KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 86-26

SEISMIC REFLECTION STUDY OF A LAMPROITE INTRUSION, SILVER CITY DOME, WOODSON COUNTY, KANSAS

by

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INTRODUCTION

The Silver City Dome is a NE-SW trending ellipsoidal anticline (5.2 by 2.9 km) located in the southern part of Woodson County and the northern part of Wilson County (T.26S and 27S, R.14E and 15E). The dome is believed to have been formed by intrusion of lamproite magma along a steep fault on the northern flank of the dome and its subsequent southward injection as numerous sills into the Pennsylvanian sequence (Wagner, 1954). The K-Ar ages determined on three samples of phlogopite indicate that the lamproite intruded during Late Cretaceous time, 90 Ma ago (Zartman et al., 1967). At the time of intrusion, the lamproite, now present at the surface, was overlain by about 600 m of Pennsylvanian and Permian sedimentary rocks.

The presence of a similar structure (Rose Dome) 10 km to the NE as well as intervening NE-trending linear features may suggest that the location of both domes was controlled by a major deep-seated fracture zone.

The purpose of this study was to determine the tectonic structure of the dome and to recognize individual lamproite sills using reflection seismic methods. Two seismic profiles were designed--one across the northern margin and another across the southern margin of the dome (see Fig. 1). The data were acquired by the Kansas Geological Survey crew during the summer of 1985. Field parameters are listed in Table 1. The north profile is 2.6 km long; the south profile is 2.0 km long. The profiles do not overlap. The location of common depth points (CDP) is shown in Fig. 2. Processing of the seismic data was carried out at the Kansas Geological Survey Data General MV-8000 computer using SPEX

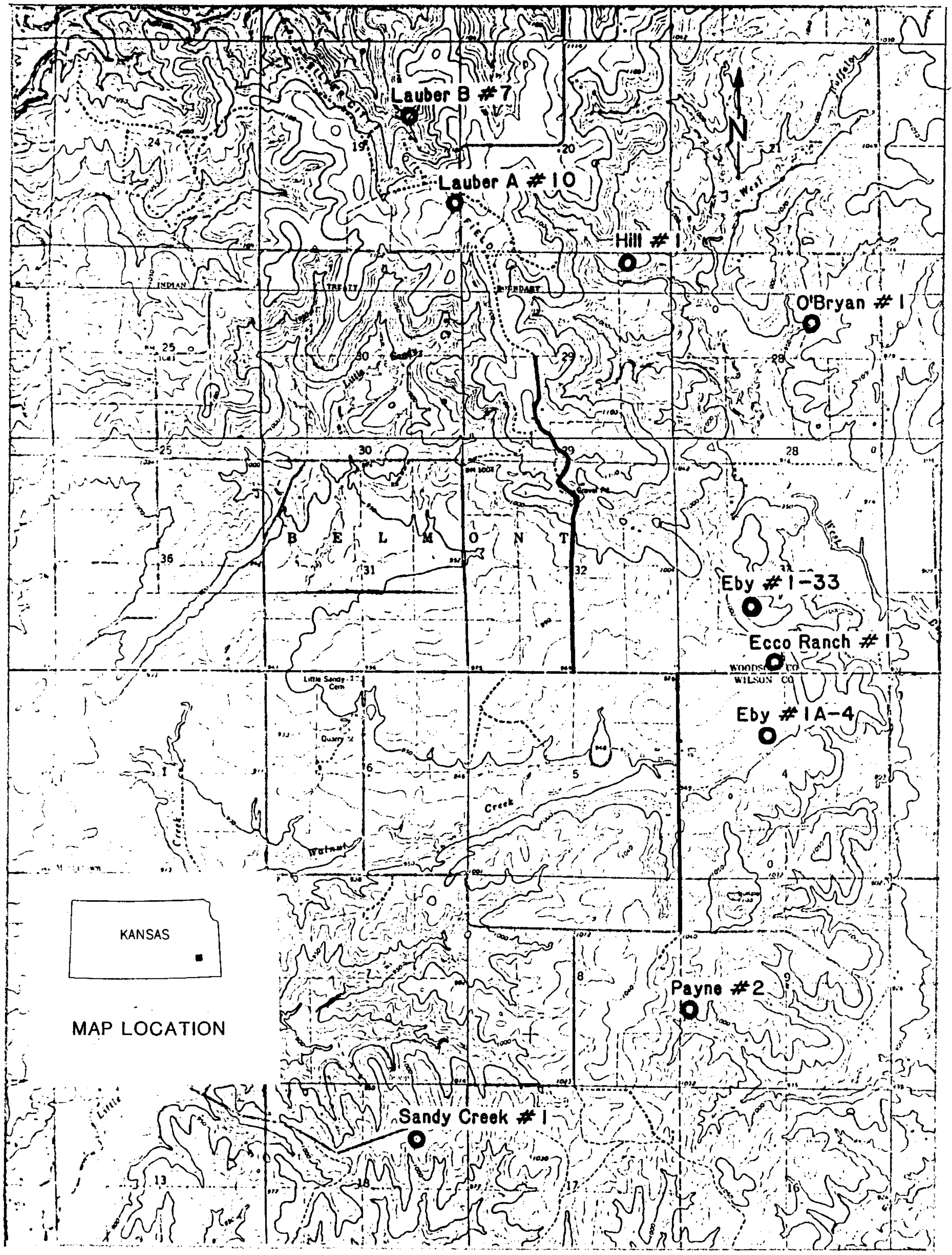

Fig. 1. Location of seismic reflection profiles and wells used in stratigraphic interpretation.

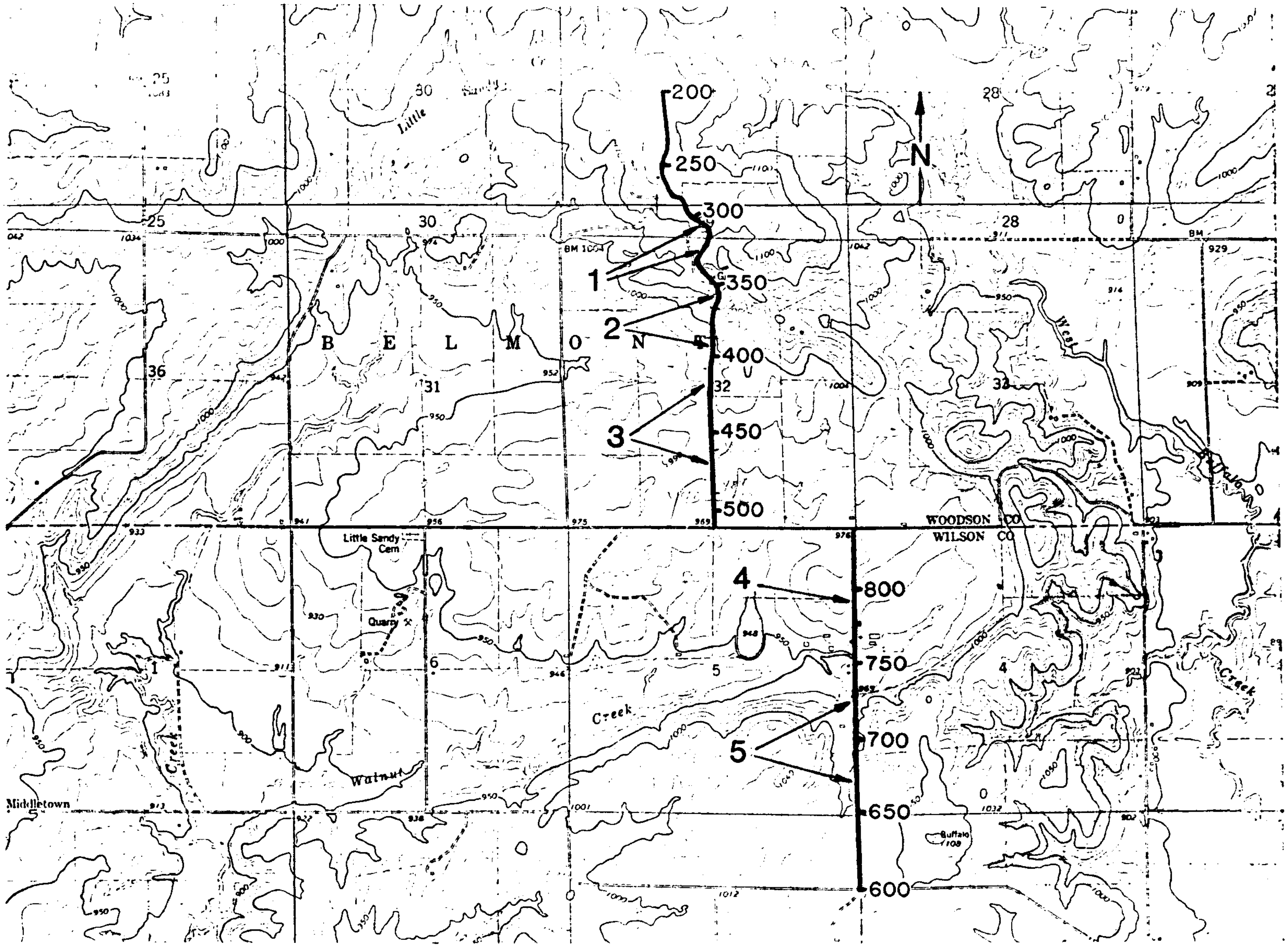

Fig. 2. Location of common depth points and some of the interpreted structures: 1 - northern graben, 2 - maximum doming, 3 - collapsed zone, 4 - major fault, 5 - southern graben.

TABLE 1. DATA ACQUISITION PARAMETERS

Recording: 24-channel Input/Output seismic system
Record length: 1000 ms
Sample rate: 2 ms
Source: 3 MiniSOSIE earth compactors (or 2)
Vertical stack: 2,000 pulses per shotpoint (or 1,500)
Filters: low-cut 55 Hz
high-cut 125 Hz
notch 60 Hz
Geometry: split-spread
Source spacing: 55 ft, offset from group centers by 27.5 ft
Receiver spacing: 55 ft, near offset 192.5 ft, far offset 797.5 ft
Receiver grouping: linear, ten 30 Hz geophones in one group

TABLE 2. PROCESSING - NORTHERN LINE

FILTER: low-cut, 50% frequency 20 Hz; slope 15 Hz; length 64 ms
SCALE: automatic gain control; operator length 200 ms
MUTE: first arrivals
EDIT: initial editing of bad traces
SORT: CDP gather
STATICS: elevation varies from 0 ft at SP #257 to +174 ft at SP #102; datum chosen at 93 ft that corresponds to about 1040 ft above sea level; weathered velocity 7000 ft/s
CROOKED LINE PROCESSING: completion of reel headers with adequate x and y coordinates of source and receiver; analysis of spatial distribution of actual common mid-points
EDIT: final editing
VELOCITY ANALYSIS: initial
SURFACE CONSISTENT STATICS: gate size 250 ms
SURFACE CONSISTENT STATICS: gate size 30 ms
VELOCITY ANALYSIS: final
STACKING VELOCITIES:

CDP	TIME	VELOCITY (ft/s)
225	80	7,500
	160	9,500
	330	11,000
245	70	7,500
	165	8,800
	210	10,750
270	50	7,500
	90	8,800
	160	9,250
	340	10,750
300	60	8,000
	80	8,500
	135	9,250
	220	10,250
	350	11,000
340	90	8,800
	390	10,000
390	80	9,200
	110	10,000
	220	10,500
	410	11,500
410	130	10,000
	220	10,750
	300	11,500
460	110	10,250
	310	11,500
490	380	11,750

Table 2. (continued)

NORMAL MOVEOUT: maximum allowable sample strength 0.75 (133%)
STACK
FREQUENCY ANALYSIS
FILTER: band-pass 10-20-120-180
SCALE: automatic gain control; operator length 150 ms
PLOT: 18 traces/inch real dip plot; also 40 and 80 traces/inch
COHERENCY FILTER

TABLE 3. PROCESSING - SOUTHERN LINE

MUTE: first arrivals
EDIT: bad traces
SORT: CDP gather
STATICS: elevation varies from 0 ft at SP #377 to 99 ft at SP #301; datum chosen at 49 ft that corresponds to 990 ft above sea level; weathered velocity 7,000 ft/s
VELOCITY ANALYSIS: initial
SURFACE CONSISTENT STATICS: gate size 250 ms
VELOCITY ANALYSIS: final
STACKING VELOCITIES:

CDP	TIME	VELOCITY (ft/s)
630	120	9,250
	200	9,750
	420	10,250
670	90	9,000
	200	9,750
710	100	9,500
	160	10,000
740	140	9,000
	200	9,750
	420	10,250
755	100	10,500
	200	11,000
790	110	10,750
	270	11,000
810	110	10,250
	310	11,000
830	110	11,000

NORMAL MOVEOUT: maximum allowable sample strength 0.75 (133%)
STACK
FREQUENCY ANALYSIS
FILTER: band-pass 10-20-120-180; length
SCALE: automatic gain control; operator length 150 ms
PLOT: 18 traces/inch real dip plot; also 40 and 80 traces/inch
COHERENCY FILTER

package as well as supplementary programs written by R. Knapp and the author.

PROCESSING

The processing sequence of both seismic reflection lines has followed a standard processing path (see Tables 2 and 3). In the case of the northern profile, however, crooked line processing had to be applied because significant curvature of this profile distorted the data quality noticeably. The first step was to complete reel headers with actual x and y coordinates and to calculate actual common mid-point positions ([redacted]). After this step, the data quality had already been improved substantially. The relationship between source-receiver position and location of common mid-points was presented in the form of several scattergrams. These scattergrams, obtained by KGS Surface II program, were the bases for spatial editing of traces. Neither spatial editing nor phase-shift editing brought further improvement; therefore, those procedures were not applied. Finally, the two lines were pasted together producing a continuous composite seismic section running from north to south all the way across the dome. The resulted time shift (14 ms) corresponds very well to the difference in datum elevation (17 m). Several display versions of studied seismic reflection sections are presented on Plates 1 through 6.

INTERPRETATION

The geologic interpretation of seismic reflection data was based on normal plots (Plates 2, 3, 5). Coherency-filtered plots (Plates 2, 4,

6) were used as a supplementary source of information. Final results are presented on "squash" plot (Plate 3) that enhances structural effects. It should be mentioned that the interpretation presented gives only a rough image of the structure because of its three-dimensional character and because there is a gap between the two lines (0.6 km measured perpendicularly to the major tectronic trend N55E). Notwithstanding, even a quick glance at the seismic section indicates that the Silver City Dome is a structural dome indeed, and moreover, the magnitude of doming increases up the stratigraphic succession; that fact supports a sill injection model of the dome origin. The whole structure is dissected by numerous faults that form tectonic grabens at its margins (1 and 5 at Fig. 2 and Plate 3). Another important aspect is the presence of a distorted and collapsed zone at the center portion of the dome (3 at Fig. 2 and Plate 3) suggesting that the feeder along which magma had intruded was located at the center rather than at the northern margin of the Silver City Dome.

Both ends of the composite seismic section represent a normal stratigraphic sequence that was not affected by the thickness increase due to lamproite injection. The stratigraphic interpretation of particular seismic events involved an analysis of geophysical logs of several boreholes from the neighboring area (for location see Fig. 1). The data from well interpretation are presented in Table 4. The comprehensive stratigraphic data were transformed to nonlinear depth scale based on velocity functions for northern and southern end of the section, respectively. The results of the geologic correlation (see Fig. 3) are in a good agreement with the correlation based on reflection character. The main event (150 ms at N end and 100 ms at S end) can be identified as

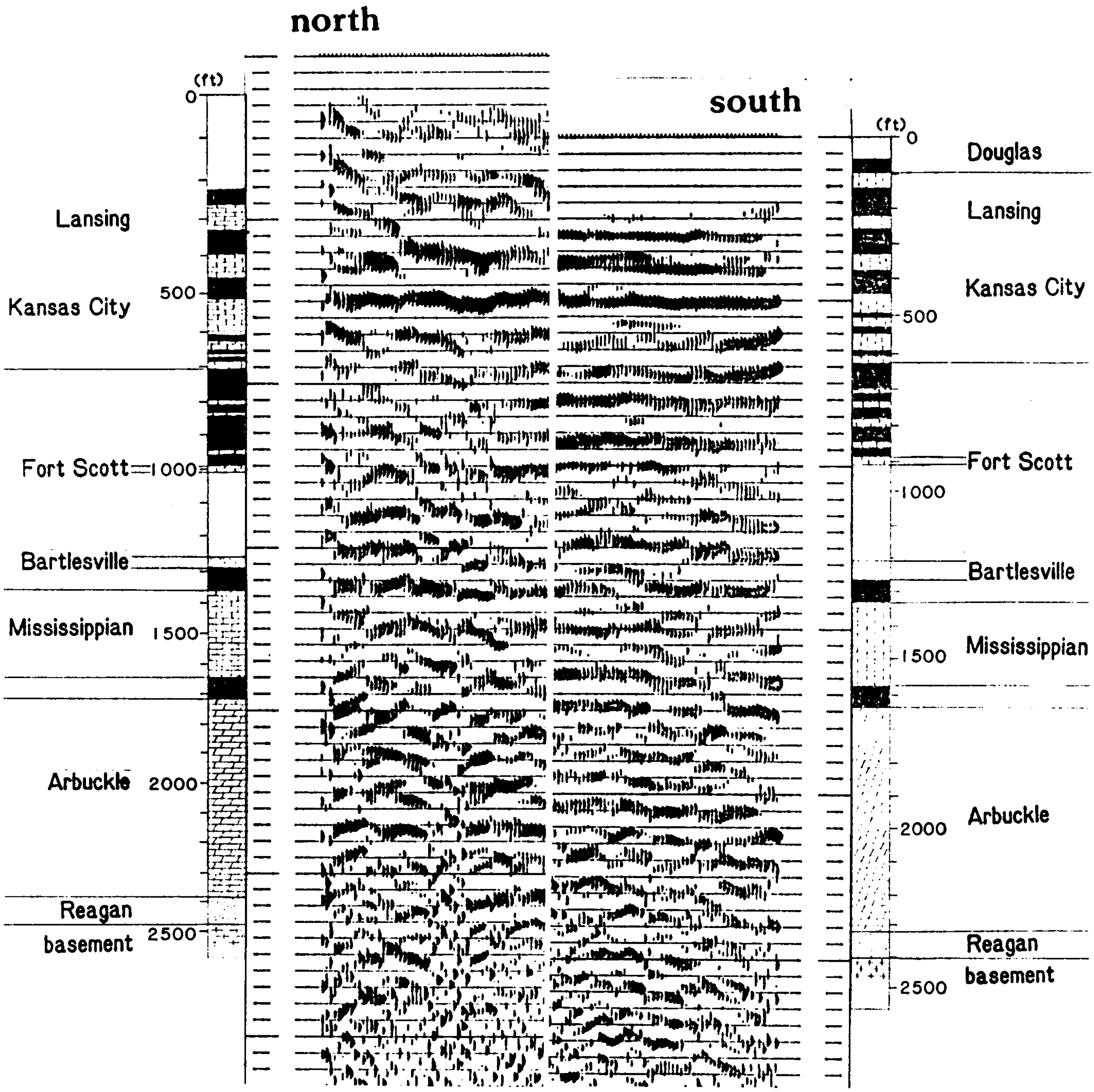

Fig. 3. Correlation between northern and southern end of northern and southern seismic profiles, respectively.

TABLE 4. DATA USED IN STRATIGRAPHIC INTERPRETATION

Well Name Location Elevation	Lansing Top	Kansas City Base	Fort Scott Top	Bartlesville		Mississippian Top	Arbuckle Top	Reagan Top
				Base	Top			
Lauber B #7 19/26S/15E elev. 1056 ft	816	286	-4	-276	-307			
Lauber A #10 19/26S/15E elev. 1141 ft				-292	-322	-400 350	-750	-1,470
O'Bryan #1 28/26S/15E elev. 950 ft		242	-38	-332				
Hill #1 29/26S/15E elev. 1010 ft		235	-40	-322				
Ecco Ranch #1 33/26S/15E elev. 985 ft	922	350	50	-223	-255			
Eby #1-33 33/26S/15E elev. 1065 ft		390		-199	-272	-335		
Eby #2-33 33/26S/15E elev. 1026 ft		340		-197	-287	-348		

TABLE 4. - page 2

Well Name Location Elevation	Lansing Top	Kansas City Base	Fort Scott Top	Bartlesville Base	Bartlesville Top	Mississippian Top	Arbuckle Top	Reagan Top
Clinesmith #1-3 3/27S/15E elev. 899 ft		361		-191	-248	-312 328	-640	
Clinesmith SWD #1 4/27S/15E elev. 990 ft		365	52	-215	-275	-340 372	-660	
Clinesmith #1-4 4/27S/15E elev. 1060 ft		385		-208	-280	-360		
Clinesmith #2-4 4/27S/15E elev. 996 ft		378				-331		
Clinesmith #3-4 4/27S/15E elev. 995 ft		393		-175	-261	-343		
Eby #1-4 4/27S/15E elev. 977 ft		375						
Eby #1A-4 4/27S/15E elev. 978 ft		378	46	-196	-254	-339		

TABLE 4. - page 3

Well Name Location Elevation	Lansing Top	Kansas City Base	Fort Scott Top	Bartlesville Base	Bartlesville Top	Mississippian Top	Arbuckle Top	Reagan Top
Eby #2-4 4/27S/15E elev. 976 ft		378		-185	-278	-336		
Eby #3-4 4/27S/15E elev. 996 ft		349	60	-154		-329		
Payne #2 9/27S/15E elev. 990 ft	892	362	96	-184	-240			
Sandy Creek #1 18/27S/15E elev. 1019 ft	822	264	-3			-384 377	-711	

the boundary between the Dennis Limestone and the Cheryvale Shale, which is also a boundary between Bronson and Linn subgroups of the Kansas City Group. While that event is persistent throughout the section, there is a noticeable difference in seismic response between blocks bordering the structure from north and south. This difference is partly connected to different surface conditions, but may also affect lateral stratigraphic changes within the Kansas City Group, namely the changes in limestone/shale ratio throughout the stratigraphic sequence. These changes, expressed as changes in amplitude, frequency and continuity of seismic events, are dramatical at a steep fault in a southern part of the dome (4 at Fig. 2 and Plate 3). This fault probably continues to the NE towards the Rose Dome, a similar and contemporaneous structure, and may be associated with an older (Precambrian) trend. Thus, the stratigraphic changes within the Kansas City Group occurring at the fault may suggest that this zone was active during Early Pennsylvanian time.

The Kansas and Marmaton cyclothems with their characteristically strong acoustic contrast between successive limestone and shale layers give a good seismic response but also screen the underlying units, dissipating and partitioning elastic wave energy, particularly the higher frequencies. Furthermore, rhythmic alternation of limestone and shale provides an excellent source of multiples. Some multiples were elimininated by high stacking velocities. Some were recognized as they have suspiciously lower stacking velocities and/or they have mimicked the topography of the interface they originated from. Despite those inconveniences, the southern end of the section especially provides a good opportunity to recognize major geological boundaries. So a strong reflection at 185 ms may correspond to Pawnee or Fort Scott Limestone;

events at 175 ms and 255 ms are probably the tops of the Bartlesville Sandstone and Mississippian Limestone, respectively; the distinct reflection at 350 ms coincides very well with the top of the Arbuckle Group with an event at 410 ms representing marked changes of porosity within the Arbuckle Group (change from 20% to 5% recorded at Lauber A #10); and finally a weak reflector at about 500 ms may be associated with the Precambrian basement. The above events can be connected with their equivalents from the northern end of the section; this correlation, however, considering the data quality, might be problematic.

The position of the feeder along which the lamproite magma was distributed is marked by a central depression within the dome (from CDP 410 to CDP 480), bounded by high-angle normal faults and noticeably disturbed. The depression formed probably as the result of a collapse subsequent to the ceasation of magmatic activity. The collapsed zone divides the studied structure into two parts. The maximum doming is located in the northern portion of the structure (2 at Fig. 2 and Plate 3). The closure there is about 20 ms, as measured at the major seismic horizon within the Kansas City Group. This magnitude is an equivalent to about 25-30 m total thickness of an alien rock inserted into the normal stratigraphic succession during magmatic activity. The doming magnitude decreases distinctly down the stratigraphic succession to only a few milliseconds at the top of the Arbuckle Group and seems to concentrate within the Kansas City and Marmaton Groups. This fact suggests that Pennsylvanian cyclothems provided the best conductors for the magma to penetrate along; however, it may be also an effect of an upward decrease of overburden pressure. Nevertheless, the lamproite sills themselves are difficult to recognize on the seismic reflection section. The most likely looking suspects are a relatively high amplitude event at 110 ms and 130 ms (between CDP 375 and CDP 395), and distortions of a seismic image at 80 to 100 ms located between CDP 360 and CDP 390. The doming within the southern portion of the structure reaches about 10 ms and is not associated with any stratigraphic level; thus, it might have been caused by a deeper-seated magmatic nest.

The dome is surrounded by ring fractures that appear as graben-like structures. The northern graben (1 at Fig. 2 and Plate 3) extends from CDP 302 to CDP 330 and is formed by two high-angle normal faults; vertical offset is about 20 m. The more complex southern graben (5 at Fig. 2 and Plate 3) extends from CDP 685 to CDP 760 and is dissected by several high-angle normal and reverse faults; total vertical offset is about 25 m.

The events that led to the development of the Silver City Dome and the Rose Dome may be related to the beginning of the Laramide orogeny 80 Ma ago (the age after Burchfiel and Davis, 1975). The shallow subduction of the Farallon plate during the Laramide time caused a cratonward transport of tectonic stress and might have caused a weakening of an older fracture trending NE-SW and where mantle material might have been introduced afterwards. The discrepancy between the supposed age of the lamproite intrusion and the time when the Laramide orogeny began may arise from an error in K-Ar dating method. The faulting of the dome occurred in two phases: faulting of marginal grabens, penecontemporaneous with the intrusion, and subsequent collapse faulting of the central feeder zone.

CONCLUDING REMARKS

The seismic reflection study of the Silver City Dome significantly improved our understanding of this structure, especially its tectonics. The lamproite sills could not be definitely identified directly, yet some premises place the bulk of the sills within Pennsylvanian cyclothems. The further development of the Woodson County ultramafic intrusions project should involve:

1. Identification of lamproite sills within shallow subsurface (down to 100 ms).
2. Use of higher energy and higher frequency source to improve the data quality, especially below the Marmaton Group.
3. Quasi three-dimensional study of the whole structure.
4. Comparative study of the Rose Dome.

REFERENCES

Burfiel, D, and Davis, G.A., 1975, Nature and controls of Cordilleran orogenesis, Western United States: Extensions of an earlier synthesis, Am. Jour. Sci., 275-A, p. 363-396.

Wagner, N.C., 1954, Geology of the Fredonia quadrangle, Kansas: U.S. Geol. Survey Map, GQ49.

Zartman, R.E., Brock, G.R., Heyl, A.V., and Thomas, N.N., 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from central and eastern United States: Am. Jour. Sci., 265, p. 848-870.

LIST OF PLATES

PLATE 1 - Silver City Dome seismic section - normal plot, 18 traces/inch (real dip)

PLATE 2 - Silver City Dome seismic section - coherency-filtered plot, 18 traces/inch (real dip)

PLATE 3 - Silver City Dome seismic section with interpretation - normal plot, 40 traces/inch. Number corresponds to those at Fig. 2 and denote: 1 - northern graben, 2 - maximum doming, 3 - collapsed zone, 4 - major fault, 5 - southern graben.

PLATE 4 - Silver City Dome seismic section - coherency-filtered plot, 40 traces/inch.

PLATE 5 - Silver City Dome seismic section - normal plot, 80 traces/inch.

PLATE 6 - Silver City Dome seismic section - coherency-filtered plot, 80 traces/inch.

APPENDIX 1

```
      PROGRAM ZIGZAG
*
* This orogram completes trace headers
* with x and y coordinates of receiver
* and source, then calculates actual x,y
* position of common midpoint
*
* enter
*  DATAIN  input SEGY data
*  TABLEIN table: station number, x, y
*  DATAOUT output SEGY data (regained)
*  SOUROUT output: source x and y coordinates
*  CDPOUT  output: cdp x and y coordinates
*  OUTPUT  output list
*
*
      integer*2 j,reel1(1600),k,reel2(200),trh(120)
      integer*2 incre,itype,nsamp
      integer tabr(3,700)
      integer no,xx,yy,no0,xx0,yy0
      real*4 tabs(3,700)
      real*4 cdpx,cdpy,sxx,syy
      real*4 cdpno,cdnum,trnum
      real*4 hamp(2000)
      real*4 dist,sx,sy,rx,ry
      character input*30,datain*30,dataout*30
      character sourout*30,cdpout*30,tablein*30
      equivalence (trh(37),sx),(trh(39),sy)
      equivalence (trh(41),rx),(trh(43),ry)
      equivalence (trh(19),dist)
*
      write(*,*)'GIVE INPUT DATA FILE: '
      read '(a30)', datain
      write(*,*)'GIVE INPUT TABLE FILE: '
      read '(a30)', tablein
      write(*,*)'GIVE OUTPUT DATA FILE: '
      read '(a30)', dataout
      write(*,*)'GIVE OUTPUT SOURCE X&Y FILE: '
      read '(a30)', sourout
      write(*,*)'GIVE OUTPUT CDP X&Y FILE: '
      reac '(a30)', cdpout
*
      write(*,*)'**********************************************************'
      write(*,*)'                              ZIGZAG                      '
      write(*,*)' '
      write(*,1001)'input data file = ',datain
      write(*,1001)'input table file = ',tablein
      write(*,1001)'output data file = ',dataout
      write(*,1001)'source coordinates = ',sourout
      write(*,1001)'CDP coordinates = ',cdpout
1001  format(2a30)
      open(1,file=datain,iointent='input',moce='binary',recfm='dynamic',form='un
      open(2,file=tablein,recfm='ds',pad='yes')
      open(3,file=dataout,iointent='output',mode='binary',recfm='dynamic',form='
      open(18,file=sourout,recfm='ds',pad='yes')
      open(19,file=cdpout,recfm='ds',pad='yes')
*
      do 11 k=1,700
       tabr(1,k)=0
       tabr(2,k)=0
       tabr(3,k)=0
       tabs(1,k)=0.
       tabs(2,k)=0.
```

```
11      continue
*
12      continue
        read(2,1004,end=99)no,xx,yy
1004    format(i5,1x,i5,1x,i5)
        tabr(1,no)=no
        tabr(2,no)=xx
        tabr(3,no)=yy
        if(no.eq.86) goto 95
        sxx=(float(xx)+float(xx0))/2.
        syy=(float(yy)+float(yy0))/2.
        tabs(1,no)=float(no)
        tabs(2,no)=sxx
        tabs(3,no)=syy
        write(18,1005)sxx,syy
1005    format(f10.2,1x,f10.2)
        if(no.eq.272) goto 96
*
95      continue
        no0=no
        xx0=xx
        yy0=yy
        goto 12
*
96      continue
        sxx=float(xx)+27.5
        syy=float(yy)
        tabs(1,no)=float(no)
        tabs(2,no)=sxx
        tabs(3,no)=syy
        write(18,1005)sxx,syy
        goto 12
*
99      continue
*
        read(1)j,(reel1(i),i=1,n),(reel2(i),i=1,k)
        incre=reel2(9)
        nsamp=reel2(11)
        itype=reel2(13)
        reel2(13)=1
        write(3)j,(reel1(i),i=1,j),(reel2(i),i=1,k)
*
10      continue
        call tread(trh,hamp,nsamp,itype,1,ierr)
        if(ierr.ne.0) then
          write(6,1001)'file end encountered tape end',datain
          goto 26
        endif
*
        cdnum=float(trh(12))
        trnum=float(trh(19))/100.
        cdpno=cdnum+trnum
        sx=float(tabs(2,trh(87)))
        sy=float(tabs(3,trh(87)))
        rx=float(tabr(2,trh(86)))
        ry=float(tabr(3,trh(86)))
        if(trh(86).gt.trh(87)) then
          dist=sqrt((sx-rx)**2+(sy-ry)**2)
          else
          dist=-sqrt((sx-rx)**2+(sy-ry)**2)
        endif
15      continue

*
        call zigout(sx,sy,rx,ry,cdpx,cdpy)
        write(19,1003)cdpx,cdpy,cdpno
1003    format(f10.2,1x,f10.2,1x,f10.2)
*
```

```
      write(3)j,trh,(hamp(i),i=1,lenhamp)
      go to 10
26    close(1)
      close(2)
      close(3)
      close(18)
      close(19)
      stop
      end
*
*****************************************************
*
      subroutine [illegible](sx,sy,rx,ry,cdpx,cdpy)
      cdpx=(sx+rx)/2
      cdpy=(sy+ry)/2
      return
      end
*
*****************************************************
*
         SUBROUTINE TREAD(TRH,HAMP,LENGTH,ITYPE,IUNIT,IEND)
*
* Written by RALPH W. KNAPP  May 17, 1985
*
* read SEGY data traces according to ITYPE
*
* ITYPE =1     32 bit floating point (IBM)
*       =2     32 bit integer
*       =3     16 bit integer
*
*        LENGTH=REEL2(11)
*        ITYPE =REEL2(13)
*        IUNIT =input unit number
*        TRH   =trace header (120 16-bit words)
*        HAMP  =output trace
*
         INTEGER*2 IAMP2(2048),J,TRH(120),LENGTH,ITYPE
         INTEGER*4 IAMP4(2048)
         REAL*4 HAMP(1)
         IEND=0
         DO 100 I=1,LENGTH
100      HAMP(I)=0.
         GO TO (1,2,3) ITYPE
         RETURN
1        READ(IUNIT,END=10000)J
         LENGTH =(J-120)/2
         READ(IUNIT,END=10000)  TRH,(HAMP(I),I=1,LENGTH)
         RETURN
2        READ(IUNIT,END=10000)J
         LENGTH=(J-120)/2
         READ(IUNIT,END=10000)  TRH,(IAMP4(I),I=1,LENGTH)
         DO 20 I=1,LENGTH
20       HAMP(I)=IAMP4(I)
         RETURN
3        READ(IUNIT,END=10000)J
         LENGTH=J-120
         READ(IUNIT,END=10000)  TRH,(IAMP2(I),I=1,LENGTH)


         DO 30 I=1,LENGTH
30       HAMP(I)=IAMP2(I)
         RETURN
10000    CONTINUE
         IEND=1
         RETURN
         END
```


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PLATE 1


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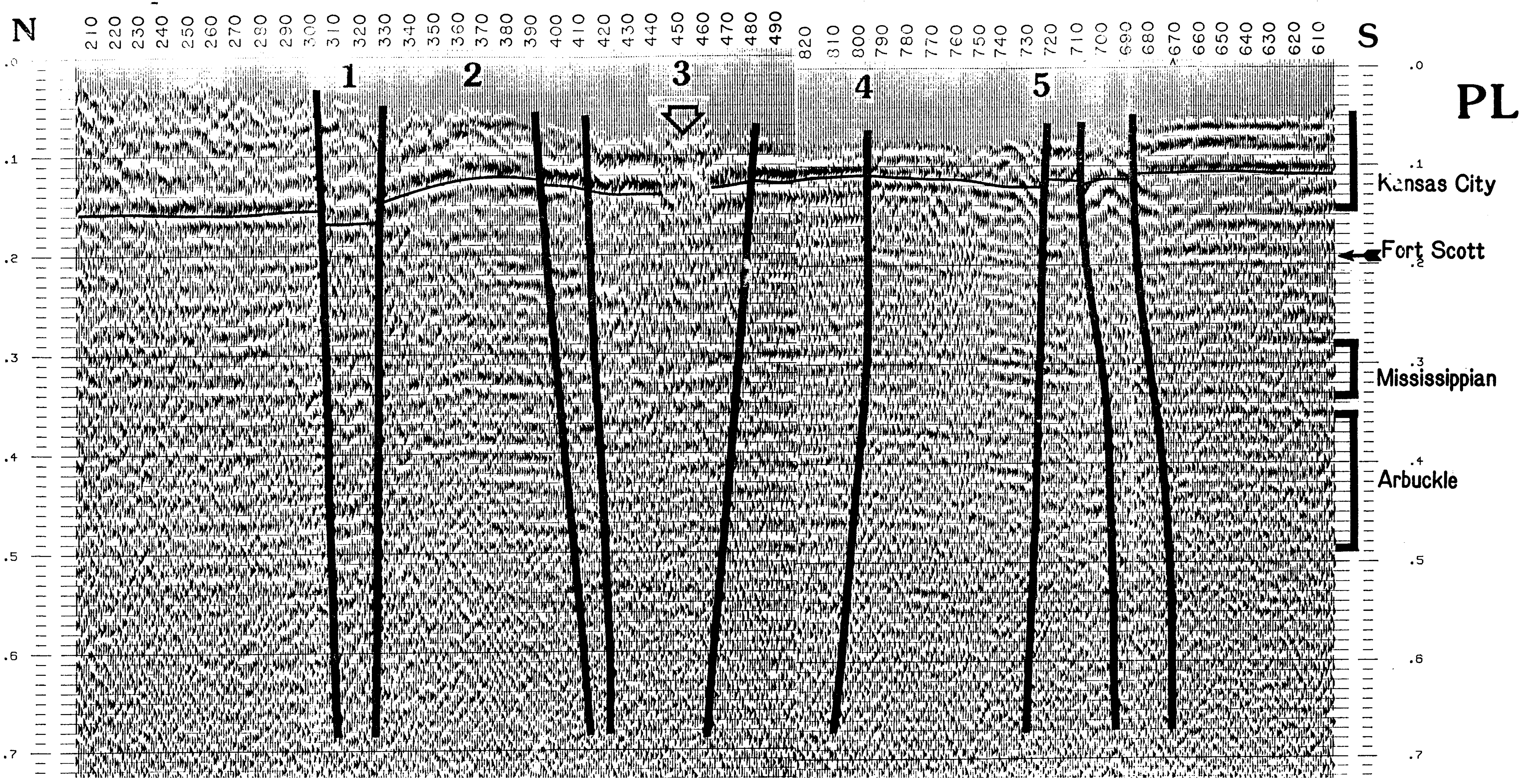
PLATE 2

PLATE 3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820 810 800 790 780 770 760 750 740 730 720 710 700 690 680 670 660 650 640 630 620 610
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Fort Scott
Mississippian
Arbuckle

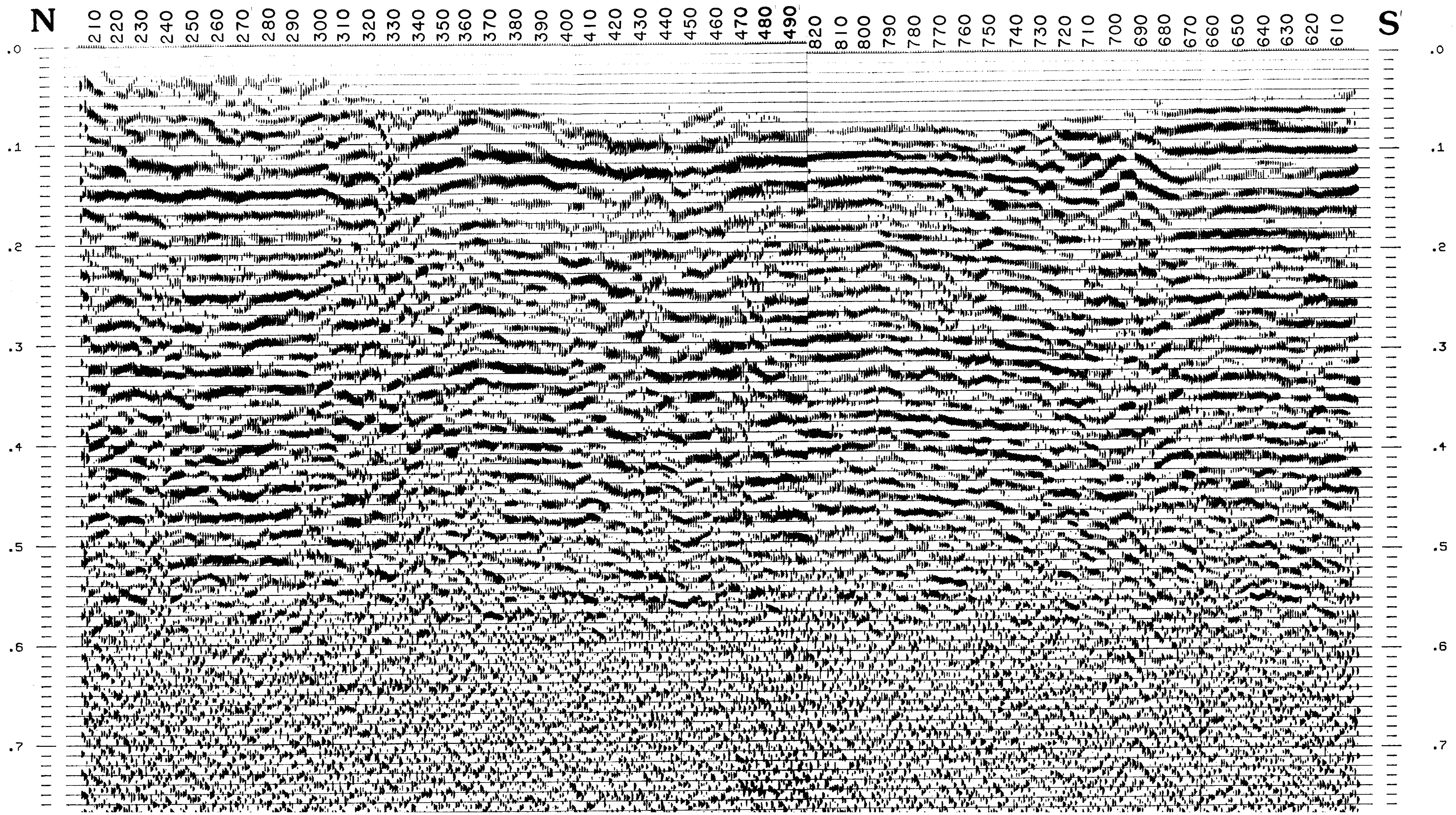
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PLATE 4

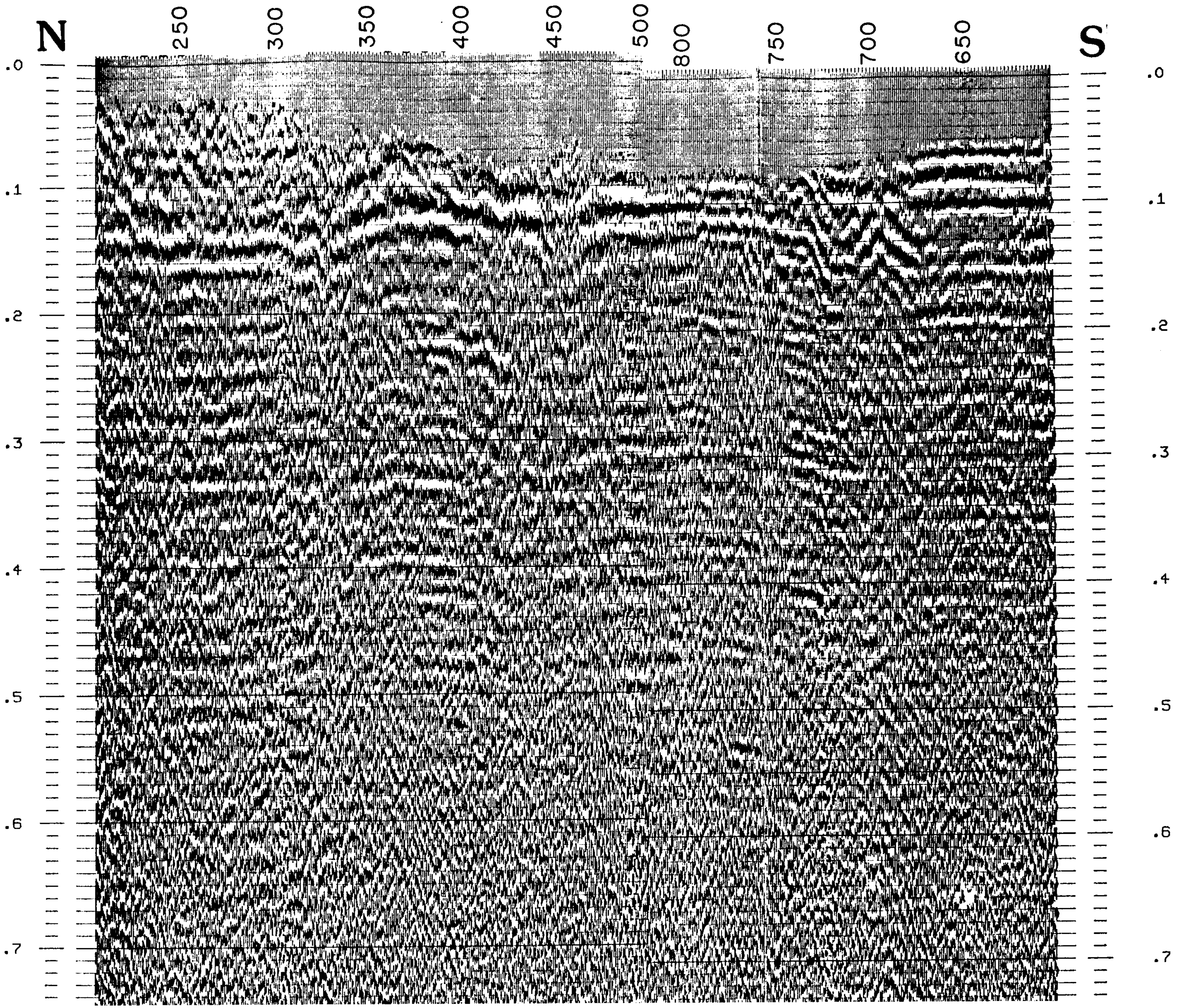

PLATE 5

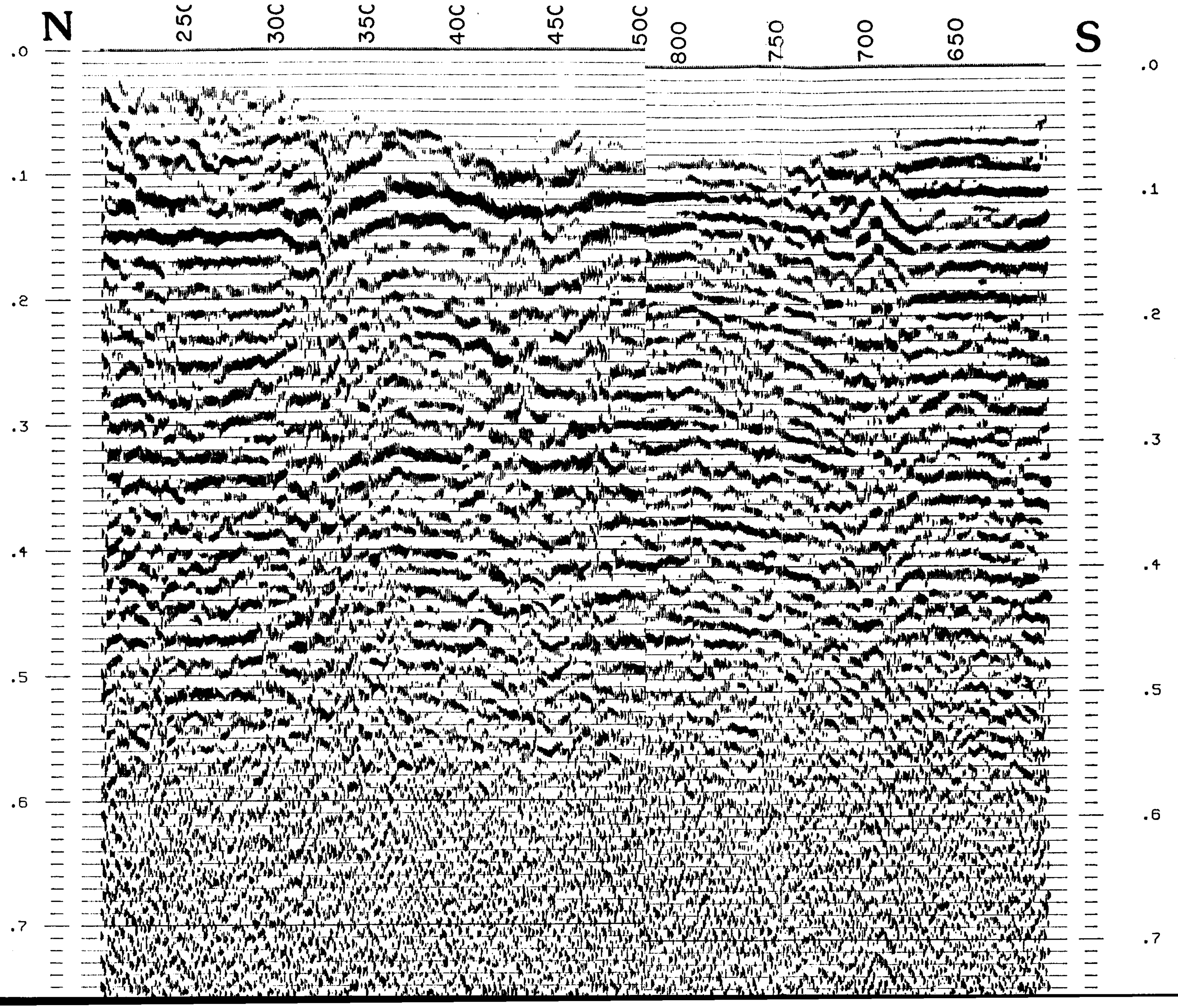

PLATE 6