwash sand and gravel occurs at several locations within the glacial deposits. These aquifer materials yield small amounts of water sufficient for domestic purposes, but not adequate for large groundwater supplies. They were not considered for exploration in this project.

Resistivity Investigations

The potential for significant deposits of alluvial sand and gravel deposits within the lowlands of the Mackinaw River Valley was investigated using the electrical earth resistivity (EER) method. Coarse-grained glacial deposits that may occur beneath the alluvium or surrounding uplands were not investigated. Regional data on file at the State Geological Survey indicate that glacial deposits at intermediate depth are not likely to yield significant amounts of water. The method does not directly locate groundwater resources, only the possible presence of coarse-grained sediments. Test drilling is necessary to confirm the presence and thickness of sand and gravel deposits and to determine their water-yielding potential.

Methods

In the EER procedure, an electric current is applied to the ground through two current electrodes, and the potential difference is measured across a pair of potential electrodes. Apparent resistivity is calculated on the basis of the measured potential drop, applied current, and electrode spacing (Dobrin, 1976, chapter 17). As the distance of the electrode pair from the center point is systematically increased, changes in apparent resistivity can be related to variations in resistivity of earth materials with depth (fig. 3). Units of resistivity reported in this study are in ohm-feet.

For this study, the Wenner electrode configuration was employed, using a Terrameter ASA 300B resistivity meter. The electrodes were laid out in a line with the current electrodes (I_1 and I_2) positioned at the outside ends and the potential electrodes (P_1 and P_2) forming the was expanded from the center point. Originally, the Schlumberger electrode configuration was considered for application during this study. It is very similar to the Wenner array, except that the current electrode spacing is allowed to increase more rapidly than the potential electrode spacing. The Schlumberger configuration tends to focus the electrical response at shallow depths relative to the Wenner configuration. Because of the depths investigated, the configuration was changed to the Wenner configuration.

The method of expanding the electrode configuration systematically from the center point, measuring the current and potential differences, and calculating the apparent resistivity values is called vertical electrical sounding (VES). A plot of apparent resistivity values versus electrode spacings is a VES curve (Heigold et al., 1985).

The VES data obtained during this study were analyzed quantitatively using an inversion technique developed by Zohdy and Bisdorf (1975). The inversion technique converts VES curves into a sequence of layers representing types of earth materials of varying thickness and calculated "true" resistivity. These "true" resistivities and thicknesses are called layering parameters. This technique provides only one of many geoelectrically equivalent, layering-parameter solutions for a given VES curve (Heigold et al., 1985). Prior knowledge of the general geologic conditions in the study area can eliminate this ambiguity.

Results

Sixty-three VES stations were occupied. Locations of the soundings and elevation slice maps are shown in figure 4. Appendix A contains apparent resistivity and layering parameter data. For this discussion, the resistivity survey area is divided into areas 1, 2, and 3 (fig. 4).

Results of the resistivity survey are presented in elevation slice maps, which are areal maps depicting the "true" resistivity values at specified elevations. Areal maps aid in visualizing the extent of relatively high resistivity values. Land surface elevation of the VES stations were estimated from topographic maps accurate to ±5 feet.

Resistivity area 1 is located in the northern half of section 5, Hudson Township, McLean County, and includes 26 VES profiles: 1 through 16, 30 through 35, and 59 through 62 (fig. 4). Geologic control for this area was provided by engineering reports on borings for a bridge (Route 51) over the Mackinaw River. Thin, silty sand and gravel deposits (usually less than 10 ft thick) were reported in these borings at elevations ranging from slightly greater than 640 to approximately 630 feet above mean sea level (msl).

Elevation slice maps of area 1 (fig. 5) indicate a small area west of the bridge along the south side of the Mackinaw River where "true" resistivity values are more than 200 ohm-feet. Past experience with using EER surveys to locate sand and gravel in the unconsolidated sediments of Illinois suggests that 200 ohm-feet is the minimum value for indicating the possible presence of silty sand and gravel (Heigold, personal communication). Correlation of resistivity values obtained during this study with data from the bridge borings confirms the 200 ohm-feet rule of thumb for this project. VES data do not indicate the presence of an extensive area of earth materials with "true" resistivity values greater than 200 ohm-feet.

Resistivity area 2 extends roughly east-west across the center of section 6 in Hudson Township (fig. 4). Twenty-three VES profiles, 36 through 58 and profile 63, are included in this area. Elevation slice maps (fig. 6) delineate an area of approximately one-eighth square mile where "true" resistivity values are greater than 200 ohm-feet. Highest "true" resistivity values in this area are obtained in the vicinity of an old gravel pit. Extremely high resistivity values (greater than 500 ohm-ft) obtained at very shallow depths predominantly north and east of the gravel pit may indicate dry, rather than saturated coarse-grained sediments.

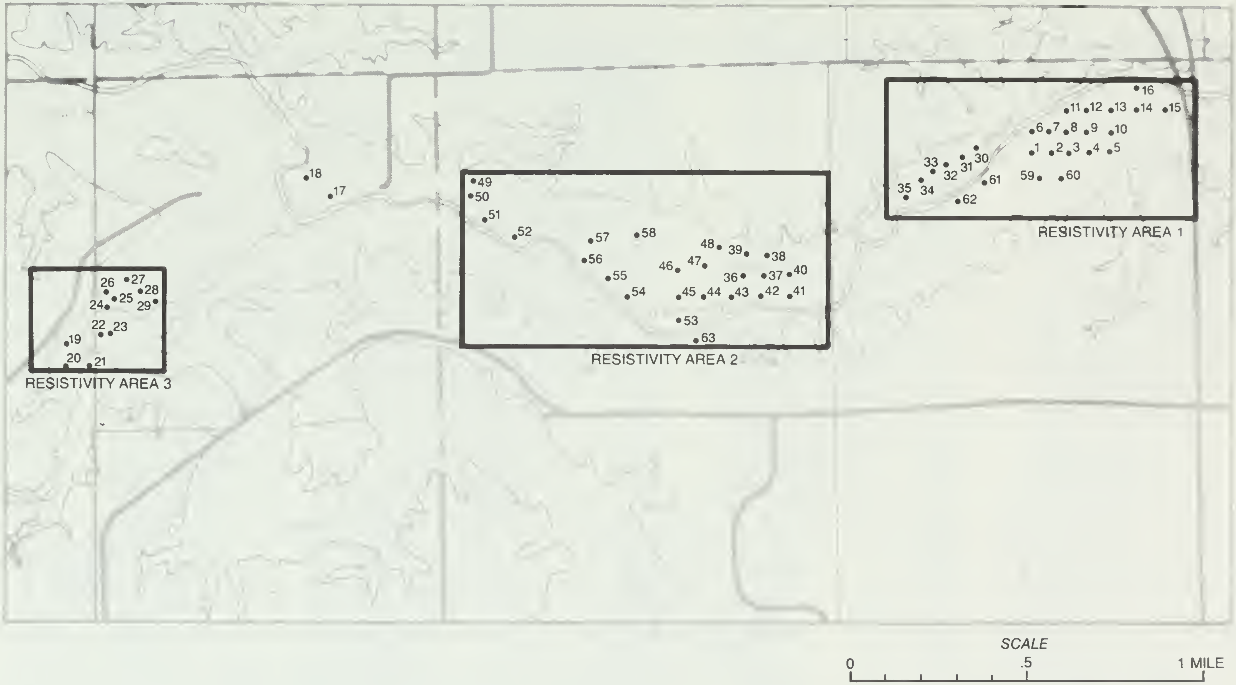


Figure 4 Detailed site map of resistivity study area showing location of VES stations and three sub-areas.

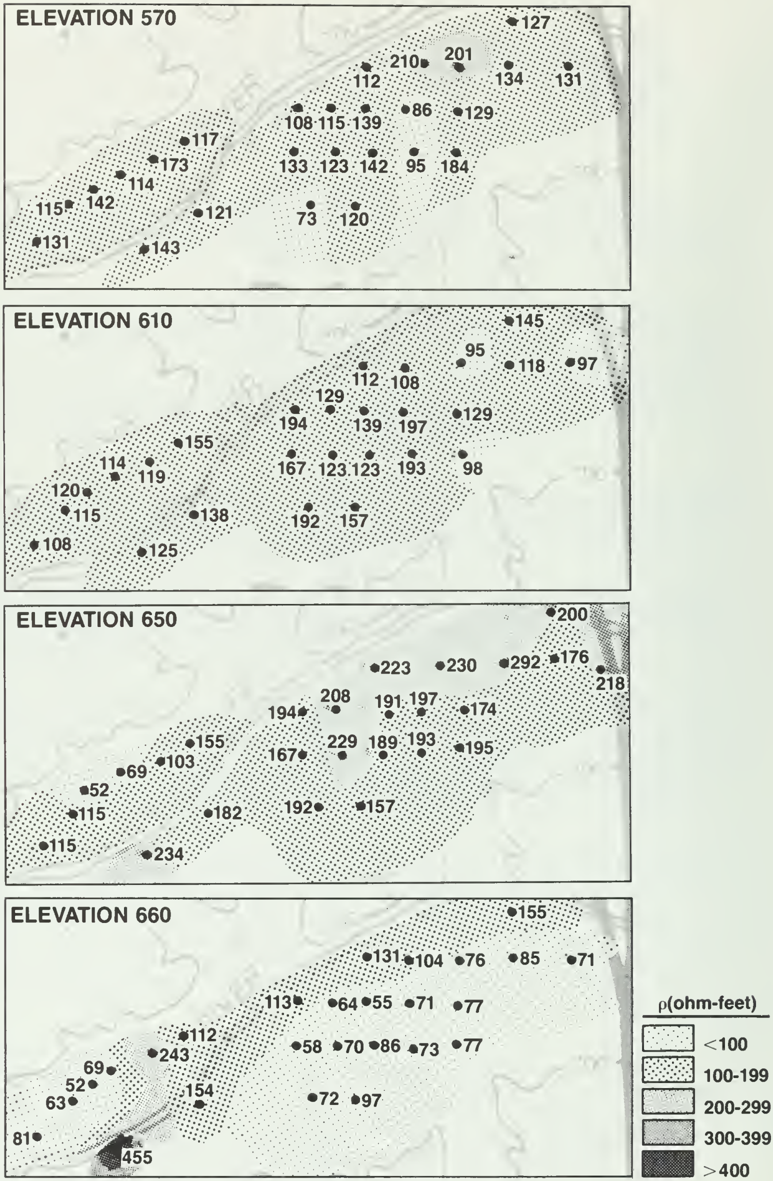


Figure 5 Representative elevation slice maps for resistivity area 1.

Resistivity area 3 is located along a part of Six Mile Creek in sections 1 and 2 (T25N, R1E), Woodford County (fig. 4). Eleven VES profiles were located in area 3: profiles 19 through 29. Although sandy soil was noted at land surface for some profiles, elevation slice maps of the resistivity data (fig. 7) do not indicate any significant areas of 200 ohm-feet or greater resistivity values at shallow depths. Highest values, recorded at greater depths, may represent a channel deposit of coarse-grained sediments, but are more likely to represent glacial outwash deposits below the alluvium. The extent of these possible deposits appears to be limited. Due to restricted access and problems attendant on developing a possible supplemental supply outside the McLean County boundaries, resistivity survey work was limited in these sections.

Seismic Refraction Investigations

The seismic refraction method was chosen to delineate the configuration of the bedrock surface and the location of the Danvers Bedrock Valley. The method cannot be used to determine the thickness or character of basal sands; however, if sand is present, it is expected to occur along the axis of the bedrock valley. Once the axis of the bedrock valley has been determined from seismic refraction, test drilling will be needed to confirm the presence or absence of basal sand.

Shallower sand and gravel aquifers may also be present in the area. Seismic refraction is not intended to determine the presence or character of these shallower aquifers. Regional data suggest that these shallower aquifers are not sufficient for large municipal water supplies.

Methods

A seismic refraction survey is a program to map geologic structure by using seismic waves. Seismic waves involve energy that enters a high-velocity medium (refractor) near the critical angle of refraction. They travel in the high-velocity medium nearly parallel to the refractor surface before returning to the ground surface where they are detected by special sensors called geophones. Refracted wave arrivals are identified in terms of time after the shot and distance from the shot. The objective is to determine the arrival times of the refracted seismic waves in order to map the depth to the refractors in which they traveled. Shots are recorded from both ends of the detector line in the reversed refraction configuration. The information provided from the reversed line allows calculation of both the depth to the refractor and its seismic velocity (Dobrin, 1976, chapter 9).

All seismic refraction lines obtained in this study were reversed. Dynamite charges weighing 0.5 to 1.5 pounds buried in 5-foot-deep boreholes provided seismic energy. The shots were normally offset a distance of 50 feet from the first geophone; 24 geophones were spaced at 100-foot intervals in each line. The records were obtained with an EG&G model 2415 signal enhancement seismograph. Where possible, adjacent seismic lines overlapped 50 percent.

A graphic interpretation method used intercept times and inverse slopes obtained from least squares regression of first arrival times at each geophone. First arrival times were picked manually from the seismic records to a precision of 0.001 second (s), with an accuracy of about 0.002 s. This resulted in an uncertainty in depth determinations of about 10 feet. The method assumes three seismic layers, including a very shallow upper layer assigned a constant velocity of 1250 feet per second (ft/s). The method, described by Mota (1954), results in two types of information: (1) seismic velocities are determined for the middle and lower seismic layers; and (2) depths are calculated to the interfaces between seismic layers and plotted beneath the shot points.

An error in the calculated depth to bedrock is expected when thick, clean basal sands are present in the bedrock valley. The sand usually has a seismic velocity lower than either the

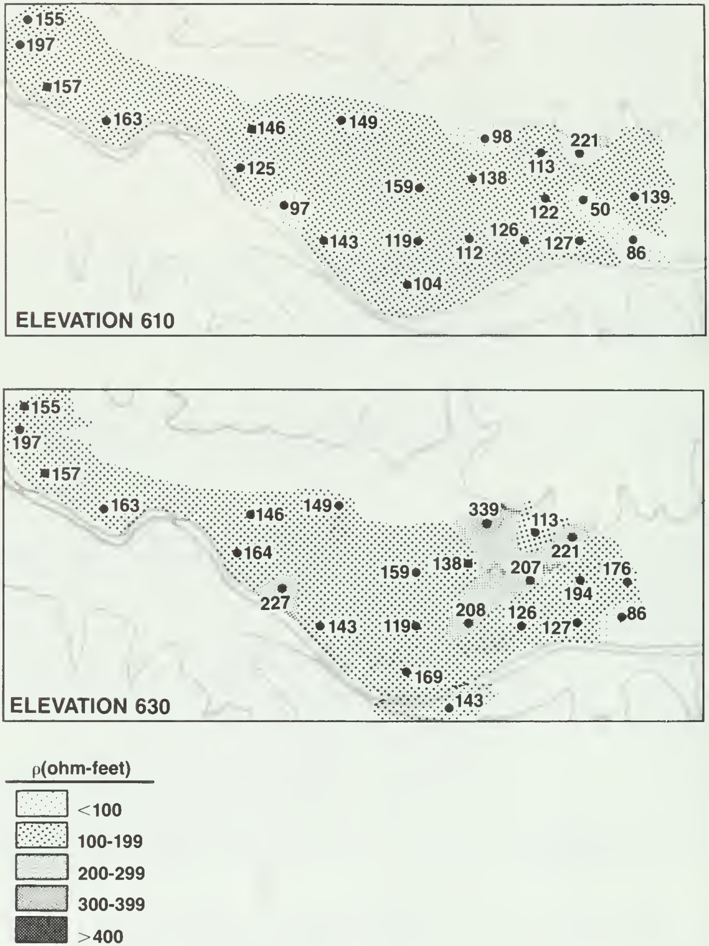
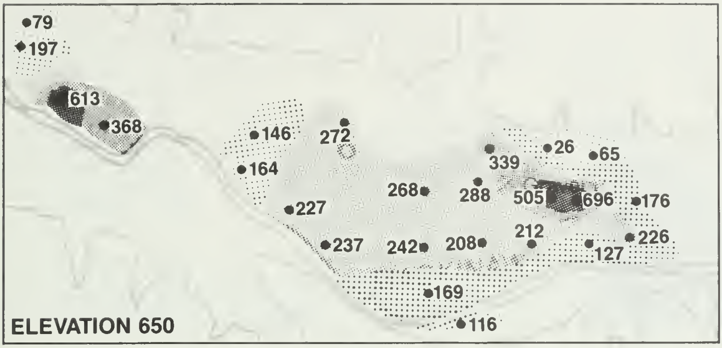


Figure 6 Representative elevation slice maps for resistivity area 2.



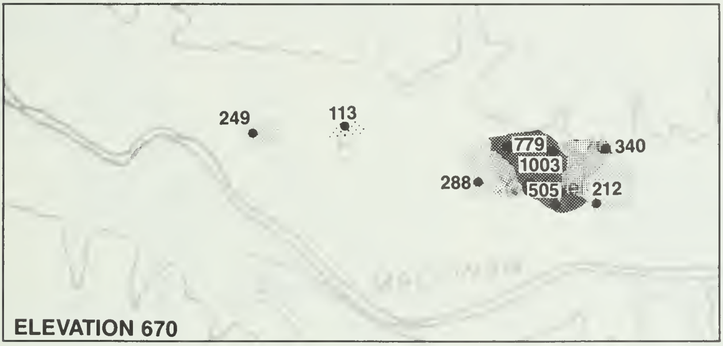


Figure 6 *continued*

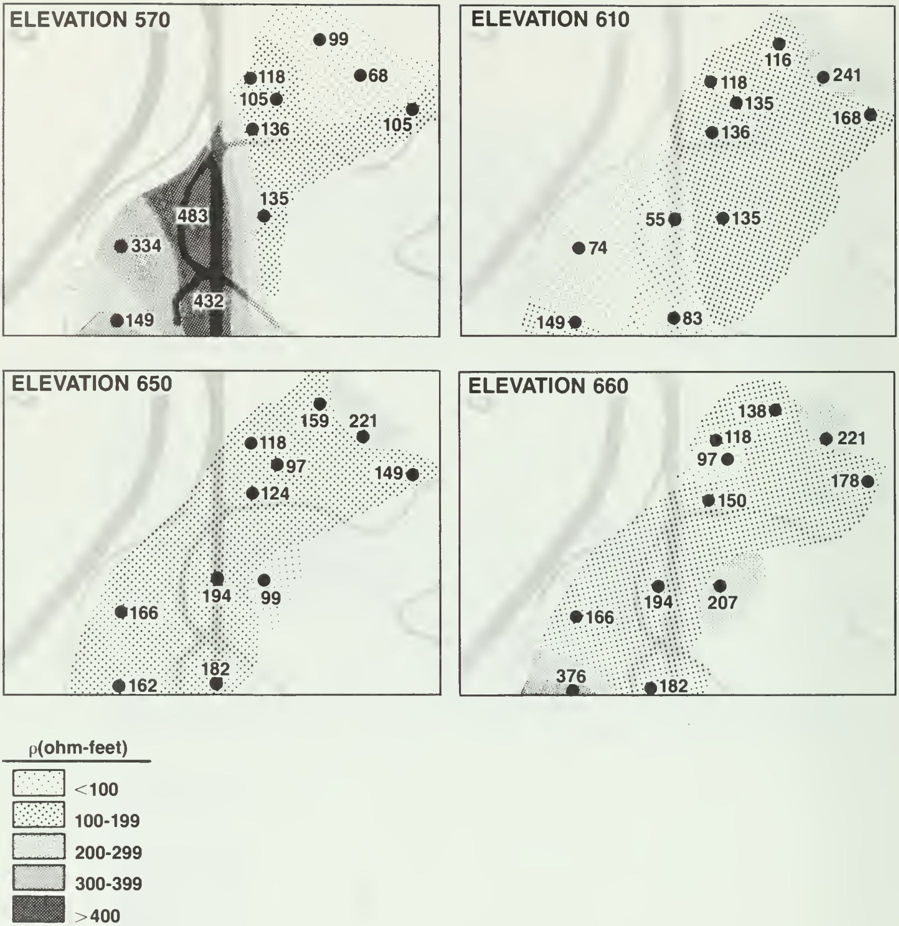


Figure 7 Representative elevation slice maps for resistivity area 3.

bedrock or glacial till. In this case, no critical refraction occurs at the interface between the till above and the sand below. The seismic waves continue to the bedrock surface where they can be critically refracted. However, the entire section above the bedrock takes on the seismic character of till and appears to be thicker than it actually is. This type of error aids in locating the valley axis by accentuating its depth.

The lower seismic layer represents bedrock. Elevations of the bedrock surface were plotted as the difference between surface elevation (estimated to within 5 ft, using topographic maps) and calculated depths. An average value was plotted when more than one depth value was determined for any location. A final map was based on refraction and well data.

Results

Twenty-seven reversed seismic refraction lines were obtained (Appendix B). Locations of lines and shotholes are shown in figure 8. Table 1 gives calculated seismic velocities of seismic layers 2 and 3 for each line, depths to the layer interfaces, and elevations of the bedrock surface beneath each shot point. Representative well records are shown in figure 9.

Table 1 Results of seismic refraction survey. Locations of seismic lines and shot points are shown in figure 8. Velocities (ft/s) are calculated for each seismic line. Depths (ft) and elevations (ft) are calculated at both shot points, labeled A and B, on each seismic line.

Seismic line	Velocities Layer 1	Velocities Layer 2	Depths base of soil A	Depths base of soil B	Depths top of bedrock A	Depths top of bedrock B	Ground surface elevation at A	Ground surface elevation at B	Bedrock surface elevation beneath A	Bedrock surface elevation beneath B
1	6264	10954	9	9	335	336	756	755	421	419
2	6071	11110	8	10	347	328	757	754	410	426
3	6024	10727	11	8	315	326	755	756	440	430
4	6434	10406	14	14	314	268	756	753	442	485
5	6293	10732	11	12	294	289	756	748	462	459
6	6738	10390	14	13	331	230	753	753	422	523
7	6348	10306	9	11	344	313	758	762	414	449
8	6576	10232	11	10	342	339	763	760	421	421
9	6634	10753	11	10	363	341	760	760	397	419
10	6750	10498	10	11	365	315	755	765	390	450
11	6771	10278	15	10	308	338	760	758	452	420
12	6981	10272	13	11	396	353	752	744	356	391
13	6575	10282	10	11	299	364	752	747	453	383
14	6622	10485	11	13	324	335	748	740	424	405
15	6617	10349	12	9	315	349	747	738	432	389
16	6762	10620	9	7	350	331	752	735	402	404
17	6339	9770	9	12	289	340	773	751	484	411
18	6133	10493	6	8	322	345	760	742	438	397
19	6395	10539	8	11	376	254	751	750	375	496
20	6732	11194	12	11	388	386	746	758	358	372
21	6723	10323	6	12	267	389	735	747	468	358
22	6709	10474	13	11	380	355	746	753	366	398
23	6583	10365	11	14	358	352	758	752	400	400
24	6415	10049	11	10	299	369	753	753	454	384
25	6922	10596	9	10	362	330	757	752	395	422
26	6996	10017	12	11	295	346	755	758	460	412
27	6922	10596	9	10	362	330	759	757	397	427
min	6024	9770	6	7	267	230	735	735	356	358
max	6996	11194	18	20	396	389	773	765	484	523
avg	6591	10457	11	11	336	334	754	752	418	418

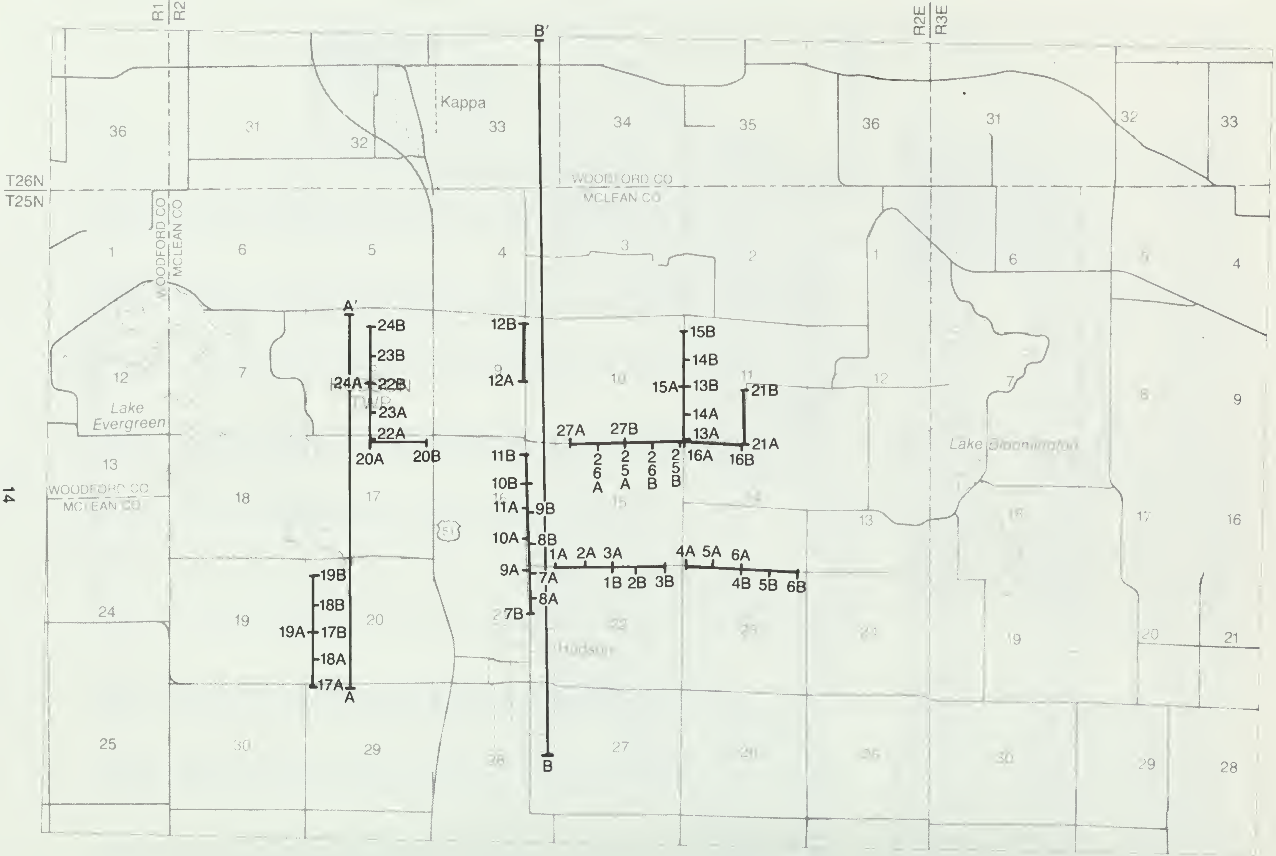


Figure 8 Site map of seismic refraction study area showing location of seismic lines and cross sections.

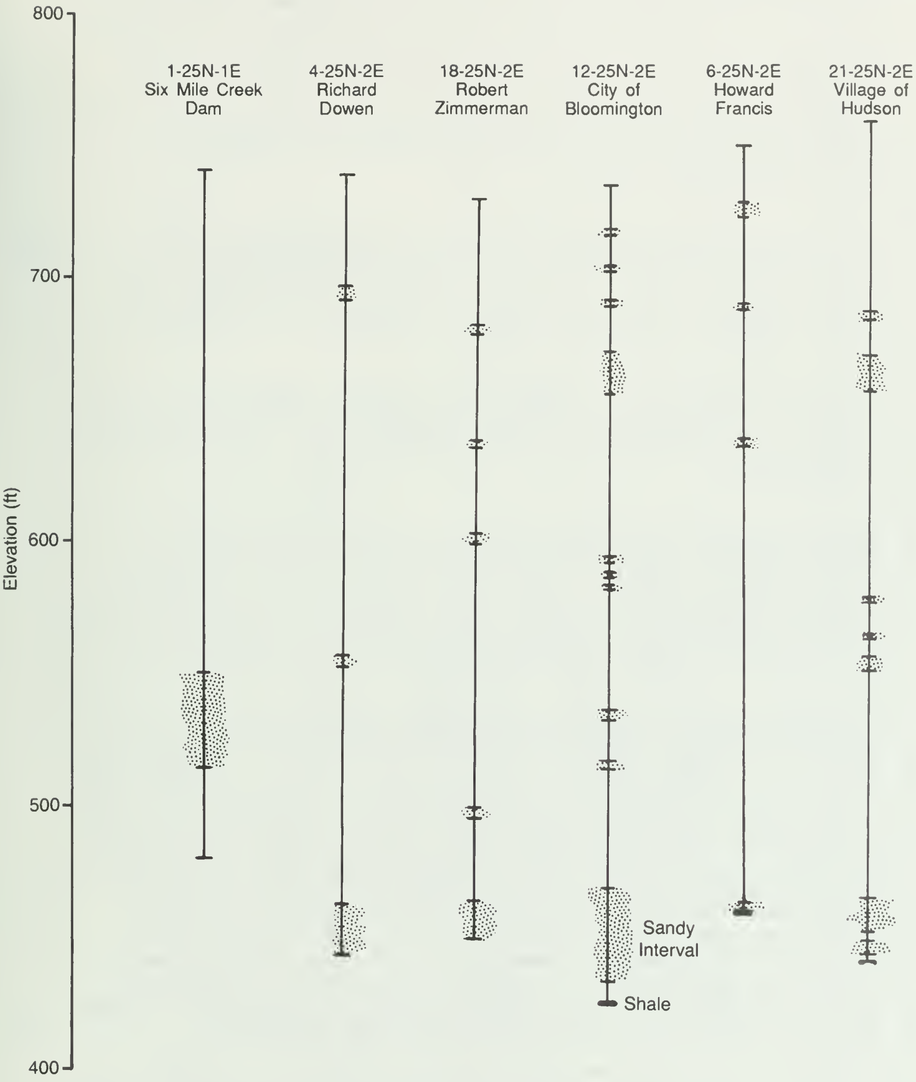


Figure 9 Representative well logs for shallow wells within the study area.

The seismic velocity of layer 2 ranges between about 6,000 and 7,000 ft/s, averaging 6,600 ft/s. These velocities are higher than typical Wisconsinan tills (averaging about 5,000 ft/s) but are typical of compacted Illinoian and older tills (Heigold, personal communication). These higher velocities are consistent with the assumption that the Wisconsinan deposits form only a veneer over older Illinoian and pre-Illinoian deposits that constitute most of the valley fill.

The seismic velocity of layer 3 ranges between about 9,800 and 11,200 ft/s, averaging 10,500 ft/s. These values are typical velocities for predominantly clastic Pennsylvanian bedrock. Drilling reports from the region indicate the upper bedrock is shale, but some evidence suggests thin limestone beds are also present. This latter interpretation is consistent with the average seismic velocity, which is an intermediate value between shale (8,000 ft/s) and limestone (16,000 ft/s).

Seismic layer 1 ranges in thickness between 6 and 20 feet with an average thickness of 11 feet. This seismic layer is not easily correlated with any stratigraphic horizon. Rather, it represents a shallow, weathered soil zone. This zone may represent the unsaturated soil above the water table, but we have no direct evidence to confirm this interpretation. The primary usefulness in calculating the thickness of this seismic unit is in the improved accuracy obtained for deeper seismic interfaces.

Seismic layer 2, interpreted as unconsolidated glacial sediments, ranges between about 260 and 380 feet thick, averaging about 325 feet. These values are consistent with Piskin and Bergstrom's (1975) estimate of 200 to 400 feet of glacial drift within Hudson Township. The seismic data can be used to refine Piskin and Bergstrom's estimate, which was based on regional well data.

Bedrock surface elevations estimated from seismic refraction data range from about 355 to 525 feet above mean sea level (msl), averaging about 420 feet. The higher values of bedrock elevation are consistent with available well control, in which bedrock is encountered above an elevation of 400 feet. Through much of the study area, however, well control is inadequate, particularly where the bedrock surface is calculated from seismic data as below 400 feet in elevation. Wells in these areas tend to be finished in sand and gravel at an elevation of about 450 feet and do not penetrate the full thickness of the glacial sediments.

Estimated bedrock surface elevations, based on seismic and well data, are shown in figure 10. This map depicts the buried Danvers Bedrock Valley trending southwest through the study area. The valley is relatively narrow when it enters the area from the north-northeast, opens to a fairly wide and flat plain in the center, and then becomes more restricted in the southwest. The southeast valley wall is well defined and can also be seen in the two cross sections of figure 11. The cross sections are based primarily on seismic data. Locations of the seismic lines, projected onto the bedrock surface, indicate the available control. Seismic data suggest that the axis of the buried Danvers Bedrock Valley may be at an elevation of less than 400 feet in sections 19 and 20 and possibly section 16. This is 40 to 60 feet below the bedrock surface encountered on the slopes of the valley to the southeast in section 21 and to the northwest in section 18. Both wells along the flanks of the valley encountered sand at an elevation of about 460 feet. If this sand is continuous across the valley, it may indicate the presence of a significant volume of sand. However, the well in section 21 encountered clay beds within the basal deposits. The relative volume of sand and clay in the deepest part of the valley can only be determined by test drilling.

A bedrock high, lying approximately beneath Lake Evergreen, separates the southern channel from a northern channel located in the northwest quadrant of the area. Both seismic

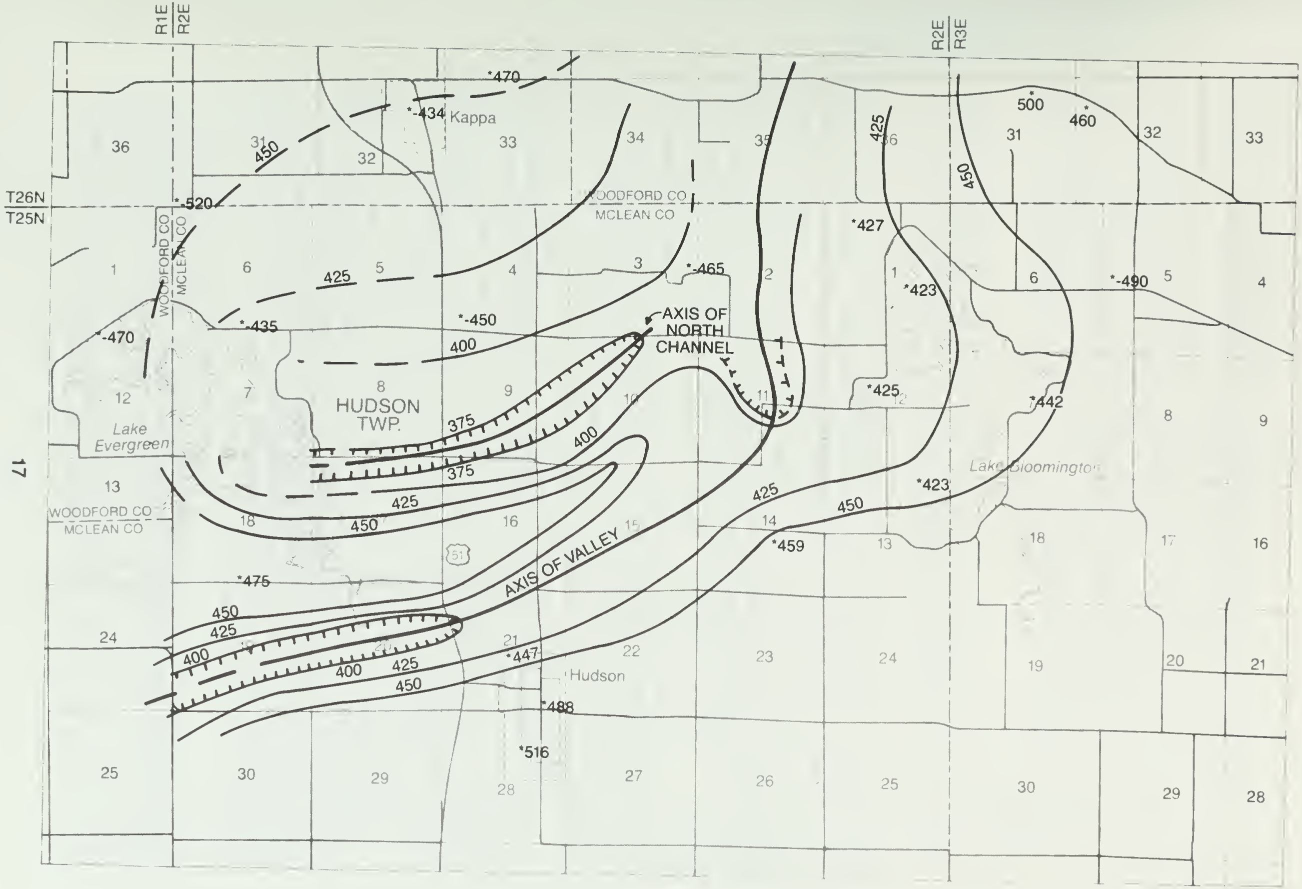


Figure 10 Estimated elevation of bedrock surface in feet above msl. Elevations are based on seismic and available geologic data.

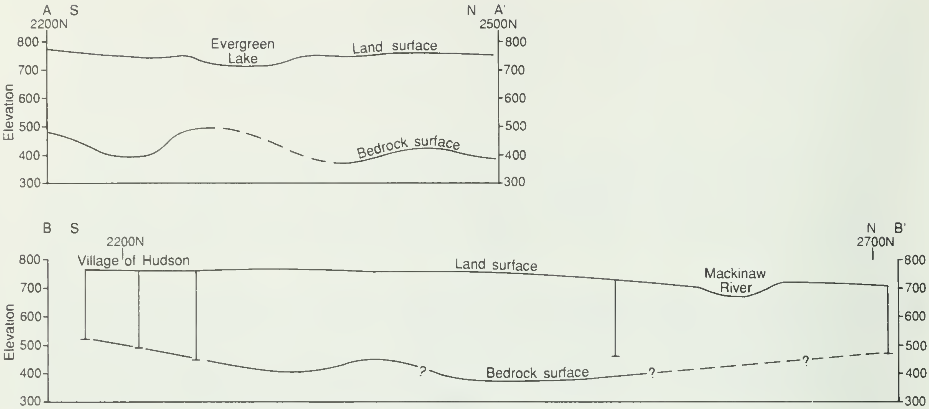


Figure 11 Idealized north-south cross sections through the Danvers Bedrock Valley.

and well data indicate the presence of the bedrock high. This high is depicted in the cross sections of figure 11. Bedrock was encountered in a well in section 18, on the south side of the high at an elevation of 460 feet. Contrary to earlier interpretations (Horberg, 1953), which depict the bedrock surface continuing to rise to the northwest, several wells in sections 4 and 6 failed to encounter bedrock at comparable elevations. These wells terminate in sand and gravel at elevations of about 440 to 450 feet. North-south and east-west seismic lines in sections 8 and 16 indicate that the bedrock high dips abruptly to the north in sections 17 and 18. It is not known whether the bedrock high is an island or is connected to the bedrock uplands to the west. Seismic operations were restricted by Lake Evergreen and the Mackinaw River.

The northern channel appears to have a steep southern wall. The east-west orientation of the northern channel where it crosses the two seismic lines supports the hypothesis that the bedrock high is an island within the Danvers Bedrock Valley. The lowest bedrock elevations encountered in this study consistently occurred along the southern margin of the northern channel. The channel profile flattens to the north. The northern wall of the valley is not well defined, but probably rises much more gently than the southern valley wall.

The eastern edge of the Danvers Valley is determined primarily from well data in the vicinity of Lake Bloomington and one long east-west series of seismic lines ending at the southeast corner of section 14. Seismic data suggests that the valley widens in sections 10, 11, and 15 and in places may reach elevations below 400 feet. The configuration of the channel beneath sections 2 and 3 is not well defined. The few well logs in these sections terminate within the glacial sediments at elevations greater than 450 feet, and the presence of Money Creek restricts collection of seismic data.

The water-bearing character of the basal sediments within the Danvers Valley cannot be precisely defined without further information. Two very different scenarios can be imagined depending on the western configuration of the northern channel. If this channel continues west and south, it is probably part of the main Danvers Valley system; and it is more likely that the deeper portions of the channel may contain thick sand and gravel. If the channel terminates to the west, however, it is more likely to be a tributary to the main Danvers

Valley and less likely to contain thick sand and gravel deposits. In either case, a test hole is necessary to determine the thickness and character of deposits within the channel.

The basic outline of the buried Danvers Bedrock Valley is evident from well data. The seismic data provide additional detail. In particular, the seismic data suggest the presence of two channels separated by a narrow bedrock high centered on Lake Evergreen. South and east of the bedrock high the valley is relatively narrow. Immediately east and north of the bedrock high, at the location of the confluence of the two channels, the valley becomes broader and perhaps deeper. According to the seismic data, the deepest portions of the valley are immediately north of the bedrock high. It is not certain whether the two channels form one continuous valley system or whether the northern channel is a tributary valley.

Summary

Electrical earth resistivity investigations within the Mackinaw River Valley indicate that some alluvial sand and gravel deposits are present. However, these deposits appear to be limited in extent and are either not very coarse or contain a significant percentage of silt or clay.

Seismic refraction investigations successfully located the southern and southeastern boundary of the Danvers Bedrock Valley within Hudson Township. Refraction data also reveal the presence of a second bedrock channel separated from the previously known southern channel by a bedrock high in the vicinity of Lake Evergreen. It is not known whether the two channels form one continuous system, or whether the northern channel is a tributary channel of the southern channel. In either case, seismic refraction data indicate that the thalweg of each channel is deeper than any existing drilling data. The character of the basal deposits within these channels is unknown and can only be determined by test drilling.

Acknowledgments

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Appendix A. Resistivity Data

The following tables are taken from computer output generated by the resistivity inversion routine described by Zohdy and Bisdorf (1975). In these tables, AB/2 refers to one-half the distance between the two potential electrodes (fig. 3), and OBS corresponds to apparent resistivity (ohm-feet). These are the input parameters to the program for each station. Output parameters are the layering parameters: THICKNESS (of each layer, in feet), DEPTH (to layer bottom, in feet), RESISTIVITY ("true" resistivity, in ohm-feet). The program assumes the bottom layer approaches infinite thickness. Station locations are shown on figure 4, and station elevations, reported in feet above msl, were estimated from topographic maps.

VES STATION # 1 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	73.950	7.47803	7.47803	58.06569
20.000	101.000	78.66100	86.13903	167.33720
30.000	120.600	99999910.00000	100000000.00000	133.02640
40.000	132.400			
50.000	140.700			
60.000	148.900			
70.000	154.300			
80.000	154.300			
90.000	151.500			
100.000	150.100			
110.000	149.900			

VES STATION # 2 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	98.510	6.90988	6.90988	70.70109
20.000	137.500	33.12666	40.03654	229.00120
30.000	159.800	99999950.00000	99999990.00000	123.11990
40.000	171.600			
50.000	174.300			
60.000	167.300			
70.000	161.400			
80.000	156.300			
90.000	154.300			
100.000	153.300			
110.000	150.600			

VES STATION # 3 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	111.700	.55143	.55143	60.21048
20.000	144.500	.63258	1.18402	141.71960
30.000	159.400	4.83025	6.01427	86.99506
40.000	166.100	37.18379	43.19806	189.78930
50.000	168.000	24.49266	67.69072	123.82410
60.000	166.600	99999930.00000	99999990.00000	142.60060
70.000	163.100			
80.000	155.800			
90.000	154.900			
100.000	152.000			
110.000	150.600			

VES STATION # 4 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	87.080	8.26515	8.26515	73.84682
20.000	120.100	60.00389	68.26904	193.58920
30.000	145.100	99999910.00000	99999980.00000	95.73998
40.000	155.300			
50.000	160.200			
60.000	160.500			
70.000	162.200			
80.000	158.800			
90.000	154.900			
100.000	151.400			
110.000	147.200			

VES STATION # 5 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	92.290	8.64638	8.64638	77.57518
20.000	122.100	35.31688	43.96326	195.83210
30.000	144.700	48.35961	92.32286	98.94446
40.000	155.000	99999900.00000	99999990.00000	184.54580
50.000	151.100			
60.000	149.600			
70.000	146.400			
80.000	144.200			
90.000	145.300			
100.000	143.200			
110.000	143.700			

VES STATION # 6 ELEV: 662

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	124.400	7.02689	7.02689	113.90540
20.000	160.800	56.50795	63.53483	194.73770
30.000	175.400	99999930.00000	99999990.00000	108.53740
40.000	178.900			
50.000	177.500			
60.000	173.400			
70.000	171.000			
80.000	166.300			
90.000	160.500			
100.000	157.700			
110.000	152.700			

VES STATION # 7 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	84.500	7.61909	7.61909	64.74970
20.000	115.800	33.86639	41.48548	208.47290
30.000	145.300	40.15845	81.64394	129.12710
40.000	161.000	99999910.00000	99999990.00000	115.84070
50.000	161.700			
60.000	159.400			
70.000	153.000			
80.000	149.700			
90.000	149.200			
100.000	146.300			
110.000	144.400			

VES STATION # 8 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	82.240	5.45446	5.45446	55.12244
20.000	117.200	6.75758	12.21204	156.10880
30.000	137.200	24.74522	36.95726	191.10890
40.000	144.700	99999960.00000	100000000.00000	139.21230
50.000	150.400			
60.000	156.000			
70.000	153.900			
80.000	152.300			
90.000	147.500			
100.000	145.100			
110.000	145.100			

VES STATION # 9 ELEV: 664

A8/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	84.690	8.51689	8.51689	71.75315
20.000	116.400	59.39304	67.90993	197.34170
30.000	142.800	99999910.00000	99999980.00000	86.83418
40.000	154.300			
50.000	159.900			
60.000	163.200			
70.000	161.400			
80.000	154.300			
90.000	150.400			
100.000	147.600			
110.000	143.000			

VES STATION # 10 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	100.200	6.34672	6.34672	77.90123
20.000	129.900	33.14946	39.49618	174.83780
30.000	151.300	99999960.00000	100000000.00000	129.67480
40.000	153.500			
50.000	156.100			
60.000	149.200			
70.000	145.100			
80.000	142.200			
90.000	141.300			

VES STATION # 11 ELEV: 662

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	150.700	6.84508	6.84508	131.79460
20.000	181.900	30.57193	37.41701	223.61570
30.000	194.100	55.45997	92.87698	112.93850
40.000	184.700	99999900.00000	99999990.00000	198.34560
50.000	181.500			
60.000	172.600			
70.000	167.100			
80.000	160.300			
90.000	156.000			
100.000	155.800			
110.000	155.500			

VES STATION # 12 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	130.000	6.92181	6.92181	104.93610
20.000	167.100	30.33371	37.25552	230.44950
30.000	185.000	54.96864	92.22417	108.02600
40.000	181.200	99999900.00000	99999990.00000	210.36280
50.000	181.200			
60.000	171.500			
70.000	164.000			
80.000	156.800			
90.000	157.700			
100.000	154.500			
110.000	154.800			

VES STATION # 13 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	99.270	7.17722	7.17722	76.77942
20.000	142.800	2.51442	9.69164	112.27200
30.000	160.400	19.83583	29.52747	292.20490
40.000	165.300	62.35623	91.88370	95.70876
50.000	165.500	99999890.00000	99999980.00000	201.12860
60.000	160.500			
70.000	157.000			
80.000	150.700			
90.000	147.500			
100.000	142.600			
110.000	145.100			

VES STATION # 14 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	104.000	6.71147	6.71147	85.48539
20.000	133.800	37.95238	44.66386	176.79580
30.000	152.100	49.44605	94.10991	118.90380
40.000	155.500	99999900.00000	100000000.00000	134.46020
50.000	154.800			
60.000	150.700			
70.000	144.700			
80.000	144.200			
90.000	143.600			
100.000	143.800			
110.000	142.300			

VES STATION # 15 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	88.590	8.81888	8.81888	71.42182
20.000	122.100	28.90723	37.72611	218.19610
30.000	140.800	56.33694	94.06305	97.74141
40.000	150.700	99999900.00000	99999990.00000	131.45890
50.000	149.500			
60.000	146.600			
70.000	142.000			
80.000	138.700			
90.000	134.000			
100.000	131.900			
110.000	130.600			

VES STATION # 16 ELEV: 662

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	161.400	7.97428	7.97428	155.21900
20.000	182.500	35.67788	43.65216	200.98280
30.000	187.700	46.89272	90.54488	145.87220
40.000	182.700	99999900.00000	99999990.00000	127.67190
50.000	182.500			
60.000	176.800			
70.000	172.800			
80.000	167.300			
90.000	162.800			
100.000	158.300			
110.000	155.500			

VES STATION # 17   ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	559.800	.60000	.60000	1314.25400
20.000	403.300	.07069	.67069	9977.36900
30.000	386.400	1.07451	1.74520	790.95360
40.000	369.400	1.87097	3.61617	2446.18300
50.000	314.100	4.95154	8.56771	145.48610
60.000	272.100	5.41909	13.98680	2093.11500
70.000	228.200	99999930.00000	99999940.00000	131.02970
80.000	196.500			
90.000	169.000			
100.000	157.000			
110.000	150.600			

VES STATION # 18   ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	191.000	5.14097	5.14097	159.27660
20.000	234.700	33.23558	38.37655	260.49620
30.000	225.800	99999950.00000	99999990.00000	115.25530
40.000	221.900			
50.000	209.500			
60.000	195.200			
70.000	180.300			
80.000	168.300			
90.000	151.500			
100.000	142.600			
110.000	140.300			

VES STATION # 19   ELEV: 667

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	167.100	30.71955	30.71955	166.94300
20.000	162.400	60.70288	91.42243	74.16592
30.000	152.400	99999820.00000	99999900.00000	334.38720
40.000	135.200			
50.000	127.500			
60.000	118.300			
70.000	113.900			
80.000	113.000			
90.000	114.200			
100.000	114.300			
110.000	118.100			

VES STATION # 20   ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	309.100	7.96845	7.96845	376.51930
20.000	196.400	18.59528	26.56374	162.79610
30.000	181.500	63.20333	89.76707	102.03790
40.000	148.000	99999900.00000	99999990.00000	149.06650
50.000	132.200			
60.000	123.200			
70.000	116.500			
80.000	114.600			
90.000	113.000			
100.000	114.900			
110.000	117.400			

VES STATION # 21 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	177.100	23.14142	23.14142	182.51610
20.000	159.500	32.80973	55.95114	83.45307
30.000	143.200	21.12425	77.07539	63.19795
40.000	134.400	17.38640	94.46179	110.80300
50.000	124.700	99999770.00000	99999860.00000	432.61900
60.000	121.700			
70.000	116.500			
80.000	115.600			
90.000	115.900			
100.000	118.100			
110.000	123.000			

VES STATION # 22 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	192.800	30.04468	30.04468	194.66520
20.000	180.900	8.67126	38.71593	73.50621
30.000	173.000	43.14616	81.86210	55.09751
40.000	146.700	99999740.00000	99999820.00000	483.63740
50.000	127.500			
60.000	120.600			
70.000	118.700			
80.000	112.000			
90.000	110.800			
100.000	111.200			
110.000	116.700			

VES STATION # 23 ELEV: 668

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	228.000	6.55612	6.55612	297.79520
20.000	148.200	2.84597	9.40209	207.00020
30.000	117.900	22.13243	31.53452	99.54055
40.000	119.600	9999964.00000	9999996.00000	135.18830
50.000	123.100			
60.000	123.200			
70.000	123.500			
80.000	125.100			
90.000	123.800			
100.000	126.900			
110.000	127.800			

VES STATION # 24 ELEV: 663

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	144.200	7.64889	7.64889	150.75980
20.000	129.600	16.11032	23.75920	124.20770
30.000	132.600	69.44824	93.20744	136.19430
40.000	132.100	99999900.00000	100000000.00000	122.19080
50.000	132.800			
60.000	132.300			
70.000	129.300			
80.000	131.100			
90.000	135.100			
100.000	137.500			
110.000	135.400			

VES STATION # 25 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	98.450	17.56664	17.56664	97.47478
20.000	104.200	74.94563	92.51227	135.92360
30.000	111.200	99999900.00000	100000000.00000	105.94670
40.000	116.800			
50.000	119.600			
60.000	123.600			
70.000	124.400			
80.000	129.100			
90.000	128.900			
100.000	125.000			
110.000	123.800			

VES STATION # 26 ELEV: 667

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	114.000	100000000.00000	.00000	118.74230
20.000	110.200			
30.000	114.900			
40.000	118.300			
50.000	119.300			
60.000	124.700			
70.000	123.100			
80.000	125.100			
90.000	125.500			
100.000	125.600			
110.000	125.700			

VES STATION # 27 ELEV: 666

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	138.200	13.10973	13.10973	138.21260
20.000	143.200	33.69054	46.80027	159.15780
30.000	147.700	42.89543	89.69569	116.99230
40.000	147.000	99999900.00000	99999990.00000	99.38177
50.000	146.700			
60.000	142.100			
70.000	139.800			
80.000	133.700			
90.000	128.300			
100.000	126.900			
110.000	124.400			

VES STATION # 28 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	170.800	.80000	.80000	199.04560
20.000	160.800	.09162	.89162	14.83696
30.000	127.700	2.65348	3.54509	144.43740
40.000	119.100	11.64003	15.18512	221.42470
50.000	121.500	11.94077	27.12589	49.89651
60.000	124.000	39.12109	66.24698	241.70450
70.000	128.400	99999890.00000	99999950.00000	68.51552
80.000	131.600			
90.000	131.700			
100.000	131.900			
110.000	127.800			

VES STATION # 29 ELEV: 662

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	175.200	10.90313	10.90313	178.02800
20.000	164.700	16.07034	26.97348	149.05360
30.000	153.000	47.34659	74.32007	168.64370
40.000	157.000	99999920.00000	99999990.00000	105.10360
50.000	162.100			
60.000	157.200			
70.000	154.300			
80.000	150.700			
90.000	147.500			
100.000	144.500			
110.000	140.900			

VES STATION # 30 ELEV: 659

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	118.100	8.63629	8.63629	112.54040
20.000	129.300	66.82900	75.46529	155.58600
30.000	141.300	99999920.00000	99999990.00000	117.42290
40.000	149.500			
50.000	149.800			
60.000	149.600			
70.000	148.200			
80.000	145.200			
90.000	143.600			
100.000	140.100			
110.000	138.900			

VES STATION # 31 ELEV: 659

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	148.900	4.42140	4.42140	243.09790
20.000	123.900	.58574	5.00714	133.60370
30.000	135.700	9.96342	14.97056	103.47050
40.000	141.200	27.74550	42.71606	156.87960
50.000	140.100	45.20918	87.92525	119.93630
60.000	139.800	99999900.00000	99999990.00000	173.03450
70.000	139.800			
80.000	139.200			
90.000	138.500			
100.000	139.400			
110.000	140.900			

VES STATION # 32 ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	71.750	12.13715	12.13715	69.78114
20.000	81.300	82.88587	95.02302	114.17260
30.000	96.310	99999900.00000	100000000.00000	140.30630
40.000	103.500			
50.000	105.800			
60.000	107.000			
70.000	108.100			
80.000	108.500			
90.000	109.700			
100.000	111.800			
110.000	114.000			

VES STATION # 33   ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	58.370	11.86334	11.86334	52.71797
20.000	76.400	71.67422	83.53757	120.14440
30.000	86.700	99999910.00000	99999990.00000	142.83220
40.000	91.730			
50.000	96.750			
60.000	101.000			
70.000	104.200			
80.000	107.000			
90.000	111.300			
100.000	111.800			
110.000	114.700			

VES STATION # 34   ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	78.530	5.98739	5.98739	63.64975
20.000	96.380	89.13116	95.11855	115.73210
30.000	105.900	99999900.00000	100000000.00000	138.96260
40.000	108.500			
50.000	111.500			
60.000	114.600			
70.000	115.200			
80.000	114.100			
90.000	113.000			
100.000	114.300			
110.000	116.100			

VES STATION # 35   ELEV: 660

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	94.810	5.00899	5.00899	81.24050
20.000	108.600	26.29005	31.29905	115.03570
30.000	115.100	27.36554	58.66458	108.34970
40.000	111.000	99999940.00000	99999990.00000	131.70240
50.000	109.000			
60.000	114.600			
70.000	115.600			
80.000	118.600			
90.000	118.100			
100.000	119.300			
110.000	120.200			

VES STATION # 36   ELEV: 670

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
20.000	458.600	24.14921	24.14921	505.43680
30.000	412.700	26.77665	50.92587	207.86900
40.000	341.500	38.15314	89.07901	122.03210
50.000	276.700	99999890.00000	99999980.00000	153.50520
60.000	244.600			
70.000	219.900			
80.000	197.000			
90.000	184.300			
100.000	173.400			
110.000	167.200			

VES STATION # 37 ELEV: 670

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	266.300	8.86001	8.86001	212.62860
20.000	343.000	17.72044	26.58046	696.99170
30.000	373.200	15.29592	41.87638	194.00490
40.000	359.300	24.39773	66.27411	50.94256
50.000	314.100	99999890.00000	99999950.00000	215.52620
60.000	263.500			
70.000	239.200			
80.000	214.100			
90.000	199.600			
100.000	195.400			

VES STATION # 38 ELEV: 690

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	216.700	1.00000	1.00000	179.09060
20.000	233.700	.27877	1.27877	41.32101
30.000	193.200	3.69729	4.97606	181.74730
40.000	148.700	13.48095	18.45701	340.59400
50.000	140.100	23.65628	42.11329	65.38470
60.000	136.800	43.25249	85.36578	221.95020
70.000	140.300	99999900.00000	99999980.00000	141.38800
80.000	144.700			
90.000	141.300			
100.000	138.800			
110.000	140.300			

VES STATION # 39 ELEV: 690

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	873.400	.80000	.80000	881.27360
20.000	1060.000	.22936	1.02936	2496.63400
30.000	889.600	1.29573	2.32509	584.54660
40.000	583.000	21.48999	23.81508	1003.95400
50.000	348.700	7.07174	30.88681	468.77760
60.000	242.000	3.63561	34.52242	115.53650
70.000	186.900	2.66795	37.19037	60.28965
80.000	164.800	6.53417	43.72454	26.65431
90.000	159.400	99999860.00000	99999900.00000	113.30990
100.000	159.500			
110.000	156.800			

VES STATION # 40 ELEV: 668

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	123.700	7.13767	7.13767	112.46080
20.000	145.800	45.45749	52.59517	176.37210
30.000	164.500	43.95752	96.55269	139.15570
40.000	166.600	99999900.00000	100000000.00000	158.77050
50.000	164.900			
60.000	162.400			
70.000	163.600			
80.000	158.800			
90.000	156.000			
100.000	155.100			
110.000	155.500			

VES STATION # 41 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	107.600	7.48823	7.48823	85.54686
20.000	142.200	21.76468	29.25292	226.04630
30.000	154.900	61.25554	90.50845	86.59437
40.000	149.500	99999880.00000	99999970.00000	223.68710
50.000	145.100			
60.000	140.900			
70.000	137.600			
80.000	132.100			
90.000	127.200			
100.000	128.100			
110.000	129.200			

VES STATION # 42 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	88.020	.89853	.89853	56.64484
20.000	130.300	.59720	1.49573	31.62265
30.000	147.300	5.27664	6.77238	58.07855
40.000	136.700	4.97808	11.75046	419.23310
50.000	135.000	99999980.00000	99999990.00000	127.08340
60.000	132.700			
70.000	135.000			
80.000	132.600			
90.000	135.100			
100.000	131.900			
110.000	130.600			

VES STATION # 43 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	179.600	.11219	.11219	200.33700
20.000	187.600	4.20939	4.32158	176.89850
30.000	188.300	5.23312	9.55469	169.19300
40.000	183.200	24.39382	33.94852	212.37590
50.000	174.000	99999960.00000	99999990.00000	126.68980
60.000	163.600			
70.000	156.500			
80.000	152.800			
90.000	148.100			
100.000	148.200			
110.000	144.400			

VES STATION # 44 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	99.270	8.23985	8.23985	82.20049
20.000	133.700	40.91499	49.15483	208.12970
30.000	158.800	99999940.00000	99999990.00000	112.21200
40.000	162.300			
50.000	165.800			
60.000	159.400			
70.000	159.600			
80.000	152.600			
90.000	150.400			
100.000	148.900			
110.000	145.800			

VES STATION # 45 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	194.100	6.41119	6.41119	172.64150
20.000	213.600	26.32569	32.73688	242.51410
30.000	207.900	61.92643	94.66330	119.78120
40.000	204.000	99999900.00000	99999990.00000	180.79910
50.000	189.700			
60.000	176.400			
70.000	166.600			
80.000	160.800			
90.000	156.000			
100.000	152.000			
110.000	151.300			

VES STATION # 46 ELEV: 667

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	868.900	9.40505	9.40505	1144.31200
20.000	428.500	7.79120	17.19625	268.05390
30.000	233.100	3.56914	20.76540	71.63665
40.000	190.500	50.26783	71.03322	159.38120
50.000	173.400	99999900.00000	99999970.00000	138.66450
60.000	167.300			
70.000	160.000			
80.000	154.800			
90.000	149.200			
100.000	147.600			
110.000	147.200			

VES STATION # 47 ELEV: 673

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	290.900	32.91641	32.91641	288.53450
20.000	272.600	99999960.00000	99999990.00000	138.80430
30.000	308.700			
40.000	256.000			
50.000	236.800			
60.000	200.900			
70.000	182.000			
80.000	166.800			
90.000	166.200			
100.000	163.300			
110.000	162.400			

VES STATION # 48 ELEV: 690

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	617.600	4.31633	4.31633	442.82520
20.000	706.200	29.41146	33.72778	779.75610
30.000	625.700	38.44043	72.16821	339.85400
40.000	595.600	13.44357	85.61178	98.18905
50.000	524.600	99999580.00000	99999660.00000	46.83229
60.000	471.200			
70.000	423.100			
80.000	375.400			
90.000	301.900			
100.000	258.200			
110.000	232.200			

VES STATION # 49   ELEV: 658

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	91.480	7.99542	7.99542	79.33683
20.000	113.700	51.01255	59.00797	155.98790
30.000	128.100	99999940.00000	99999990.00000	123.21340
40.000	140.200			
50.000	144.800			
60.000	145.800			
70.000	140.300			
80.000	139.700			
90.000	136.800			
100.000	134.400			
110.000	134.000			

VES STATION # 50   ELEV: 663

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	128.800	7.00286	7.00286	116.20770
20.000	158.900	61.05562	68.05848	197.58340
30.000	173.200	99999920.00000	99999990.00000	114.92170
40.000	185.700			
50.000	185.600			
60.000	183.500			
70.000	177.600			
80.000	174.900			
90.000	169.000			
100.000	163.900			

VES STATION # 51   ELEV: 655

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	152.000	.60000	.60000	192.94450
20.000	188.800	.02878	.62878	3.58862
30.000	185.800	.98337	1.61215	137.63540
40.000	172.900	2.03491	3.64706	63.29283
50.000	161.400	1.25498	4.90205	259.59050
60.000	164.700	2.11768	7.01972	613.15800
70.000	160.000	99999990.00000	100000000.00000	157.57700
80.000	161.800			
90.000	160.000			
100.000	164.600			
110.000	163.800			

VES STATION # 52   ELEV: 655

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	342.400	16.30725	16.30725	368.96520
20.000	290.200	56.74193	73.04917	163.43570
30.000	249.300	99999920.00000	99999990.00000	133.39830
40.000	223.900			
50.000	199.400			
60.000	188.100			
70.000	179.800			
80.000	167.800			
90.000	165.100			
100.000	159.500			

VES STATION # 53 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	129.400	4.90365	4.90365	112.48840
20.000	156.600	44.71863	49.62228	169.51450
30.000	162.800	99999940.00000	99999990.00000	104.25460
40.000	160.300			
50.000	152.900			
60.000	148.100			
70.000	146.400			
80.000	141.700			
90.000	136.800			

VES STATION # 54 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	229.900	3.19696	3.19696	294.78790
20.000	210.400	6.88461	10.08157	208.81720
30.000	233.700	22.05218	32.13375	237.35040
40.000	213.800	99999960.00000	99999990.00000	143.75180
50.000	194.400			
60.000	181.300			
70.000	172.800			
80.000	164.300			
90.000	163.400			
100.000	158.900			
110.000	155.500			

VES STATION # 55 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	125.600	5.47106	5.47106	86.33028
20.000	168.300	31.60618	37.07724	227.89770
30.000	179.800	54.39030	91.46754	97.96407
40.000	180.100	99999900.00000	99999980.00000	157.86380
50.000	178.100			
60.000	168.500			
70.000	149.000			
80.000	149.200			
90.000	142.500			
100.000	143.200			
110.000	141.600			

VES STATION # 56 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	128.800	1.38362	1.38362	154.08210
20.000	153.300	1.10064	2.48427	69.63349
30.000	171.100	44.91088	47.39515	164.71230
40.000	165.800	9999950.00000	9999997.00000	125.77440
50.000	159.200			
60.000	152.600			
70.000	149.900			
80.000	145.200			
90.000	144.100			
110.000	141.900			

VES STATION # 57 ELEV: 670

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	233.700	12.80746	12.80746	249.92020
20.000	202.300	9999984.00000	9999997.00000	146.76040
30.000	177.900			
40.000	167.100			
50.000	161.700			
60.000	156.800			
70.000	153.900			
80.000	152.300			
90.000	152.100			
100.000	148.200			
110.000	146.500			

VES STATION # 58 ELEV: 675

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	143.200	6.94986	6.94986	113.47090
20.000	192.200	23.17689	30.12674	272.59120
30.000	211.100	99999970.00000	100000000.00000	149.63020
40.000	210.600			
50.000	206.300			
60.000	198.600			
70.000	183.400			
80.000	181.900			
90.000	170.200			
100.000	163.300			
110.000	160.300			

VES STATION # 59 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	87.010	8.14478	8.14478	72.53461
20.000	118.100	51.04893	59.19371	192.26750
30.000	145.800	99999910.00000	99999970.00000	73.87632
40.000	152.800			
50.000	153.900			
60.000	150.700			
70.000	146.800			
80.000	140.200			
90.000	132.800			
100.000	133.200			
110.000	127.800			

VES STATION # 60 ELEV: 665

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	107.000	7.02605	7.02605	97.42168
20.000	125.700	67.83124	74.85728	157.12320
30.000	141.700	99999920.00000	99999990.00000	120.57210
40.000	151.000			
50.000	148.900			
60.000	146.600			
70.000	150.400			
80.000	150.200			
90.000	145.800			
100.000	148.200			
110.000	145.800			

VES STATION # 61 ELEV: 664

AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	154.500	7.41818	7.41818	154.96090
20.000	177.900	37.07000	44.48818	182.84810
30.000	171.500	45.86110	90.34929	138.30570
40.000	173.200	99999900.00000	99999990.00000	121.36700
50.000	188.800			
60.000	167.000			
70.000	156.500			
80.000	153.800			
90.000	151.500			
100.000	147.000			
110.000	145.100			

VES STATION # 62 ELEV: 664

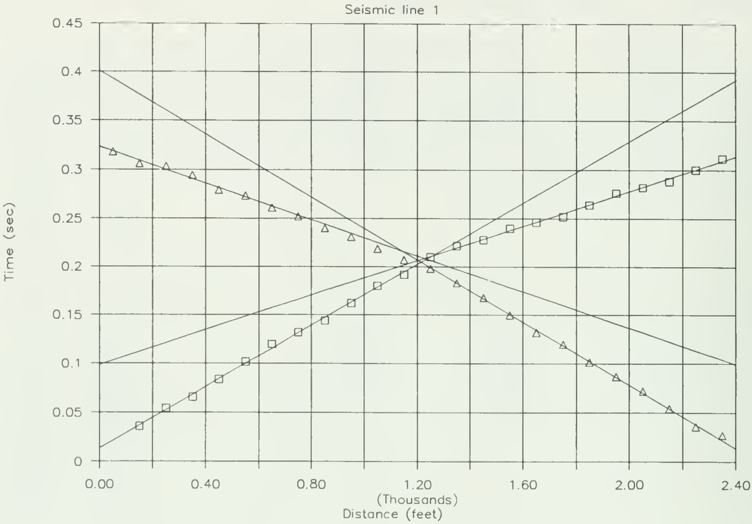
AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	419.000	12.72878	12.72878	455.42110
20.000	346.800	21.43693	34.16571	234.62390
30.000	292.100	48.30168	82.46739	125.15230
40.000	241.700	99999900.00000	99999980.00000	143.66840
50.000	201.300			
60.000	177.500			
70.000	163.100			
80.000	159.300			
90.000	155.500			
100.000	151.400			
110.000	147.900			

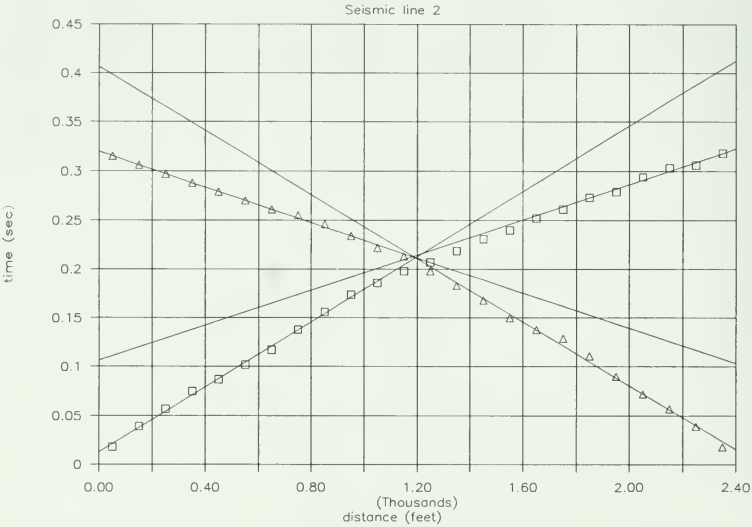
VES STATION # 63 ELEV: 664

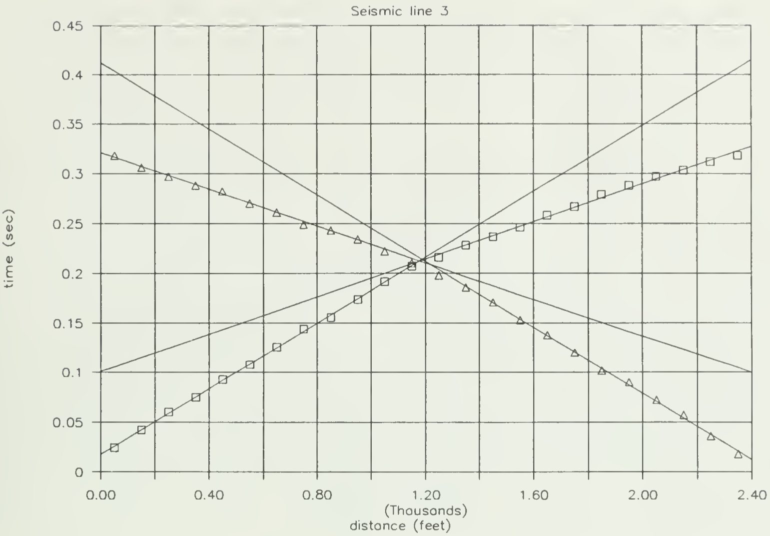
AB/2	OBS	THICKNESS	DEPTH	RESISITIVITY
10.000	118.100	14.20742	14.20742	116.96810
20.000	122.000	59.71202	73.91944	143.56450
30.000	129.600	99999930.00000	100000000.00000	120.59560
40.000	136.700			
50.000	135.700			
60.000	134.900			
70.000	134.500			
80.000	137.700			
100.000	135.000			

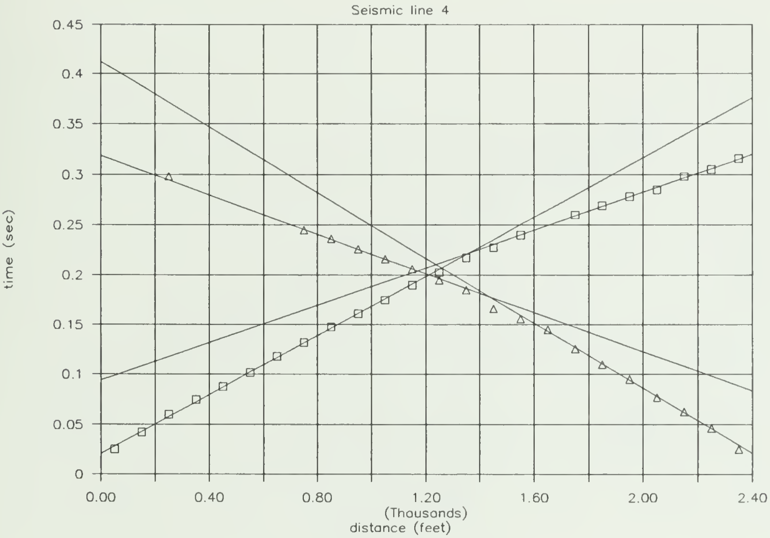
Appendix B. Seismic Refraction Data

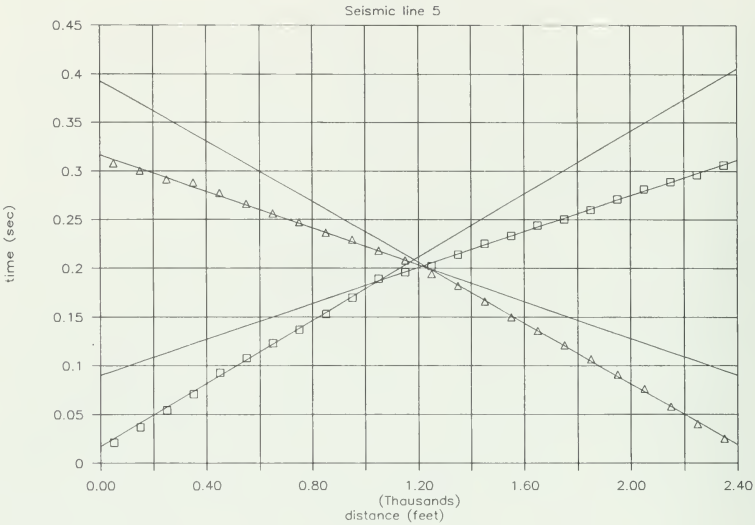
The following graphs depict the time-distance relationship for each shot recorded during this survey. Locations of each line are shown in figure 8. East-west lines are oriented so that the distance axis increases towards the west end of the line. North-south lines are oriented so that the distance axis increases towards the north end of the line. Solid lines drawn through the datum points were calculated by linear regression analysis. The reciprocal of the slope of the regression lines provides the velocity information; the time-intercept of the regression lines provides the depth information.

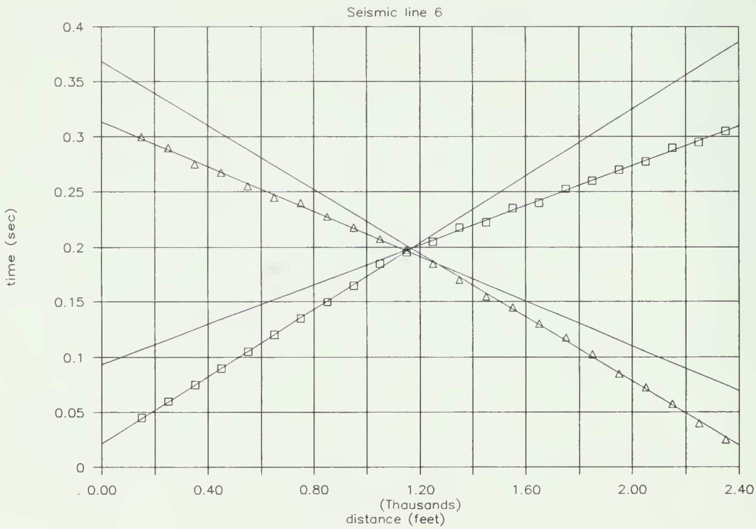

Seismic line 1
Time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
Distance (feet)

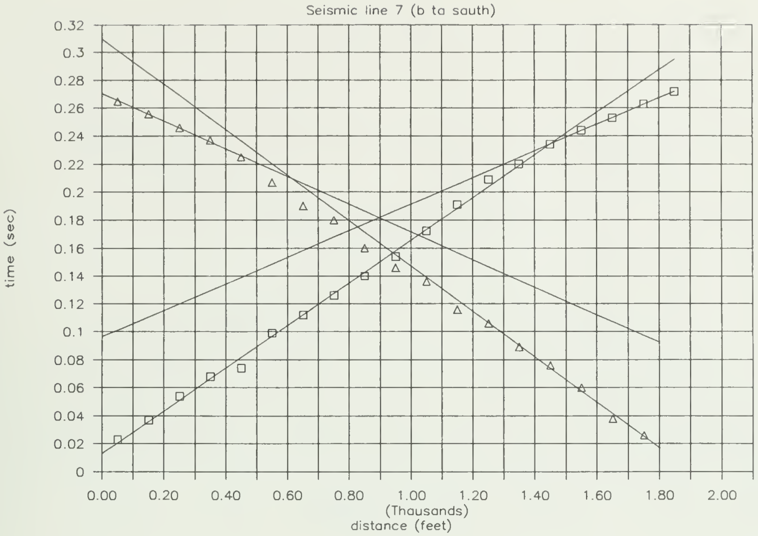

Seismic line 2
time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

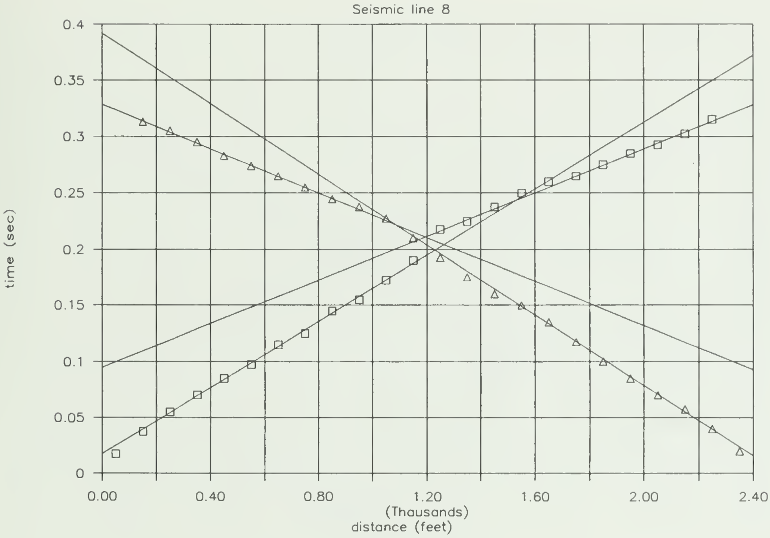

Seismic line 3
time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

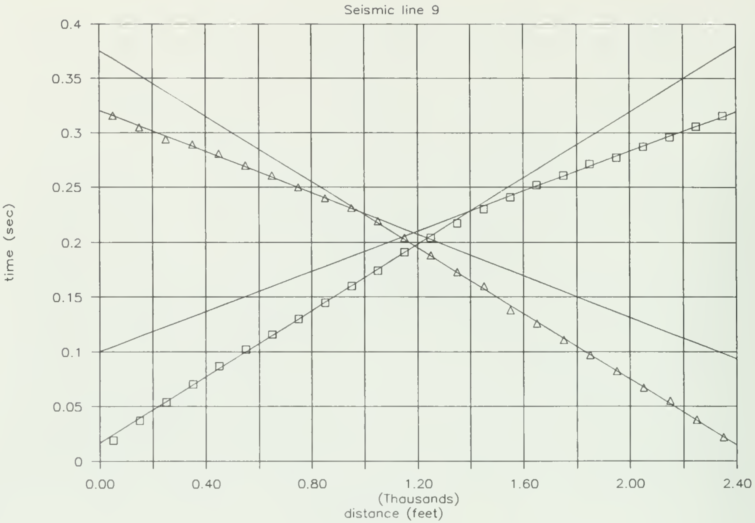

Seismic line 4
time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

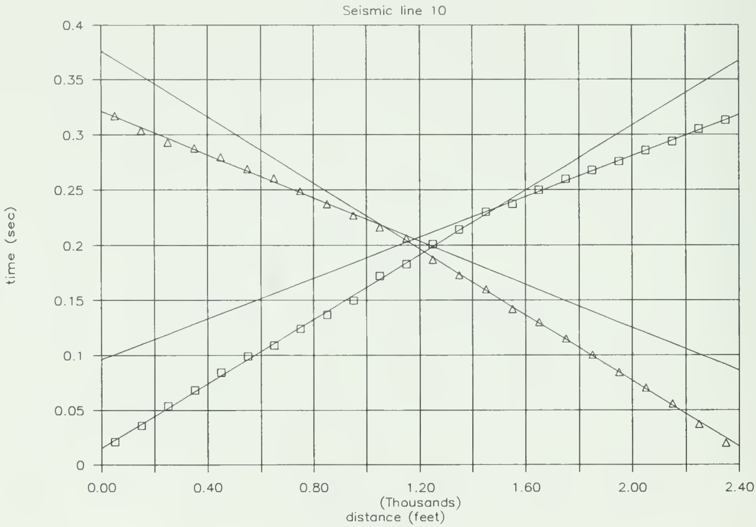

Seismic line 5
time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

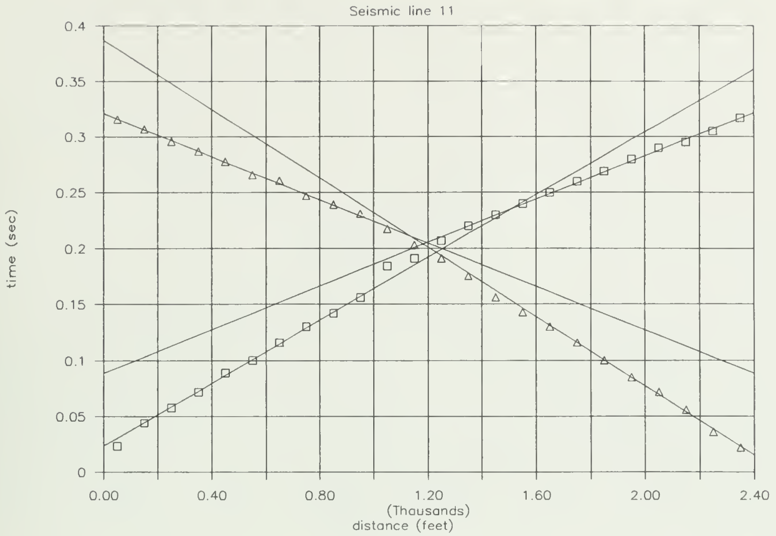

Seismic line 6
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

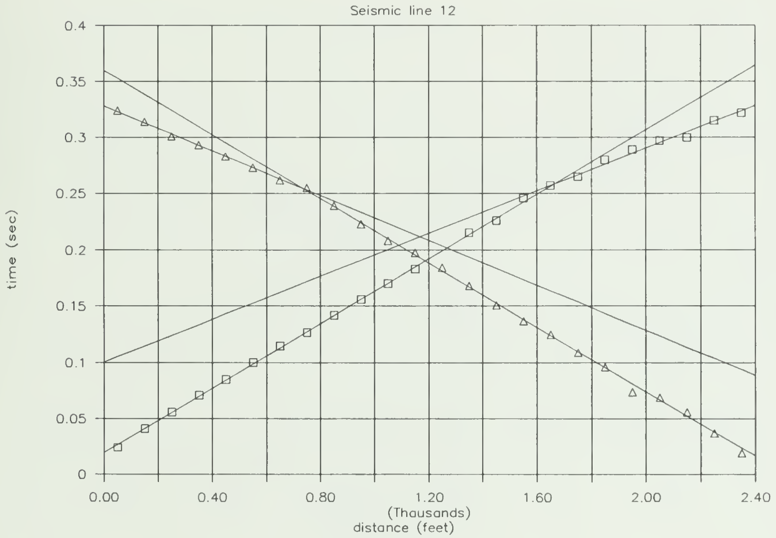

Seismic line 7 (b to south)
time (sec)
0.32
0.3
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
1.80
2.00
(Thousands)
distance (feet)

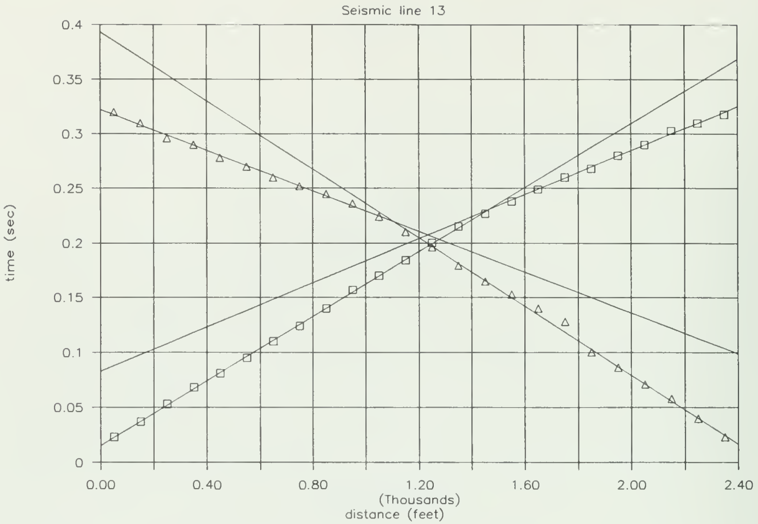

Seismic line 8
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

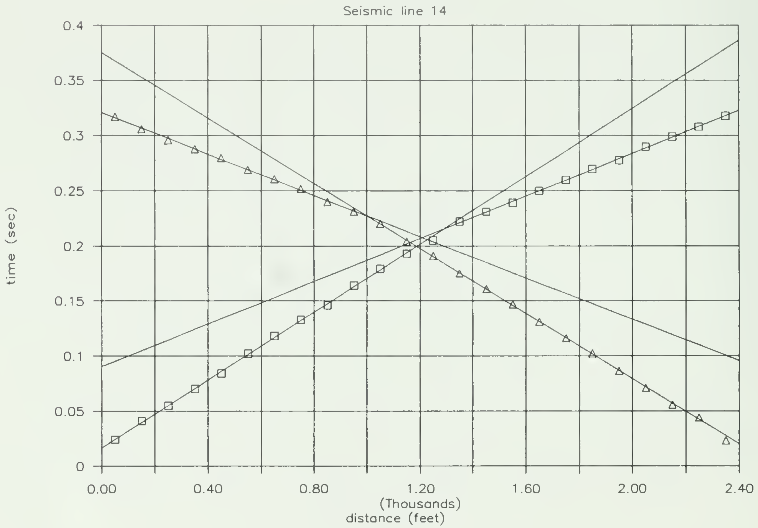

Seismic line 9
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

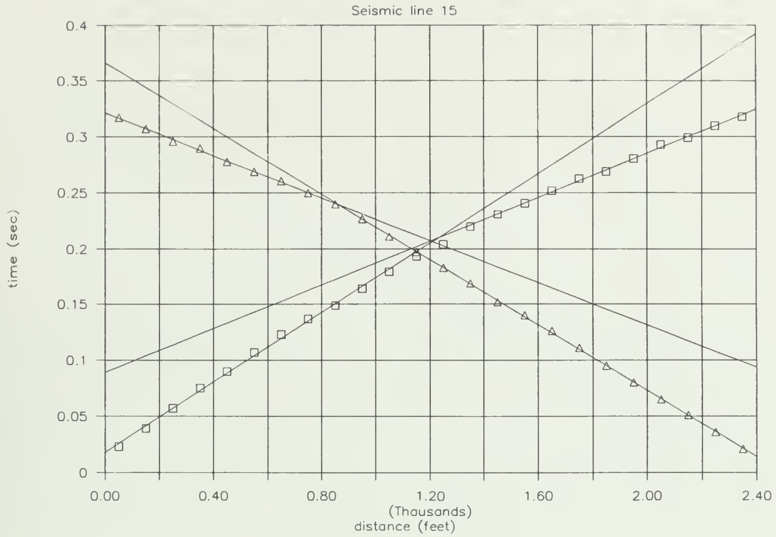

Seismic line 10
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

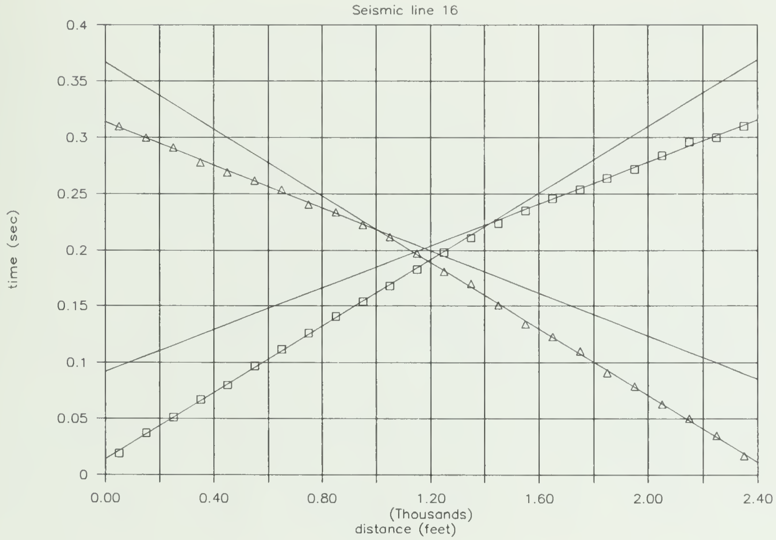

Seismic line 11
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

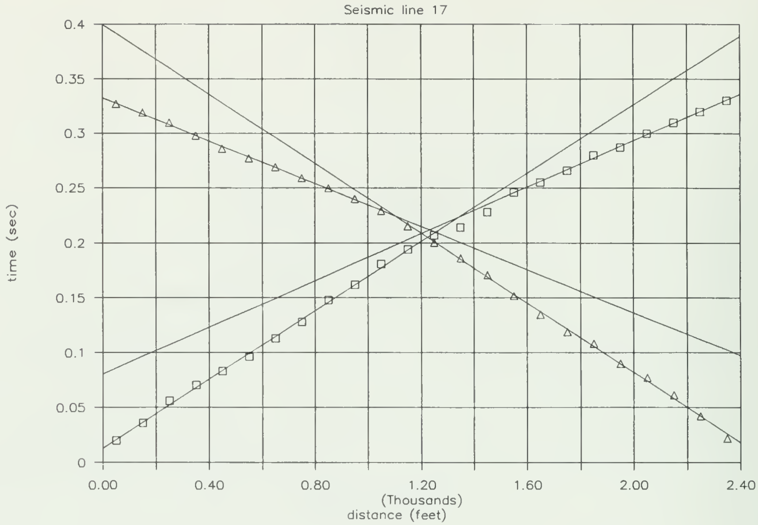

Seismic line 12
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

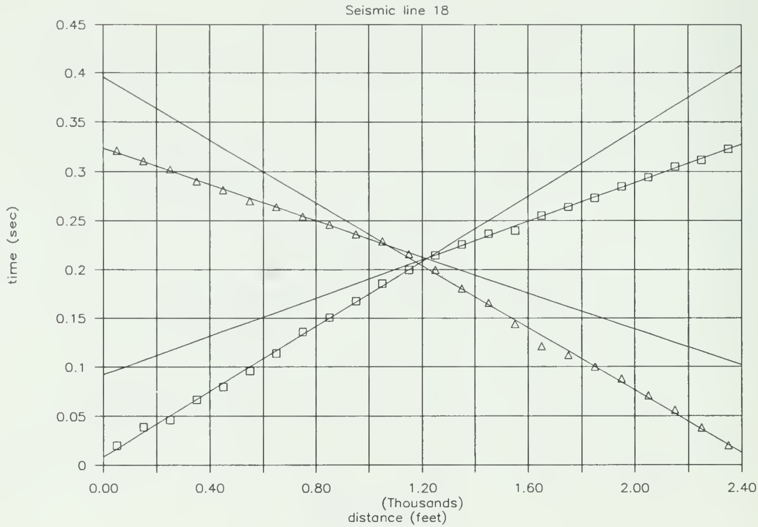

Seismic line 13
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

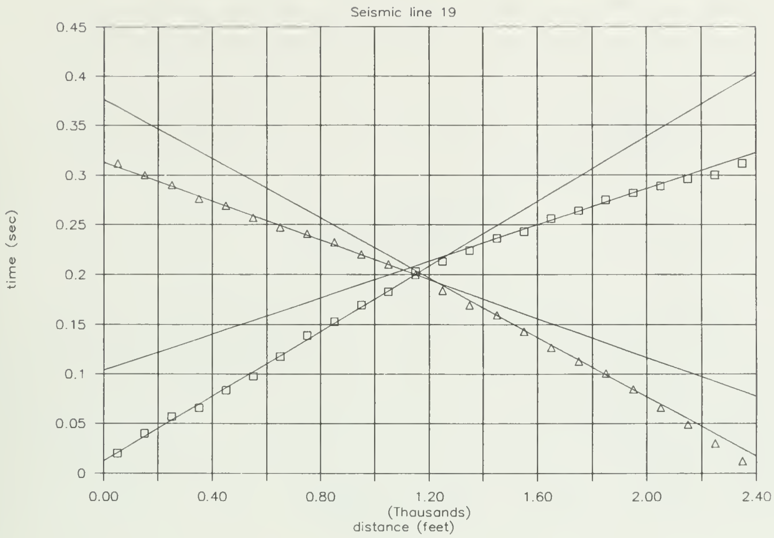

Seismic line 14
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

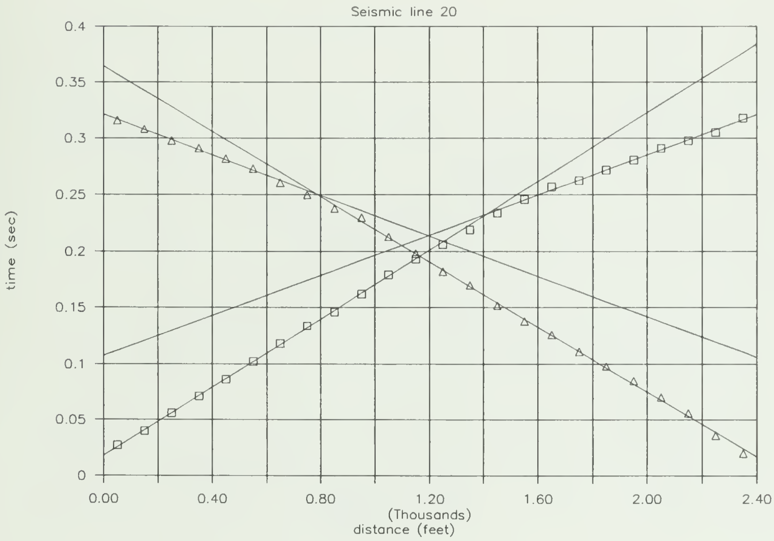

Seismic line 15
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

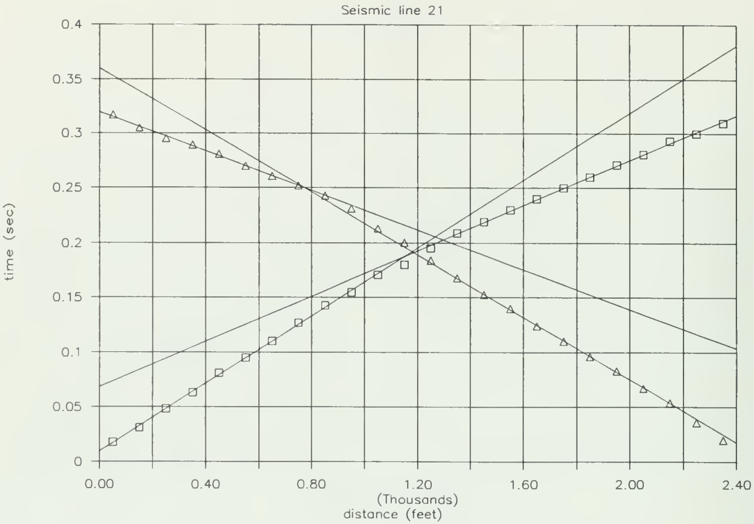

Seismic line 16
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)


Seismic line 17
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

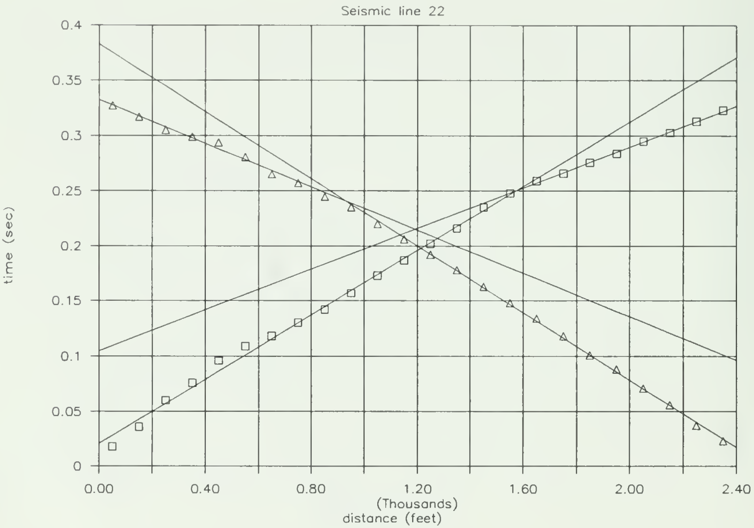

Seismic line 18
time (sec)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)


Seismic line 19
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time (sec)
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

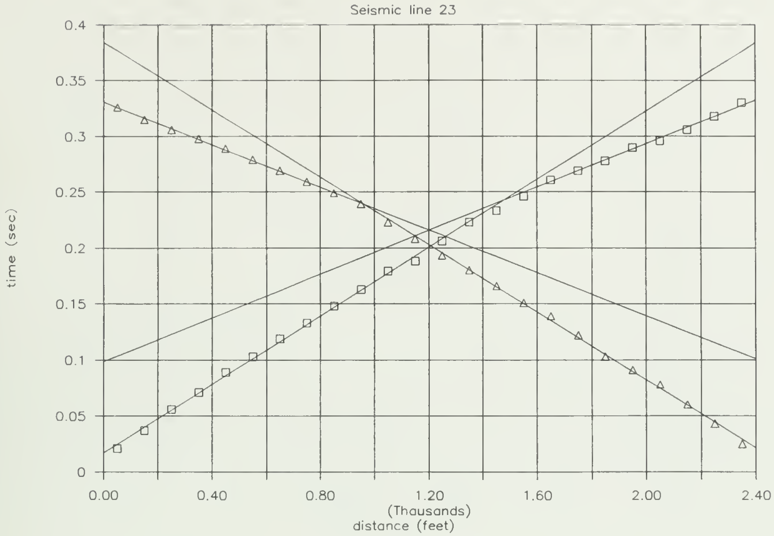

Seismic line 20
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time (sec)
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

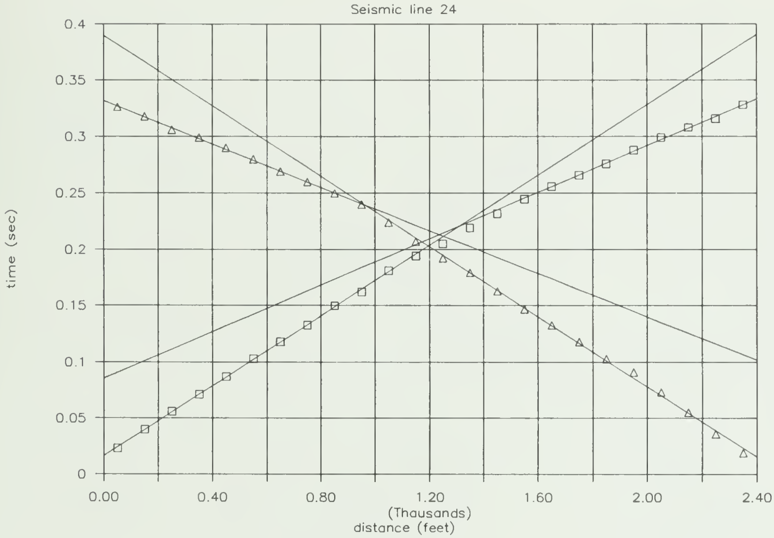


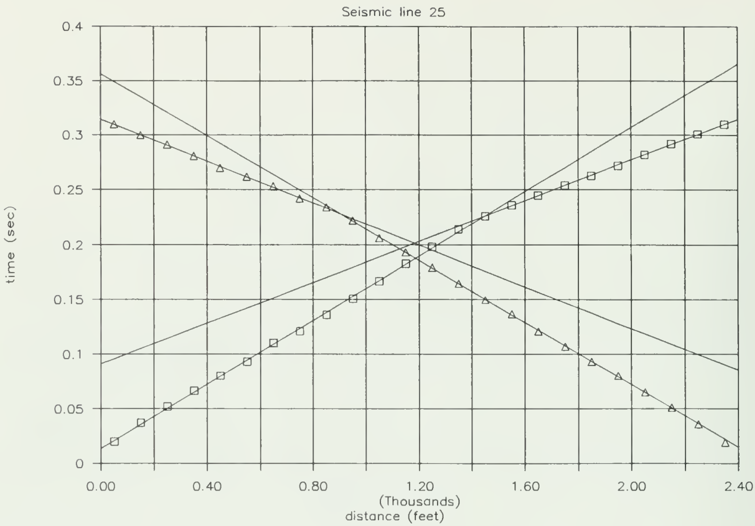
Seismic line 21
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)



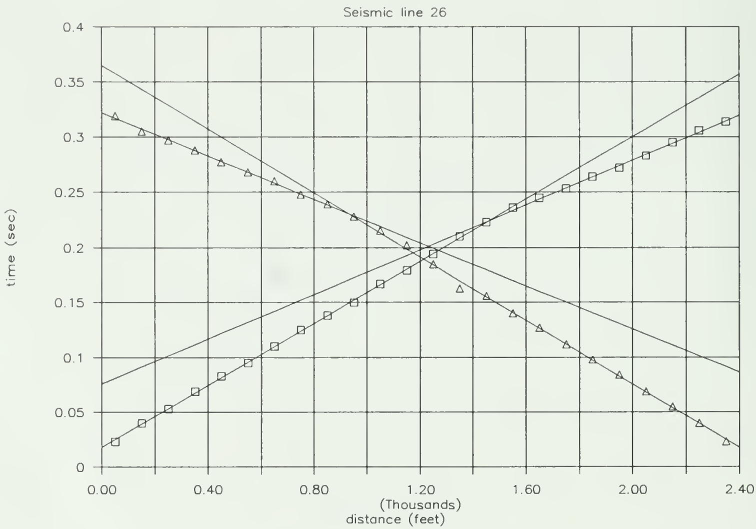
Seismic line 22
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)


Seismic line 23
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)

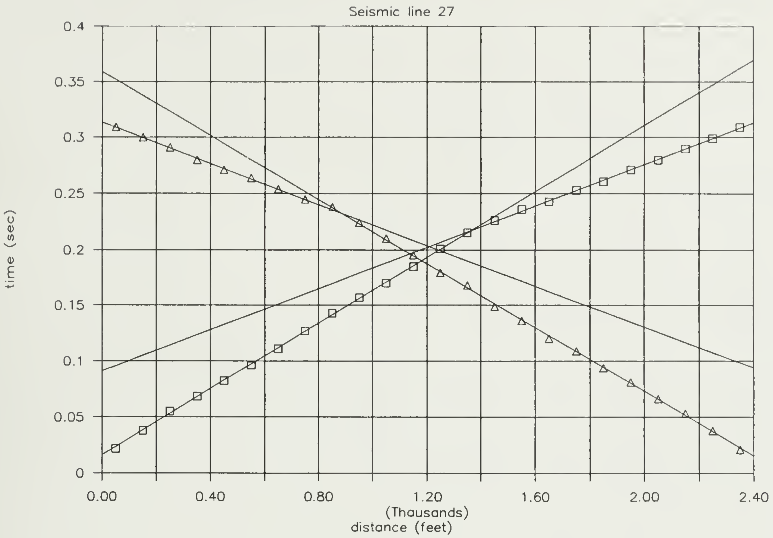

Seismic line 24
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)



Seismic line 25
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)



Seismic line 26
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)



Seismic line 27
time (sec)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.00
0.40
0.80
1.20
1.60
2.00
2.40
(Thousands)
distance (feet)