7/

UTILISATION OF SYNTHETIC VELOCITY LOGS AND SEISMIC ATTRIBUTES TO PREDICT SAND DISTRIBUTION WITHIN THE PALEOCENE INTERVAL OF THE COD FIELD, NORWAY

E-A Seismic Stratigraphy Section

PHILLIPS PETROLEUM 66

E-A SEISMIC STRATIGRAPHY SECTION

UTILISATION OF SYNTHETIC VELOCITY LOGS AND SEISMIC ATTRIBUTES TO PREDICT SAND DISTRIBUTION WITHIN THE PALEOCENE INTERVAL OF THE COD FIELD, NORWAY

G.J.O. TINN

DECEMBER 1981

APPROVED BY:

R.P.Mott

R.P.Mott

FIGURES AND ENCLOSURES

FIGURES:

ENCLOSURES:

RECOMMENDATION AND CONCLUSIONS

Recommendation:

No further studies of the Cod Field, utilising Synthetic Velocity (S.V.) Logs and Seismic Attributes, should be undertaken unless seismic data with a substantially broader frequency spectrum is available.

Conclusions:

(1) Analysis of filtered integrated sonic logs indicates that S.V. logs, generated from the available seismic data, should display a response to the major sand units within the Cod Formation provided that the lithology has sufficient lateral continuity.

(2) No acceptable correlation between S.V. logs and filtered sonic logs was achieved and hence the S.V. logs are considered to be unreliable for the reservoir interval. This is thought to be due to rapid variations in lithology.

(3) The seismic attribute displays possess no indicators of hydrocarbon accumulation and yield only limited information about the Cod Formation.

INTRODUCTION

The E-A Seismic Stratigraphy Section was requested to assist in the delineation of sand bodies within the Paleocene interval of the Cod Field, Block 7/11 Norway.

Hydrocarbon accumulations, mainly gas-condensate, exist within thin sand beds constituting part of a submarine channel and fan depositional sequence. The trapping mechanism is both structural, with an up-doming of sediments due to salt movement, and stratigraphic where sands terminate into shales. The latter evidently plays an important role due to the rapid lateral variation in lithology observable through sub-surface control.

Previous relevant studies have been conducted by L.G.Kessler et al (1978)[1] and A.L.Coxon (1978)[2]. L.G.Kessler reported the depositional environment of the reservoir interval of the Cod Field was deep marine turbidite deposition, following a study of gamma ray logs and conventional cores. He also suggested possible evidence for "pod-shaped" bodies observable in the seismic data, conceivably representing individual submarine fan lobes. A.L.Coxen conducted a hydrodynamic analysis on flow tests and concluded that a minimum of nine non-communicative hydrocarbon accumulations are present.

It was hoped that, utilising modern seismic stratigraphic techniques, some mechanism for predicting sand distribution could be established and provide assistance in the delineation of individual reservoirs.

It should be stated here that the chances of success were appreciated to be low and that the work was undertaken because the complexity of the reservoir interval has made the economic development of the Cod Field quite difficult.

IDENTIFICATION OF CHRONOSTRATA

Utilising synthetic seismograms from the 7/11-3x and 7/11-A5 wells, the top of the Cod, Danian, and Maastrichtian intervals were identified on 14 seismic lines forming a grid (Enclosure 1) over the Cod structure. This data was acquired in 1976 and reprocessed in 1980 using standard deconvolution and filtering techniques.

In order to firmly establish the seismic events corresponding to the top of the Cod Formation, the top of the Danian chalk and the top of the Maastrichtian interval it was necessary to determine the frequency and phase characteristics of the basic wavelet inherent in the final seismic data. This was achieved via a suite of synthetic seismograms for the 7/11-3x and 7/11-A5 wells, produced by E.McGuire (1981)[3]; these were tied to lines PGE 7/11-P and F respectively. Although a certain degree of ambiguity existed, the ties displayed in Enclosures 2 and 3 yielded the most satisfactory correlation. This implied that the properties of the basic wavelet approximated to the following:

(1) The signal frequency spectrum is 5/10-30/40 Hz

(2) The basic wavelet is zero phase.

(3) An isolated white trough is caused by a decrease in acoustic impedance.

The poor tie observed at the Danian level for the 7/11-3x well is thought to be due to the sonic log terminating just beneath the top of the Danian interval.

Using the remaining pertinent sub-surface control for the field, the top of the Cod Formation and the top of the Maastrichtian interval were identified over the whole survey area as black events, representing an increase in acoustic impedance. The top of the Danian interval was also correlated with a black event over a majority of the area, the western flank proving problematical due to a lack of continuity of the signal. This is thought to indicate that the Danian interval has a higher percentage of clastic material towards the west.

An example of this structural interpretation is displayed in Figure 1 along a portion of Line PGE 7/11 E in the region of the 1x well.

THEORETICAL SEISMIC RESPONSE TO LITHOLOGY

The integrated sonic logs for the 7/11-1x, 3x and A5 wells were filtered to match the bandwidth of the seismic data. This demonstrated that it was theoretically possible to obtain a resolvable seismic response to sand units greater than approximately 75 feet in thickness.

An understanding of the properties of the basic wavelet is imperative in determining what bed thicknesses it is theoretically possible to observe within the seismic data. For a zero-phase wavelet with a bandwidth of 5/10-30/40 Hz, an isolated sand unit (i.e. one with a very thick, lower acoustic impedance shale above and below) with a velocity of 11,000 feet per second would have a tuning thickness of 125 feet (23 msecs. two-way time). Beneath this thickness the amplitude of the event will decrease and will no longer be observable once the noise level has been reached.

Moving away from this near ideal case, if one considers a succession of sand and shale units of varying thicknesses, interference will create resolution problems well before the noise level becomes a major factor, assuming that the S/N ratio is adequately high. In order to establish the theoretical seismic response to the Cod sand units, the integrated sonic logs for the 7/11-1x, 3x and A5 wells were bandpass filtered to 5/10-30/40 Hz. These are displayed in Figures 2,3 and 4 respectively. For each well the lithologic column was simplified into units of shale, "mostly shale" and "mostly sand"; these are also displayed along with the unfiltered integrated sonic log.

All three filtered sonic logs indicate a response at the top of the Cod Formation. This is due to the increase in velocity going from the Eocene into the Paleocene aged sediments and is clearly more or less independent of the lithology. Hence the sand distribution at this level cannot be resolved seismically. The two thickest sand units in the 1x well appear as high velocity layers while the lower two thin units do not. Both thick sand units in the 3x well and three sand units in the A5 well also demonstrate discrete high velocity responses.

These results imply that a response should be observable on the seismic data for sand units of approximately 75 feet or thicker provided that:

(1) The basic wavelet is, or close to, zero-phase.

(2) The frequency spectrum of the signal is no narrower than 5/10-30/40 Hz.

(3) The noise level is minimal.

(4) Lateral variations in lithology are gradual enough such that Fresnel zone considerations are satisfied (i.e. the acoustic impedance boundaries are continuous over a sufficiently large area to adequately effect the wave front)

SYNTHETIC VELOCITY LOGS

Synthetic velocity logs were generated for three seismic lines but these proved to be unreliable because of poor correlation with sub-surface information.

The study conducted on filtered integrated sonic logs indicated that the utilisation of S.V.logs could provide a mechanism for the prediction of sand distribution. S.V. logs were generated in Bartlesville for Lines PGE 7/11E, J and P under the polarity determination achieved with the synthetic seismograms. A portion of line E is displayed in Figure 5 as an example. A discussion of S.V. logs is given in Appendix 1.

In order to check the reliability of these S.V. logs, the filtered sonic logs for the 1x and 3 wells were compared to lines E and P respectively.

No satisfactory correlation could be achieved. This meant that the S.V. logs could not be reliably interpreted. It is suggested that the major factor contributing to this conclusion is the rapid lateral variations in lithology. A particular lithologic column does not have sufficient spatial continuity to be seismically visible.

Although the S.V. logs do not provide reliable information within the complex Cod Formation, it is felt to be reasonable to make a few observations about the Danian and Pre-Tertiary intervals. An apparent low velocity zone can be observed within the Danian sediments along all three lines. Sub-surface control indicates this may be due to shale content rather than porosity. The chalk interval can be easily correlated to a high velocity zone on all the lines. The truncation of Pre-Cretaceous beds is clearly observable on the north-western end of line E.

SEISMIC ATTRIBUTES

In addition to S.V. logs, a suite of seismic attribute displays were generated; however, they yielded only a limited amount of information.

Hilbert Transform amplitude envelope, instantaneous frequency, instantaneous phase and apparent polarity displays were produced for lines E,J and P. A portion of line E is given as an example of each of these in Figures 6,7,8 and 9. A discussion on these seismic attributes is given in Appendix 1.

Although the reliability of these displays in the region of the Cod Formation is questionable, as with the S.V. logs, the following comments are considered to be valid.

Amplitude Envelope: Some high reflection strength anomalies exist within the Cod Formation; these are considered to be due to tuning phenomena as opposed to hydrocarbon content.

Instantaneous Frequency: No low-frequency shadow zones are apparent on any of the Instantaneous Frequency displays; their presence can be indicative of gas/gas condensate accumulations.

Some anomalous high frequencies can be seen within the Cod Formation, possibly due to thin beds and/or pinch outs of sand units.

Instantaneous Phase: These displays were assistive with the chronostratigraphic interpretation. The Cod Formation appears as a confused zone implying a lack of lateral continuity of lithology. The truncation of Pre-Cretaceous beds is again readily observable towards the north-western end of line E.

Apparent Polarity: A meaningless, random apparent lateral change in polarity is displayed throughout the Cod Formation. This is probably due to tuning phenomena created by the thinness of the beds and the relatively narrow bandwidth of the seismic data.

SUMMARY

A study of filtered integrated sonic logs yielded encouraging initial results, indicating that with seismic data, having a sufficiently high S/N ratio and broad frequency spectrum, the major Cod sand reservoir units should be observable on S.V. logs provided the lateral variations in lithology were not too rapid. Unfortunately, the geology of the Cod Formation proved to be too complex for sand distribution to be predicted via S.V. logs without first acquiring seismic data with a substantially broader frequency spectrum. Not only would this increase the vertical resolution of the data but the higher dominant frequency would narrow the Fresnel zone and hence the data would have increased lateral resolution. The remaining seismic attribute displays yield limited information about bedding and possess no indicators of hydrocarbon content.

REFERENCES

(1) Kessler L.G. - Stratigraphy and Sedimentology of a Paleocene Submarine Fan Complex, Cod Field Norwegian North Sea. 1978

(2) Coxen A.L. - Hydrodynamic Analysis of the Cod Sand and Danian Lime Sections, Cod Field, North Sea, Norway. 1978

(3) McGuire E. - Synthetic Seismogram Reports, Cod 7/11-3x and A5. 1981

APPENDIX 1

SEISMIC ATTRIBUTE DISPLAYS -

A SUMMARY

R P MOTT
MARCH, 1980

Synthetic Velocity Logs (CLRVLOG)

Modern seismic reflection data may be carefully data processed to produce seismic sections which closely approximate the reflection coefficient series of a sedementary section. The inversion of the series of reflection coefficients produces a low-cut filtered acoustic impedence log. Applying additional corrections for the replacement of missing low-frequency components and the effects of density variations produces a synthetic velocity log for each original seismic trace.

On a CLRVLOG the vertical and horizontal variation in seismic-derived velocities are displayed by colour variations. The vertical scale on a CLRVLOG is the seismic two-way travel time. The traces on a CLRVLOG are the original seismic wiggle-traces. Additional black and white displays are available on which wiggle-traces represent velocity logs or sonic logs as a function of time or depth.

The constancy and reliability of synthetic velocity logs permits a new technique of seismic interpretation based on the direct measurement of quantative differences occurring on synthetic velocity-log data. Velocity variations observed on velocity logs derived from seismic data can be interpreted to determine subsurface lithologies, porosities, pore-fluid contents (direct hydrocarbon indicator), pressures and environments of deposition. Synthetic velocity logs have the additional benefit of acting as an excellent communication device to bridge the gap between the geologist's sonic logs and the geophysicist's seismic sections.

Hilbert Transform Amplitude Envelope (CLRENVL)

The complex trace consists of a real part which is the recorded seismic trace and an imaginary part which is the Hilbert transform of the real part. If the real part is x (t) and the imaginary part is y (t) then, an amplitude quantity a (t) can be calculated for every sample point as

$$a(t) = \sqrt{x^2(t) + y^2(t)}$$

The amplitude is <u>not</u> simply the magnitude of the real seismic trace. Maximum amplitudes do not necessarily coincide with the maximum amplitudes of the original recorded seismic trace. The amplitude function of the complex trace is a measure of the total energy involved in a seismic reflection response including both kenetic and potential energies. On a CLRENVL display, the amplitude of the complex trace is displayed as variations in colour from magenta for the strongest events to pale blue for the weakest. Each colour change on the colour scale repersents a logarithmic increase or decrease in amplitude usually in 1 db steps. The vertical axis on CLRENVL is two-way seismic time. The traces on CLRENVL are the original variable area seismic traces.

High amplitude-envelopes are often associated with gas accumulation particularly where trapping conditions are favourable. Strength of reflections from unconformities may vary as subcropping beds change. Reflection strength measurements can aid in the lithologic identification of subcropping beds if it can be assumed that deposition is constant above the unconformity. Gradual lateral changes in reflection strength over large distances my be attributed to changes in the interference of closely spaced reflections. This may serve as an indicator of bed thickness variations. Abrupt changes in strength may indicate faulting or hydrocarbon accumulations.

Hilbert Transform Instantaneous Frequency and Weighted Intantaneous Frequency (CLRMFREQ)

The construction of a complex trace, consisting of the real componant from the recorded seismic trace and the imaginary component from the Hilbert transform of the real componant, permits the calculation of a instantaneous frequency at each sample point of the complex trace. Instantaneous frequency is defined at the "rate of change of the phase" and therefore can be calculated by taking the derivative of the phase with respect to time. Therefore the calculation of instantaneous frequency function (w (t)) can be written, $w(t) = \frac{d\,\emptyset(t)}{dt}$

On CLRMFREQ plot, a time section is displayed with colours indicating variation in the frequency content of the seismic signal. The colour assigned to a sample is determined by comparing the instantaneous frequency for the sample against the mean frequency of all the input traces. There are 17 colours in the colour scale, with reds representing the highest frequencies, yellows representing intermediate frequencies and greens representing low frequenies. The frequency increment covered by each colour change can be varied from 0.5 Hz. to 4 Hz. Eight colours are assigned to frequencies greater than the mean frequency and eight colours are assigned to frequencies less than the mean frequency. The frequencies can be smoothed to temper unrealistically high frequencies which are occasionally a artifact of the instaneous frequency calculation. The traces on a CLRMFREQ display are the original variable area seismic traces.

Instantaneous frequency displays often provide a useful correlation tool. In general the frequency character of composite reflections, made of a number of closely spaced reflectors will change gradually as the sequence of layers gradually changes in thickness or lithology. Rapid lateral variations in instaneous frequency are usually attributable to pinchouts and edges of hydrocarbon-water interfaces. A shift toward lower frequencies ("low - frequency shadow") is often observed on reflections beneath gas sands, condesate, and oil reservoirs. The mechanism for this low-frequency shift has not been adequately explained. Fracture zones in brittle rocks are also sometimes associated with low-frequency shadows. Although generally not displayed, negative frequency values and values greater than Nyguist frequency may be indicators of wavelet interference or overlapping. Therefore these anomalous frequencies may prove useful in defining pinchouts and onlaps along unconformities.

Hilbert Transform Instantaneous Phase (CLRPHASE)

The conventional seismic trace can be viewed as the real componant of a complex trace. The Hilbert transform can be utilized to generate the imaginary component (quadrature trace) of the complex trace from the actual seismic trace. Together both components define a continuous time function of complex numbers, the complex trace.

The instantaneous phase (Ø) is calculated by the usual method used to define the phase angle associated with complex numbers

$$\text{Ø}(t) = \tan^{-1} \frac{\text{Imaginary part of complex number}}{\text{Real part of complex numbers}}$$

This calculation is performed at each point of the complex trace yielding a continuous measurement of the phase angle. Although the phase function increases monotomically with reflection time, the plotted function is restricted to angles from -180° to $+180^{\circ}$. This creates a sawtooth-type appearance which is a convenient display format for interfacing phase plots with the original seismic wiggle trace. On CLRPHASE plots, the phase angles from -180° to -60° are magenta, the angles from -60° to $+50^{\circ}$ are yellow, and angles from $+50^{\circ}$ to $+180^{\circ}$ are blue. The vertical axis on CLRPHASE plots is two-way seismic time while the wiggly trace is the original seismic trace.

Because phase in independant of reflection strength, it makes weaker coherent reflections clearer to interpret. Phase displays are effective in showing discontinuities, faults, pinchouts, angularities and events with different dip attitudes. Prgrading sedimentary layer patterns and regions of off-lap and on-lap often show with particular clarity on phase displays which serves as an important aid to seismic stratigraphic analysis.

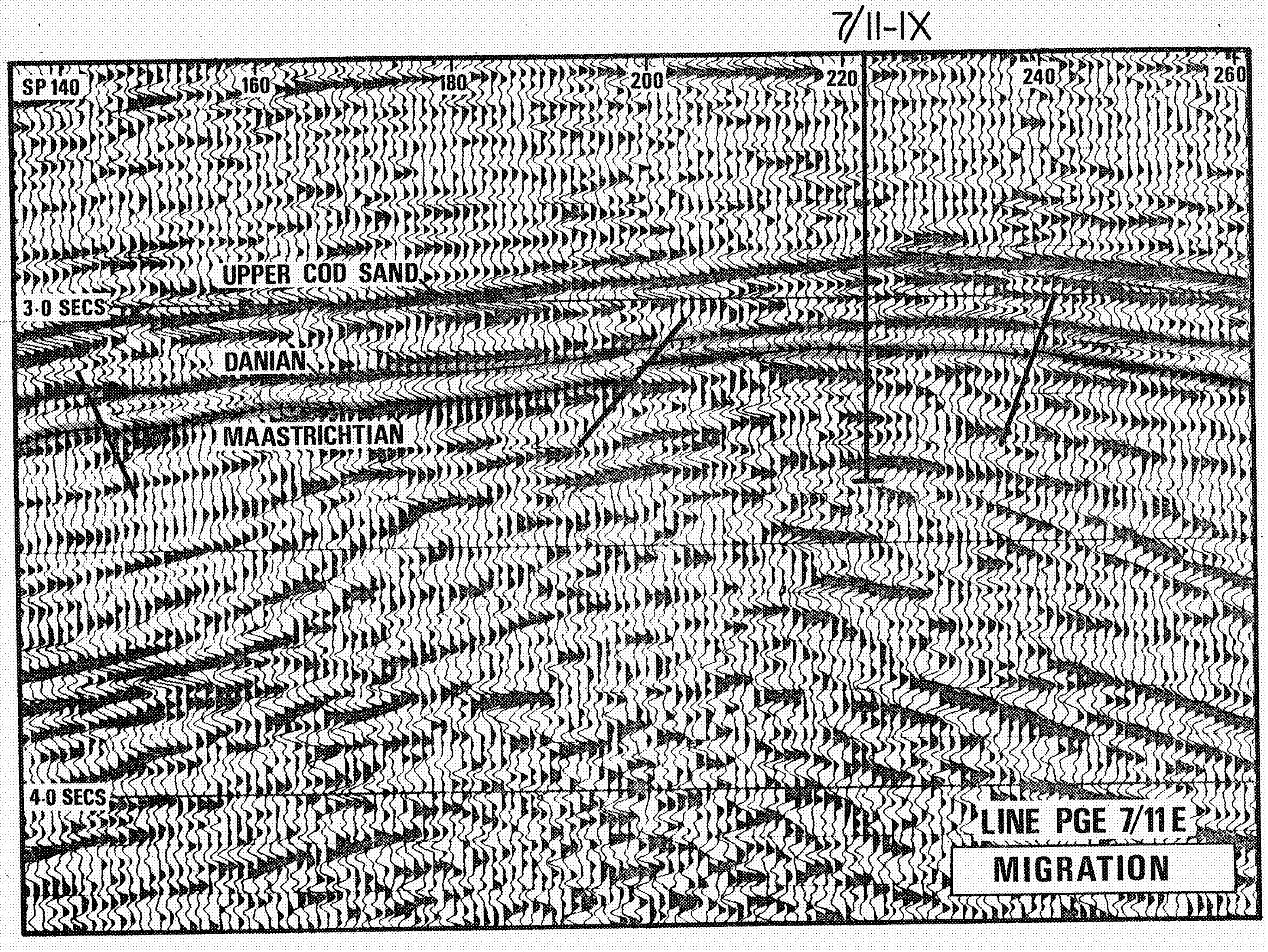
Hilbert Transform Apparent Polarity (CLRPOLAR)

The data window between two successive minima on the amplitude envelope function of the complex seismic trace defines a single reflection event called a reflection "wave packet". The wave packet may be a reflection from a single interface, or it may be a composite of several reflections. Once a reflection packet is defines, the polarity of the event is defined as the algebraic sign of the reflection leg nearest the amplitude maxima of the packet. On a CLRPOLAR display, the colour on the time section represents the polarity of the events. The blue colour represents a negative reflector and the magenta colour is assigned to positive polarities. The intensity of colours represents the confidence in polarity assignment and white areas representing totally unreliable polarity determinations.

Apparent polarity measurements are expecially sensitive to data quality. The analysis of apparent polarity assumes an isolated single reflector, a zero-phase wavelet, and no ambiquity in the polarity of the original seismic data. Since most reflection events are composites of several reflections, polarity often lacks a clear correlation to the sign of a reflection coefficient. Polarity sometimes distinguishes between bright spots associated with gas-filled and reserviors and those associated with occasional limestone stringers. Bright spots associated with gas-filled clastic reservoirs usually display a negative polarity reflector at the top of the reservoir and positive reflection from gas-oil or gas-water interface (flat-spots).

GEOLOGICAL INDICATIONS BY SEISMIC PARAMETERS

	Phase	Reflection Strength	Polarity	Frequency
STRUCTURAL FEATURES				
Correlation	emphasizes continuity of weak events			
Unconformities	angularities show well	often strong and variable		
Faults	show clearly	pattern helps correlation across fault		
STRATIGRAPHIC FEATURES				
Major breaks in section	show on-lap, off-lap patterns	often strong; nature of contrast may indicate clastic to carbonate or vice-versa		moderately low frequency
Pinchouts	often show clearly	variation in pattern		
Prograding	often show clearly			
Turbidites	local irregular mound pattern			
Reefs	local pattern	interruption in patterns, lower frequency		
FLUID CONTENT				
Gas		often strong	often negative	low frequency shadow underneath
Condensate		some increase		sometimes low frequency shadow
Flat Spot	shows clearly		positive	
Limits to Production				change in pattern
Distinguish gas from lime buildup, conglomerate, etc.		sometimes distinctive	sometimes distinctive	


7/11-1X
SP 140
160
180
200
220
240
260
UPPER COD SAND
3·0 SECS
DANIAN
MAASTRICHTIAN
4·0 SECS
LINE PGE 7/11E
MIGRATION

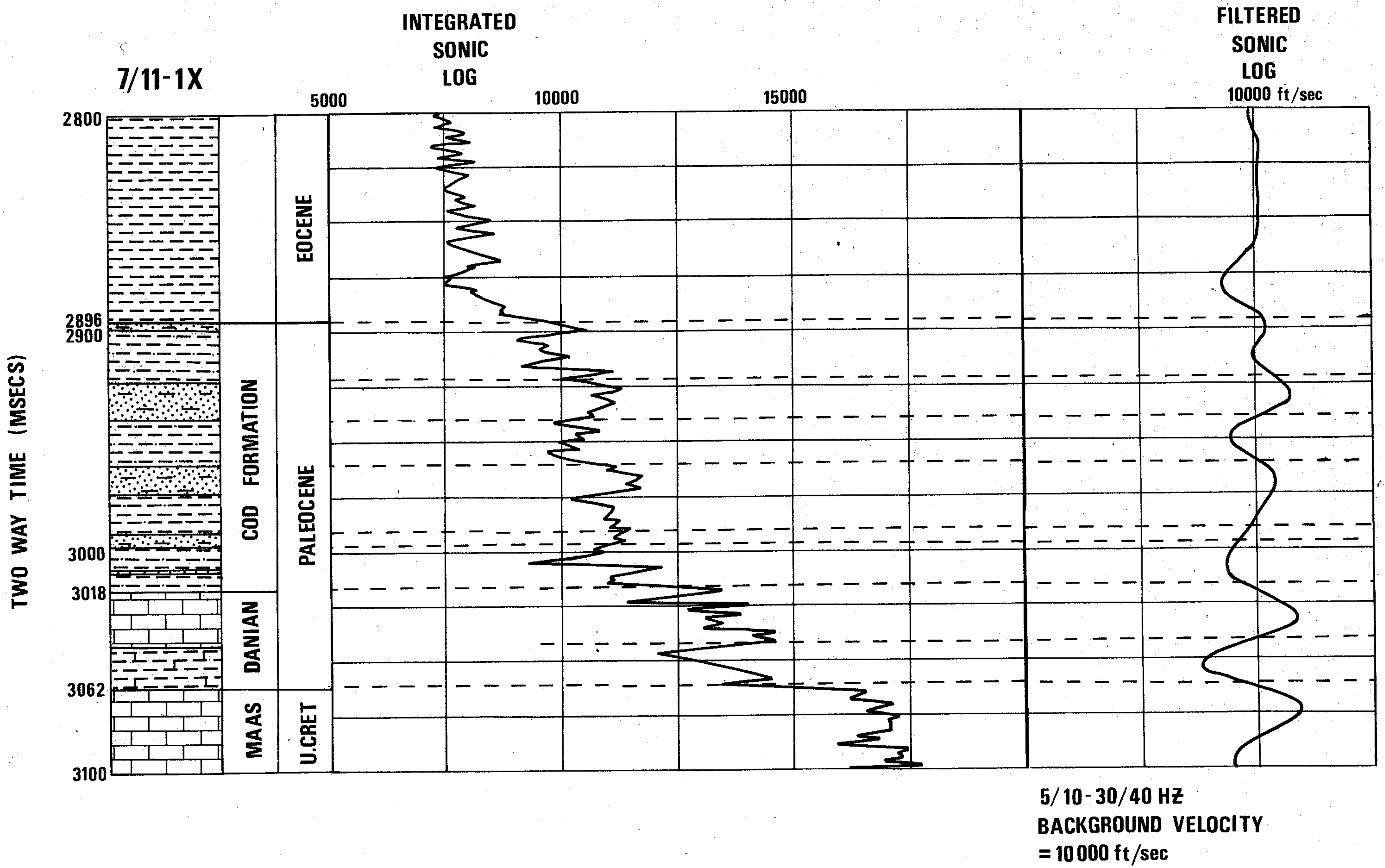

7/11-1X
INTEGRATED SONIC LOG
FILTERED SONIC LOG
5000
10000
15000
10000 ft/sec
TWO WAY TIME (MSECS)
2800
2896
2900
3000
3018
3062
3100
EOCENE
COD FORMATION
PALEOCENE
DANIAN
MAAS
U.CRET
5/10-30/40 HZ
BACKGROUND VELOCITY
= 10000 ft/sec

FIG.2

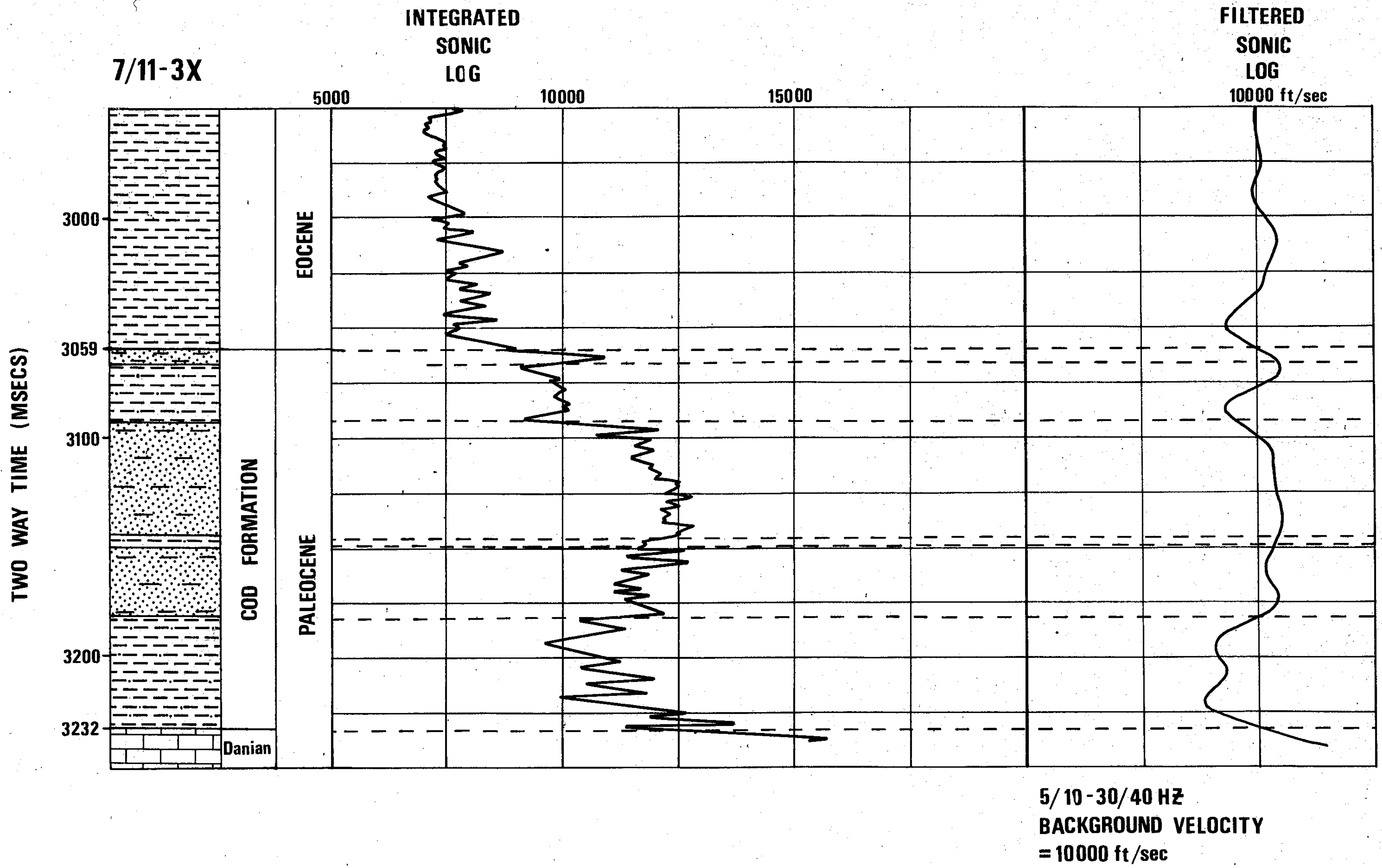
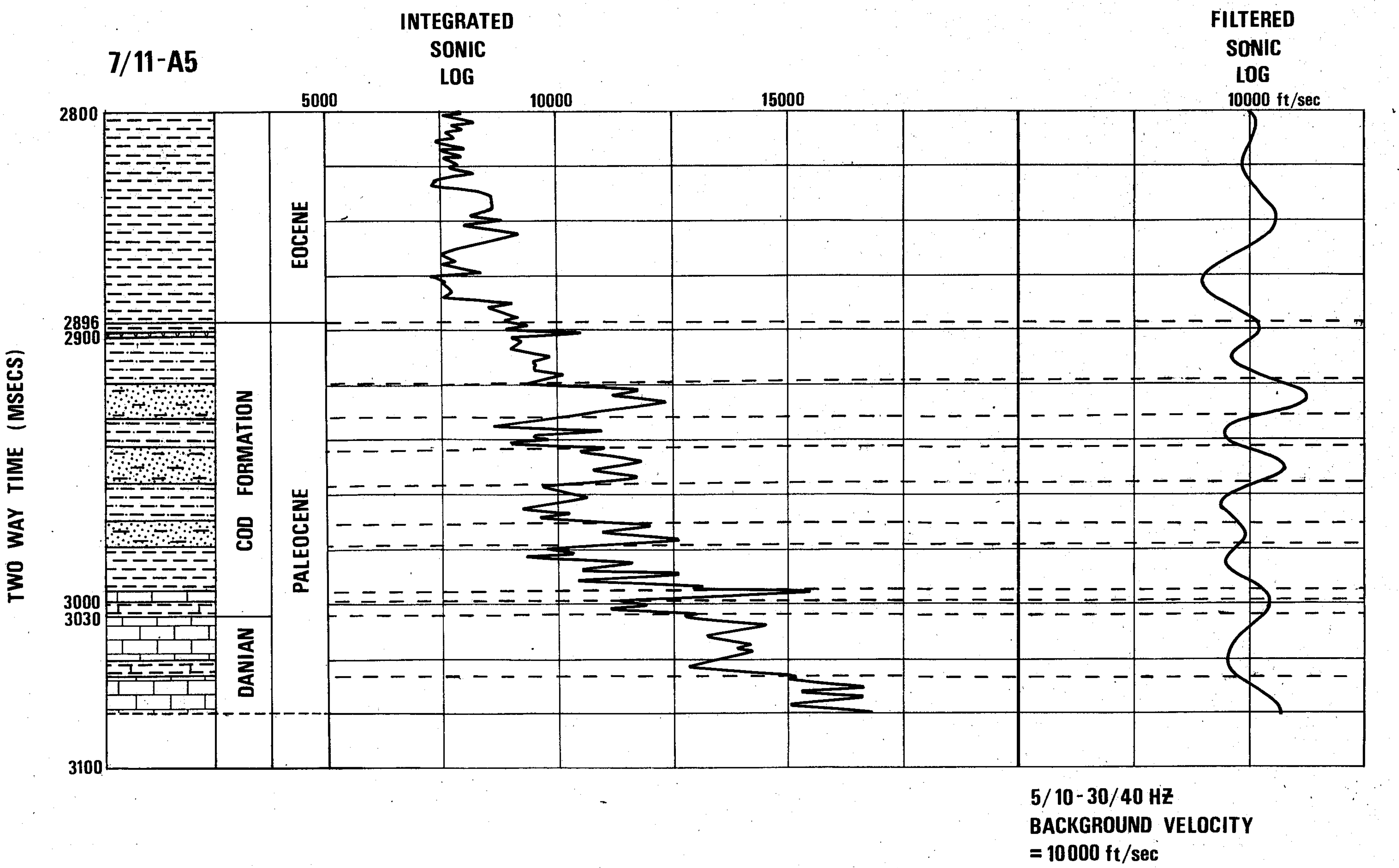
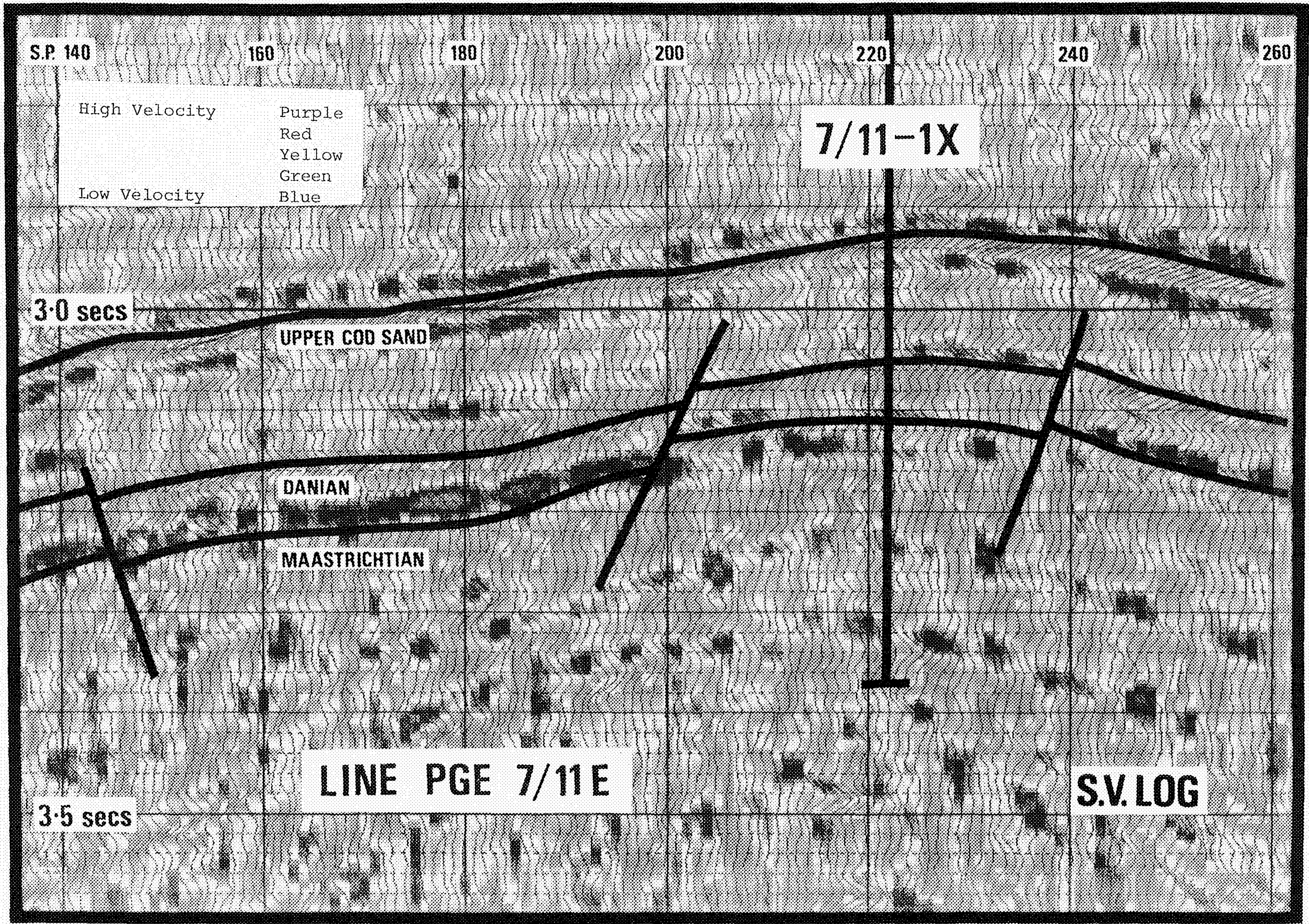

7/11-3X
INTEGRATED SONIC LOG
FILTERED SONIC LOG
5000
10000
15000
10000 ft/sec
TWO WAY TIME (MSECS)
3000
3059
3100
3200
3232
EOCENE
PALEOCENE
COD FORMATION
Danian
5/10-30/40 HZ
BACKGROUND VELOCITY
=10000 ft/sec

FIG.3

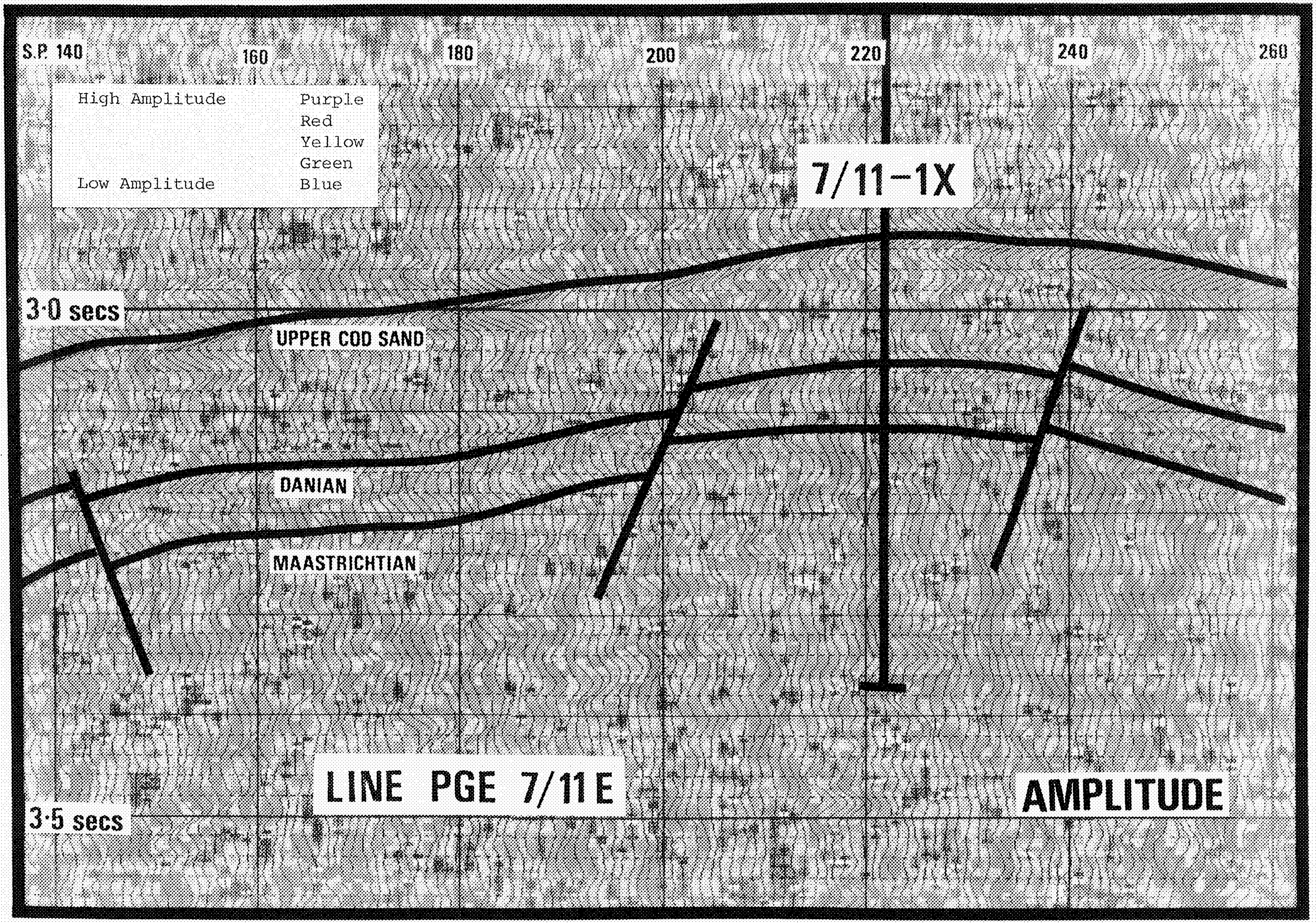


7/11-A5
INTEGRATED SONIC LOG
FILTERED SONIC LOG
5000
10000
15000
10000 ft/sec
2800
2896
2900
3000
3030
3100
TWO WAY TIME (MSECS)
EOCENE
COD FORMATION
PALEOCENE
DANIAN
5/10-30/40 HZ
BACKGROUND VELOCITY
= 10000 ft/sec

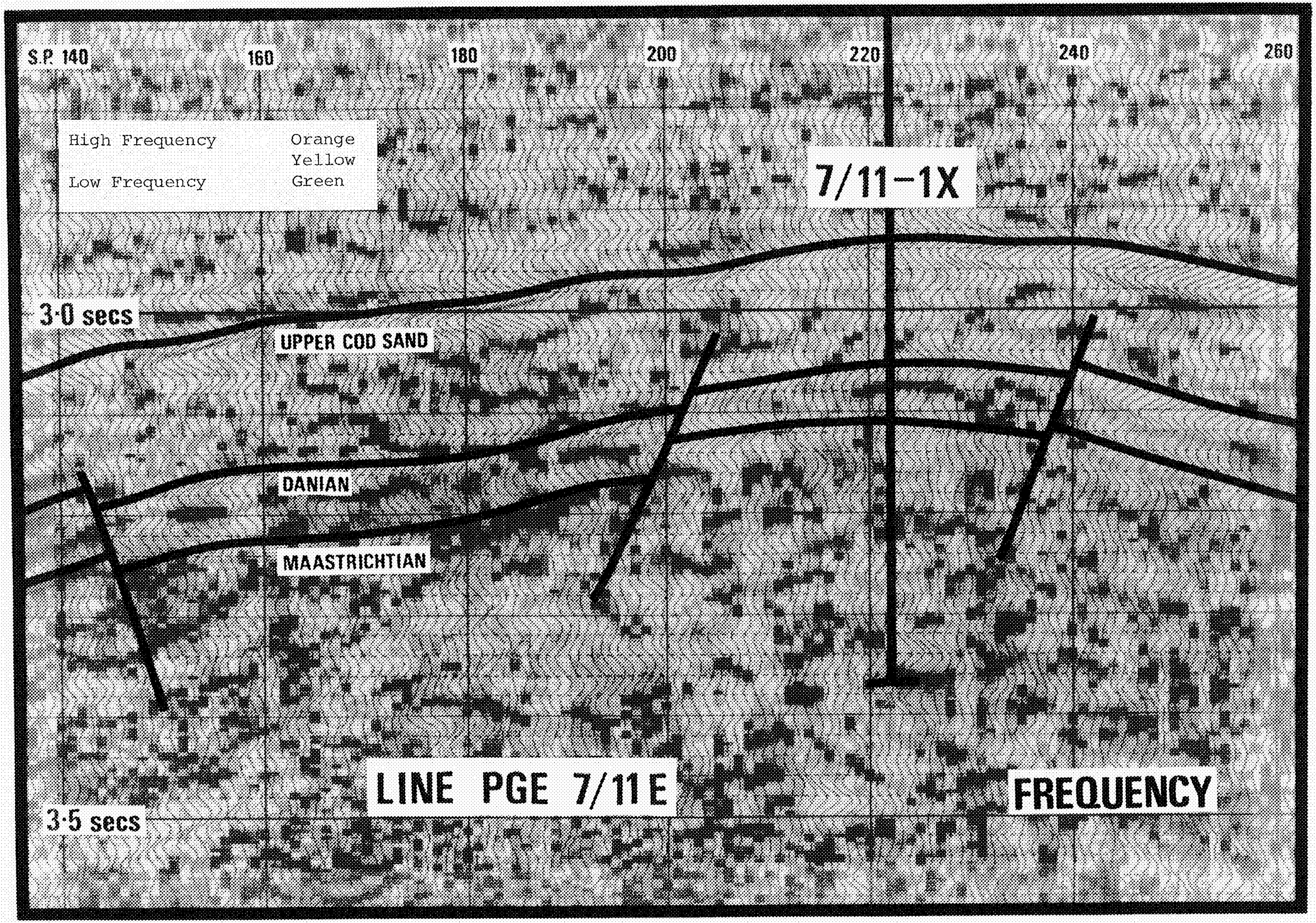
FIG.4

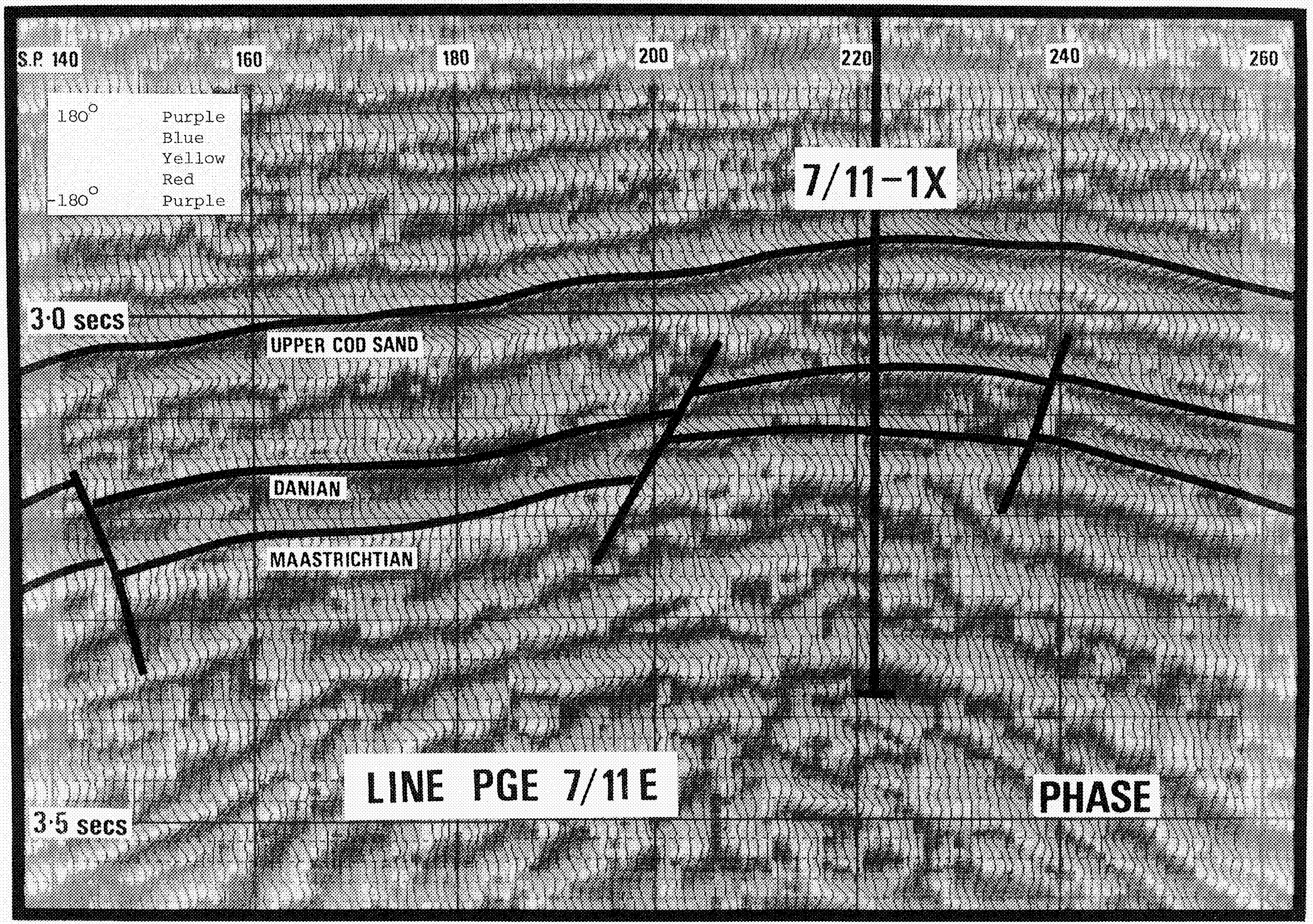


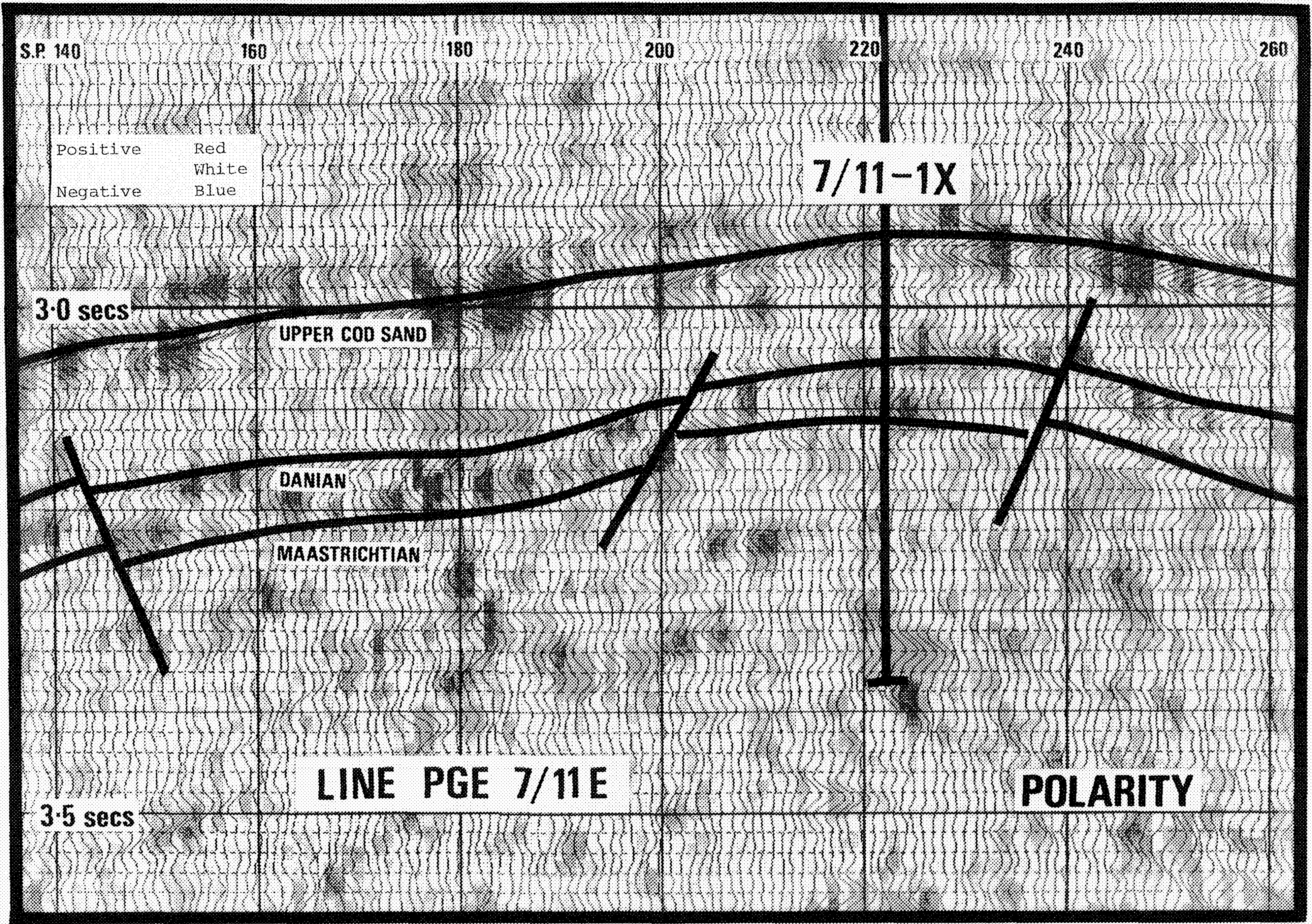
S.P. 140
160
180
200
220
240
260
High Velocity
Low Velocity
Purple
Red
Yellow
Green
Blue
7/11-1X
3·0 secs
UPPER COD SAND
DANIAN
MAASTRICHTIAN
LINE PGE 7/11 E
S.V. LOG
3·5 secs



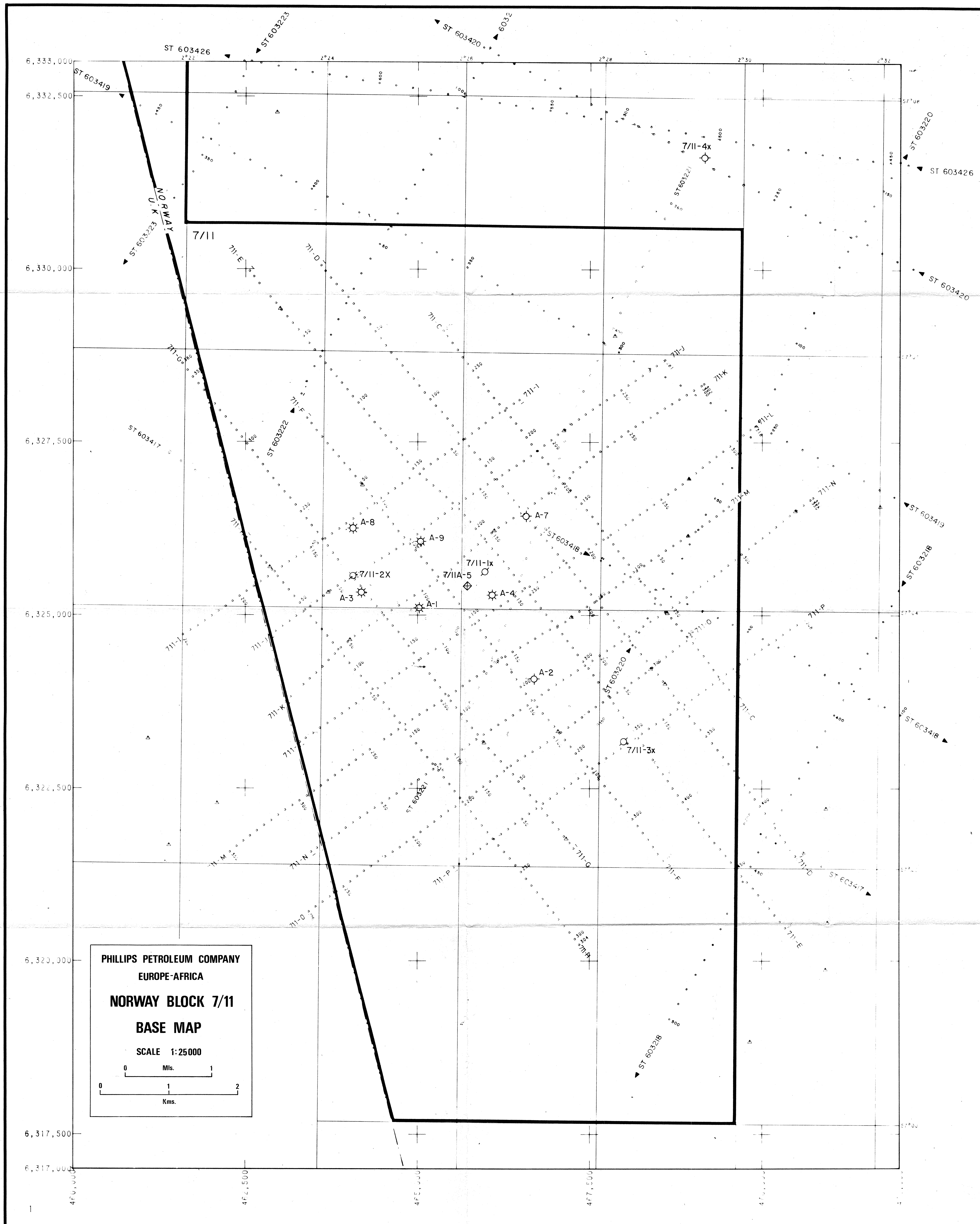
S.P. 140
160
180
200
220
240
260
High Amplitude
Low Amplitude
Purple
Red
Yellow
Green
Blue
7/11-1X
3·0 secs
UPPER COD SAND
DANIAN
MAASTRICHTIAN
LINE PGE 7/11 E
AMPLITUDE
3·5 secs


S.P. 140
160
180
200
220
240
260
High Frequency
Orange
Yellow
Low Frequency
Green
7/11-1X
3·0 secs
UPPER COD SAND
DANIAN
MAASTRICHTIAN
3·5 secs
LINE PGE 7/11 E
FREQUENCY


S.P. 140
160
180
200
220
240
260
180°
Purple
Blue
Yellow
Red
-180°
Purple
7/11-1X
3·0 secs
UPPER COD SAND
DANIAN
MAASTRICHTIAN
LINE PGE 7/11 E
PHASE
3·5 secs

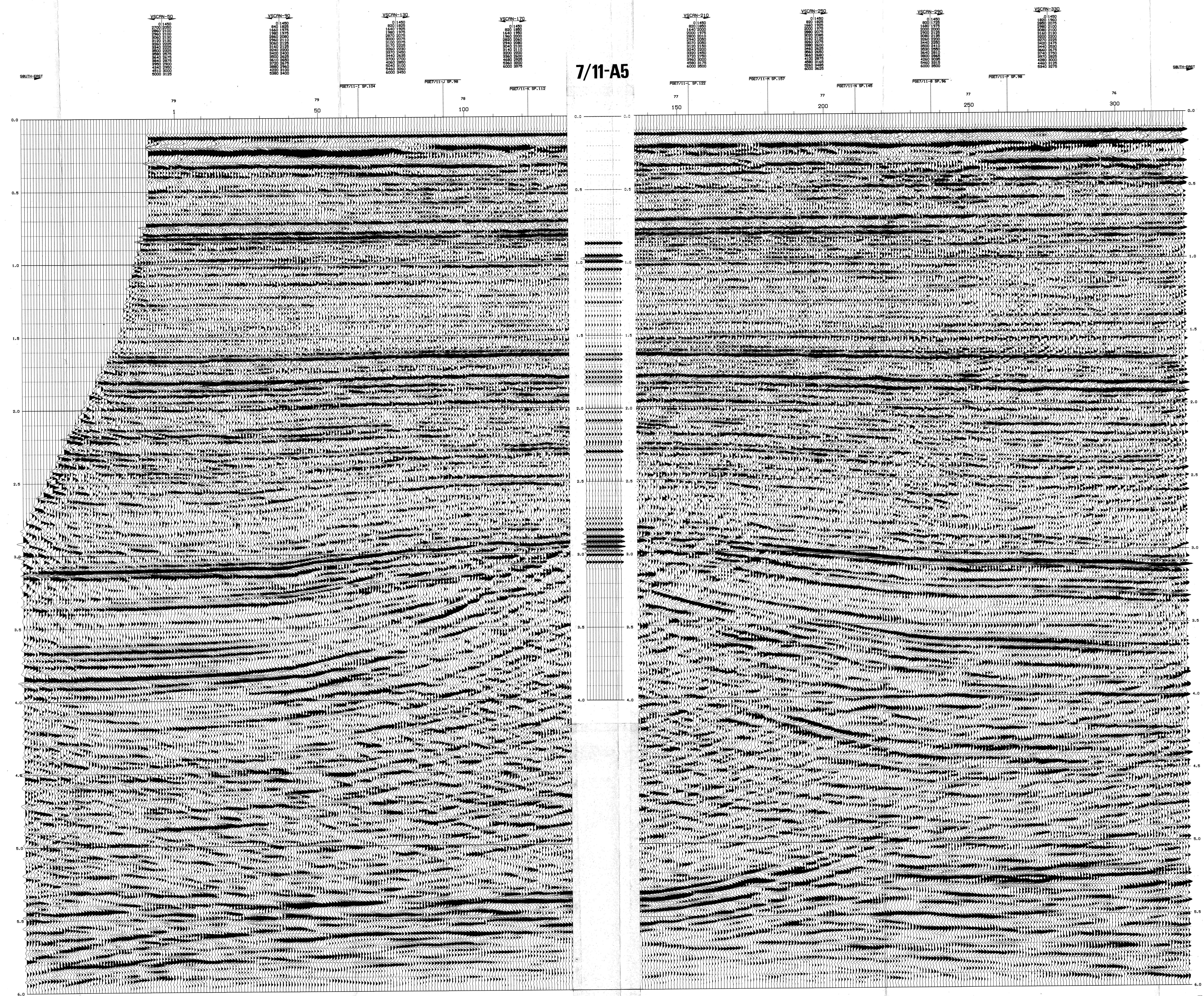


S.P. 140
160
180
200
220
240
260
Positive Red
White
Negative Blue
7/11-1X
3·0 secs
UPPER COD SAND
DANIAN
MAASTRICHTIAN
LINE PGE 7/11 E
3·5 secs
POLARITY



PHILLIPS PETROLEUM COMPANY
EUROPE-AFRICA
NORWAY BLOCK 7/11
BASE MAP
SCALE 1:25000
0 Mls. 1
0 1 2 Kms.
7/11
NORWAY
U.K.
7/11-4x
7/11-1x
7/11-2X
7/11-3x
7/11A-5
A-1
A-2
A-3
A-4
A-7
A-8
A-9
ST 603426
ST 603223
ST 603420
ST 603419
ST 603220
ST 603417
ST 603222
ST 603418
ST 603221
ST 603218
6,333,000
6,332,500
6,330,000
6,327,500
6,325,000
6,322,500
6,320,000
6,317,500
6,317,000

PHILLIPS PETRØLEUM CØMPANY NØRWAY LINE PGE 7/11-F STNS 1 TØ 330



LINE DIRECTIØN

VELØCITY FUNCTIØN (METERS/SEC)

DIRECTIØN

LINE INTERSECTIØN

WATER DEPTHS (METERS) [redacted]

STATIØNS

PHILLIPS PETROLEUM EUROPE/AFRICA

LONDON SEISMIC DATA PROCESSING CENTRE

LINE: PGE 7/11-F

AREA: CØD STNS: 1 TØ 330
BLØCK: NØ 7/11 SHØT: NW - SE
PRØC: D.A.S. + FILTER + A.G.C.
FREQ. DØMAIN MIGRATIØN

INPUT REEL HEADER INFØRMATIØN

REEL NUMBER	C98-D
DATE CREATED	01/15/79
NUMBER SAMPLE/TRACE	1500
SAMPLE RATE IN MILLS	4.00
PRØCESSØR	
LINE NUMBER	
JØB NUMBER	9999
SECTIØN NUMBER	0012
PRØCESSING STEP	0020

FIELD INFØRMATIØN

RECØRDED BY:	GECØ A/S	SØURCE:	AIRGUN ARRAY
VESSEL:	M/V LØNGVA	GUN DEPTH:	7.5 METRES
DATE SHØT:	30TH NØVEMBER 1976	NØ. GUNS:	13
S.P.SPACING:	25 METRES		
NAVIGATIØN:	SAT. NAV.	CAPACITY:	3600 CU.INS.
INSTRUMENT:	DFS IV	CABLE:	TI/NAC
FILTERS LØW:	8 HZ/18 DB/ØCT	LENGTH:	2400 METRES
HIGH:	124 HZ	DEPTH:	12 TØ 14 METRES
RECØRD LGTH:	6 SECØNDS	GRØUPS:	48(ØF 30 PHØNES)
SAMPLE RATE:	2 MSECS	INTERVAL:	50 METRES
TAPE FØRMAT:	9 TRACK (SEG-C)	NR. ØFFSET:	REPØRTED 253 METRES

PRØCESSING SEQUENCE

DATA PRØCESSED THRØUGH TØ STACK BY GEØSØURCE U.K. LTD.
PØST STACK PRØCESSING AND ANALYSIS ØF VELØCITIES BY PHILLIPS PETRØLEUM CØMPANY NØRWAY.

DEMUX:- DEMULTIPLEX INTØ MULTIPLEX-1 FØRMAT AND RESAMPLING TØ 4 MSECS SAMPLE RATE WITH ANTI-ALIAS FILTER ØF ØUT - 62/100 HZ. APPLIED.

SCALE:- APPLYING GAIN RECØVERY USING THE CURVE:
GAIN(DB) = 0.1*T + 30LØG(T) + 85.00

SØRT:- TØ GATHER DATA INTØ DEPTH PØINT ØRDER AND APPLYING + 16 MSECS GUN AND CABLE STATIC.

VELSTK:- VELØCITY ANALYSIS EVERY 1000 METRES USING CØNSTANT VELØCITY SCANS. THE DATA WAS FILTERED AND DECØNVØLVED BEFØRE VELØCITY ANALYSIS.
(VSCAN-24C-6CDP-HIST-AGWS-NØ)

DECØN:- TIME DØMAIN DECØNVØLUTIØN BEFØRE STACK USING TWØ 160 MSECS ØPERATØRS WITH A PREDICTIVE LAG EQUAL TØ THE SECØND ZERØ CRØSSING (APPRØX: 32 MSECS).
THE ØPERATØR LENGTH IS THAT ØF THE AUTØCØRRELØGRAM, AND 0.5% WHITE NØISE IS ADDED IN THE ØPERATØR CALCULATIØN.
DESIGN WINDØWS: 500 - 3000 + 2500 - 5000 (NEAR TRACE)
2500 - 4000 + 3000 - 5000 (FAR TRACE)

STACK:- 2400% CDP STACK CØRRECTED TØ SEA LEVEL.
VELØCITIES INTERPØLATED BY ISØVELØCITY BETWEEN SPECIFIED FUNCTIØNS, BUT BECAUSE ØF SØFTWARE LIMITATIØNS SØME V/T PAIRS IN THE SHALLØW SECTIØN ARE NØT DISPLAYED.
TRACE MUTES ARE APPLIED AFTER N.M.Ø.

DECØN:- TIME DØMAIN DECØNVØLUTIØN AFTER STACK USING TWØ 160 MSECS ØPERATØRS WITH PREDICTIVE LAGS EQUAL TØ THE SECØND ZERØ CRØSSING (APPRØX 40 MSECS), AND WITH A MAXIMUM ØF 50 MSECS. THE ØPERATØR LENGTH IS THAT ØF THE AUTØCØRRELØGRAM, AND 0.5% WHITE NØISE IS ADDED IN THE ØPERATØR CALCULATIØN.
DESIGN WINDØWS: 800 - 2600 + 2600 - 5900 MSECS
APPLY WINDØWS: 0 - 2600 + 2600 - 6000 MSECS
WITH A 200 MSECS ØVERLAP ZØNE.

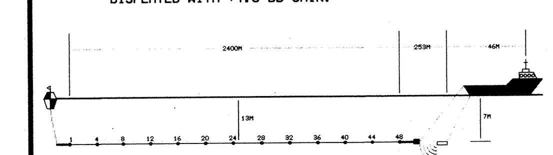
FILTER:- BANDPASS FILTER USING A 400 MSECS ØPERATØR WITH CUT-ØFF FREQUENCIES ØF 3/8 - 50/55 HERTZ.

FREEDØM:- FREQUENCY DØMAIN MIGRATIØN USING STACKING VELØCITIES WITH A 500 MSECS TIME SMØØTHING AND A 150 TRACE SPATIAL SMØØTHING FACTØR.
ALPHA = 100
BETA = 100
FRMAX = 650

FILTER:- BANDPASS FILTER USING CUT-ØFF FREQUENCIES ØF 3/8 - 45/65 HERTZ.

A.G.C.:- AUTØMATIC GAIN CØNTRØL USING A 1000 MSECS WINDØW AND A 25% THRESHØLD LEVEL.

SSD:- PHØTØDØT PRESENTATIØN
HØRIZØNTAL SCALE: 12.7 TR/INCH (1:12500)
VERTICAL SCALE: 10 CM/SEC
TRACE SPACING: 25 METRES
A CØMPRESSIØNAL WAVE IS RECØRDED AS A NEGATIVE NUMBER ØN TAPE AND IS DISPLAYED AS A WHITE PULSE.
SHØT PØINTS ARE ANNØTATED AT ANTENNA PØSITIØNS.
DISPLAYED WITH +4.5 DB GAIN.



****** FILMING PARAMETERS ******

PERCENT GAIN	168
HØRIZØNTAL SCALE	12.700 TR/IN
VERTICAL SCALE	10.000 CM/SEC
FILMING DIRECTIØN	LTØR
PERCENT BAR	0
PØLARITY	BLACK=PØSITIVE
DATE FILMED	01/21/80

DATA PRØCESSED BY
PHILLIPS E/A SDPC

SYNTHETIC SEISMOGRAM

7/11-A5

ZERO PHASE

5/10-30/40 HZ BANDPASS

LEVELLED 1000 ms WINDOW

PHILLIPS PETRØLEUM CØMPANY

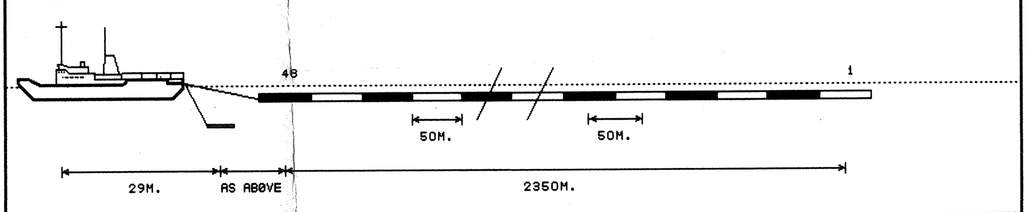
LINE PGE 7/11P [redacted]

NØRWAY N. SEA BLØCK 7/11 CØD PRØSPECT
STNS. 1 TØ 248
TVDBS - STK - TVDAS - FILT - MIGRATIØN - FILT -AGC
EQUALISED MIGRATIØN

PETTY-RAY LØNDØN DATA PRØCESSING CENTRE

GEOSOURCE

RECØRDING PARAMETERS		RECØRDING GEØMETRY	
RECØRDED BY	GECØ PARTY 101	SØURCE	AIRGUN ARRAY
VESSEL	M.V. LØNGVA	SØURCE CAPACITY	3600 CU.IN.
DATE SHØT	24TH NØVEMBER 1976	SØURCE PRESSURE	2000 P.S.I.
SHØØTING DIRECTIØN	54 DEGREES	NØ. ØF GUNS	13
NAVIGATIØN PRIMARY	MAGNAVØX SAT. NAV.	PØP INTERVAL	25 M
SECØNDARY	DECCA	FØLD	4800%
ANTENNA - BØAT STERN	29 M	SØURCE DEPTH	7.5 M
STATIØN INTERVAL	25 M	CABLE DEPTH	14 M
LØCATIØN	ANTENNA PØSITIØN	CABLE LENGTH	2400 M
INSTRUMENT	DFS 4	CABLE TYPE	TI/NAC
LØW CUT FILTER	8 HZ	GRØUP INTERVAL	50 M ALL LIVE
SLØPE	18 DB/ØCT	NØ. GEØPHØNE GRØUPS	48
HIGH CUT FILTER	124 HZ	NUMBER PER GRØUP	30
TAPE FØRMAT	SEG-C	ØFFSET (GUN-CH.48)	220 M - REPØRTED
SAMPLE INTERVAL	2 MS	WTR-BRK/DPTH TRANS	
RECØRD LENGTH	6 SECS	BETWEEN SECTIØNS	S/48,41/40,31/30,21/20,11/10,4/S
RECØRDING PØLARITY	CØMPRESSIØN = NEGATIVE NUMBER		
GAIN CØNSTANT	30 DB		



PRØCESSING SEQUENCE

1. DEMULTIPLEX TØ PETTY-RAY MULTIPLEX-1 FØRMAT.
2. RESAMPLE TØ 4 MS RATE.
3. GAIN RECØVERY USING THE FØLLØWING SYNTHETIC GAIN CURVE : GAIN(DB) = 0.10T + 30 + LØG(10)T - 15
4. ANTI-ALIAS ØRMSBY TYPE LØWPASS FILTER ØF 200 MS LENGTH WITH 0 DB AND 34 DB DØWN PØINTS AT 62,100 HZ.
5. CØMMØN DEPTH PØINT SØRT WITH 16 MS BULK STATIC TØ CØMPENSATE FØR DEPTH ØF GUN AND CABLE.
6. TIME DØMAIN DECØNVØLUTIØN BEFØRE STACK USING TWØ 160 MSECS ØPERATØRS WITH PREDICTIVE LAGS EQUAL TØ THE SECØND ZERØ CRØSSING (APPRØX: 48 MSECS).THE ØPERATØR LENGTH IS THAT ØF THE AUTØCØRRELØGRAM AND 0.5% WHITE NØISE IS ADDED IN THE ØPERATØR CALCULATIØN.

ØPERATØR (MS)	PRED (MS) INCLUSIVE	DESIGN WINDØW (MS) TR.1	DESIGN WINDØW (MS) TR.48	APPLY WINDØW (MS) TR.1	APPLY WINDØW (MS) TR.48
160	2ND ZERØ (48)	2500-4000	500-3000	0-3000	0-2500
160	2ND ZERØ (48)	3000-5000	2500-5000	3000-5000	2500-5000

7. VELØCITY ANALYSIS EVERY 1 KM.
   VELSTACK ANALYSIS ØF 24 VELØCITY/TIME CURVES CARRIED ØUT ØVER 40 MSEC. WINDØWS WITH 20 MSEC. ØVERLAP.
   VELØCITY ANALYSIS PICKED BY PHILLIPS PETRØLEUM.
   (VSCAN-24C-6CDP-HIST-AGWS-NØR)
8. 4800% CDP STACK CØRRECTED TØ SEA LEVEL WITH VELØCITIES INTERPØLATED BY ISØTIME BETWEEN SPECIFIED FUNCTIØNS. (SØME SHALLØW V/T PAIRS ARE ØMITTED DUE TØ SØFTWARE LIMITATIØNS IN THE DISPLAY PRØGRAM.) TRACE MUTES APPLIED AS DETAILED BELØW AFTER N.M.Ø. CØRRECTIØN.
9. TIME DØMAIN DECØNVØLUTIØN AFTER STACK USING TWØ 160 MSECS ØPERATØRS WITH PREDICTIVE LAGS EQUAL TØ THE SECØND ZERØ CRØSSING (APPRØX: 48 MSECS).THE ØPERATØR LENGTH IS THAT ØF THE AUTØCØRRELØGRAM AND 0.5% WHITE NØISE IS ADDED IN THE ØPERATØR CALCULATIØN.

ØPERATØR (MS)	PRED (MS) INCLUSIVE	DESIGN WINDØW (MS)	APPLY WINDØW (MS)
160	2ND ZERØ (48)	800-2800	0-2600
160	2ND ZERØ (48)	2600-4800	2600-6000

10. ØRMSBY TYPE BANDPASS FILTER : 3,8,50,65 HZ ØF 400 MS LENGTH WITH CUT-ØFF FREQUENCIES 34 DB DØWN.
11. WAVE EQUATIØN MIGRATIØN USING 60 MSEC TIME STEPS (0-2500 MSECS) AND 40 MSEC TIME STEPS (2500-6000 MSECS). 100% ØF THE INPUT SELECTED AND SMØØTHED STACKING VELØCITIES ARE USED TØ CALCULATE MIGRATIØN VELØCITIES.
12. TIME VARIANT ØRMSBY TYPE BANDPASS FILTER USING 400 MSECS ØPERATØRS WITH THE FØLLØWING CUT-ØFF FREQUENCIES 34 DB DØWN

START TIME (MSECS)	FREQUENCIES (HZ)
0	3/8-45/55
4000	3/8-35/45
5000	3/8-25/35

13. TRACE EQUALISATIØN.
    AUTØMATIC GAIN CØNTRØL USING A 1000 MSECS WINDØW AND A 25% THRESHØLD LEVEL.
14. PHØTØDØT PRESENTATIØN USING GEØSØURCE SSD PRØGRAM.
    SHØT PØINTS ANNØTATED AT ANTENNA PØSITIØN
    HØRIZØNTAL SCALE : 12.7 TR/IN.
    TRACE SPACING : 25 M.
    VERTICAL SCALE : 10 CM/SEC.
    RECØRDING PØLARITY : CØMPRESSIØN = NEGATIVE NUMBER
    DISPLAY PØLARITY : CØMPRESSIØN = WHITE PULSE

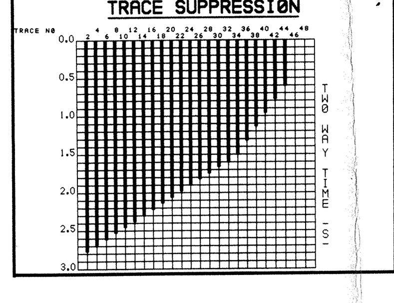
SCALE = 1:12500

MILES 0 1
KILØMETRES 0 1 2

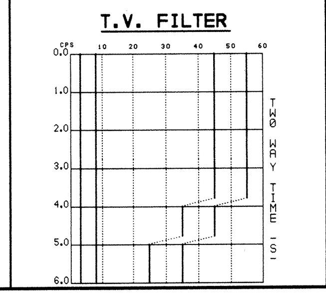
DATA PRØCESSED BY GEOSOURCE

CHECKED	NAME	
	DATE	
APPRØVED	NAME	
	DATE	

TRACE SUPPRESSIØN



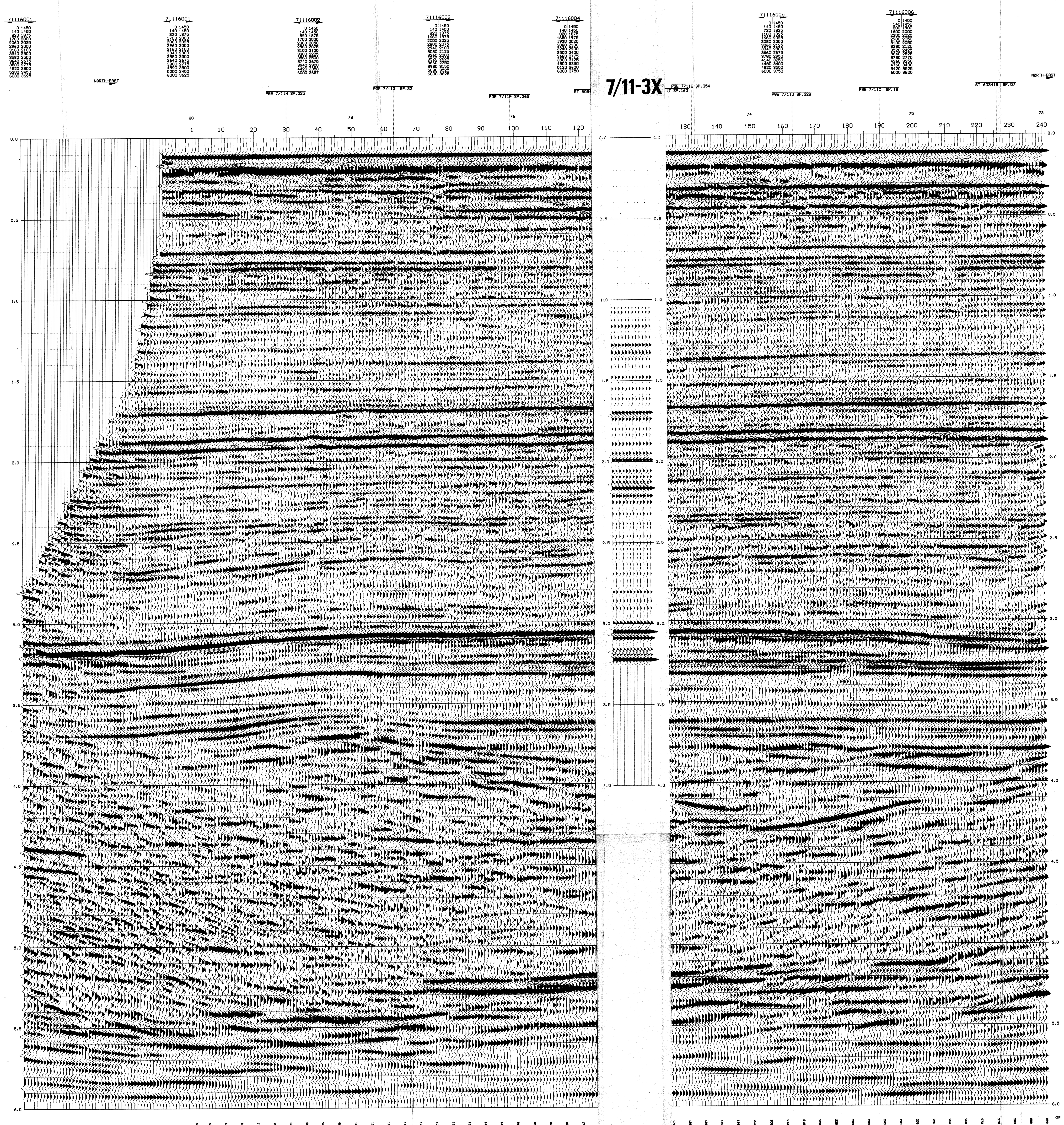
T.V. FILTER



****** FILMING PARAMETERS ******

FILM REEL NUMBER	- 09281
GAIN VALUE	- 168
PØLARITY	- BLACK +VE
HØRIZØNTAL SCALE	- 12.700 TR/IN
VERTICAL SCALE	- 10.000 CM/SEC
FILMING DIRECTIØN	- L/R
DATE FILMED	- 13/06/80
INPUT REEL NUMBER	-

PHILLIPS PETRØLEUM NØRWAY LINE 7/11P STNS 1 TØ 248



LINE DIRECTIØN

VELØCITY FUNCTIØN (METERS/SEC) [redacted]

DIRECTIØN

LINE INTERSECTIØN

WATER DEPTHS (METERS)

STATIØNS

PHILLIPS PETROLEUM

LINE : PGE 7/11P

STNS 1 - 248
NØRTH SEA BLØCK 7/11
CØD PRØSPECT
EQUALISED MIGRATIØN

INPUT REEL HEADER INFØRMATIØN

REEL NUMBER	12702
DATE CREATED	06/28/80
NUMBER SAMPLE/TRACE	1500
SAMPLE RATE IN MILLS	4.00
PRØCESSØR	
LINE NUMBER	1
JØB NUMBER	
SECTIØN NUMBER	
PRØCESSING STEP	

FIELD INFØRMATIØN

PRØCESSING SEQUENCE

DEMUX - DECIMATE - GAIN RECØVERY - ALIAS FILTER - SØRT - TVDBS STACK - TVDAS - FILTER - WAVE EQUATIØN MIGRATIØN - FILTER - AGC

GEOSOURCE

****** FILMING PARAMETERS ******

PERCENT GAIN	168
HØRIZØNTAL SCALE	12.700 TR/IN
VERTICAL SCALE	10.000 CM/SEC
FILMING DIRECTIØN	LTØR
PERCENT BAR	0
PØLARITY	BLACK=PØSITIVE
DATE FILMED	06/28/80

DATA PRØCESSED BY GEØSØURCE U.K. LTD

SYNTHETIC SEISMOGRAM
7/11-3X
ZERO PHASE
5/10-30/40 Hz BANDPASS
LEVELLED 1000 ms WINDOW