To the Graduate Council:

I am submitting herewith a thesis written by Vindell Hsu entitled "Seismic Refraction Survey of a Power Plant Site, Northeast Mississippi." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

W. P. Staub, Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:

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T

SEISMIC REFRACTION SURVEY OF A POWER PLANT SITE, NORTHEAST MISSISSIPPI

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Vindell Hsu

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ABSTRACT

A seismic refraction survey was conducted in the Yellow Creek embayment region of northeastern Mississippi where a proposed power plant site is located. The survey area is on the eastern edge of the Mississippi embayment where thick sequences of Cretaceous and Cenozoic unconsolidated sediments lie uncomformably on Mississippian carbonates and clastic siltstones.

The seismic refraction data provided datum corrections for a vibroseis reflection survey by Western Geophysical Company of Houston, Texas. Near surface velocity anomalies which are caused by rapid changes in thickness of the unconsolidated Cretaceous and Cenozoic sediments were thereby eliminated in the interpretation of the reflection data.

The refraction data also were used to compile a map of the bedrock surface which apparently represents a paleodrainage system on the Mississippian Fort Payne Formation beneath the Cretaceous Tuscaloosa gravel. A contour map of reflection times from near the top of the Knox Group indicates that a syncline coincides with the trend of the above paleodrainage system. This suggests that either the surface velocity anomalies were not completely removed or that the drainage system developed in the syncline.

The results of this survey have demonstrated the applicability of refraction surveys in removing near surface velocity anomalies from

vibroseis data. Refraction data have also proved to be effective in distinguishing between tectonic features and buried topography.

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CHAPTER I

INTRODUCTION

Location

The power plant site is located in the Yellow Creek area of Tishomingo County in the northeastern corner of the state of Mississippi (Figure 1). The Tennessee river flows northwest making up the eastern boundary of the study area. Pickwick Lake and the Yellow Creek embayment are impounded by Pickwick Dam, which lies 8 miles north of the plant site. The survey covers an area of 24 square miles surrounding the proposed plant site (Figure 2).

Corinth, Mississippi, the nearest town, is 22 miles southwest of the plant site. The Yellow Creek area can be reached from Corinth by taking U.S. Highway 72 or Mississippi State Highways 366 and 25.

Purpose of the Investigation

Datum Corrections for a Vibroseis Survey

Seismic refraction data were collected in order to supply datum corrections for a vibroseis survey completed in the spring of 1975 by Western Geophysical Company for the Tennessee Valley Authority. The wide range of thicknesses of the post-Paleozoic unconsolidated strata in this area produced velocity anomalies in the reflection data. Datum corrections were supplied in order to remove the effects of velocity variations in the shallow subsurface. The corrected seismic section was

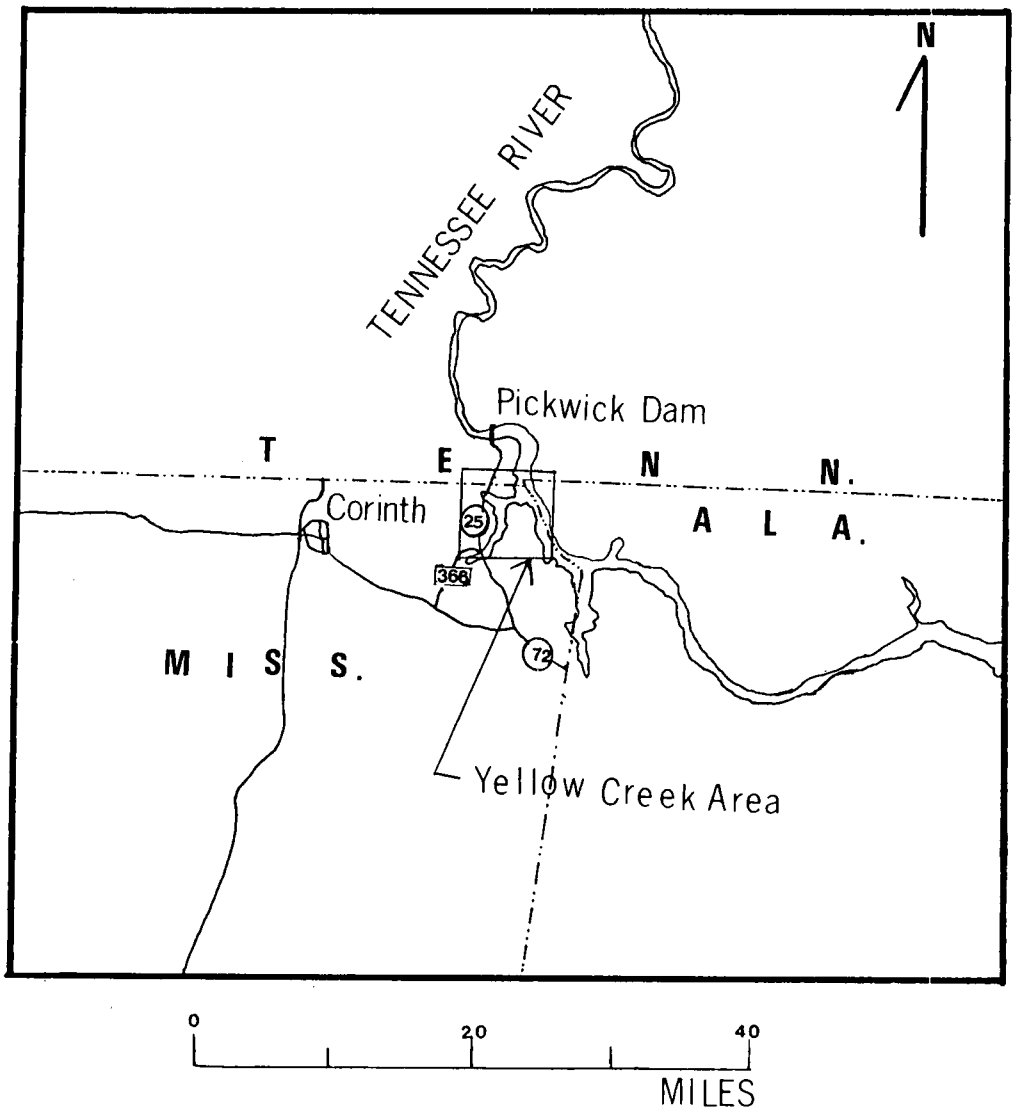

Figure 1. Location of the Yellow Creek area.

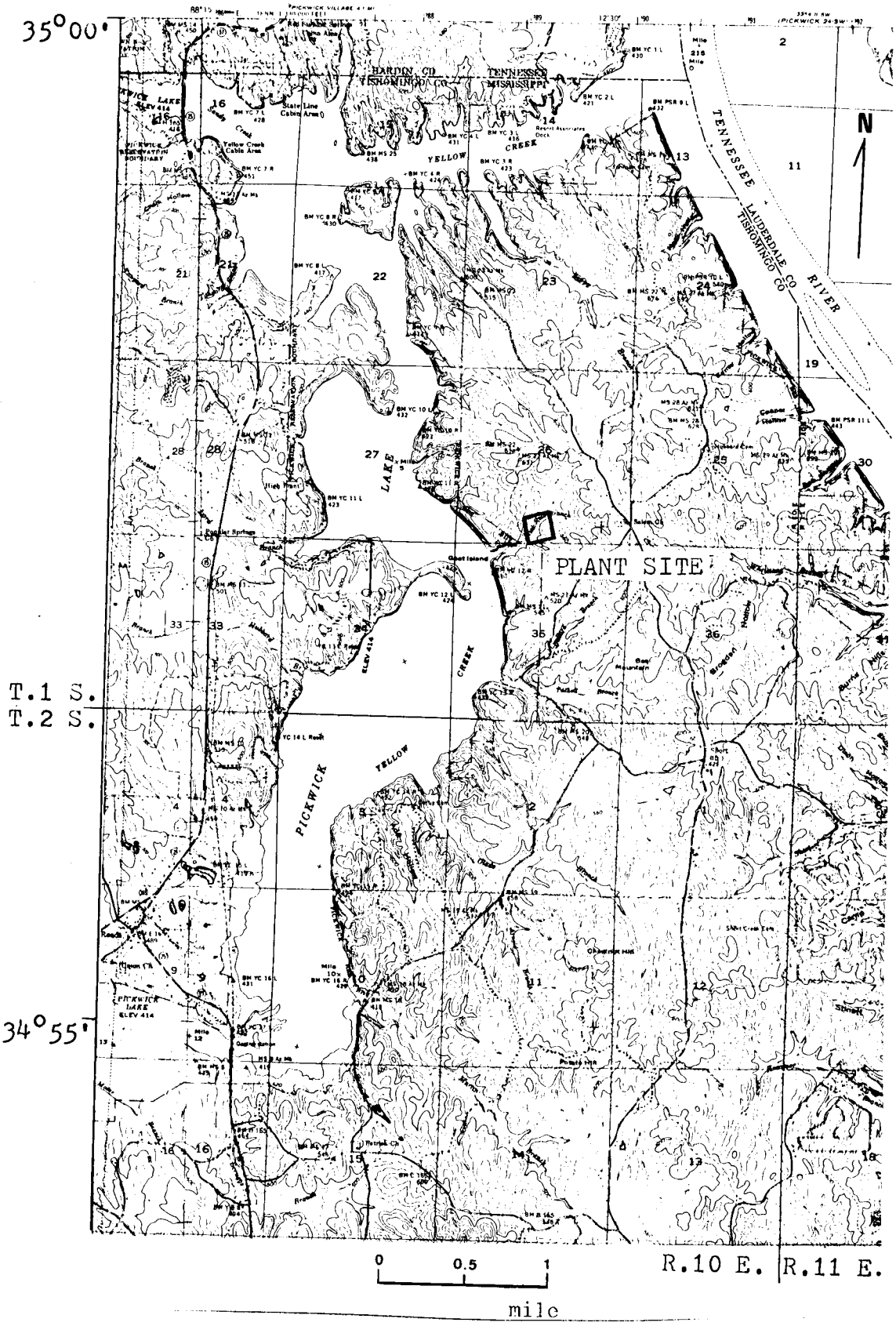

Figure 2. The survey area showing the proposed power plant site.

then used by Western Geophysical Company to interpret geologic structure.

A Topographic Map of the Bedrock Surface

The refraction data that were used to obtain datum corrections were also used to calculate the depth to the high velocity layer, in this case, the bedrock. The overlying strata are various low velocity layers of weathered or unconsolidated sediments. Depths to bedrock were converted to elevations which, in turn, were used to construct a topographic map of the bedrock surface. Finally, the map of the bedrock surface suggests a paleodrainage system which existed on the Mississippian Fort Payne and was covered by Cretaceous and Cenozoic unconsolidated sediments.

The bedrock elevations do not necessarily represent the position of the valley floor. It may well be that the actual valley floor once lay between a few feet to 150 feet above the bedrock surface. At the time the ancient valley developed there may have been up to 150 feet of residual Fort Payne soils wherein the stratification is still preserved.

Results

Western's initial interpretation of their vibroseis data was based on simple topographic corrections which failed to take into account the variable thickness of several low and intermediate velocity layers. As a result, a syncline was indicated with a trend to the southeast from shot point 195 in section 33, T1S, R10E, to the center of

section 34. This syncline had a relief of 165 milliseconds (400 meters).

The final interpretation utilized complete datum corrections which removed the effects of near surface velocity anomalies. The relief on the structure was reduced to 65 milliseconds (150 meters).

Seismic refraction tends to overestimate the average velocity of various stratigraphic units. The effect of this result is an underestimate of the datum correction. Therefore, most, if not all, of the remaining structure may actually be the persistent remains of the velocity anomaly which was supposedly removed by making "complete" datum corrections.

The above conclusion is supported by the topographic map of the bedrock surface. The syncline in the Knox Formation lies in precisely the same location as a bedrock valley developed on the Fort Payne. Perhaps the valley developed in the syncline. It is more likely, however, that the syncline is an illusion created by an incomplete removal of velocity anomalies within the thick section of low velocity sediments which fill the ancient valley between the Fort Payne and the surface.

CHAPTER II

REVIEW OF LITERATURE

Geology of the Yellow Creek Area

Regional Setting

Geologically, the Yellow Creek area is located near the eastern edge of the Mississippi embayment of the Gulf coastal plain province (Figure 3). The literature on the Mississippi embayment region is extensive. An intensive review is given by Johnson (1975).

In general, the Mississippi embayment region is a downwarped trough of Paleozoic rocks which has been subsequently filled with unconsolidated sands, marls, and clays of upper Cretaceous. Tertiary, and Quaternary age (Born, 1935). It is bounded and underlain by Paleozoic sedimentary rocks.

Sediments within the embayment have a maximum thickness of 3,300 feet, are unconsolidated, and contain fresh water (Schwalb, 1971). Detailed descriptions of post Paleozoic beds along with structure contour maps of formation horizons are covered in papers by Mellon and Moore (1962), Mellon (1964), Cushing, Boswell, and Hasman (1964), Boswell et al. (1965), and Boswell (1968) who conducted research on ground water of the Mississippi embayment.

At the close of the Pennsylvanian Period about 280 million years ago, the northern part of the Mississippi embayment was occupied by a

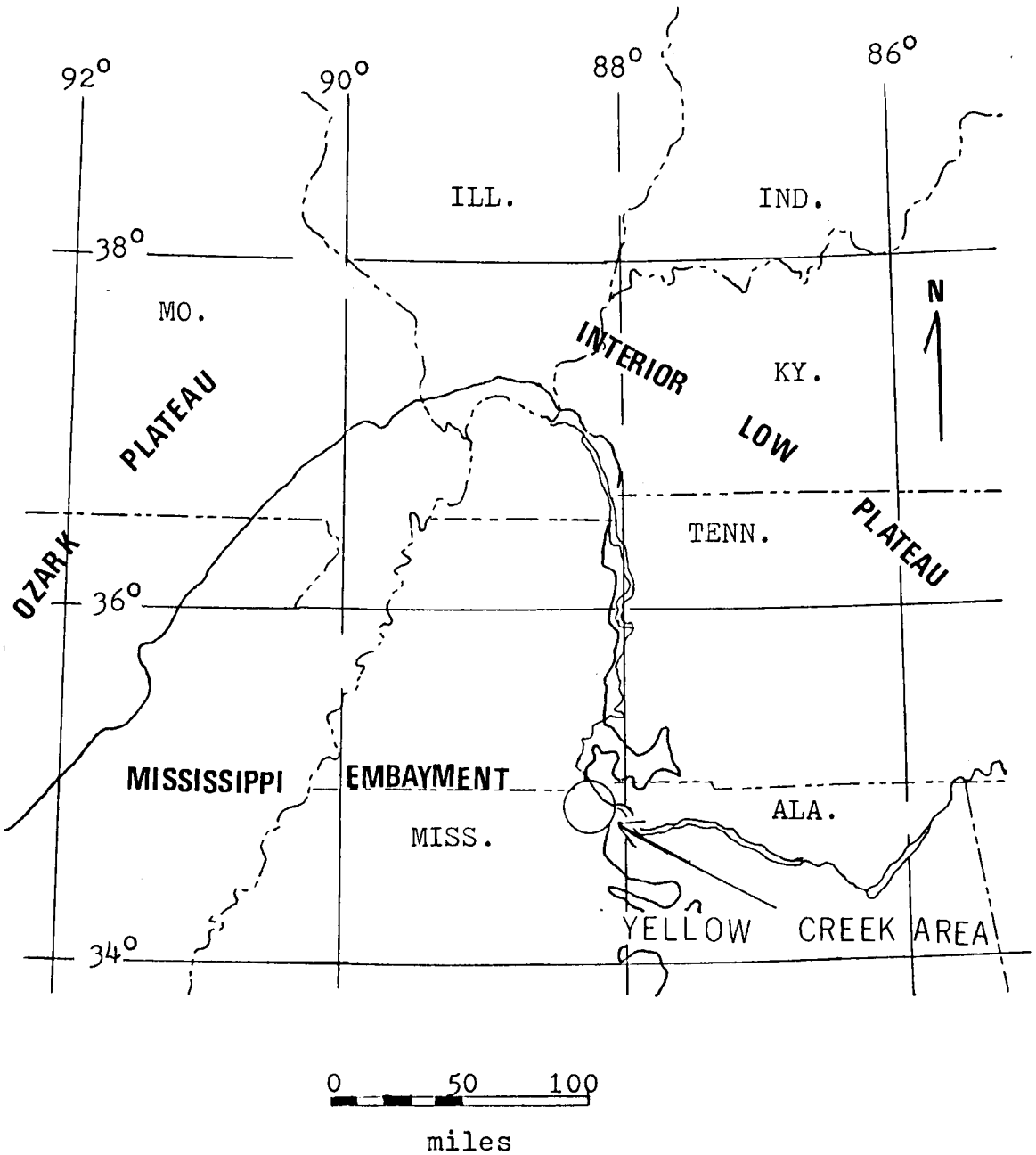

Figure 3. The Yellow Creek area of the Mississippi embayment region (after Johnson, 1975).

structural high which connected the Ozark and Nashville domes. This structure was first postulated by Wilson (1939) and called the Pascola arch by Grohskopf (1955). The Yellow Creek area lay on the southwest flank of this arch (Figure 4). Erosion of the arch persisted for about 100 million years. By Middle Cretaceous time, erosion had exposed the lower Mississippian in the Yellow Creek area (TVA, 1975). Then the Mississippi embayment trough began to subside with its axis generally following the modern Mississippi River course.

Later in early Cretaceous time, the sea advanced and retreated four times (Russell, 1965) northwestward across the former Pascola arch. Interbedded marine and terrestrial sediments covered the Pascola arch and filled the Mississippi embayment trough. Late Tertiary and early Quaternary alluvial materials were deposited on top of this sequence and Pleistocene loess lies at the surface.

The Cretaceous sediments of the Mississippi embayment are relatively undisturbed. At least two major faults occur in the Paleozoic rocks beneath the embayment but are not reflected at the surface (Schwalb, 1971). One parallels the Mississippi River and the other intersects the Mississippi River fault near the junction of the Tennessee, Missouri, and Arkansas state lines. The latter fault brought upper Cambrian and Ordovician rocks into juxtaposition. Stearns and Wilson (1972) described the faulted area in western Tennessee, northern Mississippi, and northern Alabama. They believe that faults are few, relatively short, and are characterized by minor displacement.

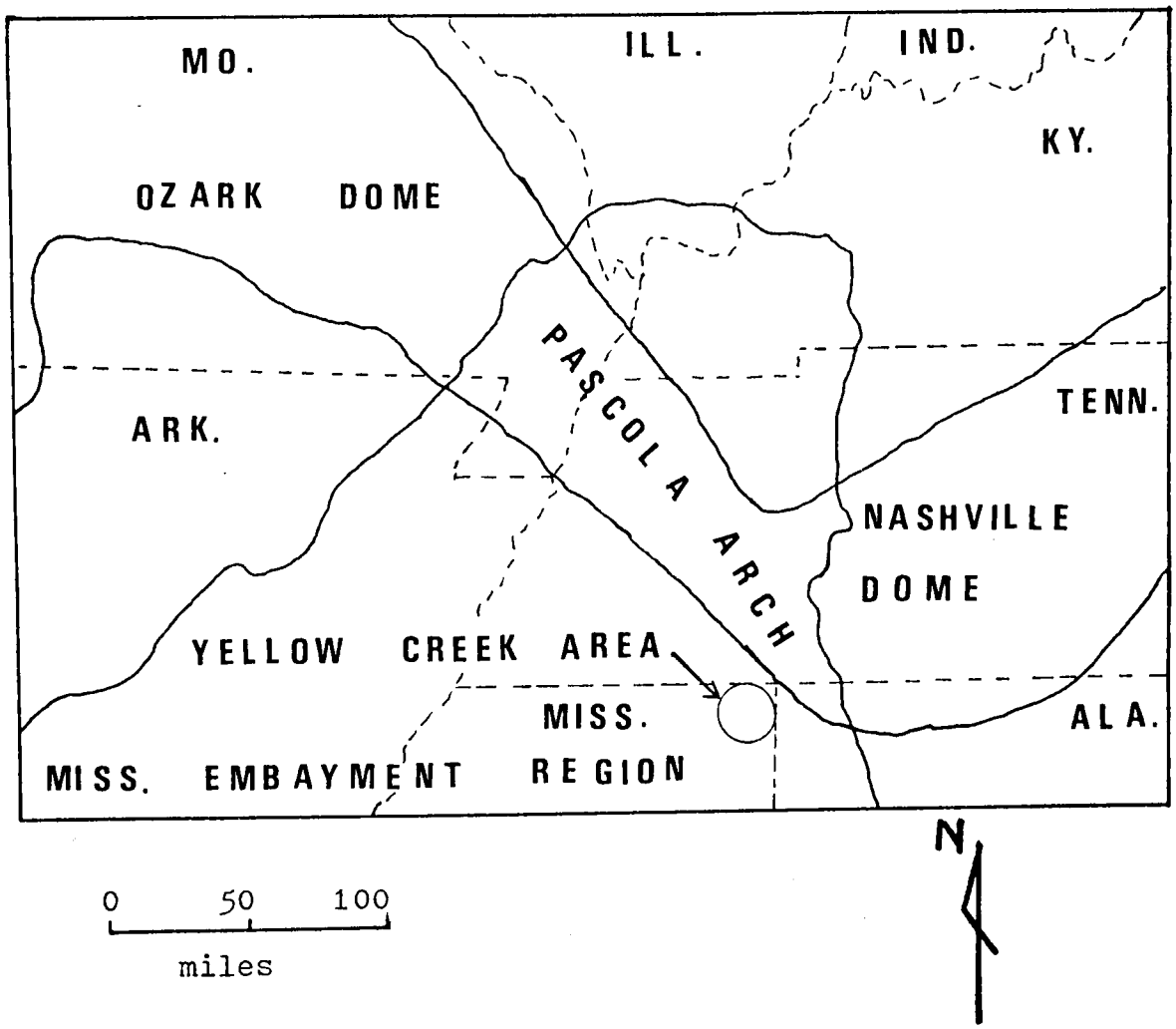

Figure 4. The ancient Pascola arch (after Johnson, 1975).

Stratigraphy

The strata in the Yellow Creek area range in age from Devonian to recent. They are described here sequentially from oldest to youngest. A stratigraphic column is shown in Figure 5.

The Ross Formation (Devonian) is a fine grained limestone, thin bedded to massive and dense. Maximum exposed thickness is 10 feet.

The Chattanooga Shale (Devonian and Mississippian) lies unconformably upon the Ross Formation. It is a carbonaceous shale. Thickness is from 1 foot to 28.5 feet.

The Fort Payne Formation (Mississippian) is the most common Paleozoic rock exposed in the study area. It is subdivided into upper and lower parts. The lower part is silty limestone, fine grained with a few cherty and glauconitic zones. Thickness is from 98 to 113 feet. The upper part has been weathered to siliceous residual soil and clays. It contains beds of dense to porous blocky chert from 2 to 10 inches thick. Thickness is from 0 to 150 feet.

The Tuscaloosa Formation (late Cretaceous) lies unconformably upon the Fort Payne. It contains unconsolidated cherty gravel consisting of small pebbles to cobbles, and it may locally contain silt matrix or be cemented by silica. Channels and lenses of white to reddish-brown tripolitic silt are present locally. Thickness is from 0 to 120 feet.

The Eutaw Formation rests unconformably upon the Tuscaloosa. The Upper or Tombigbee member consists of silty and clayey unconsolidated quartz sand, very fine grained. Locally it contains fossil molds and carbonized wood. Thickness is from 70 to 100 feet. The lower member

Geologic Time	Rock Unit		Thickness* (ft)	Seismic Wave Velocity (ft/sec)
HOLOCENE	Alluvium		0 to 20	1000 to 6000
HOLOCENE and TERTIARY	Yellow Creek fluvial deposits	Tennessee River fluvial deposits	0 to 50	
CRETACEOUS	Coffee Sand		140	
	Unconformity			
	Eutaw Formation	Tombigbee Member	70 to 100	
		Lower Member	0 to 120	5000 to 7000
	Unconformity			
	Tuscaloosa Formation		0 to 150	
	Unconformity			
MISSISSIPPIAN	Fort Payne Formation	Upper part	0 to 150	
		Lower part	98 to 113	
	Chattanooga Shale		1 to 28.5	10000 to 20000
DEVONIAN	Unconformity			
	Ross Formation		10	

Figure 5. Stratigraphic column of the Yellow Creek area with approximate thicknesses and seismic wave velocities.

*The thickness of the section between the surface and the top of the lower Fort Payne varies between 0 and 600 feet.

contains fine to very fine grained unconsolidated quartz sand, thin bedded, micaceous and glauconitic. Thickness is from 70 to 100 feet.

The Coffee Sand rests uncomformably upon the Eutaw. It contains light-gray, fine grained unconsolidated quartz sand, thin to irregularly bedded, slightly micaceous and sparsely glauconitic. Maximum preserved thickness is 140 feet.

Tertiary and Holocene sediments are divided into Yellow Creek and Tennessee River fluvial deposits. They contain poorly sorted gravel and sand, with quartz grains. Thickness is from 0 to 50 feet.

Local Setting

The geologic information used here is adopted mainly from the geologic map (Figure 6), by Russell (1975).

The Fort Payne Formation, the most common Paleozoic rock exposed in the study area. is mainly confined to the shorelines of Pickwick Lake and the Yellow Creek embayment, whereas Cretaceous and Tertiary sediments cover the higher ground on the peninsula and most areas west of Yellow Creek. The Ross Formation (Devonian) and Chattanooga Shale (Devonian and Mississippian) outcrop only on the "Big Island" in the northern section of the Yellow Creek embayment and on the shore across Yellow Creek from the "Big Island."

Generally, bedding in the Fort Payne Formation is nearly horizontal on the peninsula between Yellow Creek and the Tennessee River. The contact between the Fort Payne Formation and the Cretaceous sediments on the west shore of Yellow Creek is 60 feet below the same

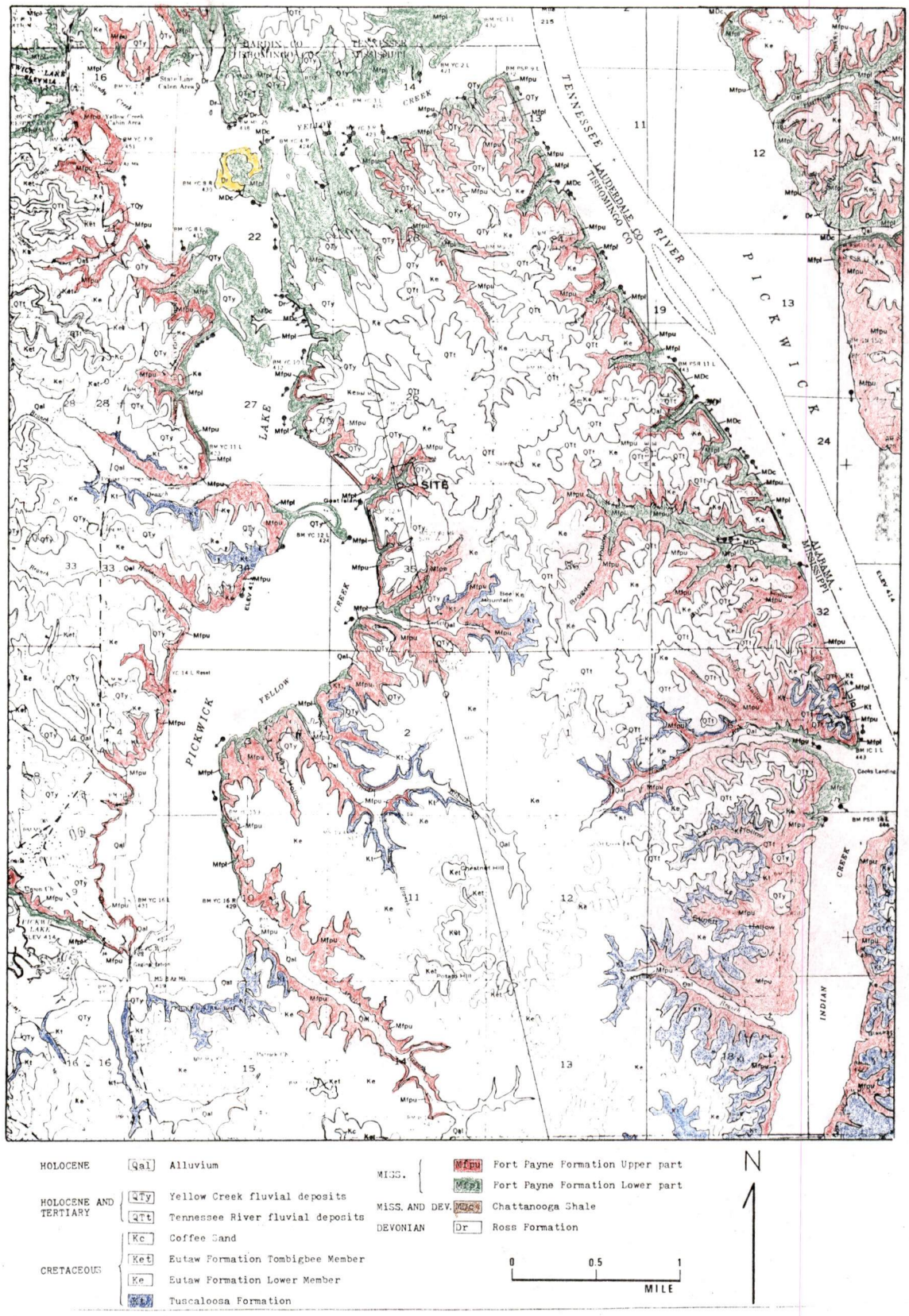

Figure 6. Geologic map of the Yellow Creek area (Russell, 1975, Courtesy of TVA).

contact on the east shore. This fact is consistent with the regional pattern of the Mississippian embayment, wherein strata dip gently toward the west.

The thickness of the post-late Cretaceous unconsolidated sediments increases rapidly toward the west. On Goat Island, the peninsula on the west shore of Yellow Creek, test holes were drilled to a point 350 feet above sea level without encountering Paleozoic rock. However, at the plant site, east of Yellow Creek, the top of the Fort Payne Formation lies between 450 and 470 feet above sea level. Refraction data also indicate a thickness of more than 500 feet of unconsolidated sediments at seismic stations on U.S. Highway 25, west of Goat Island.

The irregular surface at the bottom of the Cretaceous section is here interpreted as a paleodrainage system which was developed on the Fort Payne and older strata prior to Cretaceous time. Others (Johnson, 1975) have suggested a tectonic origin for the irregular Fort Payne surface that lies beneath Goat Island.

Johnson (1971) also did a joint pattern study over the Yellow Creek area. He reported the joint pattern in this area to be N54°W and N38°E, parallel and perpendicular, respectively, to the axis of the Pascola arch. He interpreted these patterns as release joints.

Only one location, 1/3 mile north of the mouth of Short Creek on the west shore of Pickwick Lake, suggests a fault in the Fort Payne. This steeply dipping fault with north side up is short and of very small displacement (Russell, 1975).

Previous Geophysical Surveys

Gravity Survey

Johnson (1975) did a detailed gravity survey over the Yellow Creek area as part of the geophysical surveys of the proposed Yellow Creek power plant site. His objective was to differentiate regions underlain by thick residual soils and unconsolidated sediments from regions where bedrock lies at shallow depth. He interpreted negative gravity anomalies to be due to thick residual soils. He showed a prominent negative anomaly at the Goat Island area. Thick residual soils and unconsolidated sediments were found there by recent drilling and the present refraction survey.

Seismic Reflection Survey

The study area was surveyed by the seismic reflection method by Western Geophysical Company. Vibroseis equipment was used as the energy source on land while air gun and sparker were used on Pickwick Lake and the Yellow Creek embayment. Tennessee Valley Authority permitted the author to use these reflection data.

Drill Data

More than 150 holes were drilled at the Yellow Creek area since 1971. Most of them are concentrated at the plant site for foundation investigations. Eleven holes were drilled for the purpose of geologic correlation. They are located in Figure 7 together with the elevations of bedrock at each hole.

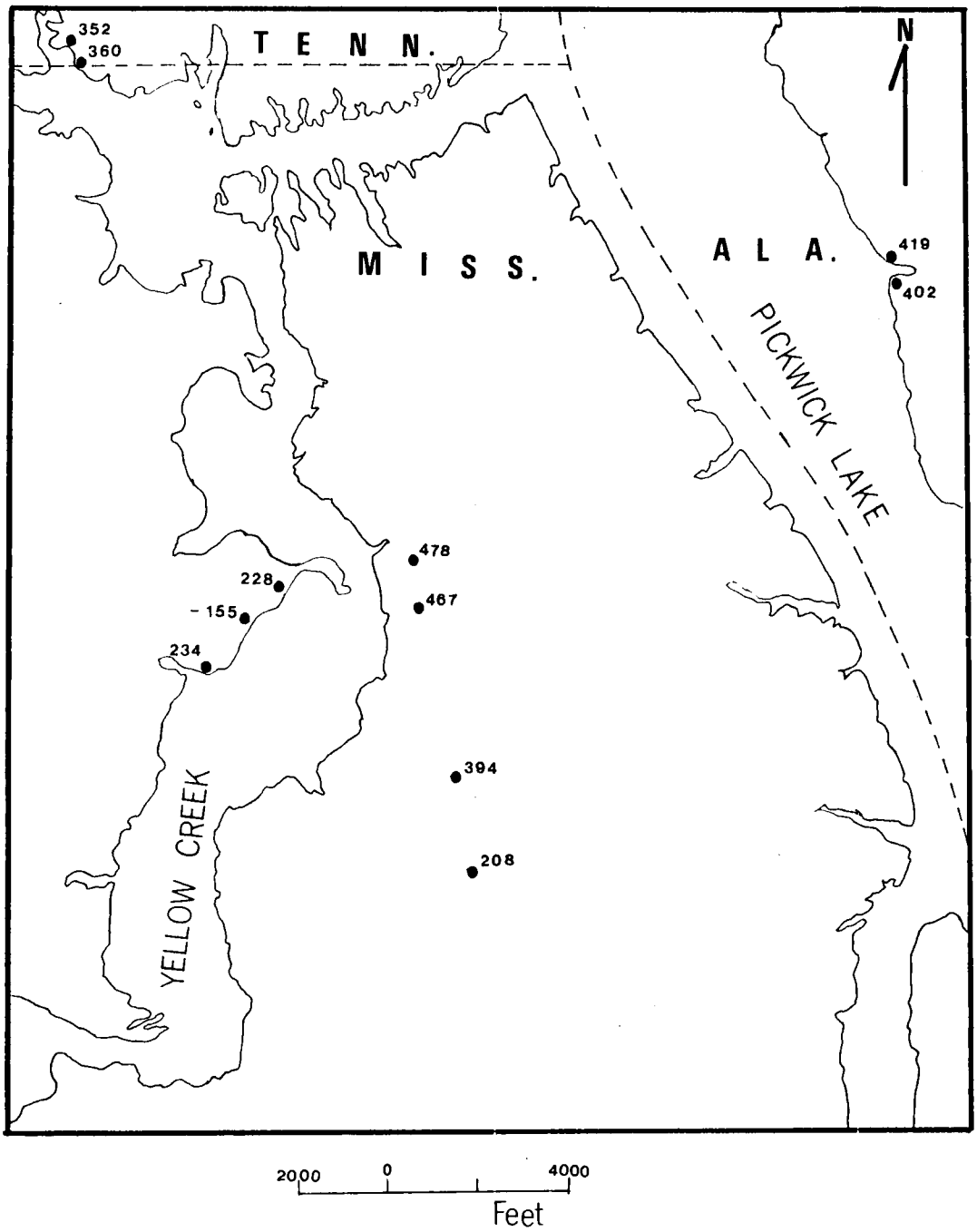

Figure 7. Locations of geological correlation drill holes (TVA, 1975, Courtesy of TVA).

Note: Numbers indicate elevation of bedrock in feet.

CHAPTER III

PROCEDURES

Field Procedures

The seismic refraction survey was initiated in the summer of 1975. Fifty-seven shot point stations are shown on the location map of Figure 8. Stations were spaced at 1300 feet intervals along U.S. Highway 25 to the west of Yellow Creek and along highways and gravel roads on the peninsula. From one to six shot holes were drilled at each station. Shot holes were normally ten feet deep.

Geophones were usually placed at 50 feet and 100 feet intervals but intervals of 25 feet were also occasionally used. Geophone spread lengths were 650 feet and 1850 feet. The shot-geophone arrangements and shooting sequence are illustrated in Figure 9.

Equipment

The equipment used in this survey was a seismic reflection recorder manufactured by Texas Instruments Company which was mounted on an F-500 four wheel drive Ford truck (Figure 10). The truck was donated to The University of Tennessee by Exxon Corporation in 1971. Instruments in the truck are described as follows:

Amplifiers. Twenty-four TI 9000 seismic amplifiers with high-low cut filters, 60-cycle notch filter and automatic or fixed gain controls.

Recording Oscillograph. Twenty-seven channel Southwestern Industrial Electronics (SIE model).

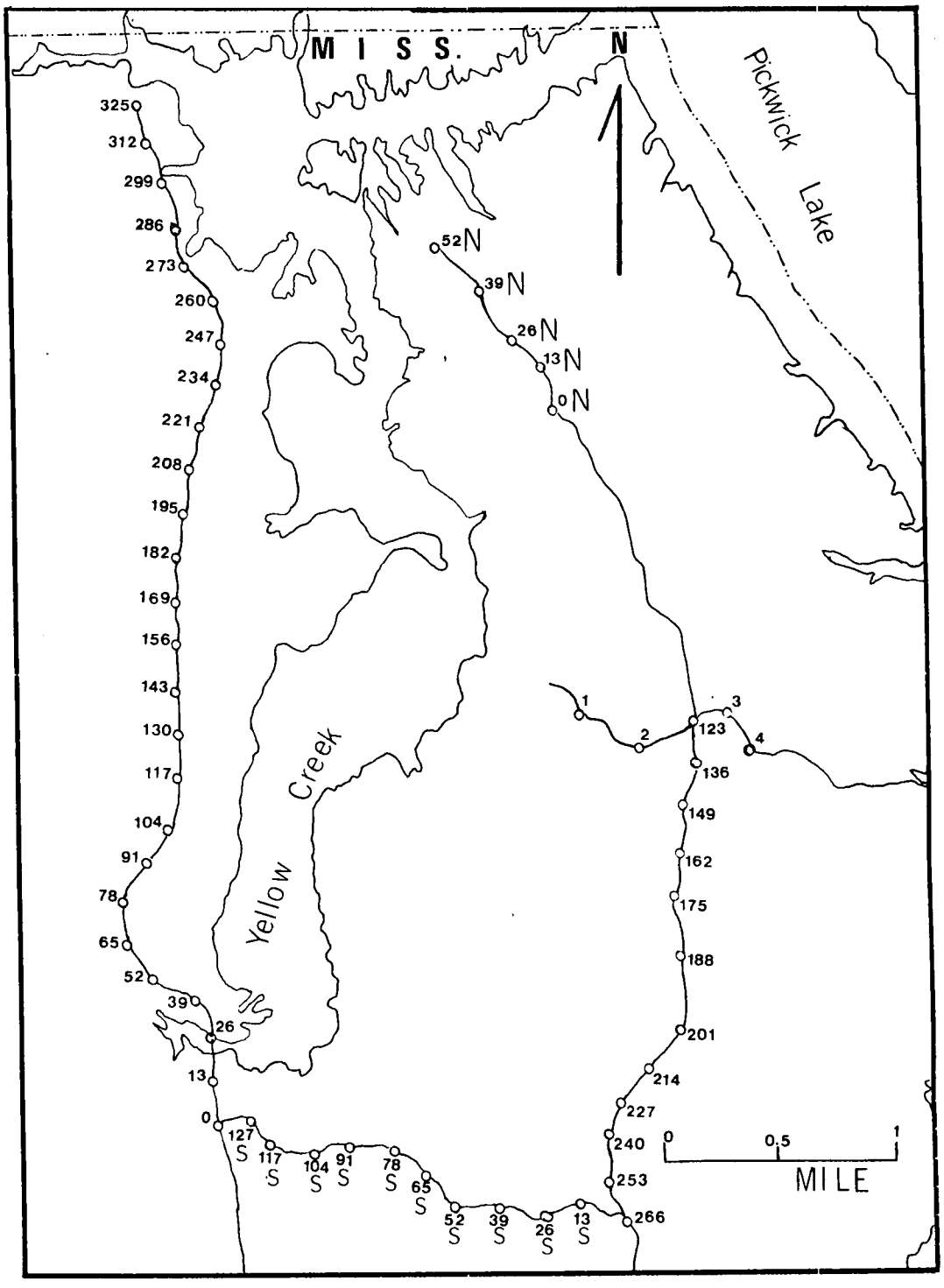

Figure 8. Location map of the shot hole stations.

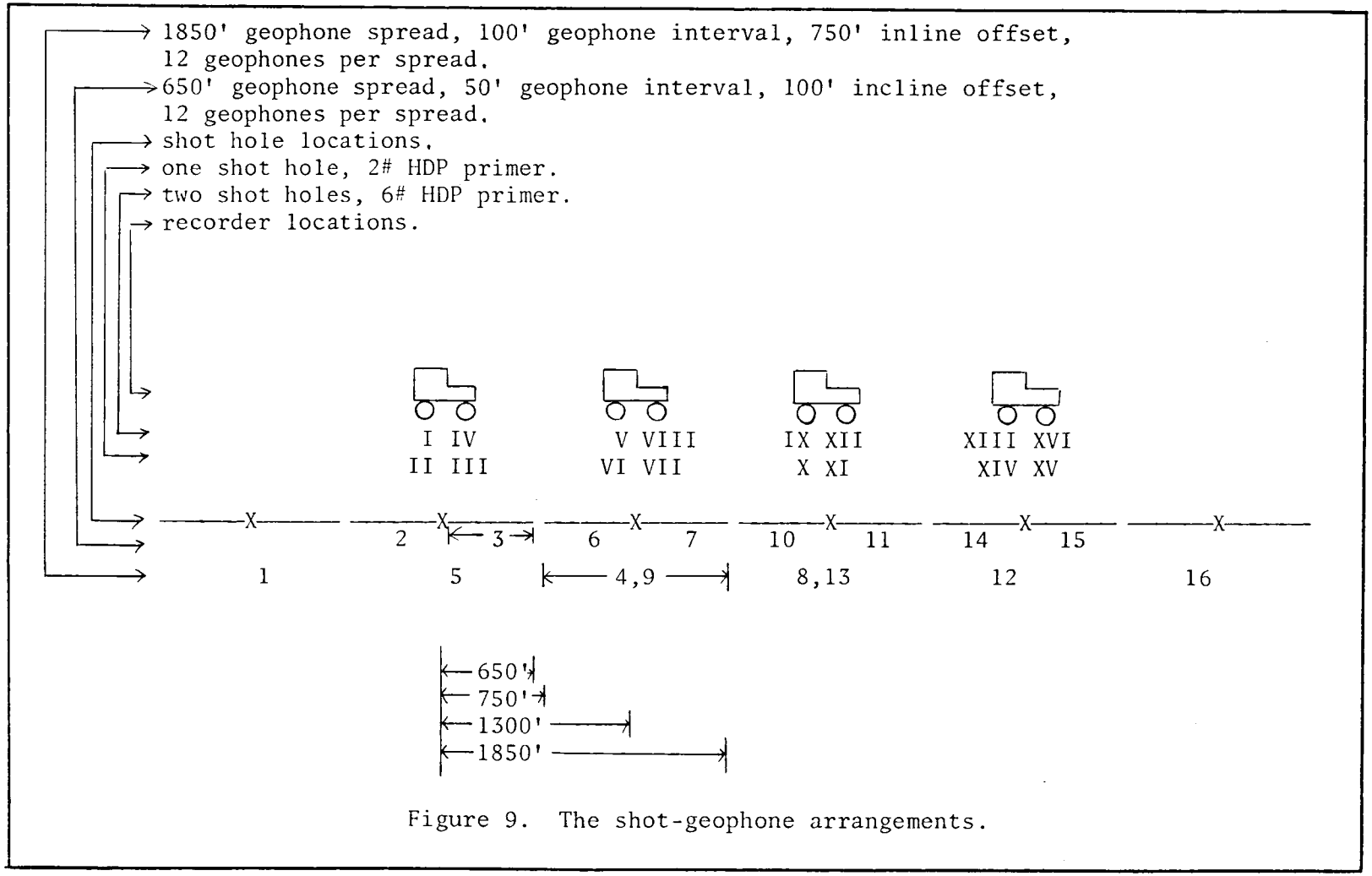

Figure 9. The shot-geophone arrangements.



Figure 10. The seismic recording truck.

A typical seismogram is shown in Figure 11. The 12 amplifiers on the right were set on fixed gain with low initial gains. The 12 amplifiers on the left were also set on fixed gain but with high initial gain. The left and right sides of the seismogram are dual recordings of a single 12 trace geophone spread. The signals were unfiltered except that 60-cycle high line notch filters were used when the occasion demanded.

Data Processing

Seismic Refraction Data

A time-distance graph (Figure 12) was constructed from forward and reverse shots at opposite ends of each geophone spread. Apparent velocities and intercept times were determined by a linear least squares fit of each straight line segment. These data were then translated into true velocities, depths and dip angles by means of a computer program based on mathematical expressions for two sloping interfaces. Formulas used are given in Appendix A.

Datum Correction

A datum correction is the time needed for the seismic wave to travel from the surface directly downward to an arbitrary datum elevation and back to the surface. Because the datum chosen here is sea level, the formula for the datum correction is:

$$D = (H_1/V_1 + H_2/V_2 + (E-H_1-H_2)/V_3) \times 2$$

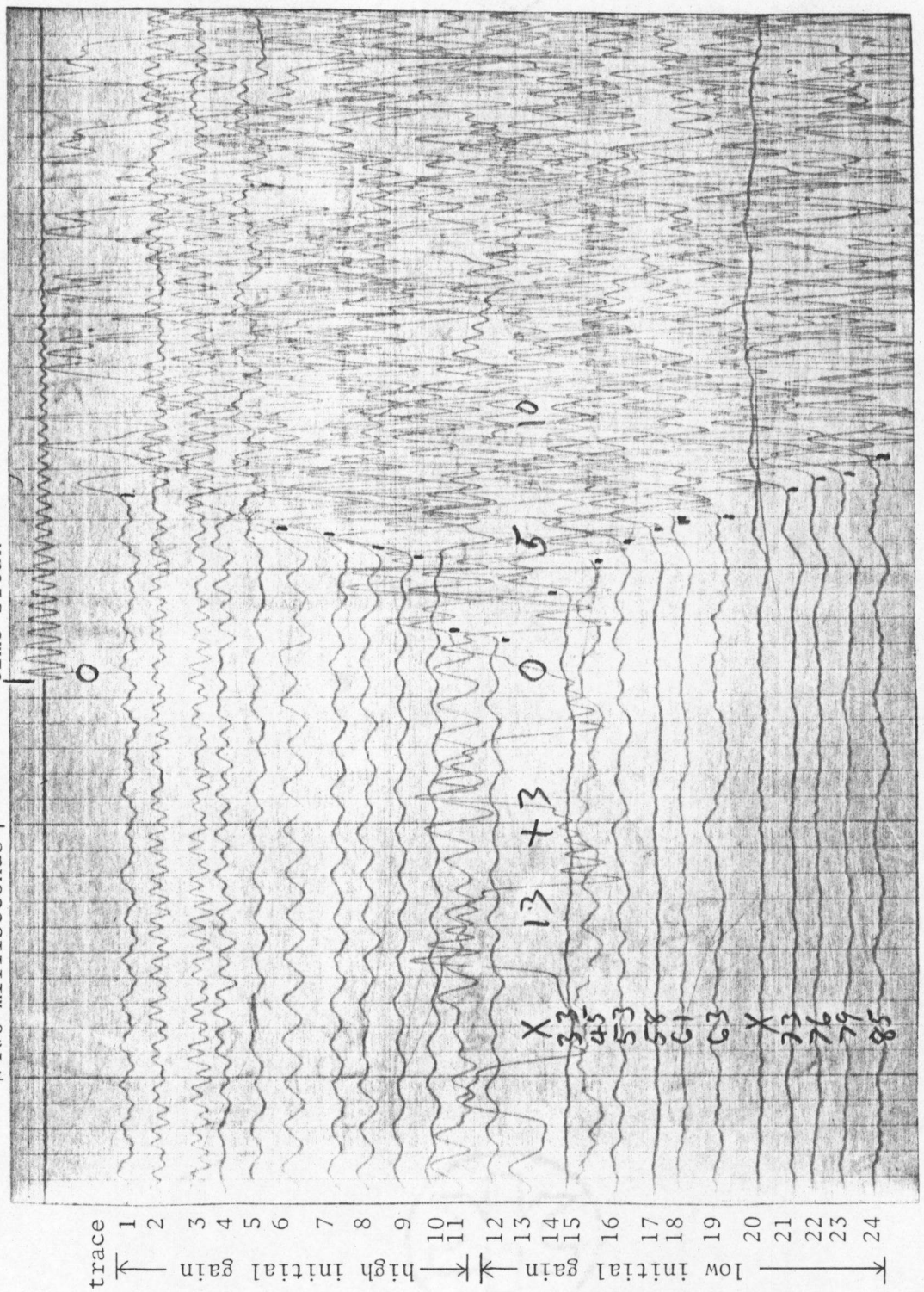

Figure 11. A typical refraction seismogram.

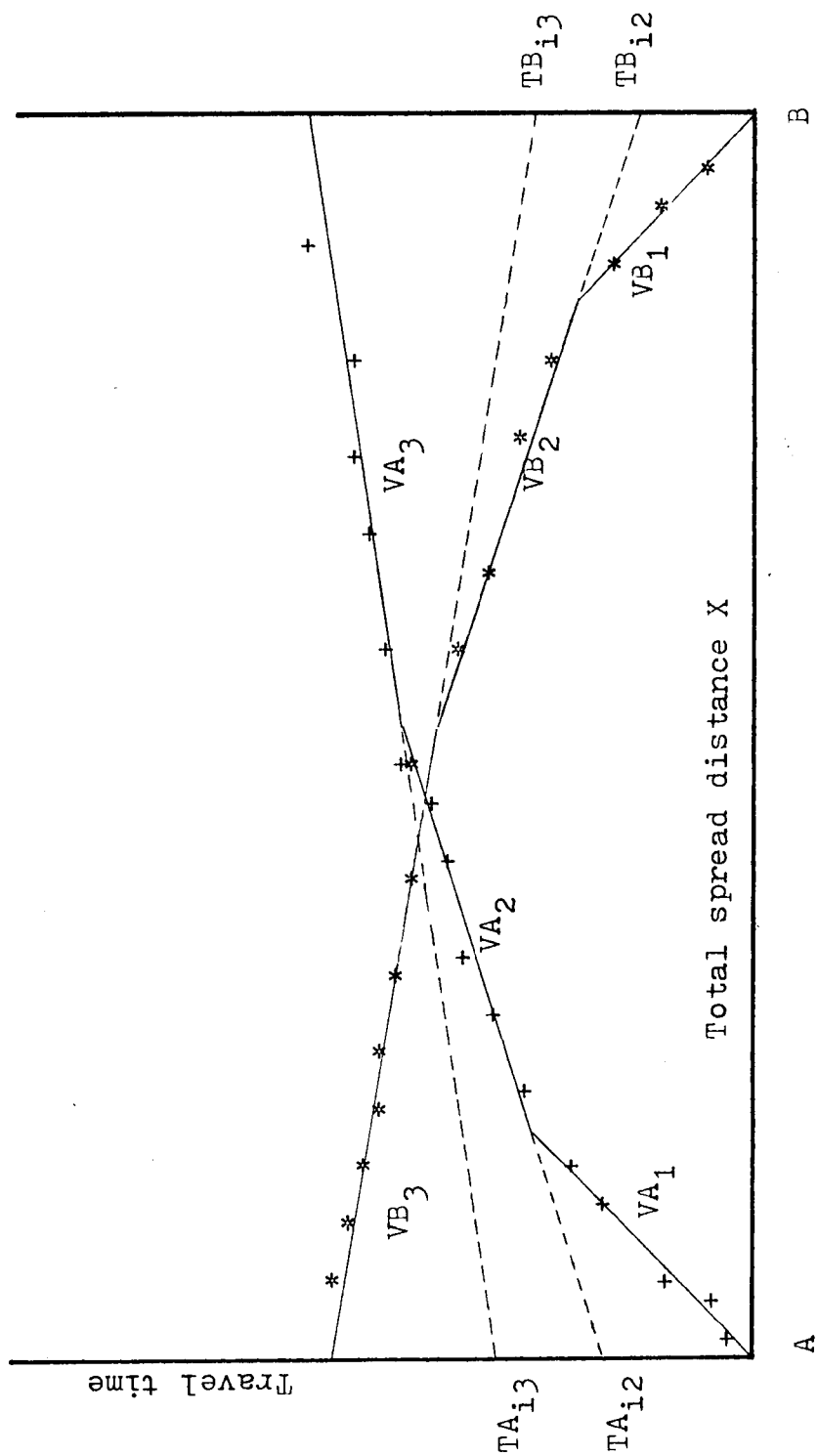

Figure 12. A time-distance graph for a structure consisting of two sloping interfaces.

where:

D is the datum correction;

E is the elevation of the station;

H_1 and H_2 are thicknesses for the first and second layers;

V_1, V_2, and V_3 are wave velocities in the first, second, and third layers respectively.

The datum corrections are negative, that is, they are substracted from vibroseis reflection times.

Computer Program

A computer program called FRACT1 which deals with seismic refraction data is provided by Bryan (1975). FRACT1 can solve the multiple-layered dipping planar interface problem for an arbitrary number of layers by inputting apparent velocities and intercept times. It can also produce a printer-plotted time-distance graph from input time-distance data.

FRACT1 was rewritten and named FRACT2 by the author. FRACT2 retains all the functions of FRACT1 but also applies the statistical linear least squares fit method to regress the time-distance data. By using input critical distances the program regresses each line segment in the time-distance graph and provides more objective apparent velocities and intercept times for the calculating procedures.

FRACT2 is stored on the tape of the IBM 360/65 computer at The University of Tennessee Computing Center. Job control language and format for inputing data are described in Appendix B.

CHAPTER IV

INTERPRETATION

Datum Corrections for Near Surface Velocity Anomalies

Table I in Appendix C lists the results of the refraction survey for all the stations. Datum corrections are at column IX which are in fact the time needed for seismic waves to travel down to sea level and back to the surface. These datum corrections are then substracted from the two-way travel times for all the reflection signals from all the interfaces directly below the stations to produce the seismograms.

Figure 13 shows two profiles from near the top of the Knox Dolomite along stations on Highway 25 before and after the datum corrections. The lower profile which utilizes only a topographic correction shows a synclinal structure in the middle of the profile, near Goat Island, and a relief of 165 milliseconds. In the upper profile which utilizes the complete datum correction the synclinal structure is reduced and the relief of the whole profile is 65 milliseconds. It is evident that the relief before the datum correction was caused by near surface velocity anomalies. The effect of datum corrections was distinct.

The residual structure in the corrected profile might be an accurate representation of the top of Knox but it is possible that the datum correction did not remove the near surface velocity anomaly completely. The refraction method lacks the necessary precision for determining

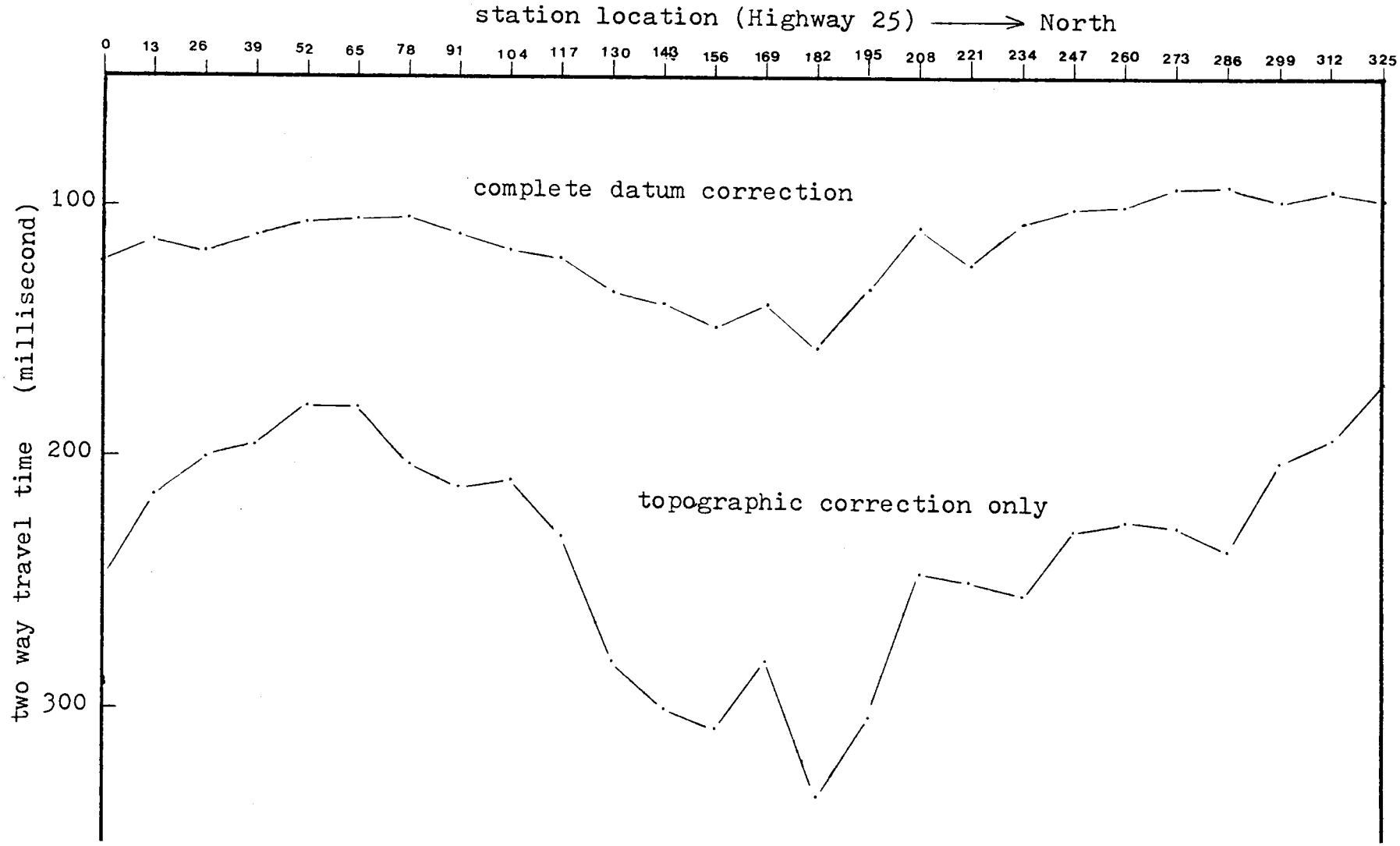

Figure 13. Seismic time profiles of near the top of Knox Dolomite, along stations on Highway 25, before and after datum corrections.

datum correction to the precision desired. In critical areas these results should be checked by means of a shallow uphole velocity survey.

Subsurface Geology

Top of High Velocity Layer

Figure 14 is a geologic map of the survey area together with contour lines showing the elevation of the high velocity layer (bedrock surface). Generally the elevation of this surface is lower toward the west. This agrees with the regional pattern of the Mississippi embayment.

Figure 14 suggests an old river system developed on the Fort Payne and older strata may have existed before the late Cretaceous time. It was then buried by late Cretaceous sediments when the Mississippi embayment began to subside.

Further evidence is the limited exposure of Tuscaloosa gravels in the survey area. This formation is of fluvial origin and exists only in the southern part of the survey area (Figure 14). It is exposed at the Goat Island area, along Tuckett Branch, Glade Branch, Short Branch and at the head of the Yellow Creek embayment. The postulated old river passes the Tuscaloosa outcrops at Goat Island and at the head of Yellow Creek embayment. Other outcrops on the peninsula may represent tributaries of the ancestral stream.

The post-Tuscaloosa or pre-Eutaw erosion is believed to have removed the Tuscaloosa gravels in most of the survey area and only the gravels in the old river channels were preserved. Now the Eutaw sand lies uncomformably on top of this erosion surface. The present drainage

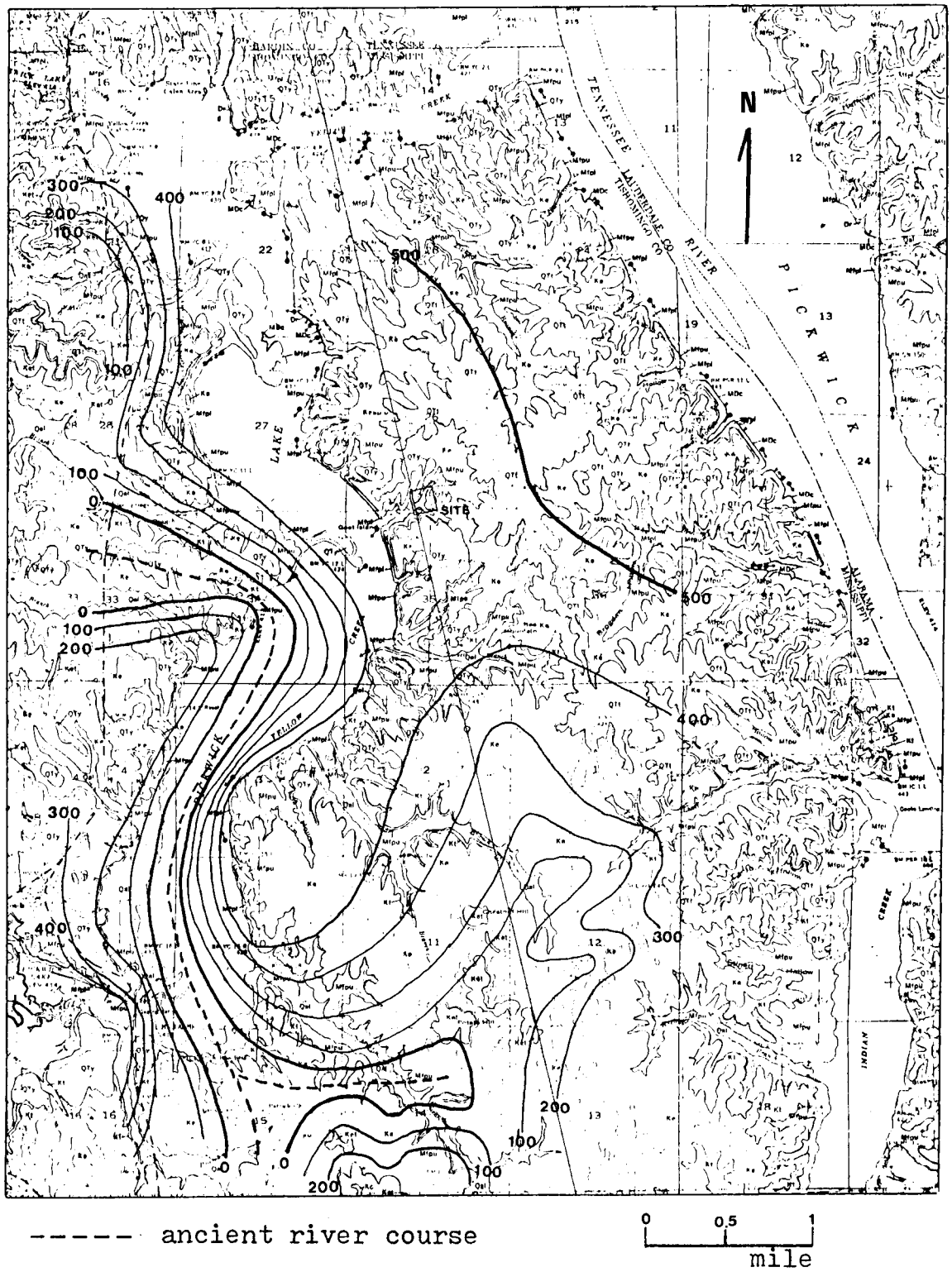

Figure 14. Elevation of the Paleozoic bedrock surface.

system cuts across the old channel as marked by the Tuscaloosa gravels, the old drainage indicator, at the locations indicated in Figure 14.

Top of Knox Dolomite

Figure 15 is an isochron map of the reflection times to near the top of the Knox Dolomite. Two trends of high reflection time, or structural low, were found. One extends from the Goat Island area eastward across the survey area, and the other trends southeastward from Goat Island, following the postulated paleodrainage system.

The structural low extending eastward may be correct but it seems unlikely for the southeastward trending trough to coincide with the paleodrainage pattern on the bedrock surface. It is believed rather that the southeastward trending depression is caused by a residual near surface velocity anomaly which was not completely removed by the datum corrections.

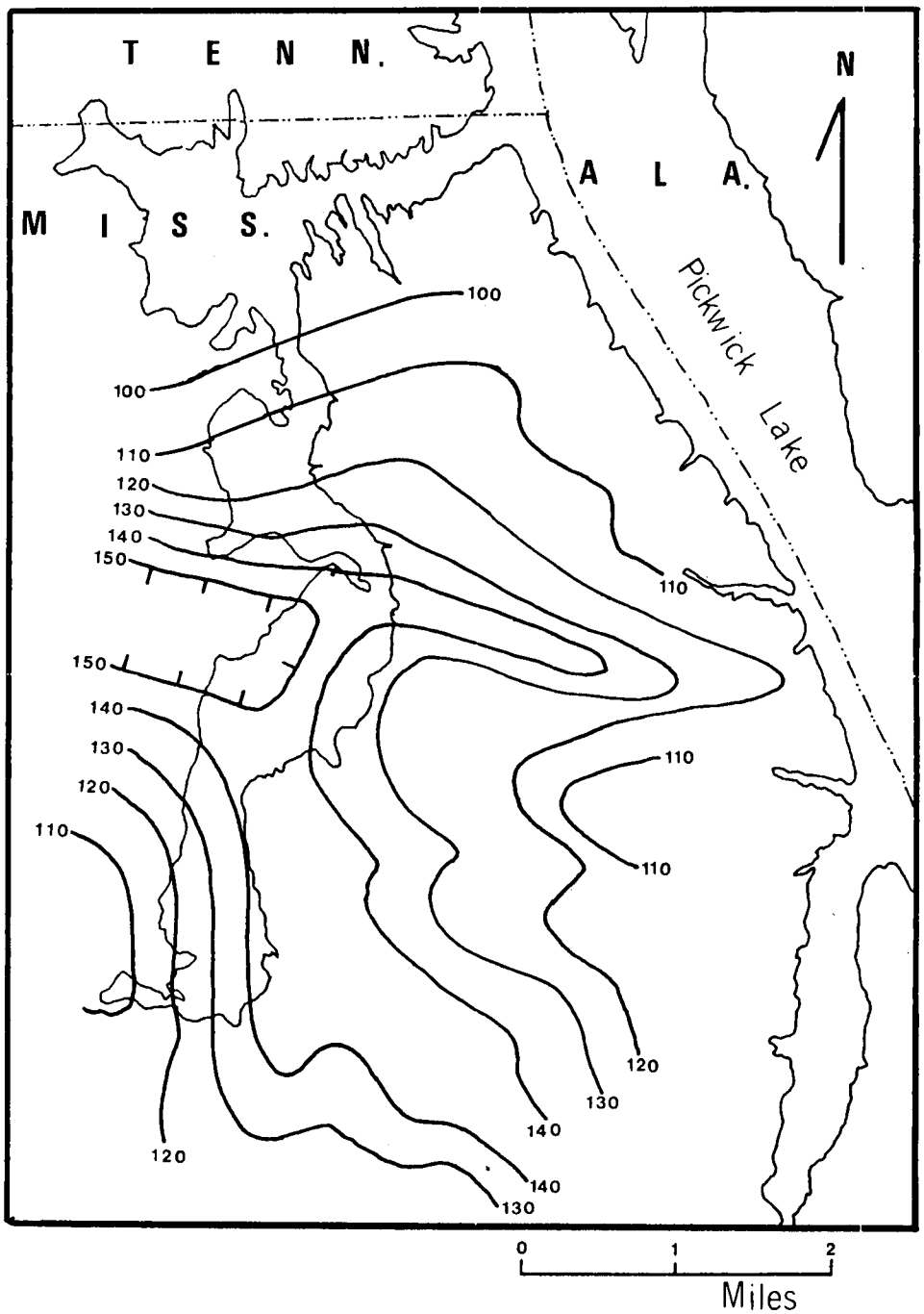

Figure 15. Isochron map of near the top of Knox Dolomite in the Yellow Creek area.

Note: Contour interval = 10 milliseconds.

CHAPTER V

CONCLUSION

This survey has demonstrated the capability of refraction data in removing near surface velocity anomalies from reflection seismograms and in delineating subsurface geology in a seismic survey of a power plant site. Apparent Paleozoic structure beneath the survey area was largely eliminated by the datum correction provided by refraction data. Bedrock surface features interpreted from refraction data suggest a paleodrainage system which existed in pre-late Cretaceous time.

The residual structure in the corrected Knox profile might be an accurate representation of the top of Knox but it is possible that the datum correction did not remove the near surface velocity anomalies completely. The refraction method lacks the necessary precision for determining datum correction to the precision desired. In critical areas these results should be checked by means of a shallow uphole velocity survey.

SELECTED REFERENCES

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APPENDIXES

APPENDIX A

CALCULATING FORMULAS FOR REFRACTION DATA OF TWO SLOPING INTERFACES

The following calculating procedures use data read from a typical 2 sloping interface time-distance graph as represented by Figure 12, p. 23.

A. First Layer

VA_1 and BV_2 are computed from the first slopes. The two velocities must be approximately equal; if not, the surface layer is not uniform from one end of the line to the other. $V_1 = (VA_1 + VB_2)/2$ is the true velocity for the first layer.

B. Second Layer (refer to Figure 16)

Compute angles A_1 and B_1 from:

$$\sin A_1 = V_1/VB_2 \qquad \sin B_1 = V_1/VA_2$$

Compute angles of incidence,

$$a_1 = b_1 = (A_1 + B_1)/2$$

Compute dip angle,

$$W_2 = (A_1 - B_1)/2$$

where: negative W_2 indicates downward dip from A-end and positive W_2 indicates upward dip from A-end.

Compute true velocity in second layer,

$$V_2 = V_1/\sin a_1$$

Compute a preliminary quantity which we will call P,

$$P = V_1/(\cos A_1 + \cos B_1)$$

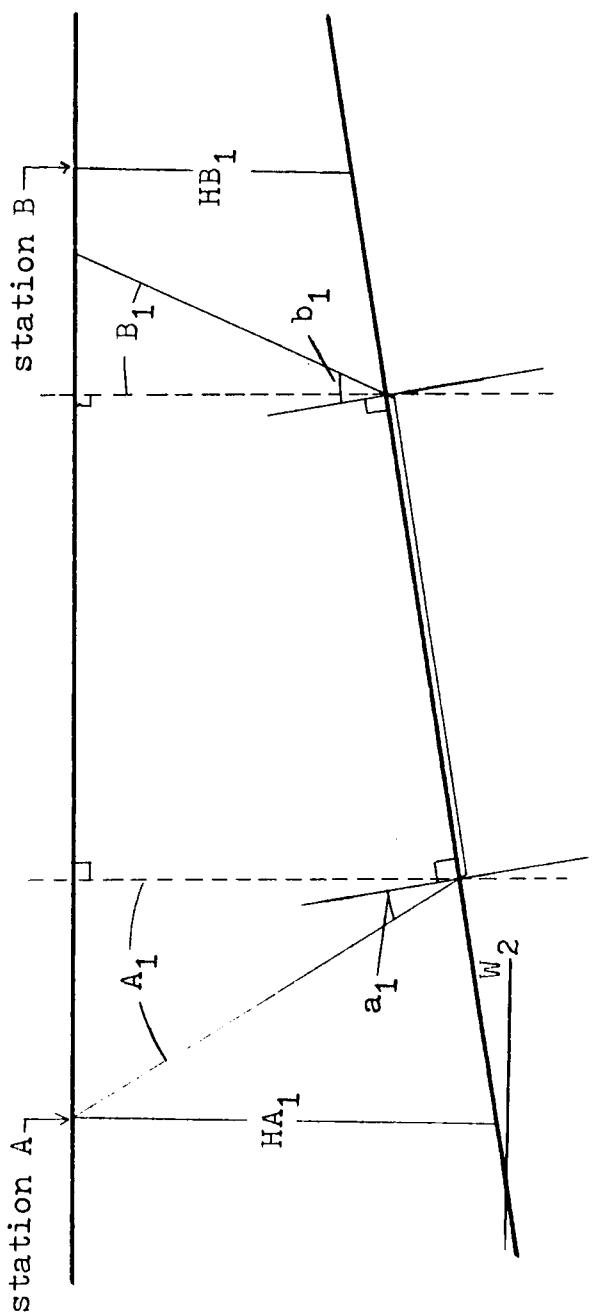

Figure 16. The travel path of the refracted wave between the surface and the first interface.

Compute layer thicknesses

$$HA_1 = (P)(TA_{i2})$$

$$HB_1 = (P)(TB_{i2})$$

C. Third Layer (refer to Figure 17)

Compute new angles A_1' and B_1' from:

$$\sin A_1' = V_1/VB_3 \qquad \sin B_1' = V_1/VA_3$$

Compute new a_1 and b_1 from

$$a_1' = A_1' - W_2$$

$$b_1' = B_1' + W_2$$

Compute preliminary quantities which will be called P_2 and Q_2:

$$P_2 = \sin^{-1} \left(\frac{V_2}{V_1} \sin a_1'\right)$$

$$Q_2 = \sin^{-1} \left(\frac{V_2}{V_1} \sin b_1'\right)$$

Compute angles of incidence at top of third layer,

$$a_2 = b_2 = (P_2 + Q_2)/2$$

Compute dip at top of third layer

$$W_3 = W_2 + (P_2 - Q_2)/2$$

where: negative W_2 indicates downward dip from A-end and positive W_2 indicates upward dip from A-end.

Compute angles of incidence measured from the vertical,

$$A_2 = a_2 + W_3 \qquad B_2 = b_2 - W_3$$

Compute true velocity in the third layer,

$$V_3 = V_2/\sin a_2$$

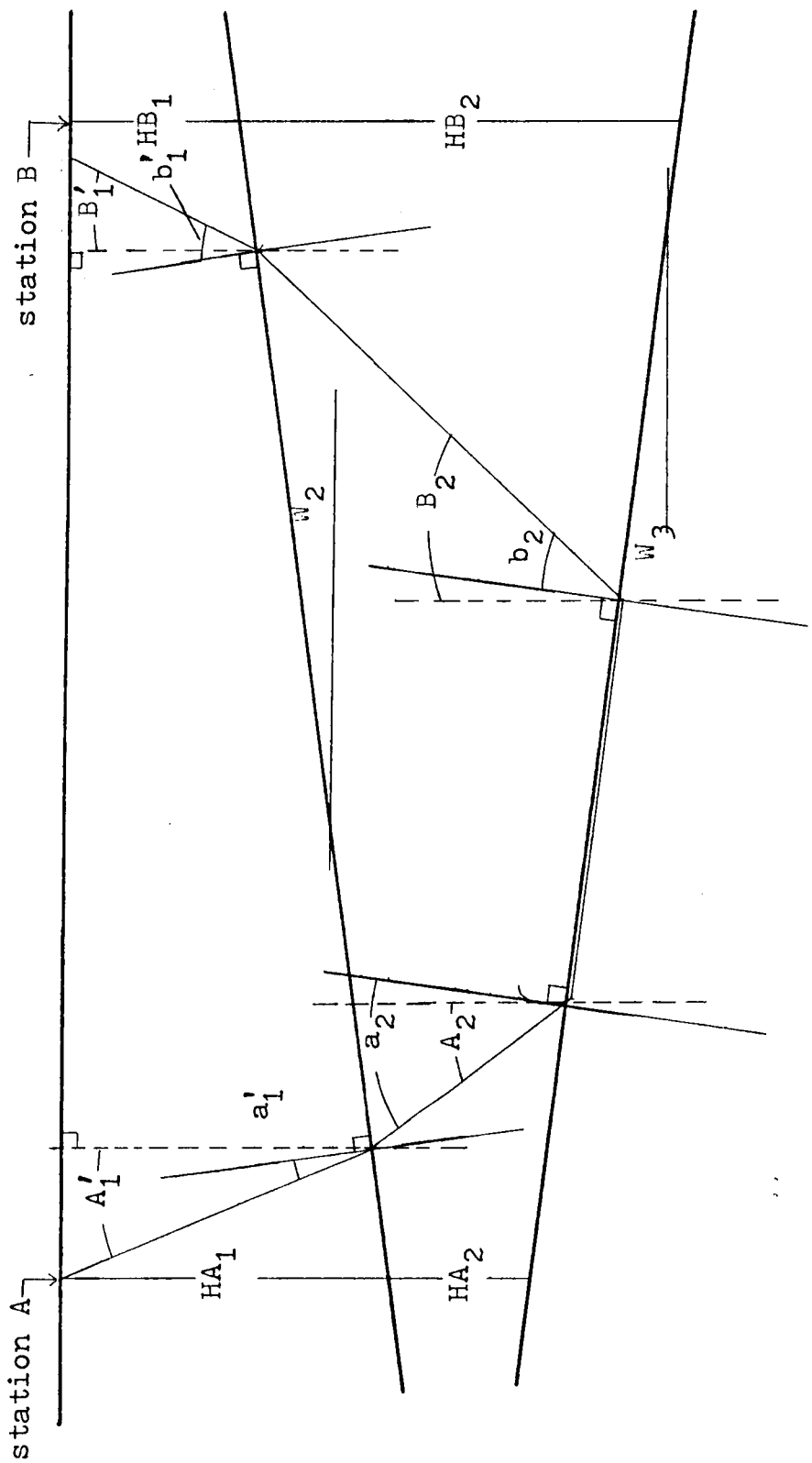

Figure 17. The travel path of the refracted wave between the surface and the second interface.

Compute layer thicknesses,

$$HA_2 = V_2/(\cos A_2 + \cos B_2)(TA_{i3} - HA_1/V_1\ (\cos A_1' + \cos B_1'))$$

$$HB_2 = V_2/(\cos A_2 + \cos B_2)(TB_{i2} - HB_1/V_1\ (\cos A_1' + \cos B_1'))$$

APPENDIX B

JOB CONTROL LANGUAGE AND FORMAT OF DATA FOR USING PROGRAM FRACT2 IN TAPE OF UNIVERSITY OF TENNESSEE COMPUTING CENTER

Job Control Language

```
//FRACT2 JOB (34131,045628,BINS),Smith
//*TAPE         001072,R
//S1 EXEC FORTGCLG
//FORT.SYSIN DD UNIT=3400-4,DSN=FRACT2,
//DISP=(OLD,KEEP),VOL=SER=001072,
//DCB=(RECFM=FB,LRECL=80,ELKSIZE=1600)
//GO.FT06F001 DD SYSOUT=A,DCB=(LRECL=133,RECFM=FBA,BLKSIZE=3458),
//*              SPACE=(CYL,(1,1),RLSE)
//GO.FT01F001 DD SYSOUT=A,DCB=(LRECL=133,RECFM=FBA,BLKSIZE=3458),
//*              SPACE=(CYL,(1,1),RLSE)
//GO.FT02F001 DD SYSOUT=A,DCB=(LRECL=133,RECFM=FBA,BLKSIZE=3458),
//*              SPACE=(CYL,(1,1),RLSE)
//GO.FT03F001 DD SYSOUT=A,DCB=(LRECL=133,RECFM=FBA,BLKSIZE=3458),
//*              SPACE=(CYL,(1,1),RLSE)
//GO.FT04F001 DD SYSOUT=A,DCB=(LRECL=133,RECFM=FBA,BLKSIZE=3458),
//*              SPACE=(CYL,(1,1),RLSE)
//GO.SYSIN DD *
                .
                .
              DATA
                .
                .
```

Format of Data

```
YELLOW/CREEK/SITE     S59 7/1975 DR/STAUB     GEO/SPACE     HDP-3/PRIMER  2/LB     590
  10      6217              1875                            27 25 2 1 31       500 591
        0         0          0         0                                            592
       25        18        220       100                                            592
       50        35        425       118                                            592
      100        60        475       123                                            592
      150        85        525       150                                            592
      200       109        575       159                                            592
      250       122        750       181                                            592
      400       146        800       190                                            592
      450       150        850       200                                            592
      500       158        900       206                                            592
      550       165       1050       215                                            592
      725       191       1100       216                                            592
      775       196       1150       220                                            592
     1025       210       1200       206                                            592
     1075       216       1250       232                                            592
     1175       221       1300       235                                            592
     1225       226       1325       238                                            592
     1325       234       1375       239                                            592
     1375       238       1425       239                                            592
     1425       240       1475       238                                            592
     1475       244       1525       238                                            592
     1525       246       1625       247                                            592
     1575       249       1725       248                                            592
     1725       258       1825       255                                            592
     1775       260       1875       258                                            592
     1825       266                                                                  592
     1875       268                                                                  592
 200 220                                                                             594
 780 910                                                                             594
18761876                                                                             594
```

In the preceding data set, each line represents one card. There are four types of card in the data set.

The first type is called the header card and it is the first card. It must be punched 0 at column 80. From column 1 to column 20 is the survey area. From column 21 to column 24 is the station name. From column 25 to column 32 is the date. From column 33 to column 44 is the observer. From column 45 to 56 is the equipment. From column 57 to 68 is the energy source. From column 69 to 76 is the amount of energy used. From 77 to 79 is a code which must be the same throughout the whole data set.

The second type is called the parameter card. It must be punched 1 at column 80. From column 1 to 5 is the shot hole depth in feet. The first digit must be at column 4. From column 6 to 13 is the station elevation. The first digit must be at column 12. From column 24 to 31 is the length of the geophone spread. The first digit must be at column 30. From column 56 to 58 is the number of data points from the "A" end. From column 59 to 61 is the number of data points from the "B" end. If column 63 is punched 1 all the output will use seconds for the time unit. If it is punched 2 the output will use milliseconds. If column 65 is punched 1 the output of distance will be in feet, 2 in miles, 3 in meters, and 4 in kilometers. Column 67 is the number of layers. If column 68 is punched 1 the program will produce a printer-plot time-distance graph. Column 73 to 76 is an upper time limit for the plot which must be evenly divisible by 5. Column 77 to 79 is the code.

The third type is the time-distance card. There can be a number of such cards but they must all be punched 2 at column 80. From column 1 to

10 is the geophone distance from the "A" end. The first digit must be at column 9. Column 11 to 20 is the arrival time. The first digit must be at column 19. From column 21 to 30 is the geophone distance from the "B" end. The first digit must be at column 29. From column 31 to 40 is the equivalent arrival time. The first digit must be at column 39. Column 78 to 79 is the code.

The fourth type is the critical distance card. The number of these cards must be the same as the number of layers and must all be punched 4 at column 80. From column 1 to 4 is the critical distance from the "A" end with the first digit at column 4. From column 5 to 8 is the critical distance from the "B" end with the first digit at column 8. The last critical distance card must have any distance bigger than the farthest geophone distance. Column 78 to 79 is the code.

If several sets of data are stacked together the program will process them all at once.

APPENDIX C

RESULTS OF SEISMIC REFRACTION SURVEY

Column I: Station name.

Column II: Elevation (in feet).

Column III: Thickness of the first weathered layer (in feet).

Column IV: Thickness of the second weathered layer (in feet).

Column V: Elevation of bedrock (in feet).

Column VI: Seismic wave velocity in the first weathered layer (in feet per second)

Column VII: Seismic wave velocity in the second weathered layer (in feet per second).

Column VIII: Seismic wave velocity in bedrock (in feet per second)

Column IX: Datum correction (in seconds).

TABLE I

RESULTS OF SEISMIC REFRACTION SURVEY

I	II	III	IV	V	VI	VII	VIII	IX
52N	520	9	31	479	2000	3300	17500	-0.084
39N	545	8	49	488	2100	3100	17200	-0.096
26N	605	6	124	475	2100	3200	17200	-0.138
13N	616	5	120	491	2000	3400	17100	-0.134
ON	610	1	132	476	2000	3300	16900	-0.139
1	550	35	212	304	1800	6300	17000	-0.140
2	585	77	198	310	1800	6300	17000	-0.183
3	645	117	115	414	2200	5600	16800	-0.196
4	625	93	183	349	2200	5600	16800	-0.191
123	616	64	164	388	1800	6200	14300	-0.179
136	593	70	149	374	1800	6000	15900	-0.173
149	592	54	339	200	2000	6300	21300	-0.180
162	572	43	434	95	1900	6800	19200	-0.185
175	585	56	234	295	1800	7200	14400	-0.167
188	605	83	475	48	2000	7300	25300	-0.217
201	622	83	302	236	1900	6700	25800	-0.198
214	602	75	308	219	2000	6600	20700	-0.192
227	583	58	379	147	2000	6800	24700	-0.182
253	536	12	403	121	1600	6700	15000	-0.151
266	576	43	445	88	1600	7600	16600	-0.183
13S	505	7	466	32	2000	6500	14400	-0.155
26S	566	39	192	335	1900	6200	13800	-0.152
39S	568	58	279	231	2400	6900	13800	-0.162
52S	577	89	402	86	2900	7800	17000	-0.174
65S	597	114	284	199	2800	7800	18300	-0.176
78S	543	69	533	-59	2400	7700	16900	-0.188
91S	525	24	517	-16	2000	7500	17000	-0.160
104S	544	44	638	-138	1500	7400	18900	-0.218
117S	546	49	382	115	1500	7400	18900	-0.183
127S	525	46	351	128	1600	6400	18000	-0.182
0	463	9	307	147	2000	6000	19400	-0.126
13	445	12	214	219	2000	6600	17700	-0.101
26	415	19	92	304	2000	7700	15500	-0.082
39	445	23	0	422	2000	0	16000	-0.083
52	486	16	194	277	2000	13900	18100	-0.074
65	484	16	138	330	2000	12400	17900	-0.075
78	492	42	95	355	2000	10800	18200	-0.099
91	469	13	223	233	2000	7600	16500	-0.101

TABLE I (continued)

I	II	III	IV	V	VI	VII	VIII	IX
104	463	8	177	278	2000	6700	16500	-0.091
117	470	17	216	237	1900	6800	16700	-0.110
130	504	51	220	232	1900	6800	17100	-0.146
143	523	62	228	234	2100	6000	18300	-0.160
156	521	61	260	200	2300	6200	18200	-0.159
169	453	13	443	-3	2000	6900	20600	-0.141
182	496	45	427	24	1800	6900	20600	-0.178
195	449	14	508	-73	1800	6300	19100	-0.169
208	456	6	420	30	2200	6500	16800	-0.138
221	509	33	217	259	2400	6500	16200	-0.126
234	505	59	205	242	2300	5900	17900	-0.148
247	489	34	203	251	2100	6100	17200	-0.129
260	469	18	291	161	2000	6400	18200	-0.126
273	434	19	364	51	2000	6500	23500	-0.135
286	478	33	322	123	1800	6700	21700	-0.145
299	445	20	190	235	1900	6900	17100	-0.104
312	466	18	145	303	2000	6200	17700	-0.099
325	415	4	82	329	2000	5500	17200	-0.072

VITA

Vindell Hsu was born in Taiwan, Republic of China, on August 24, 1950. He attended elementary school and junior high school in his home town at TaoYuan. In 1965 he went to Taipei to attend Chingkong Senior High School. He graduated in June 1968. The following October he entered National Taiwan University at Taipei, and in June 1972, he received a Bachelor of Science degree in Geology. He was then drafted to serve in the Army as a second lieutenant for two years.

In the fall of 1974, he accepted an assistantship at The University of Tennessee and began study toward a Master's degree. He received this degree in August 1976. He is a member of the Society of Exploration Geophysicists.

He is married to the former Catherine Yau of Ping-Tong, Taiwan.