

Description

This invention relates to seismic data processing. In one aspect, this invention relates to a method for producing an enhanced seismic display from a plurality of seismic wiggle traces.

The seismic method for mapping geological subsurfaces involves the use of a source of seismic energy and its reception by an array of seismic detectors, generally referred to as geophones. When used on land, the source of seismic energy generally is a high explosive charge electrically detonated in a bore hole located at a selected grid point in a terrain or is an energy source capable of delivering a series of impacts on the earth's surface such as that used in Vibroseis. The acoustic waves generated in the earth by the explosion or impacts are transmitted back from strata boundaries and reach the surface of the earth at varying intervals of time, depending on the distance and the nature of the subsurface traversed. These returning acoustic waves are detected by the geophones, which function to transduce such acoustic waves into representative electrical signals. The plurality of geophones are arrayed in a selected manner to detect most effectively the returning acoustic waves and generate electrical signals representative thereof from which data may be deduced concerning the geological subsurface of the earth. Such electrical signals are generally referred to as seismic wiggle traces.

A typical array of seismic sources and detectors is illustrated in Figure 1. A plurality of seismic sources 21—25 and a plurality of seismic receivers 31—35 are arranged around a common midpoint. For the sake of illustration, the seismic sources are equidistantly spaced and the seismic receivers are equidistantly spaced but this is not required and typically would not occur in seismic prospecting because of obstructions and other factors. However, each source-receiver pair would be equally spaced from the common midpoint to the extent possible. Assuming a reflecting plane 37 which is substantially parallel to the surface on which the sources and receivers are located, acoustic waves from each of the seismic sources is reflected from the common depth point and received by a respective one of the seismic receivers as is illustrated. The output from the seismic receivers 31—35 might be as illustrated in Figure 2.

The group of seismic wiggle traces illustrated in Figure 2 is typically referred to as a common depth point gather since all of the wiggle traces result from reflections from the common depth point. In some instances, a common depth point gather such as that illustrated in Figure 2 is utilized by interpreters directly. However, more commonly, the seismic wiggle traces, such as illustrated in Figure 2, are summed to produce a composite trace for enhancing the subsurface structure information represented by the features of the seismic wiggle traces. The result of such a summation is a single seismic wiggle trace for the common depth point. The purpose of such summing is to give prominence to some of the important features in the seismic signal and to reduce or remove those features which obscure the important parts of the signal. A result of a common depth point stack for a plurality of common depth points is illustrated in Figure 3. Figure 3 would generally be referred to as a vertical seismic section of stacked data.

While data such as that illustrated in Figure 3 is very commonly used by interpreters of seismic data it is sometimes very difficult to pick peaks and troughs from such data. As used herein, the term "peak" refers to a point such as the point A on trace R_{35} in Figure 2. The term "trough" refers to a point such as the point B on trace R_{35} in Figure 2.

The article by Taner, et al in Geophysics, Vol. 44, No. 6 June 1979, pp. 1041—1063, describes the use of complex seismic trace analysis to obtain certain attributes such as the instantaneous phase, which can be color-encoded to produce a seismic display.

GB-A-21 39 758 describes a method for quantifying and rasterizing attribute variables to obtain a gridded variable area display wherein color intensity of the grid units is some function of the instantaneous variable.

The non-prepublished EP-A-0 154 396 discloses a method of developing a specific seismic data parameter by rectifying the seismic trace data, producing the Hilbert transform thereof and determining the instantaneous phase of the transformed rectified data.

The object of this invention is to provide a method for producing an enhanced seismic display from a plurality of seismic wiggle traces such as illustrated in Figure 3. By enhanced seismic display it is meant that information such as the location of peaks and troughs and other information of interest to interpreters can be more easily obtained from the seismic display of the present invention than from the plurality of seismic traces from which the seismic display is generated.

In accordance with the present invention a method of producing a color-coded seismic display is provided as defined in claim 1. A plurality of seismic wiggle traces, such as those illustrated in Figures 2 and 3, which are considered real seismic traces, are converted into imaginary seismic traces. The instantaneous phase of the complex seismic wiggle traces (composite of real and imaginary) is then determined at a plurality of sample points. Also, the amplitude, real or envelope, at the sample points is determined. A color is then assigned to each sample point based on the amplitude and the instantaneous phase for such sample point. A seismic display is then generated using such assigned colors. The result, which is sometimes referred to hereinafter as a variable amplitude/phase seismic display, enhances continuity of reflection events, provides a clearer picture of the location of pinchouts, emphasizes small scale faults and is more useful for reflection character correlation than a display such as that illustrated in Figure 3.

As used herein, the phrase "real seismic wiggle trace" refers to a seismic wiggle trace as actually

recorded. The phrase "imaginary seismic wiggle trace" refers to the Hilbert transform of the real seismic trace. The phrase "complex seismic wiggle trace" refers to a composite trace consisting of a real trace, which is identical to the real seismic wiggle trace, and an imaginary trace which is the Hilbert transform of the real seismic wiggle trace.

Other objects and advantages of the invention will be apparent from the foregoing brief description of the invention and the claims as well as the detailed description of Figures 4—10.

All of the drawings are briefly described as follows:

Figure 1 is an illustration of a typical seismic exploration array;

Figure 2 is an illustration of the waveforms which might be received from the seismic array illustrated in Figure 1;

Figure 3 is an illustration of a plurality of seismic wiggle traces which have been common depth point stacked;

Figure 4 is an illustration of a preferred set of colors for use in generating a variable amplitude/phase seismic display in accordance with the present invention;

Figure 5 is an illustration of the seismic wiggle traces of Figure 3 converted to a variable amplitude/phase seismic display in accordance with the present invention using real amplitude;

Figure 6 is an illustration of the seismic wiggle traces of Figure 3 converted to a variable amplitude/phase seismic display in accordance with the present invention using envelope amplitude;

Figure 7 is an illustration of the variable amplitude/phase seismic display applied to three-dimensional seismic data;

Figure 8 is an illustration of the color code utilized to generate the seismic display of Figure 9;

Figure 9 is an illustration of a conventional color three-dimensional seismic display based only on amplitude; and

Figure 10 is an illustration of the variable amplitude/phase seismic display of Figure 5 without image enhancement.

The invention is described in terms of common depth point stacked data such as that illustrated in Figure 3 because this type of data is commonly used to determine features of the subsurface of the earth. However, the invention may be applied to any suitable set of seismic wiggle traces. As an example, the invention may be applied to a common depth point gather set of seismic wiggle traces such as that illustrated in Figure 2. Also, the invention may be applied to three-dimensional data such as will be illustrated in the examples.

The steps utilized to produce the variable amplitude/phase seismic display of the present invention from a plurality of seismic wiggle traces such as illustrated in Figure 3 are as follows. Some of the steps may be accomplished in a different order if desired.

1. Select Sample Rate

A sinusoidal wiggle trace obtained in reflection seismology typically has a length in the range of about 4 seconds to about 8 seconds. A 6 second length is typical.

Any suitable data sample rate may be utilized for such a sinusoidal wiggle trace. However, the data sample rate should be such as to provide sufficient data points or provide meaningful statistics. The data sample rate will typically be in the range of about 2 milliseconds to about 4 milliseconds with a 4 millisecond sample rate being preferred.

2. Determine Amplitude

Once a data sample rate has been established, the amplitude of each real seismic trace at each sample point is preferably determined. The real amplitude is available directly from real seismic wiggle traces, such as are illustrated in Figure 3, as is well known to those skilled in the art of interpretation of seismic data.

It is noted that the real amplitude as opposed to the envelope amplitude is preferred but envelope amplitude can be used if desired. The real amplitude refers to the actual amplitude of the real seismic wiggle trace at the sample point. The envelope amplitude at a sample point refers to the square root of the sum of the squares of the real and imaginary amplitudes of the complex seismic trace at that sample point. Use of real amplitude as opposed to envelope amplitude allows clearer delineation of faults and pinchouts, makes correlation across small faults easier and generally provides for easier interpretation of the variable amplitude/phase seismic display. Thus, while envelope amplitude can be used if desired and will provide beneficial information, the discovery of the benefits of using real amplitude as opposed to envelope amplitude is a particularly important part of the present invention.

3. Calculate Imaginary Seismic Trace from Real Seismic Trace

Hilbert Transform is applied to a real seismic wiggle trace to convert the real seismic trace to an imaginary seismic trace. Such an application of the Hilbert Transform is described in an article entitled Application of Amplitude, Frequency, the Other Attributes To Stratigraphic and Hydrocarbon Determination, by M. T. Tanner and R. E. Sheriff, which appeared in Memoir 26, Seismic Stratigraphy — Applications to Hydrocarbon Exploration, which was edited by Charles E. Payton, American Association of Petroleum Geologists, 1977.

4. Determine Instantaneous Phase of Complex Seismic Trace

The instantaneous phase of the complex seismic trace at a sample point $P(t)$ is as defined by equation 1

$$(1) \quad P(t) = \tan^{-1} [h(t)/g(t)]$$

where $h(t)$ is the amplitude of the imaginary seismic trace at the sample point and $g(t)$ is the amplitude of the real seismic trace at the sample point. Again, the amplitude is available directly from both the imaginary seismic trace and real seismic trace.

5. Interpolation

Colors may be assigned for only the sample points, as will be described more fully hereinafter, if desired. However, using only the sample points may result in a variable amplitude/phase seismic display which has an unpleasing appearance and which may be difficult to interpret. Preferably, image enhancement techniques are utilized to provide better apparent resolution.

Essentially, a plurality of points is selected between two sample points. An amplitude and instantaneous phase is assigned to each such point such as that a smooth transition in colors between two sample points is provided.

The number of points filled in will vary depending upon the scale of the seismic display and also depending upon the plotting equipment. Preferably, sufficient points are filled into to provide a smooth color transition regardless of the scale of the plotting equipment used.

6. Graphics Processing

Once a real amplitude and an instantaneous phase has been assigned to each point which is to appear in the variable amplitude/phase seismic display, colors are assigned to each point based on the real amplitude and instantaneous phase.

Any suitable color scheme may be utilized. At least four distinguishable colors or distinguishable shades of color are required. However, larger numbers of colors or shades of colors are preferred because more colors or shades of colors give better apparent resolution which gives a more pleasing appearance and allows for greater ease in interpretation. In particular, the use of four colors for phase is extremely beneficial as will be described more fully hereinafter.

A preferred set of colors used with an Applicon plotter is illustrated in Figure 4. Referring now to Figure 4, sixteen shades of the four basic colors (green, blue, pink and orange) are utilized. Each shade of color is representative of a different amplitude with the darkest color preferably being representative of the lowest amplitude. The range between the highest amplitude and lowest amplitude is preferably divided into equal intervals with each shade of color being representative of such an interval. For Figure 3, as an example, the amplitudes range from 0 to 6,000 and each shade covered a range of 400.

Each of the four colors illustrated in Figure 4 is representative of a phase range. The range assigned for the colors of Figure 4 is as follows:

Color	Range
green	-90° to -180°
blue	0° to -90°
magenta	0° to +90°
orange	+90° to +180°

Less than four colors can be utilized for the phase if desired. As an example, the green of Figure 4 could represent 0 to -180° and the blue could represent 0 to +180°. However, the use of fewer than four colors will result in a loss of some information. Likewise, more than four colors could be utilized. However, again, the use of more than four colors will result in the loss of information as is more fully described hereinafter.

Seismic peaks occur at 0° phase. Seismic troughs occur at + or -180° phase. Seismic zero crossings, such as point C illustrated in Figure 2, occur at + or -90° phase.

Because of these relationships, it has been discovered that the use of four colors covering the ranges illustrated in Figure 4 is particularly desirable. A transition between colors immediately informs an interpreter that an event of interest (peak, trough or zero crossing) has occurred. This will be more fully illustrated in the examples.

The use of more than four colors, such as six colors, can add confusion and lose information since the events of interest are occurring at particular instantaneous phases and the transition between colors may not occur at these instantaneous phases. Thus, the discovery of the benefit of using four colors is another particularly beneficial aspect of the present invention.

If desired, the transition between colors can be set at phases other than 0°, 90° and 180°. In some instances, an interpreter may be interested in a phase such as 50°. In such cases, the transition between

blue and pink in Figure 4 could be set at 50° and the other phases changed accordingly. This would enable the interpreter to determine the position of events occurring at 50° phase, 140° phase, etc.

Thus, in general, when using four colors the colors are assigned based on a base angle (BA) as follows with the ranges assigned for Figure 4 being preferred.

Color	Range
one	(BA - 90°) to (BA - 180°)
two	BA to (BA - 90°)
three	BA to (BA + 90°)
four	(BA + 90°) to (BA + 180°)

7. Generate Variable Amplitude/Phase Seismic Display

Once colors have been assigned to all points to be utilized in the variable amplitude/phase seismic display, the information is sent to a plotter which generates the desired variable amplitude/phase seismic display. Any suitable plotter may be utilized. An example of a suitable plotter is the Applicon plotter.

Any suitable computer program may be utilized to generate the variable amplitude/phase seismic display in accordance with the present invention. A suitable computer program for use with an IBM 3084 computer is set forth in Appendix I. The computer program is self explanatory to one skilled in the use of the IBM 3084 computer.

The following examples are presented in further illustration of the invention.

Example I

The plurality of seismic wiggle traces illustrated in Figure 3 were converted to a variable amplitude/phase seismic display in accordance with the present invention using the colors illustrated in Figure 4 and using real amplitude. The result is illustrated in Figure 5.

Referring now to Figure 5, it can be seen that peaks, troughs and zero crossings are very well defined. As an example, the very clear transition between blue and pink illustrates the location of peaks. In like manner, the transition between green and blue illustrates zero crossings and the transition between green and orange illustrates troughs.

The high amplitude, which can also be seen from the seismic wiggle traces illustrated in Figure 3, is illustrated by darker colors in the central portion of Figure 5.

It is also noted that faults, pinchouts and event correlations are much more easily discovered in Figure 5. Also, shifts in strong color lines in area of faults indicate the nature and size of the fault. The presence of white lines between colors also provides for easier interpretation.

Example II

The plurality of seismic wiggle traces illustrated in Figure 3 were converted to a variable amplitude/phase seismic display in the same manner as in Example I but envelope amplitude was used instead of real amplitude. The result is illustrated in Figure 6.

Referring now to Figure 6, it can again be seen that valuable information is available. However, some information has been lost and it is more difficult to correlate across small faults in Figure 6 than in Figure 5. Also, the absence of the white between colors makes interpretation of Figure 6 more difficult than interpretation of Figure 5. Finally, the overall appearance of Figure 6 is visually pleasing to an interpreter. Thus, the preference for the use of real amplitude.

Example III

As has been previously stated, the variable amplitude/phase seismic display can be applied to three-dimensional seismic data. As an example of this, the present invention was applied to a time slice of the area covered by the seismic wiggle traces illustrated in Figure 3. The results is illustrated in Figure 7 using the color code of Figure 4.

As a comparison, a conventional, color, three-dimensional seismic display based only on amplitude was generated using the same data as utilized to generate the seismic display of Figure 7 and using the color code illustrated in Figure 8. This display is illustrated in Figure 9.

A comparison of Figures 7 and 9 shows that more seismic information is available to the interpreter in Figure 7 than in Figure 9. In particular, the location of peaks, troughs and zero crossings are available from Figure 7 and are not available from Figure 9.

Example IV

The seismic display illustrated in Figure 5 was generated without interpolation with the result being as illustrated in Figure 10. The display illustrated in Figure 10 could be used but the blocky appearance is not visually appealing to an interpreter. Also the clarity of the seismic display of Figure 5 has been lost to some

extent which would increase the difficulty of interpretation.

The invention has been described in terms of a preferred embodiment. Reasonable variations are possible within the scope of the invention. Such reasonable variations are within the scope of the present invention, as claimed.

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C      *****
C      ***** SOURCE CODE FOR VERTICAL AMPLITUDE-PHASE PLOT *****
C      ***** SPS FORMAT *****
C      *****
C
      DIMENSION TARRAY(4096), BUFF(5000), ENV(4096), SLOC1(2), SLOC2(2)
      DIMENSION NUMTRC(3000)
      COMMON /CTRL/NX, NY, NTREC, DELT, NT, TPI, SPI, NREC, SCALE, LINC, ZMAX
      COMMON/PAARM/XORGIN, YORGIN, IORGIN, PLOTX, PLOTY, XINC, YINC, SIZE, SIZE1
      COMMON/CTRL2/IFLAG, IXFRST, IXLIN, IP, TAR, IN, NN, IPLTE
      COMMON/CTRL3/IOP, IOPT1, IOPT2, IOPT3, IOPT4, IOPT5
      COMMON/CTRL4/ICDPS, ICDPE, ITST, ITED, NSAMP, ICDPN

C
      INTEGER*4 JBUFF(5000), MLINE(3), ICDPON, INKSON, IBLANK
      INTEGER*4 IDIR, IDIRR, IDIRL, DDNAME(2), ILOC(2), ILOC2(2)
      INTEGER*2 IBUFF(10000), ITRHE, IHEAD, IPCODE, IVOL(3), IPROS(4)
      EQUIVALENCE (BUFF(1), IBUFF(1), JBUFF(1))
      EQUIVALENCE (ILOC(1), SLOC1(1)), (ILOC2(1), SLOC2(1))

C
      DATA IDIR/' ', IDIRR/'RTOL', IDIRL/'LTOR'
      DATA INKSON/' ', ICDPON/' ', IBLANK/' '
      DATA IHEAD/'TP'
      DATA ITRHE/'HE'
      DATA IPCODE/' '
      DATA DDNAME/'FT29', 'F001'

C
      WRITE(6,1075)
C      *****
C      ***** CHECK TIME OF DAY AND SET INTERVAL TIMER *****
C      *****
      CALL TIMINT(KK)
      CALL TIME(SLOC1)

C
      NX=0
      READ(10,1000) TPI, SPI, ICDPS, ICDPE, ITST, ITED, IPCODE
      READ(10,1010) IDIR, ICDPON, INKSON, ZMAX
      WRITE(6,1080)
      WRITE(6,1055) TPI, SPI, ICDPS, ICDPE, ITST, ITED, IDIR, IPCODE

C
      IF(ZMAX.GT.0.0) IOPT1=1
      IF(INKSON.NE.IBLANK) IOPT2=1
      IF(ICDPON.NE.IBLANK) IOPT3=1
      IF(IDIR.EQ.IDIRR) IOPT4=1

C
      LN=0
20 CALL TAPEIO('TAPEIN ', BUFF, LN, 'R')
      IF(LN.LT.-1) GO TO 20
      IF(LN.EQ.-1) GO TO 400
      IF(IBUFF(1).NE.IHEAD) GO TO 100
      IPROS(1)=IBUFF(5)
      IPROS(2)=IBUFF(6)
      IPROS(3)=IBUFF(7)
      IPROS(4)=IBUFF(8)
      MLINE(1)=JBUFF(5)
      MLINE(2)=JBUFF(6)
      MLINE(3)=JBUFF(7)
      IRUN=IBUFF(39)

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WRITE(6,1050) IPROS,MLINE,IRUN
WRITE(6,1060)
NT=IBUFF(128)
LT=1024
IF (NT.GT.1024.AND.NT.LE.2048) LT=2048

IF (NT.GT.2048.AND.NT.LE.4096) LT=4096
IDELT=IBUFF(127)
NREC=IBUFF(164)
DELT=IDELT
NREC=ICDPE-ICDPS+1
CALL LIMIT
C
100 IF (IBUFF(1).NE.ITRHE) GO TO 200
C
DO 50 J=1,4096
50 TARRAY(J)=0.0
C
ICDPN=IBUFF(63)
IF (NX.EQ.NREC) GO TO 400
IF (IBUFF(6).NE.IPCODE) GO TO 200
IF (ICDPN.LT.ICDPS.OR.ICDPN.GT.ICDPE) GO TO 200
IF (IBUFF(6).EQ.IPCODE) NX=NX+1
NTRMP=IBUFF(28)
IART=IBUFF(4)
C
C
C
WRITE(6,9998)
DO 250 J=1,NTRMP
N=IART+J
TARRAY(J)=BUFF(N)
250 CONTINUE
CALL ENVELP(TARRAY,LT,ENV)
I=ITST
K=ITED
WRITE(9) (TARRAY(N),N=I,K)
WRITE(8) (ENV(N),N=I,K)
NUMTRC(NX)=ICDPN
WRITE(6,3004) ICDPN,NTRMP
200 LN=0
GO TO 20
C
C
C
*****
PLOT THE SECTION
*****
400 WRITE(6,1065)
CALL IPARM(IERROR)
IF (IERROR.EQ.1) GO TO 5000
IF (IOPT4.EQ.1) XORGIN=830
CALL IPAGB
CALL IPRINT(1)
CALL ISTART(IORGIN)
CALL ICHCOL(1)
CALL APPLE
CALL TGRID(NUMTRC)
CALL TITLE
WRITE(6,2040)
CALL ICLB(0)

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C
C ***** CHECK TIMERS *****
C
CALL TIMINT(JJ)
CALL TIME(SLOC2)
INTIME=KK-JJ
WRITE(6,1085) ILOC,ILOC2,INTIME
C
C ***** RETRIEVE VOLSER *****
C
CALL DDCK(DDNAME,IFG,IVOL,IDEN)
WRITE(6,1095) IVOL
C
WRITE(6,1090)

STOP
5000 WRITE(6,2000)
STOP
1000 FORMAT(10X,2F10.3,4I5,3X,A2)
1010 FORMAT(16X,A4,6X,A4,6X,A4,F10.2)
1050 FORMAT(40X,'FEATURE',3X,A2,/40X,'LINE',10X,3A4,/40X,'RUN #',5X,I
  &2,///)
1055 FORMAT(40X,'TPI',F11.3,/40X,'IPS',F11.3,/40X,'FIRST CDP',I5,/40
  &X,'LAST CDP',I5,/40X,'START TIME',I4,/40X,'END TIME',I4,/40X
  &X,'PLOT DIR',A4,/40X,'PC CODE',A2)
1060 FORMAT(///,35X,' *** TRACES PROCESSED ***',///)
1065 FORMAT(///,35X,' *** TRACE PROCESSING COMPLETED ***',////////)
1075 FORMAT(1H1,///,100(' '),////,35X,'THIS IS THE VARIABLE AMPLITUDE
  &PLOTING PACKAGE FOR SPS',////,35X,'FOR PROBLEMS CALL CLIFF SHOCK
  &AT X-4559',////////)
1080 FORMAT(35X,' *** INPUT PARAMETERS *****',///)
1085 FORMAT(///,35X,' START TIME',2A4,///,36X,'END TIME',2A4,
  &///,36X,'CPU IN SECONDS',I10,///)
1090 FORMAT(////////,35X,' ***** THIS IS END OF JOB *****')
1095 FORMAT(35X,' OUTPUT VOLUME',3A2,' FILE #2',I5)
2000 FORMAT(35X,'***** PROGRAM TERMINATED DUE TO CRITICAL ERROR ***')
2040 FORMAT(35X,' ***** OUTPUT INFORMATION *****',////////)
3004 FORMAT(25X,'*** CDP',I4,' WITH ',I4,' SAMPLES IS SUCCESSFULLY PRO
  &CESSED *****')
STOP
END
SUBROUTINE APPLE
COMMON /CTRL/NX,NY,NTREC,DELT,NT,TPI,SPI,NREC,SCALE,LINC,ZMAX
COMMON /PARM/XORGIN,YORGIN,IORGIN,PLOTX,PLOTY,XINC,YINC,SIZE,SIZE1
COMMON /CTRL3/IOP,IOPT1,IOPT2,IOPT3,IOPT4,IOPT5
COMMON/CTRL4/ICDPS,ICDPE,ITST,ITED,NSAMP,ICDPN
C
DIMENSION SBUFF(3000),TBUFF(3000),PBUFF(3000),ABUFF(3000)
DIMENSION U(4),AIN(100000),ZCLASS(16),PIN(100000),IBUFF(3000)
DIMENSION ISET(64),PCLASS(5)
DATA PCLASS/-3.1459,-1.57,0.0,1.57,3.1459/
C
DATA ISET/10001,20002,30003,40004,50005,60006,70007,80008,90009,10
  &0010,110011,120012,130013,140014,150015,160016,1,2,3,4,5,6,7,8,9,1
  &0,11,12,13,14,15,16,100,200,300,400,500,600,700,800,900,1000,1100,
  &1200,1300,1400,1500,1600,10100,20200,30300,40400,50500,60600,70700
  &1,80800,90900,101000,111100,121200,131300,141400,151500,161600/

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C

DATA ZCLASS/0.0, 400., 800., 1200., 1600., 2000., 2400., 2800., 3200., 3600.
 ., 4000., 4400., 4800., 5200., 5600., 6000./

C

IF (IOPT1.EQ.1) CALL NEWSCL(ZCLASS, ZMAX)

NSIGN=1

IF (IOPT4.EQ.1) NSIGN=-1

NCLZ=16

NCLZ1=NCLZ-1

REHIND 8

REHIND 9

C

C

C

***** SET PLOTTING COORDINATES *****

XSTART=YORGIN

YST=XORGIN

C

C

C

C

***** BEGIN INTERPOLATION SCHEME *****

XPIX=PLOTY/.20+1.5

NPIXX=IFIX(XPIX)

U(1)=1.

U(3)=.5

NPTS=NSAMP+1

C

NSAVE=0

NPASS=0

NINT=100000/NPIXX

10 LNT=NINT

U(2)=1./((XPIX-1.5)/(NSAMP-1))

U(4)=FLOAT(NPIXX)

NROW=0

NPTS=NSAMP+1

IF (LNT.GT.(NX-NSAVE)) LNT=NX-NSAVE

C

C

C

***** T DIRECTION INTERPOLATION *****

DO 40 I=1, LNT

NSAVE=NSAVE+1

NROW=NROW+1

READ(8) (PBUFF(K), K=1, NSAMP)

READ(9) (ABUFF(K), K=1, NSAMP)

PBUFF(NPTS)=PBUFF(NSAMP)

ABUFF(NPTS)=ABUFF(NSAMP)

CALL UNWRAP(PBUFF, NPTS)

CALL APAM('QINX', 1, TBUFF, NPIXX, 4, 0, PBUFF, NPTS, 4, 0, U, 4, 4, 0)

CALL APAM('QINX', 1, SBUFF, NPIXX, 4, 0, ABUFF, NPTS, 4, 0, U, 4, 4, 0)

CALL WRAP(TBUFF, NPIXX)

DO 30 J=1, NPIXX

N=(NROW-1)*NPIXX+J

PIN(N)=TBUFF(J)

AIN(N)=SBUFF(J)

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30 CONTINUE
C *****
C ***** CHECK FOR FINISHED T DIRECTION *****
C *****
40 CONTINUE
C *****
C ***** BEGIN X DIRECTION INTERPOLATION *****
C *****
YPIX=(NROW-1)*XINC
YPIX=YPIX/.2+1.5
NPIXY=IFIX(YPIX)
U(2)=1./((YPIX-1.5)/(NROW-1))
U(4)=FLOAT(NPIXY)
NPTS=NROW+1
C *****
C ***** START X INTERPOLATION LOOP *****
C *****
DO 200 J=1,NPIXX
DO 100 I=1,NROW
SBUF(I)=AIN(J+(I-1)*NPIXX)
TBUF(I)=PIN(J+(I-1)*NPIXX)
100 CONTINUE
C
SBUF(NPTS)=SBUF(NROW)
TBUF(NPTS)=TBUF(NROW)
C
CALL UNWRAP(TBUF,NPTS)
CALL APAM('QIN',1,PBUF,NPIXY,4,0,TBUF,NPTS,4,0,U,4,4,0)
CALL APAM('QIN',1,ABUF,NPIXY,4,0,SBUF,NPTS,4,0,U,4,4,0)
CALL WRAP(PBUF,NPIXY)
C *****
C ***** BEGIN PLOTTING X SCAN LINES *****
C *****
XB=XSTART-(J-1)*.2
DO 51 KT=1,NPIXY
A=PBUF(KT)
B=ABS(ABUF(KT))
IF(A.LT.PCLASS(1)) II=1
IF(A.GT.PCLASS(5)) II=4
DO 59 I=1,4
IF(A.GT.PCLASS(I).AND.A.LE.PCLASS(I+1)) II=I
59 CONTINUE
IF(B.GT.ZCLASS(NCLZ)) ICODE=ISET((II-1)*16+16)
IF(B.LT.ZCLASS(1)) ICODE=ISET((II-1)*16+1)
DO 31 M=1,NCLZ1
IF(B.GT.ZCLASS(M).AND.B.LE.ZCLASS(M+1)) ICODE=ISET((II-1)*16+M)
31 CONTINUE
IF(B.EQ.0.0) ICODE=0
IBUF(KT)=ICODE
IF(ICODE.EQ.0) KOUNT=KOUNT+1
51 CONTINUE
C

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DO 71 KT=1,NPIXY
YB=YST+(KT-1)*.2*NSIGN
YSIDE=.2
CALL IRECT(YB,XB,YSIDE,.20,IBUFF(KT),0)
71 CONTINUE
200 CONTINUE
C *****
C ***** CHECK TO SEE IF ENTIRE TIME SLICE *****
C ***** IS FINISHED *****
C *****
NPASS=NPASS+1
IF(NSAVE.GE.NX) GO TO 700
YST=YST+NPIXY*.2*NSIGN
BACKSPACE 8
BACKSPACE 9
NSAVE=NSAVE-1
GO TO 10
C *****
C ***** PLOTTING IS DONE, CLOSE PLOTTING FILE *****
C *****
700 CONTINUE
XSTART=XORGIN+PLOTX+25.
IF(IOPT4.EQ.1) XSTART=XORGIN-PLOTX-110.
IF(IOPT2.NE.1) CALL INKS(XSTART,ISET,PCLASS,ZCLASS)
RETURN
END
C
C
SUBROUTINE UNWRAP(SBUFF,K)
  DIMENSION SBUFF(1),WRAPN(8000)
  PI=3.14159
  TWOPI=2.*PI
  NPTS=K+1
  WRAPN(1)=0.0
C
  DO 100 I=1,K
    DIFF=SBUFF(I)-SBUFF(I+1)
    WRAPN(I+1)=WRAPN(I)
    IF(DIFF.GT.PI) WRAPN(I+1)=WRAPN(I)+1
    IF(DIFF.LT.(-PI)) WRAPN(I+1)=WRAPN(I)-1
  100 CONTINUE
C
  DO 200 J=2,NPTS
    SBUFF(J)=SBUFF(J)+WRAPN(J)*TWOPI
  200 CONTINUE
  RETURN
  END
  SUBROUTINE WRAP(TBUFF,K)
    DIMENSION TBUFF(1)
    PI=3.14159
    TWOPI=2.*3.14159
    DO 100 I=1,K
      TBUFF(I)=AMOD(TBUFF(I),TWOPI)
      IF(TBUFF(I).LT.(-PI)) TBUFF(I)=TBUFF(I)+TWOPI
      IF(TBUFF(I).GT.PI) TBUFF(I)=TBUFF(I)-TWOPI
    100 CONTINUE
  END

```

```

100 CONTINUE
    RETURN
    END
    SUBROUTINE INKS(XSTART, ISET, PCLASS, ZCLASS)
    DIMENSION ISET(1), PCLASS(1), ZCLASS(1)
    XSTART=XSTART+20.
    DO 200 I=1, 4
        X=XSTART+(I-1)*10.
    DO 100 J=1, 16
        Y=50.+(J-1)*10.
        CALL IRECT(X, Y, 10., 10., ISET((I-1)*16+J), 1)
100 CONTINUE
200 CONTINUE
    X1=XSTART-10.
    DO 150 J=1, 16
        Y=50.+(J-1)*10.
        CALL INUMB(ZCLASS(J), X1, Y, 2., 0.7, 0)
150 CONTINUE
    Y=50.-5.
    DO 300 J=1, 5
        X=XSTART+(J-1)*10.
        Z=PCLASS(J)*57.35
        CALL INUMB(Z, X, Y, 2., 270, 7, 0)
300 CONTINUE
    X=XSTART+10.
    Y=50.-18.
    CALL ITEXT('PHASE~ ', X, Y, 4.0, 0, 7)
    X=XSTART+50.
    Y=50.+60.
    CALL ITEXT('AMPLITUDE~ ', X, Y, 4.0, 90, 7)
C
    CALL LEGEND(XSTART, ISET, PCLASS, ZCLASS)
C
    RETURN
    END
    SUBROUTINE LEGEND(XSTART, ISET, PCLASS, ZCLASS)
    DIMENSION TARRAY(1024), ENV(1024), PCLASS(1), ZCLASS(1), ISET(1)
    DIMENSION YP(180), XP(180)
    INTEGER*2 JDATE(6), IDATE(4)
    DATA JDATE/' ', ' ', ' ', ' ', ' ', ' ',
    & IDATE/' ', ' ', ' ', ' ', ' ', ' '
C
C *****
C # ROUTINE TO BUILD TRACE LEGEND #
C *****
C
    CALL DATE(IDATE)
    JDATE(1)=IDATE(1)
    JDATE(3)=IDATE(2)
    JDATE(5)=IDATE(3)
C
    C=ZCLASS(16)
    D=ZCLASS(16)-ZCLASS(15)
C
    LT=1024

```

C

DO 100 J=1,720
 ANGLE=J/180.*3.14159
 TARRAY(J)=SIN(ANGLE)

100 CONTINUE

C

DO 200 J=1,360
 TARRAY(J)=TARRAY(J)*(C+D*2)

200 CONTINUE

C

DO 300 J=361,540
 TARRAY(J)=TARRAY(J)*(C-D*3)

300 CONTINUE

C

DO 400 J=541,720
 TARRAY(J)=TARRAY(J)*(C-D*9)

400 CONTINUE

C

DO 450 J=1,90
 ENV(J)=J-90.
 ENV(J+90)=J
 ENV(J+180)=90.+J
 ENV(J+270)=J-180.
 ENV(J+360)=J-90.
 ENV(J+450)=J
 ENV(J+540)=90.+J
 ENV(J+630)=J-180.

450 CONTINUE

C

DO 475 J=1,720
 ENV(J)=ENV(J)/180.*3.14159

475 CONTINUE

C

X1=XSTART+10.
 Y=256.
 KOUNT=0

C

DO 502 J=1,720,4
 A=ENV(J)
 B=ABS(TARRAY(J))
 IF(A.LT.PCLASS(1)) II=1
 IF(A.GT.PCLASS(5)) II=4
 DO 501 I=1,4
 IF(A.GT.PCLASS(I).AND.A.LE.PCLASS(I+1)) II=I

501 CONTINUE

C

C

IF(B.GT.ZCLASS(16)) ICODE=ISET((II-1)*16+16)
 IF(B.LT.ZCLASS(1)) ICODE=ISET((II-1)*16+1)

C

DO 503 K=1,15
 IF(B.GT.ZCLASS(K).AND.B.LT.ZCLASS(K+1)) ICODE=ISET((II-1)*16+K)

503 CONTINUE

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```

C      KOUNT=KOUNT+1
      Y1=Y-(KOUNT-1)*.2
      CALL IRECT(X1,Y1,20.,.2,ICODE,0)
502  CONTINUE
C
      X1=XSTART+20.
      KOUNT=0
C
      DO 600 I=1,720,4
        KOUNT=KOUNT+1
        YP(KOUNT)=Y-(KOUNT-1)*.2
        XP(KOUNT)=TARRAY(I)/(C+D*.2)*9.+X1
600  CONTINUE
C
      CALL ILINEC(XP,YP,KOUNT,7)
      CALL ILINE(X1,256.,.2,7,1)
      CALL ILINE(X1,220.,.2,7,0)
      X1=XSTART+30.
      CALL ITEXT('+~ ',X1,258.,2.,0,7)
      X1=XSTART+10.
      CALL ITEXT('~ - ',X1,258.,2.,0,7)
      X1=XSTART+20.
      CALL ITEXT('0- ',X1,258.,2.,0,7)
C
      X1=XSTART+10.
      CALL ITEXT(JDATE,X1,280.,2.,0,7)
      X1=XSTART-15.
      CALL ITEXT('PHASE VARIABLE AMPLITUDE~ ',X1,270.,3.,0,7)
C
      RETURN
      END
      SUBROUTINE TGRID(NUMTRC)
      COMMON /CTRL/NX,NY,NTREC,DELT,NT,TPI,SPI,NREC,SCALE,LINC,ZMAX
      COMMON /PARM/XORGIN,YORGIN,IORGIN,PLOTX,PLOTY,XINC,YINC,SIZE,SIZE1
      COMMON /CTRL3/ IOP,IOPT1,IOPT2,IOPT3,IOPT4,IOPT5
      COMMON /CTRL4/ICDPS,ICDPE,ITST,ITED,NSAMP,ICDPN
C
      DIMENSION TLINE(81),TNUMB(81),NUMTRC(1)
      INTEGER*2 LABEL(3),ICODE,IEXT(5),IEND,IEX
      DATA IEXT/' ',' ',' ',' ',' '/
      DATA TLINE/81*.2/,TNUMB/81*.4/,LABEL/' ',' ',' ',' ',' '/
      DATA IEX/'EX'//,IEND/'EF'//
      NSIGN=1
      IF(IOPT4.EQ.1) NSIGN=-1
C
C      ***** SET PLOT PARAMETERS *****
C
      WRITE(6,2010)
C
      X1=XORGIN-(2.*NSIGN)
      X2=XORGIN+(PLOTX+2.)*NSIGN
      XI1=XORGIN-(10.*NSIGN)
      XI2=XORGIN+(PLOTX+10)*NSIGN

```

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```

C
C      ##### BUILD REFERENCE TABLES #####
C
      DO 100 J=1,81,10
          TNUMB(J)=2.0
          TLINE(J)=.6
100 CONTINUE
C
      DO 200 J=6,81,10
          TNUMB(J)=2.0
          TLINE(J)=.4
200 CONTINUE
C
C      ##### INITIALIZE LOOPS #####
C
      M=(ITST-1)*DELTA+100
      IF(ITST.EQ.0) M=(ITST-1)*DELTA+100
      K=ITED*DELTA+100
      I=0
      T=SPI/10.*25.4
C
C      ##### PLOT TIMING LINES #####
C
      DO 300 J=M,K,100
          I=I+1
          VALUE=(J-100.)/1000.
          ILOC=J/100

          Y=YORGIN-(I-1)*T
          Y1=Y-.5

C
          CALL ILINE(X1,Y,TLINE(ILOC),7,1)
          CALL ILINE(X2,Y,TLINE(ILOC),7,0)
C
          CALL INUMB(VALUE,XI1,Y1,TNUMB(ILOC),0,7,1)
          CALL INUMB(VALUE,XI2,Y1,TNUMB(ILOC),0,7,1)
C
300 CONTINUE
C
C      ##### PLOT ANNOTATION #####
C
      READ(10,1000) IFTRC,ITINC,ITLABL,ITLINC
C
      NTRC=NX
      DO 325 K=1,NX
          IF(IFTRC.EQ.NUMTRC(K)) I=K
          IF(ITLABL.EQ.NUMTRC(K)) J=K
325 CONTINUE
          NTRCI=I+NTRC
          NTRCJ=J+NTRC
          YT=YORGIN+1.
          YT1=YORGIN+2.
          YT2=YORGIN
          YT3=YT1+1.
          YT4=YT1+4.
    
```

YB=YORGIN-PL0TY-1.
 YB1=YORGIN-PL0TY-2.
 YB2=YORGIN-PL0TY
 YB3=YB1-3.

C

X=XORGIN-12.*NSIGN
 IF(IOPT3.NE.1) CALL ITEXT('CDP~ ',X,YT3,2.,0,7)
 CALL ITEXT('EXT~ ',X,YT4,2.,0,6)

C

DO 350 K=1,NTRC
 X=XORGIN+(K-1)*XINC*NSIGN
 CALL ILINE(X,YT,.2,4,1)
 CALL ILINE(X,YT2,.2,4,0)
 CALL ILINE(X,YB,.2,4,1)
 CALL ILINE(X,YB2,.2,4,0)

350 CONTINUE

C

L=0
 DO 400 K=1,NTRC,ITINC
 L=L+1
 L1=(L-1)*ITINC
 X=XORGIN+L1*XINC*NSIGN+(I-1)*XINC*NSIGN
 CALL ILINE(X,YT1,.4,3,1)
 CALL ILINE(X,YT2,.4,3,0)
 CALL ILINE(X,YB1,.4,3,1)
 CALL ILINE(X,YB2,.4,3,0)

400 CONTINUE

C

IF(IOPT3.EQ.1) GO TO 10
 IF(ITLABL.LE.0)GO TO 10
 IF(ITLINC.LE.0)GO TO 10
 JN=0
 DO 500 K=J,NTRC,ITLINC
 JN=JN+1
 J1=(JN-1)*ITLINC
 X=XORGIN+J1*XINC*NSIGN+(J-1)*XINC*NSIGN-2.
 VALUE=NUMTRC(K)
 CALL INUMB(VALUE,X,YT3,2.,0,7,0)
 CALL INUMB(VALUE,X,YB3,2.,0,7,0)

500 CONTINUE

C

C

***** PLOT USER'S EXTERNAL ANNOTATION *****

C

10 READ(10,2000) ICODE,INTR,(IEXT(K),K=1,4)
 IF(ICODE.EQ.IEND) GO TO 600
 IF(INTR.LT.ICDPS.OR.INTR.GT.ICDPE) GO TO 10
 DO 550 K=1,NX
 IF(INTR.EQ.NUMTRC(K)) INCR=K-1
 550 CONTINUE
 X=XORGIN+INCR*XINC*NSIGN-8.
 WRITE(6,2020) ICODE,INTR,(IEXT(K),K=1,4)
 CALL ITEXT(IEXT,X,YT4,2.,0,6)
 GO TO 10
 600 WRITE(6,2030)
 RETURN
 1000 FORMAT(10X,4I10)
 2000 FORMAT(A2,I5,2X,4A2)

```

2010 FORMAT(35X,'*** USER TRACE ANNOTATION ***',///,25X,'ANNOTATION T
      TYPE',5X,'INTERNAL CDP',5X,'ANNOTATION',//)
2020 FORMAT(31X,A2,17X,I5,9X,4A2)
2030 FORMAT(//,35X,'*** USER TRACE ANNOTATION COMPLETED ***',//)
      END
      SUBROUTINE IPARM(IERROR)
      COMMON /CTRL/NX,NY,NTREC,DELT,NT,TPI,SPI,NREC,SCALE,LINC,ZHAX
      COMMON /PARM/XORGIN,YORGIN,IORGIN,PLOTX,PLOTY,XINC,YINC,SIZE,SIZE1
      COMMON /CTRL4/ICDPS,ICDPE,ITST,ITED,NSAMP,ICDPN

C      IERROR=0
      PLOTX=NX/TPI*25.4
      TIMEL=DELT*NSAMP/1000.
      PLOTY=TIMEL*25.4*SPI

C      IF(PLOTX.GT.715.) GO TO 50
      IF(PLOTY.GT.519.) GO TO 60

C      IORGIN=2
30  CONTINUE
      YORGIN=529.
      XORGIN=25.
      XINC=25.4/TPI
      SIZE=XINC/2.
      SIZE1=XINC
      YINC=(SPI*25.4)/(NSAMP/TIMEL)
      RETURN
50  WRITE(6,1000) L1,TPI,PLOTX
      IERROR=1
1000 FORMAT(10X,'***** ERROR   YOUR REQUESTED PLOT IS TOO LARGE
      * THE NUMBER OF TRACES TO PROCESS ',I10,5X,' TPI ',F6.3,10X,'TOTA
      * L LENGTH IS ',F7.2,' MM YOUR LIMIT IS 715 MM *****')
      RETURN
60  WRITE(6,1010) L1,SPI,PLOTY
      IERROR=1
1010 FORMAT(10X,'***** ERROR   YOUR REQUESTED PLOT IS TOO LARGE
      * THE NUMBER OF TRACES TO PROCESS ',I10,5X,' IPS ',F6.3,10X,'TOTA
      * L LENGTH IS ',F7.2,' MM YOUR LIMIT IS 519 MM *****')
      RETURN
      END
      SUBROUTINE NEWSCL(ZCLASS,ZHAX)
      DIMENSION ZCLASS(1)
      INT=ZHAX/15.
      DO 100 I=1,16
          ZCLASS(I)=(I-1)*INT
100  CONTINUE

      RETURN
      END
      SUBROUTINE ENVELP(PUT,LT,ENV)
      REAL RST(4096), CST(4096), ENV(4096), PUT(4096)
C      RST HOLDS THE REAL PART OF THE SEISMIC TRACE
C      CST HOLDS THE IMAGINARY (CONJAGATE) PART OF THE TRACE

```

```

COMPLEX TRACE(4096)
B=0.0
DO 10 J=1,LT
ENV(J)=0.0
TRACE(J)=CMPLX(0.0,0.0)
TRACE(J)=CMPLX(PUT(J),B)
10 CONTINUE

LH=LT/2
LH1=LH+1

CALL FFT(LT,TRACE,-1.0)

DO 20 I=1,LT
RST(I)=REAL(TRACE(I))
CST(I)=AIMAG(TRACE(I))
20 CONTINUE

DO 30 I=2,LH
RST(I)=2.0XRST(I)
CST(I)=2.0XCST(I)
30 CONTINUE

DO 40 I=LH1,LT
RST(I)=0.0
CST(I)=0.0
40 CONTINUE
DO 45 I=1,LT
TRACE(I)=CMPLX(RST(I),CST(I))
45 CONTINUE

CALL FFT(LT,TRACE,1.0)
DO 47 I=1,LT
RST(I)=REAL(TRACE(I))
CST(I)=AIMAG(TRACE(I))
47 CONTINUE

C
C *****
C      CALCULATE PHASE VALUES
C *****
C

DO 50 I=1,LT
IF(RST(I).EQ.0.AND.CST(I).EQ.0) GO TO 55
ENV(I)=ATAN2(CST(I),RST(I))
55 IF(RST(I).EQ.0.AND.CST(I).EQ.0) ENV(I)=0.0
50 CONTINUE

C
C DO 65 I=1,LT
C WRITE(6,60) RST(I),CST(I),ENV(I),PUT(I)
C 65 CONTINUE
C 60 FORMAT(10X,4F10.3)
C RETURN
C END

```

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```

SUBROUTINE FFT(LX, CX, SIGNI)
C   LX=NUMBER OF SAMPLE POINTS-MUST BE A POWER OF 2
C   CX=INPUT AND OUTPUT DATA
C   SIGNI=+1 FOR INVERSE TRANSFORM
C   SIGNI=-1 FOR FORWARD TRANSFORM
C   SIGNI IS DESIGNATED IN MAIN PROGRAM
COMPLEX CX(LX), CARG, CEXP, CH, CTEMP
J=1
SC=1./FLOAT(LX)
DO 30 I=1, LX
  IF(I.GT.J) GO TO 10
  CTEMP=CX(J)
  CX(J)=CX(I)
  CX(I)=CTEMP
10  M=LX/2
20  IF(J.LE.M) GO TO 30
  J=J-M
  M=M/2
  IF(M.GE.1) GO TO 20
30  J=J+M
  L=1
40  ISTEP=2*L
  DO 50 M=1, L
    CARG=(0., 1.)*(3.14159265*SIGNI*FLOAT(M-1))/FLOAT(L)
    CH=CEXP(CARG)
    DO 50 I=M, LX, ISTEP
      CTEMP=CH*CX(I+L)
      CX(I+L)=CX(I)-CTEMP
50  CX(I)=CX(I)+CTEMP
  L=ISTEP
  IF(L.LT.LX) GO TO 40
  IF(SIGNI.LT.0.0) RETURN
  DO 60 I=1, LX
60  CX(I)=CX(I)*SC
  RETURN
END
SUBROUTINE LIMIT
COMMON/CTRL/NX, NY, NTREC, DELT, NT, TPI, SPI, NREC, SCALE, LINC, ZMAX
COMMON/CTRL4/ICDPS, ICDPE, ITST, ITED, NSAMP, ICDPN
C
C
  ITST=ITST/DELT+1
  IF(ITST.EQ.0) ITST=1
  ITED=ITED/DELT+1
  IF(ITED.EQ.0) ITED=NT
  NSAMP=ITED-ITST+1
C  WRITE(6, 1000) ICDPS, ICDPE, ITST, ITED, NSAMP
C1000 FORMAT(//, SI10)
  RETURN
END
SUBROUTINE TITLE
COMMON /PARM/XORGIN, YORGIN, IORGIN, PLOTX, PLOTY, XINC, YINC, SIZE, SIZE1
COMMON /CTRL3/IOP, IOPT1, IOPT2, IOPT3, IOPT4, IOPT5
INTEGER*2 INOTE(3), ICHK, ISAVE(39), IEND
DATA ICHK/' ', IEND/'~ ' /

```

```
C  
C  
C  
C  
C  
  
      ***** PLOT LINE TITLE *****  
  
XSHIFT=XORGIN+PLOTX+20.  
IF(IOPT4.EQ.1) XSHIFT=XORGIN-PLOTX-110.  
YSHIFT=534.  
  
WRITE(6,1040)  
  
10 JCNT=0  
   ICNT=0  
  
C  
C  
C  
C  
C  
      ***** READ USER'S LABEL *****  
  
READ(10,1000) ISIZE,(ISAVE(K),K=1,39)  
   IF(ISIZE.EQ.0) GO TO 200  
  
C  
C  
C  
      ***** FIND THE END OF TEXT *****  
  
DO 100 J=1,39  
    IF(ISAVE(J).EQ.ICHK) ICNT=ICNT+1  
    IF(ISAVE(J).NE.ICHK) JCNT=JCNT+1  
    IF(ISAVE(J).NE.ICHK) ICNT=0  
100 CONTINUE  
  
C  
IADJ=39-ICNT  
ICNT=IADJ#2  
NCHR=110/ISIZE  
  
C  
C  
C  
      ***** PRINT THE USER'S INPUT *****  
  
WRITE(6,1030) ISIZE,ISAVE  
  
C  
IF(ICNT.GT.NCHR) GO TO 800  
ISAVE(IADJ+1)=IEND  
YSHIFT=YSHIFT-2.-ISIZE  
SIZE=ISIZE  
IF(IOPT2.EQ.0.AND.YSHIFT.LT.300.) GO TO 900  
IF(IOPT2.EQ.1.AND.YSHIFT.LT.25.) GO TO 900  
CALL ITEXT(ISAVE,XSHIFT,YSHIFT,SIZE,0,7)  
GO TO 10  
  
C  
200 WRITE(6,1010)  
     RETURN  
800 WRITE(6,1020)  
     RETURN  
900 WRITE(6,1050)  
     RETURN
```

C

```

1000 FORMAT(I1,1X,39A2)
1010 FORMAT(///,35X,'### SIDE LABEL SUCCESSFULLY GENERATED ###',////)
1020 FORMAT(///,10X,'$$$ ERROR-YOU HAVE ASKED FOR TOO MANY CHARACTERS
    *TO BE DISPLAYED $$$')
1030 FORMAT(31X,I2,10X,39A2)
1040 FORMAT(////,35X,'### SIDE LABEL GENERATION ###',////,28X,'TEXT
    *SIZE',14X,'ANNOTATION',//)
1050 FORMAT(///,10X,'$$$ ERROR-YOU HAVE ASKED FOR TOO MANY LINES $$$')
    END

```

Claims

1. A method of producing a color-coded seismic display from seismic wiggle traces and corresponding complex wiggle traces, which makes use of the instantaneous phase from said complex traces, said method characterized by the steps of:

(a) selecting a plurality of data points for each one of a plurality of real wiggle traces or sinusoidal wiggle traces, wherein said plurality of data points are equally spaced apart;

(b) in the case of real seismic wiggle traces determining the real amplitude for each one of the data points selected in step (a) and in the case of sinusoidal wiggle traces determining the envelope amplitude for each one of said plurality of data points selected in step (a);

(c) determining the instantaneous phase of a plurality of complex seismic wiggle traces corresponding to said plurality of wiggle traces at each one of the data points selected in step (a);

(d) assigning one of at least two colors to each data point selected in step (a) based on the instantaneous phase, determined in step (c), at each data point;

(e) assigning a shade of the color assigned in step (d) to each data point determined in step (a), wherein the darkness of the shade assigned is based on the amplitude determined in step (b); and

(f) plotting the color and shade of color assigned to each data point to produce a variable amplitude/phase seismic display.

2. A method of claim 1 comprising:

(d) assigning color one, color two, color three or color four to each data point selected in step (a) based on the instantaneous phase, determined in step (c), at each data point, wherein said colors are assigned in accordance with Table I and wherein BA in Table I is a base angle.

Table I

Color	Range
one	(BA - 90° to (BA - 180°)
two	BA to (BA - 90°)
three	BA to (BA + 90°)
four	(BA + 90°) to (BA + 180°)

(e) assigning a shade of color one, a shade of color two, a shade of color three or a shade of color four to each data point selected in step (a), wherein the darkness of the shade assigned is based on the amplitude determined in step (b) and wherein the particular color applied to each data point is determined by the instantaneous phase in accordance with step (d); and

(f) plotting the color and shade of color assigned to each data point to produce said variable amplitude/phase seismic display.

3. A method in accordance with claim 1 or 2 wherein said data points are four milliseconds apart.

4. A method in accordance with claims 1 or 2 wherein said step of determining the instantaneous phase of said plurality of complex seismic wiggle traces comprises:

(g) applying a Hilbert transform to each one of said plurality of real seismic wiggle traces to convert each one of said plurality of real seismic wiggle traces to a corresponding imaginary seismic wiggle trace;

(h) determining the amplitude of the plurality of imaginary seismic wiggle traces from step (g) at each data point selected in step (a); and

(i) determining the instantaneous phase $P(t)$ at each data point selected in step (a) in accordance with equation 1

$$P(t) = \tan^{-1} [h(t)/g(t)]$$

C
 1000 FORMAT (I1, 1X, 39A2)
 1010 FORMAT (//, 35X, '*** SIDE LABEL SUCCESSFULLY GENERATED ***', //)
 5 1020 FORMAT (///, 10X, '*** ERROR-YOU HAVE ASKED FOR TOO MANY CHARACTERS
 *TO BE DISPLAYED ***')
 1030 FORMAT (31X, I2, 10X, 39A2)
 1040 FORMAT (////, 35X, '*** SIDE LABEL GENERATION ***', //, 28X, 'TEXT
 KSIZE', 14X, 'ANNOTATION', //)
 10 1050 FORMAT (///, 10X, '*** ERROR-YOU HAVE ASKED FOR TOO MANY LINES ***')
 END

Claims

15 1. A method of producing a color-coded seismic display from seismic wiggle traces and corresponding complex wiggle traces, which makes use of the instantaneous phase from said complex traces, said method characterized by the steps of:

(a) selecting a plurality of data points for each one of a plurality of real wiggle traces or sinusoidal wiggle traces, wherein said plurality of data points are equally spaced apart;

20 (b) in the case of real seismic wiggle traces determining the real amplitude for each one of the data points selected in step (a) and in the case of sinusoidal wiggle traces determining the envelope amplitude for each one of said plurality of data points selected in step (a);

(c) determining the instantaneous phase of a plurality of complex seismic wiggle traces corresponding to said plurality of wiggle traces at each one of the data points selected in step (a);

25 (d) assigning one of at least two colors to each data point selected in step (a) based on the instantaneous phase, determined in step (c), at each data point;

(e) assigning a shade of the color assigned in step (d) to each data point determined in step (a), wherein the darkness of the shade assigned is based on the amplitude determined in step (b); and

30 (f) plotting the color and shade of color assigned to each data point to produce a variable amplitude/phase seismic display.

2. A method of claim 1 comprising:

(d) assigning color one, color two, color three or color four to each data point selected in step (a) based on the instantaneous phase, determined in step (c), at each data point, wherein said colors are assigned in accordance with Table I and wherein BA in Table I is a base angle.

Table I

Color	Range
one	(BA - 90° to (BA - 180°)
two	BA to (BA - 90°)
three	BA to (BA + 90°)
four	(BA + 90°) to (BA + 180°)

40 (e) assigning a shade of color one, a shade of color two, a shade of color three or a shade of color four to each data point selected in step (a), wherein the darkness of the shade assigned is based on the amplitude determined in step (b) and wherein the particular color applied to each data point is determined by the instantaneous phase in accordance with step (d); and

45 (f) plotting the color and shade of color assigned to each data point to produce said variable amplitude/phase seismic display.

50 3. A method in accordance with claim 1 or 2 wherein said data points are four milliseconds part.

4. A method in accordance with claims 1 or 2 wherein said step of determining the instantaneous phase of said plurality of complex seismic wiggle traces comprises:

(g) applying a Hilbert transform to each one of said plurality of real seismic wiggle traces to convert each one of said plurality of real seismic wiggle traces to a corresponding imaginary seismic wiggle trace;

60 (h) determining the amplitude of the plurality of imaginary seismic wiggle traces from step (g) at each data point selected in step (a); and

(i) determining the instantaneous phase P(t) at each data point selected in step (a) in accordance with equation 1

(1)

$$P(t) = \tan^{-1} [h(t)/g(t)]$$



where $h(t)$ is the amplitude of the imaginary seismic trace at a data point as determined in step (h), wherein $g(t)$ is the amplitude of the real seismic trace at the same data point as determined in step (b) and wherein each one of said plurality of complex seismic wiggle traces is composite of a real seismic wiggle trace and a corresponding imaginary seismic wiggle trace.

- 5 5. A method in accordance with claim 1 or 2 wherein in the case of said sinusoidal wiggle traces said step of determining the instantaneous phase of said plurality of complex seismic wiggle traces comprises:
- (g) determining the real amplitude for each one of said plurality of data points selected in step (a);
 - (h) applying a Hilbert transform to each one of said plurality of wiggle traces to convert each one of said plurality of wiggle traces to a corresponding imaginary seismic wiggle trace;
 - 10 (i) determining the amplitude of the plurality of imaginary seismic wiggle traces from step (h) at each data point selected in step (a); and
 - (j) determining the instantaneous phase $P(t)$ at each data point selected in step (a) in accordance with equation 1

15 (1)
$$P(t) = \tan^{-1} [h(t)/g(t)]$$

wherein $h(t)$ is the amplitude of the imaginary seismic trace at a data point as determined in step (i), wherein $g(t)$ is the amplitude of the real seismic trace at the same data point as determined in step (g) and wherein each one of said plurality of complex seismic wiggle traces is composite of a real seismic wiggle trace and a corresponding imaginary seismic wiggle trace.

6. A method in accordance with claim 1 or 2 wherein the colors assigned in step (d) are assigned in accordance with Table II

Table II

Color	Range
one	-90° to -180°
two	0° to -90°
three	0° to +90°
four	+90° to +180°

7. A method in accordance with claim 1 or 2 wherein one of sixteen shades of color one, color two, color three or color four is assigned in step (e) to each data point selected in step (a) based on the amplitude determined in step (b).

8. A method in accordance with claim 7 wherein darker shades of color one, color two, color three or color four are assigned for higher amplitudes and lighter shades are assigned for lower amplitudes.

Patentansprüche

1. Verfahren zum Erzeugen einer farbcodierten seismischen Anzeige von seismischen Wiggerspuren und entsprechenden komplexen Wiggerspuren, die von der momentanen Phase von den komplexen Spuren Gebrauch machen, wobei das Verfahren gekennzeichnet ist durch die Schritte:

(a) Auswählen einer Vielzahl von Datenpunkten für jede einer Vielzahl von reellen Wiggerspuren oder sinusförmigen Wiggerspuren, wobei die Vielzahl von Datenpunkten gleich voneinander beabstandet ist;

(b) im Fall von reellen seismischen Wiggerspuren Bestimmen der reellen Amplitude für jeden der in Schritt (a) ausgewählten Datenpunkte und im Falle sinusförmiger Wiggerspuren Bestimmen der einhüllenden Amplitude für jeden der Vielzahl von in Schritt (a) gewählten Datenpunkten;

(c) Bestimmen der momentanen Phase einer Vielzahl von komplexen seismischen Wiggerpuren entsprechend der Vielzahl von Wiggerspuren bei jedem der in Schritt (a) gewählten Datenpunkt;

(d) Zuordnen einer von mindestens zwei Farben zu jedem im Schritt (a) gewählten Datenpunkt, basierend auf der in Schritt (c) bestimmten momentanen Phase bei jedem Datenpunkt;

(e) Zuordnen eines Schattens der im Schritt (d) zugeordneten Farbe zu jedem in Schritt (a) bestimmten Datenpunkt, wobei die Dunkelheit des zugeordneten Schattens auf der in Schritt (b) bestimmten Amplitude basiert; und

(f) Aufzeichnen der Farbe und des Schattens der zugeordneten Farbe zu jedem Datenpunkt, um eine variable seismische Amplituden-Phasenanzeige zu erzeugen.

2. Verfahren nach Anspruch 1, gekennzeichnet durch:

(d) Zuordnen von Farbe 1, Farbe 2, Farbe 3 oder Farbe 4 zu jedem in Schritt (a) ausgewählten Datenpunkt, basierend auf der in Schritt (c) bestimmten momentanen Phase bei jedem Datenpunkt, wobei die Farben in Übereinstimmung mit Tabelle I zugeordnet werden und wobei BA in Tabelle I ein Basiswinkel ist.



Tabelle I

Farbe	Bereich
eins	(BA - 90°) bis (BA - 180°)
zwei	BA bis (BA - 90°)
drei	BA bis (BA + 90°)
vier	(BA + 90°) bis (BA + 180°)

(e) Zuordnen eines Schattens von Farbe 1, eines Schattens von Farbe 2, eines Schattens von Farbe 3 oder eines Schattens von Farbe 4 zu jedem in Schritt (a) ausgewählten Datenpunkt, wobei die Dunkelheit des zugeordneten Schattens auf der in Schritt (b) bestimmten Amplitude basiert und wobei die einzelne Farbe, die jedem Datenpunkt zugeordnet ist, durch die momentane Phase in Übereinstimmung mit Schritt (d) bestimmt wird; und

(f) Aufzeichnung der Farbe und des Farbschattens, die jedem Datenpunkt zugeordnet sind, um die variable seismische Amplituden-Phasenanzeige zu erzeugen.

3. Verfahren nach Anspruch 1 oder 2, wobei die Datenpunkte 4 Millisekundenteile (msec) sind.

4. Verfahren nach Anspruch 1 oder 2, wobei der Schritt zum Bestimmen der momentanen Phase der Vielzahl von komplexen seismischen Wiggler Spuren beinhaltet:

(g) Anwenden einer Hilbert-Transformation auf jede der Vielzahl von reellen seismischen Wiggler Spuren, um jede der Vielzahl der reellen seismischen Wiggler Spuren in eine entsprechende imaginäre seismische Wiggler Spur umzuwandeln;

(h) Bestimmen der Amplitude der Vielzahl von imaginären seismischen Wiggler Spuren aus Schritt (g) bei jedem in Schritt (a) gewählten Datenpunkt; und

(i) Bestimmen der momentanen Phase $P(t)$ bei jedem in Schritt (a) gewählten Datenpunkt in Übereinstimmung mit Gleichung 1

$$(1) \quad P(t) = \tan^{-1} [h(t)/g(t)]$$

wobei $h(t)$ die Amplitude der imaginären seismischen Spur bei einem Datenpunkt ist, wie er in Schritt (h) bestimmt ist, wobei $g(t)$ die Amplitude der reellen seismischen Spur bei demselben Datenpunkt ist wie er in Schritt (b) bestimmt ist und wobei jede der Vielzahl von komplexen seismischen Wiggler Spuren eine Zusammensetzung einer reellen seismischen Wiggler Spur und einer entsprechenden imaginären seismischen Wiggler Spur ist.

5. Verfahren nach Anspruch 1 oder 2, wobei in dem Fall der sinusförmigen Wiggler Spuren der Schritt der Bestimmung der momentanen Phase der Vielzahl der komplexen seismischen Wiggler Spuren beinhaltet:

(g) Bestimmen der reellen Amplitude für jeden der Vielzahl von in Schritt (a) gewählten Datenpunkten;

(h) Anwenden einer Hilbert-Transformation auf jede der Vielzahl von Wiggler Spuren, um jede der Vielzahl von Wiggler Spuren in eine entsprechende imaginäre seismische Wiggler Spur umzuwandeln;

(i) Bestimmen der Amplitude der Vielzahl von imaginären seismischen Wiggler Spuren aus Schritt (h) bei jedem in Schritt (a) gewählten Datenpunkt; und

(j) Bestimmen der momentanen Phase $P(t)$ bei jedem in Schritt (a) gewählten Datenpunkt in Übereinstimmung mit Gleichung 1

$$(1) \quad P(t) = \tan^{-1} [h(t)/g(t)]$$

wobei $h(t)$ die Amplitude der imaginären seismischen Spur bei einem Datenpunkt ist, wie er in Schritt (i) bestimmt ist, wobei $g(t)$ die Amplitude der reellen seismischen Spur bei demselben Datenpunkt ist wie in Schritt (b) bestimmt ist und wobei jede der Vielzahl von komplexen seismischen Wiggler Spuren eine Zusammensetzung einer reellen seismischen Wiggler Spur und einer entsprechenden imaginären seismischen Wiggler Spur ist.

6. Verfahren nach Anspruch 1 oder 2, wobei die in Schritt (d) zugeordneten Farben in Übereinstimmung mit Tabelle II zugeordnet werden.



Tabelle II

	Farbe	Bereich
5	eins	-90° bis -180°
	zwei	0° bis -90°
10	drei	0° bis +90°
	vier	+90° bis +180°

7. Verfahren nach Anspruch 1 oder 2, wobei einer von 16 Schatten von Farbe 1, Farbe 2, Farbe 3 oder Farbe 4 in Schritt (e) jedem in Schritt (a) ausgewählten Datenpunkt zugeordnet wird, basierend auf der in Schritt (b) bestimmten Amplitude.

8. Verfahren nach Anspruch 7, wobei dunklere Schatten von Farbe 1, Farbe 2, Farbe 3 oder Farbe 4 höheren Amplituden und hellere Schatten niedrigeren Amplituden zugeordnet werden.

Revendications

1. Procédé pour produire un affichage sismique codé en couleur à partir de tracés sismiques agités et de tracés agités complexes correspondants, qui fait appel à la phase instantanée par rapport aux traces complexes, le procédé étant caractérisé par les étapes consistant à:

(a) sélectionner une multitude de points de données pour chaque trace d'une multitude de traces agitées réelles ou de traces agitées sinusoïdales, où la multitude des points de données sont espacés de la même distance;

(b) dans le cas de traces sismiques agitées réelles, déterminer l'amplitude réelle pour chacun des points de données choisis dans l'étape (a) et dans le cas de traces agitées sinusoïdales, déterminer l'amplitude de l'enveloppe pour chaque point de la multitude de points de données choisis dans l'étape (a);

(c) déterminer la phase instantanée d'une multitude de traces sismiques agitées complexes correspondant à la multitude de traces agitées à chacun des points de données choisis dans l'étape (a);

(d) affecter l'une d'au moins deux couleurs à chaque point de donnée choisi dans l'étape (a) sur la base de la phase instantanée, déterminée dans l'étape (c), à chaque point de donnée;

(e) affecter une nuance de la couleur affectée dans l'étape (d) à chaque point de donnée déterminé dans l'étape (a), où la teinte foncée de la nuance affectée est basée sur l'amplitude déterminée dans l'étape (b); et

(f) tracer la courbe de la couleur et de la nuance de la couleur affectée à chaque point de donnée pour produire un affichage sismique à amplitude/phase variable.

2. Procédé selon la revendication 1, caractérisé en ce qu'il comprend les étapes consistant à:

(d) affecter une couleur un, une couleur deux, une couleur trois ou une couleur quatre à chaque point de donnée choisi dans l'étape (a) sur la base de la phase instantanée, déterminée dans l'étape (c), à chaque point de donnée, où les couleurs sont affectées en conformité avec le Tableau I, et dans lequel AB est un angle de base

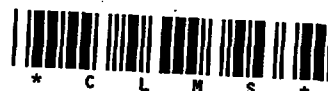
Tableau I

	Couleur	Plage
50	un	(AB -90° à (AB -180°)
	deux	AB à (AB -90°)
	trois	AB à (AB +90°)
55	quatre	(AB +90°) à (AB +180°)

(e) affecter une nuance de couleur un, une nuance de couleur deux, une nuance de couleur trois ou une nuance de couleur quatre à chaque point de donnée choisi dans l'étape (a), où la teinte foncée de la nuance affectée est basée sur l'amplitude déterminée dans l'étape (b) et où la couleur particulière appliquée à chaque point de donnée est déterminée par la phase instantanée en conformité avec l'étape (d); et

(f) tracer la courbe de la couleur et de la nuance de couleur affectées à chaque point de donnée pour produire l'affichage sismique à amplitude/phase variable.

3. Procédé selon la revendication 1 ou 2, dans lequel les points de données sont espacés de quatre millisecondes.



4. Procédé selon la revendication 1 ou 2, dans lequel l'étape consistant à déterminer la phase instantanée de la multitude de traces sismiques agitées complexes comprend les étapes consistant à:

(g) appliquer une transformée de Hilbert à chacune de la multitude de traces sismiques agitées réelles pour transformer chacune de la multitude de traces sismiques agitées réelles en une trace sismique agitée imaginaire correspondante;

(h) déterminer l'amplitude de la multitude de traces sismiques agitées imaginaires à partir de l'étape (g) à chaque point de donnée choisi dans l'étape (a); et

(i) déterminer la phase instantanée $P(t)$ à chaque point de donnée choisi dans l'étape (a) en conformité avec l'équation 1

(1)

$$P(t) = \text{tg}^{-1} [h(t)/g(t)]$$

où $h(t)$ est l'amplitude de la trace sismique imaginaire à un point de donnée tel qu'il est déterminé dans l'étape (h), où $g(t)$ est l'amplitude de la trace sismique réelle au même point de donnée que déterminé dans l'étape (b) et où chacune de la multitude de traces sismiques agitées complexes est un composite d'une trace sismique agitée réelle et d'une trace sismique agitée imaginaire correspondante.

5. Procédé selon la revendication 1 ou 2, dans lequel, dans le cas des traces agitées sinusoïdales, l'étape consistant à déterminer la phase instantanée de la multitude de traces sismiques agitées complexes, comprend les étapes consistant à:

(g) déterminer l'amplitude réelle pour chacune de la multitude de points de données sélectionnés dans l'étape (a);

(h) appliquer une transformée de Hilbert à chacune de la multitude de traces agitées pour transformer chacune de la multitude de traces agitées en une trace sismique agitée imaginaire correspondante;

(i) déterminer l'amplitude de la multitude de traces sismiques agitées imaginaires provenant de l'étape (g) à chaque point de donnée choisi dans l'étape (a); et

(j) déterminer la phase instantanée $P(t)$ à chaque point de donnée choisi dans l'étape (a) en conformité avec l'équation 1

(1)

$$P(t) = \text{tg}^{-1} [h(t)/g(t)]$$

où $h(t)$ est l'amplitude de la trace sismique imaginaire à un point de donnée tel que déterminé dans l'étape (i), où $g(t)$ est l'amplitude de la trace sismique réelle au même point de donnée que déterminé dans l'étape (g) et où chacune de la multitude de traces sismiques agitées complexes est un composite d'une trace sismique agitée réelle et d'une trace sismique agitée imaginaire correspondante.

6. Procédé selon la revendication 1 ou 2, dans lequel les couleurs affectées dans l'étape (d) le sont en conformité avec le Tableau II.

Tableau II

Couleur	Plage
un	-90° à -180°
deux	0° à -90°
trois	0° à $+90^\circ$
quatre	$+90^\circ$ à $+180^\circ$

7. Procédé selon la revendication 1 ou 2, dans lequel l'une des seize nuances de la couleur un, de la couleur deux, de la couleur trois ou de la couleur quatre est affectée dans l'étape (e) à chaque point de donnée choisi dans l'étape (a) sur la base de l'amplitude déterminée dans l'étape (b).

8. Procédé selon la revendication 7, dans lequel des nuances plus foncées de la couleur un, de la couleur deux, de la couleur trois ou de la couleur quatre sont affectées pour des amplitudes plus élevées et des nuances plus claires sont affectées pour des amplitudes plus faibles.

