SEISMIC REFLECTION DATA PROCESSING

Application of Band Pass Filter

BY

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"FINAL APPROVAL OF THESIS"

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CONTENTS

CHAPTER#1
INTRODUCTION TO SEISMIC DATA PROCESSING

CHAPTER#2 FREQUENCY FILTERING

CHAPTER#3 BAND PASS FILTER

DEDICATED TO

One and the only romance of mine that is my brother "MERO" Shahmeer Ahmad.

Acknowledgement

ACKNOWNLEDGEMENT

Above of all, I acknowledge Allah almighty, the beneficent and merciful, who endowed me with the spirit and strength for completion of the cherished dream. I am greatly indebted and pay profound gratitude to my Chairman and Supervisor Dr. Mubarik Ali, who was very kind and helpful to me during the entire course of study and particularly in the pursuit of this endeavor.

It will be sheer dishonesty on my part, if I fail not to acknowledge the invaluable cooperation extended to me by all the worthy teachers of this department whom I will love and respect in the days to come.

There is a famous saying "A man is nothing without his friends". I shall ever remember the love and cooperation of my friends and will enjoy the memories of their caring company in the department and outside the university campus, especially Waqar, Asif Mirza, Hassan Shah and all other class fellows who were very nice to me during this golden **era.** All of these have a paramount importance in my life. All there love will reminiscent me the hours, which I spent here to fulfill the dream of my beloved mother------- who is a continuous source of life and happiness for me. My (late) ***nana*** was another benefactor who encouraged me to get my degree. It would be a great pleasure for him may Allah bless him with the best.

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ABSTRACT

ABSTRACT

Unprocessed seismic reflection data, along with computer software is acquired and to enhance the signal to noise ratio, zero phase frequency filtering is applied.

The Band Pass filtering is applied to the data to remove the high frequency components of seismic data that are creating distortion. The filtered seismic version shows that the high frequency components are removed but some distortion due to Gibbs effect is produced. The effect of the different band pass filters with different bandwidth shows that the filtered seismic version with narrow band causes high frequency bearing reflectors in upper part are completely filtered out but improves the reflection in the lower part. The band pass with wide band effect on the overall reflection strength but shape distortion is decreased.

INTRODUCTION

INTRODUCTION

This dissertation is accomplished to substantiate a specific view over the processes involved in the seismic reflection data processing with especial emphasis on frequency filtering to enhance the signal to noise ratio.

The data provided is of raw form and contain both desired and undesired signal and these are affecting the seismic picture. The application of Band Pass filter on the seismic data gives rise the filtered version of seismic section that does not contain high frequency components but some distortion is produced in the section. This effect is known as Gibbs effect. The bandwidth also effects the filtered version and application of different BP filters on the seismic data shows the wide bandwidth with both low and high frequencies are necessary to improve the vertical resolution.

Chapter #1

Introduction to seismic data processing

Introduction:

Seismic Reflection method is used for the delineation of subsurface structure of formations with more precision and reliability. We can expect better seismic interpretation from good quality data produced in the field.

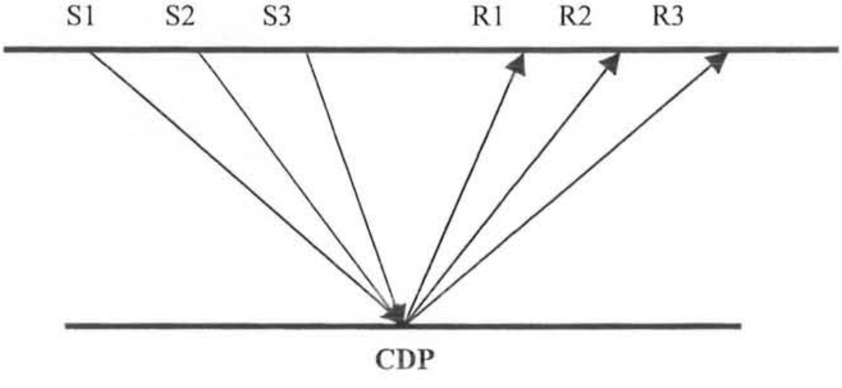
The quality is concerned with signal/noise ratio, which is improved in two phases. First, in the field with the use of careful field geometry of the seismic spread; second in the processing center, with the selection of appropriate stream of processing.

Data acquisition:

Conventional Acquisition Versus CDP acquisition:

Conventional techniques of data acquisition have been replaced by CDP technique, in which shooting patterns and acquisition layout are used to cut down the noise that can be encountered there in the field. Conventional technique being single but Signal to Noise ratio is affected by the presence of multiples and ground roll. (Yilmaz, 1987).
Conversely, CDP shooting in fact offers cancellation of coherent and random noise, and enhancement of primary signal. Increase in folds improves S/N ratio.

Mayne in 1963, introduced CDP technique, which is based on summing the traces associated with a given reflection point but recorded at different shot and receiver positions.
In the CDP profiling of two-dimensional multi-channel seismic surveying, it is arranged that a set of traces recorded at different offsets contain reflections from a common depth point (CDP) on the reflector.



The data fold in CDP can be evaluated from the following relation,

$$F = N \Delta Y / 2 \Delta X$$

Where,

N = Number of recording channels.
ΔY= Geophone interval.
ΔX= Shot interval.

Seismic Data Processing:

The field data is a combination of reflection signal, refraction, multiples, random noise, coherent noise, and the instrumental noise. Thus, the raw data is processed to improve S/N ratio using the following basic steps.

1.Demultiplexing:

The field data is recorded in multiplexed form and saved in the magnetic tapes, using any of the format; SEG A, SEG B, SEG C, or SEG Y.

Then, this data is transferred in the form of seismic traces through demultiplexing procedure i.e. the transposition in matrix form where columns can be read as seismic traces.

2. Trace Editing:

Field recorded seismic traces may have some noisy traces or some traces may have reverse polarity due to opposite connection of geophones, so editing becomes essential to remove noisy traces or mute for the usefulness of processing operations. Without that if the data is passed through processing stream, the output may be not of that quality as desired.

3. Amplitude Adjustment:

Since amplitude of seismic waves attenuates as a function of distance following spherical divergence and geometrically the reflections from deeper horizons becomes very weak and sometimes it is hard to differentiate between reflection and noise.

So we apply a correction that compensates for the effects of geometrical spreading and absorption. It will increase the amplitudes on the more distant traces. By relation,

$$K = H_o / H_x = V_{rms} t_x e^{\alpha V_{rms} t_x}$$

Where,

K= Correction factor for amplitude adjustment.

4. Stacking:

Sorting is objectively done for stacking through gather of traces relating to the same point of reflection on reflector, a set of seismic traces summed up to yield good signal to noise ratio. (Yilmaz, 1987).

Stacking not only boosts the strength of reflection but also attenuates long path multiples. In a broader sense, because of geometric absorption, edited traces and skipped shots, all the depth points do not contain the same number of traces to suppress noise, all the traces are stacked.

5. Deconvolution:

Deconvolution is an inverse filtering process to counter the Hi-cut filtering effects of Earth, also to enhance the temporal resolution of seismic data by compressing seismic wavelets.

More ever, deconvolution recovers original spike and kills short path multiples using Predictive Decon or Spiking Decon, and this is used on pre-stacked data.

Decon operation is also done on stacked data in order to remove unwanted reflections and to change the shape of the signal in desirable form.

6. Frequency Filtering:

Frequency filtering implies discrimination between desired and undesired signals and used to suppress noise frequencies. Frequency filtering discriminate against selected frequency components of an input waveform and may be low-pass, high-pass, band-pass or band-reject in terms of their frequency response.

Frequency filters are employed when the signal and noise components of a waveform have different frequency characteristics and can therefore be separated on this basis.

7. Statics:

Static is the most critical processing step for land data; important in area of rough terrains and in areas where near surface seismic velocity greatly varies laterally due to the weathering effects. Because such velocity variations and rough terrains introduce irregularities in arrival times of seismic waves at different receivers along the spread.

The static correction is a combination of weathering and elevation correction that removes the effects of the low velocity surface layer and reduces all deflection times to a common height datum.

8.Velocity Analysis:

When seismic traces are grouped to form CDP gather, information of velocities is essential required for the purpose of application of NMO correction in the next stage of processing. Velocity analysis represents the process of determination of these velocities.

9.NMO Correction:

Dynamic corrections are calculated for a range of velocity values and dynamically corrected traces are staked and stacking velocity V_{st}

which produced maximum amplitude of the reflection event is taken appropriate velocity to be used in NMO calculation.

NMO correction as a matter a fact, converts the reflection time in two-way vertical time and realigns the hyperbolic reflection into a common arrival time, i.e. equal to zero offset trace provided the reflector is horizontal. NMO corrected reflections are aligned along a straight line.

10. Time-variant Filtering(TVF):

TVF is used to suppress noisy frequency bands, because reflection signals show frequency reduction with the increase of record time. It means that different part of seismic trace will require different filtering operators at different times. So TVF is considered and made time dependant bath in its designing and application.

11. Residual static correction:

For the land data it is applied on NMO corrected CDP gather. Because CDP gather does not always confirm to a perfect hyperbolic trajectory. Residual static correction is applied to improve the stacking quality.

12. Migration:

Migration is a process of reconstruction of seismic section so that reflection events are repositioned under the mid point of the CDP gather, and at a corrected vertical reflection time. It holds great significance in seismic data processing in order to map real picture of the subsurface structures.

There are different kinds of migration techniques that includes; Kirchhoff Summation and frequency domain migration are suitable for cases with steep dips, and finite difference approach for low signal to noise ratios. Migration removes the distortion effects of dipping reflector and also the diffracted arrivals.

<u>*Chapter #2*</u>

Frequency Filtering

Waveform of geophysical interest generally represents continuous (analogue) function of time. It is a record of different amplitudes with respect to time.
Filtering of frequencies implies discrimination between desired and undesired signals and is used to suppress noise frequencies (Robinson & Coruh, 1988).

FREQUENCY FILTERING:

Frequency filtering can be applied in,

1. Frequency domain.
2. Time domain.

Every time signal can be considered to be formed of different Fourier pairs (sine &cosine series). Transformation may be used to convert a time function g(t) into a complex function of frequency G(f) as frequency spectra.

$$G(f) = A(f)\, e^{1/\varphi(f)}$$

The notation can represent the Fourier pair,

$$g(t) \leftrightarrow G(f)$$

MATHEMATICAL EXPRESION OF FOURIER TRANSFORM:

The integral expression of Fourier transform is in two parts, one for the frequency spectra G(f) in the term of time function f(t),and other for the time function in term of frequency spectra.

This reciprocal relationship has widespread applications in seismic filtering and may be written as,

$$G(f) = \int_{-\infty}^{\infty} f(t)\, e^{-i2\pi ft}\, dt$$

And,

$$f(t) = \int_{-\infty}^{\infty} G(f)\, e^{-i2\pi ft} dt$$

1. Frequency domain filtering:

In the frequency domain-filtering action results in the making of amplitude spectrum of the input function and the transform function of filter and the phase spectrum of the output signal is the sum of input signal phase spectrum and the filter phase response. Filter input signal Fi (t) may be replaced by a sequence of sinusoidal signals.

$$F_i(t) = \Sigma\ A_i(f) \cos[2\pi ft + \Phi_i(f)]$$

The filter modifies the amplitude spectrum Ai(f) and phase spectrum $\Phi c(f)$ of input signal and resulting an output signal Fc(t).

$$F_c(t) = \Sigma_f\ A_i(f) Y(f) \cos[2\pi ft + \Phi_i(f) + \Phi(f)]$$

Where,

Y(f)= amplitude spectrum.

$\Phi(f)$= phase spectrum

Of the filter. The amplitude response of output signal Ac(f) is simply the product of input signal amplitude spectrum with filter response.

$$A_c(f) = A_i(f) Y(f)$$

The phase spectrum of output signal is the sum of the input phase spectrum and filter phase,

$$\Phi_c(f) = \Phi_i(f) + \Phi(f)$$

The filter, resulting in the spectral components of the output signal, modifies the amplitude and the phase of input signal's spectral components.

$$F_c(t)= \Sigma_f A_c(f) \cos[2\pi ft+ \Phi_c(f)]$$

2. Time-domain Filtering:

Filtering action is normally executed in the time domain .The filter input signal is composed of spikes (impulse) i.e. simply the amplitude of digital signal.

Filter replaces each spike with its input impulse response signal $Y(\tau)$ through which the signal is passed,

$$Y(\tau)= \Sigma_f Y(f) \cos[2\pi ft+ \Phi(f)][2\pi ft+ \Phi(f)]$$

The polarity and peak amplitude of impulse does not change and the output signal is the sum of these impulse response signals.

$$F_c(t)= \Sigma_t F_i(t- \tau) Y(\tau)$$

Or,

$$F_c(t) = F_i(t)*Y(t)$$

MECHANISM OF FILTERING:

Convolution:

Convolution is a mathematical operation defining the change of shape of a waveform resulting form and its passage through a filter and the frequency and time domain formulation of the filtering process are based on the concept in the time series "convolution in the time domain is equivalent to multiplication in frequency domain and convolution in the frequency domain is equivalent to multiplication in the time domain. (Bracewell, 1965).

The effect of a filter is described mathematically by a convolution operator such that, if the input signal g(t) to the filter is convolved with the impulse response f(t) of the filter then filtered output Y(t) is obtained .

$$Y(t) = f(t) * g(t)$$

Systematic diagrams of design and applications of zero-phase filter in frequency and time domain.

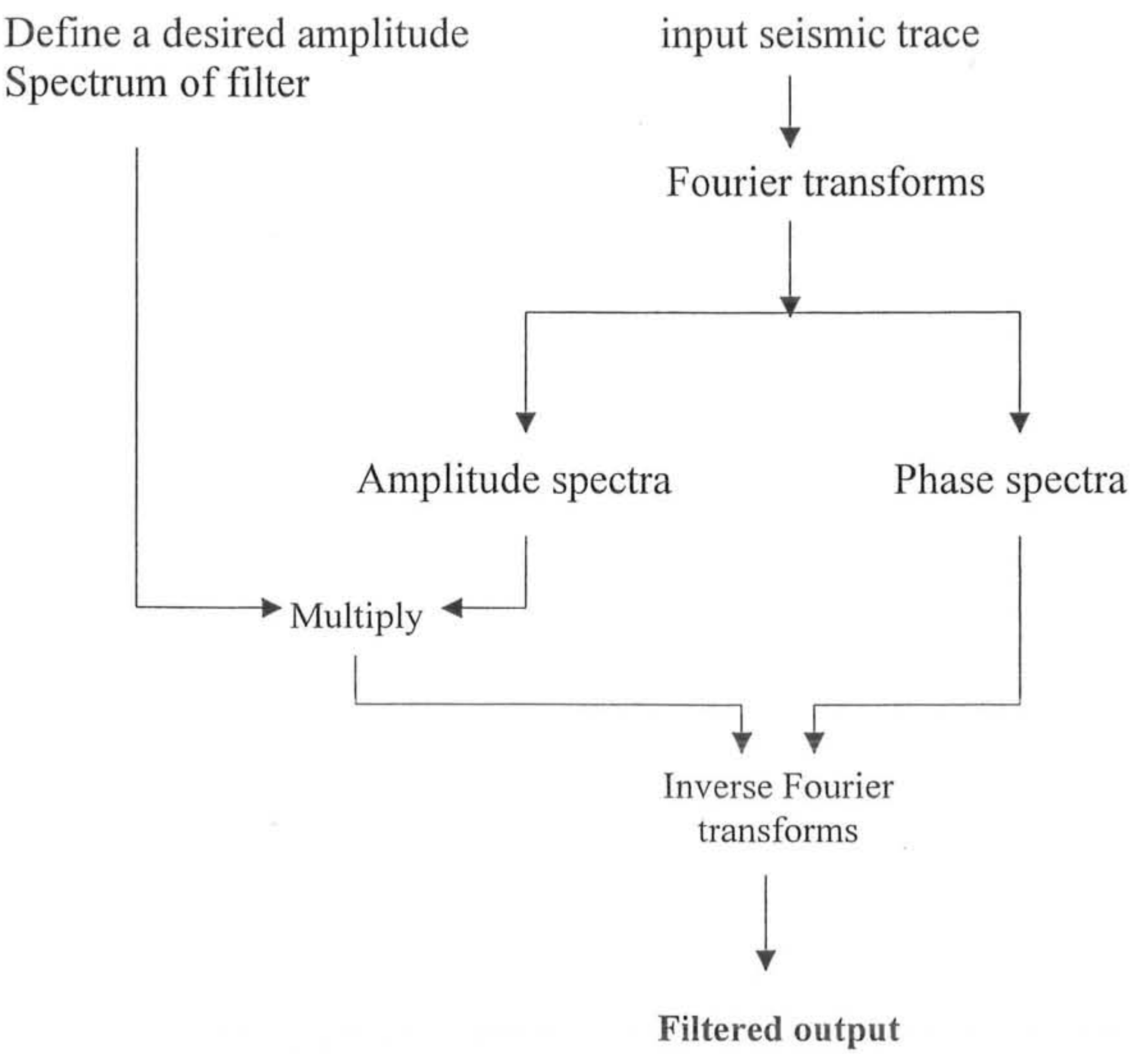


Fig. A designs and application of a zero-phase filter in the frequency domain.

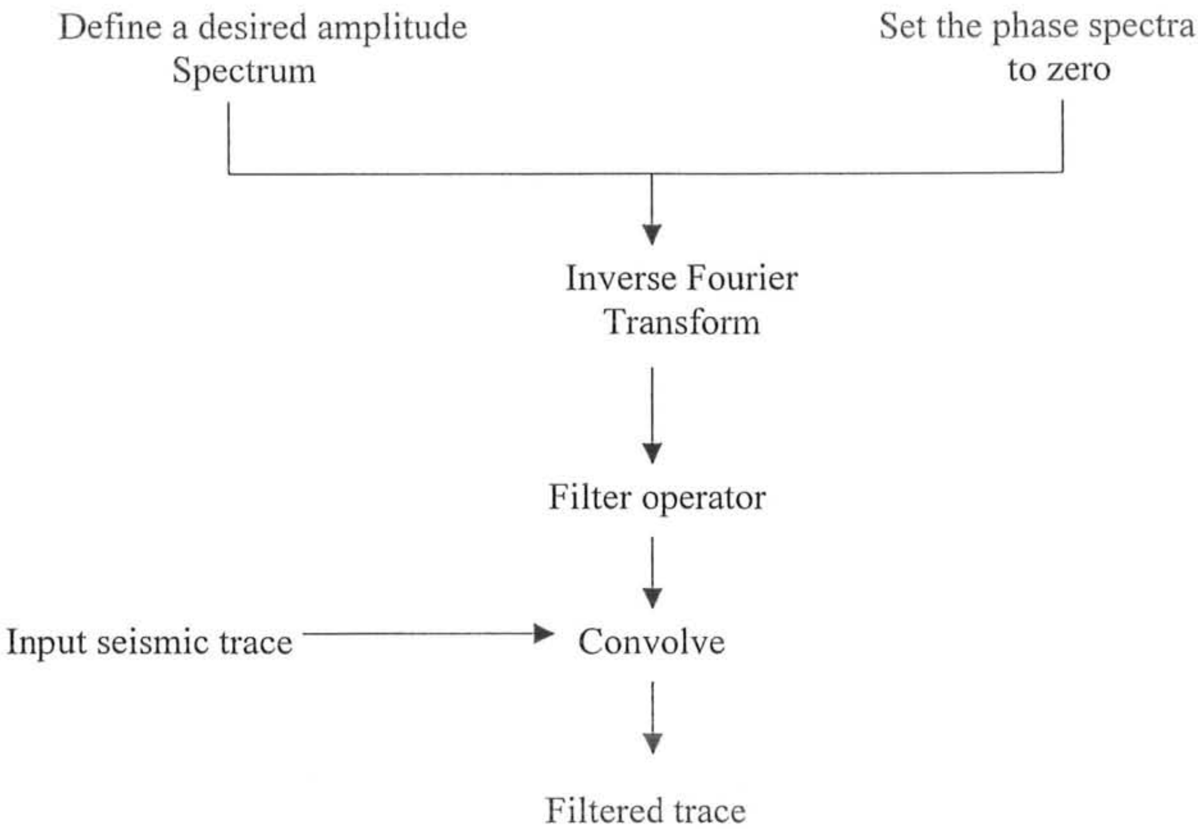


Fig. Design of zero-phase frequency filter in the time domain.

DIGITAL AND ZERO-PHASE FILTERING:

The digital filter is a numeric operator, which is convolved with a given digital function to filter out certain frequency components. Since the operator is carried out in the time domain, it is often called time domain filter.

In zero-phase filtering a zero-phase band limited wave can be used to filter a seismic trace and the output trace contain only those frequencies that make up the wavelet used in filtering. The process of zero-phase filtering does not modify the phase spectrum of the input trace, but merely band limits its amplitude spectrum.

Type of Filters:

Frequency filtering can be in the form of different filters and all of these are based on the same principle "Construct a zero-phase wavelet with an amplitude spectrum that meets one of the four specifications.

1. Low-pass filters (High Cut):

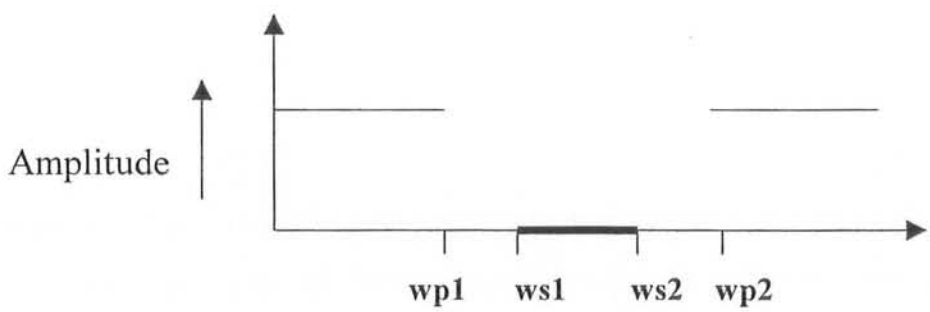
A filter whose response is of constant amplitude for all frequencies up to a fixed cut-off frequency and zero for all frequency above it.

2. High-pass filters (Low Cut):

This filter passes all frequency components above a given cut-off frequency. The amplitude response is constant the part of the spectrum above the cut-off frequency and zero below it.

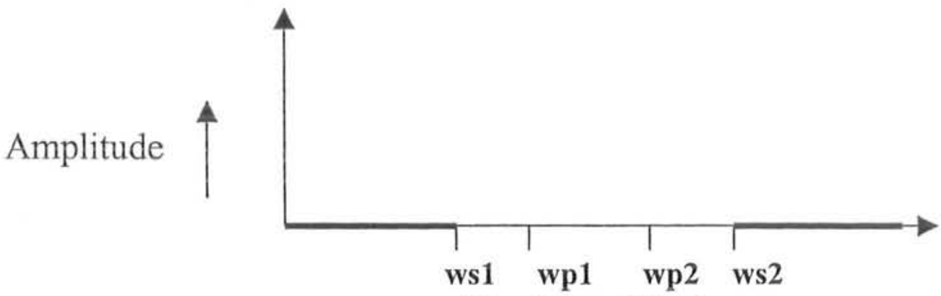
3. Band-reject filters:

A filter whose pass bands are from 0 to wp1 and from wp2 to ∞ and stop band is ws1 to ws2, where wp1<ws1<ws2<wp2.



4. Band pass Filters:

A filter whose pass band is from some frequency wp1 to some other frequency wp2 or a band of frequencies and whose stop bands are from 0 to ws1 and from ws2.



(Band-Pass filter)

The response of an ideal band pass filter is of constant amplitude over a defined frequency range and real response is zero-phase or linear phase.

Band pass filtering is used because a seismic trace typically contains some frequency noise such as ground-roll, and some high frequency ambient noise. The usable seismic reflection energy usually is confined to a bandwidth of approximately 10-70 Hz with a dominant frequency around 30 Hz.

Band pass Filters:

The response of an ideal band pass filter is constant amplitude over a defined frequency range that does not include the origin. Based on the concept of equivalent low-pass, band-pass filter is looked upon as low pass filter whose frequency response $H_l(\omega)$ is shifted along the frequency axis, if the shift is ω_b then ,

$$H_l(\omega - \omega_b) \leftrightarrow h_l(t)\, e^{i\omega_b t}$$

To get real response of the band pass (i.e. zero-phase), a symmetrical band pass filter from two equivalent low-pass filters is established,

$$H_l(\omega - \omega_b) \leftrightarrow h_l(t)\, e^{i\omega_b t}$$

$$H_l(\omega + \omega_b) \leftrightarrow h_l(t)\, e^{i\omega_b t}$$

The band pass response $H_b(\omega)$ is given by $H_l(\omega - \omega_b)$ and its inverse transform is

$$H_l(t)\, [\, e^{i\omega_b t} + e^{-i\omega_b t} \,] = 2h_l(t) \cos \omega_b t$$

For the particular case where,

$$h_l(t) = a \sin \omega_c t / \pi t$$

The band –pass response is,

$$H_b(t) = 2a/\pi t \sin\omega_c t \cos\omega_c t$$

Where,

ω_c is the cut-off frequency of equivalent low-pass filter.

$H_b(t)$ is real quantity and a zero-phase filter is obtained . (Al-sadi, 1980).

Chapter #3

Band Pass filter

Phase Considerations:

Filtering introduced phase distortion or at least phase shift to the filtered data. This is the fact that under filtering the phase characteristics of the filter is added to that of the data.

With digital data, it is possible to do the filtering in such a way that no phase shift is introduced in the filtered data. This procedure is based on two stages.

1.the input data is first convolved in the normal way with the digital filter operator.

2.the output is then reversed and passed through the same filter once more.

This reversal of the output from the second stage is of zero-shift.

The band-pass filter designed that facilitate digital filtering without altering the phase spectrum of the filtered signal.

Practical aspect of filter design:

In designing of a band-pass filter, the goal is to pass a certain bandwidth with little or no modification, and to largely suppress the remaining part of the spectrum as much as practicable. This goal can be met by defining the desired amplitude spectrum for the filter operator as follows,

$$A(f) = \begin{cases} 1, & f_1 < f < f_2 \\ 0, & \text{Elsewhere.} \end{cases}$$

Where, f_1 and f_2 are the cut-off frequencies and this is called boxcar amplitude spectrum. Following sequence of operations are performed to analyze the filter,

Define a Boxcar amplitude spectrum
And zero-phase spectrum

↓

Inverse FFT

↓

Filter operator

↓

Truncate

↓

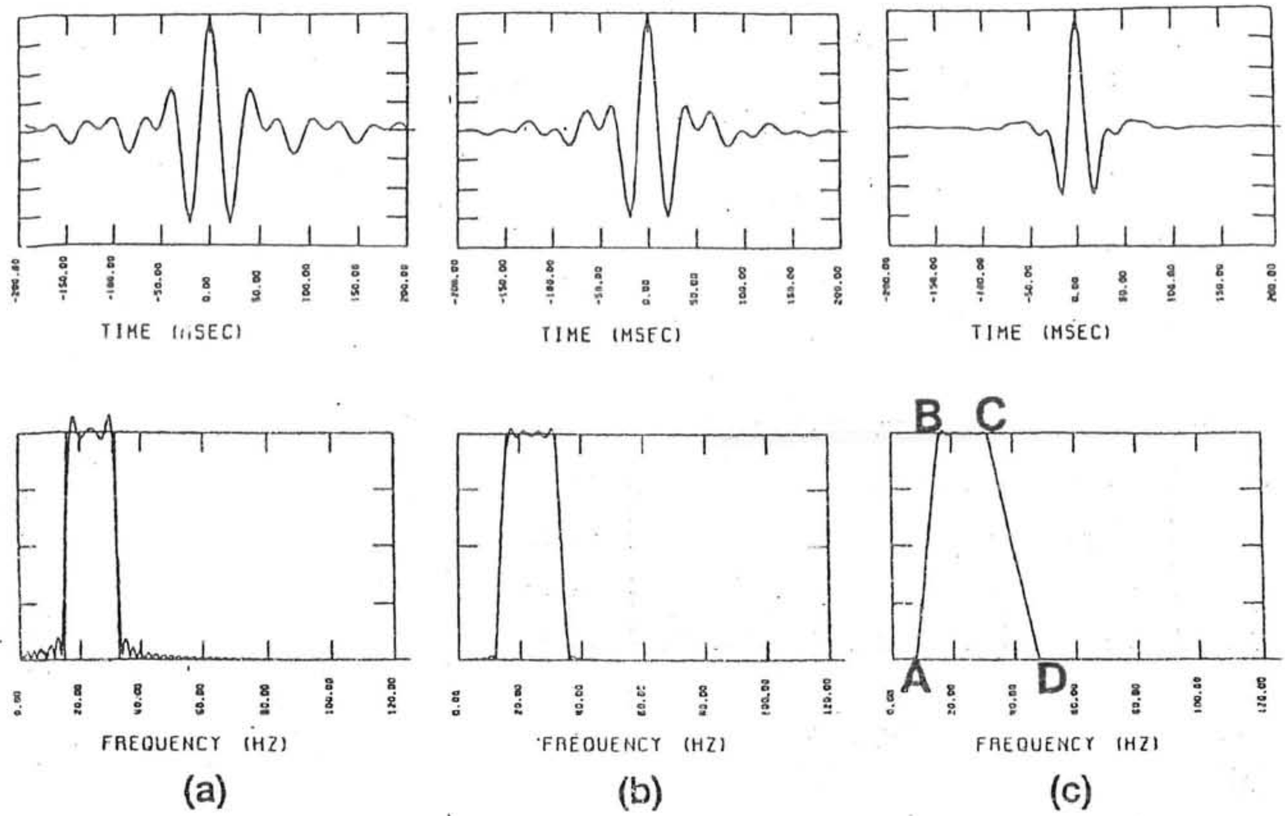
Forward FFT

↓

Compute actual amplitude
Spectrum.

By applying such sequence of operations the operator is on top and the actual and desired amplitude spectrum are superimposed on the bottom. This actual spectrum has a ringy character and this effect is known as Gibbs Effect or phenomenon. These ringy characters are undesired and some of the frequencies in the pass-band are amplified while other is attenuated and some frequencies in the reject zones on the both sides are passed.

To avoid this ripple at the discontinuities, pass-band as a boxcar is assigned slopes on the both sides thus the pass-band as a trapezoid. While defining the pass-band as a trapezoid, smoothing also must be applied at the corner frequencies. This must be done because the Fourier transform exists for continuous function only (Brace well, 1965).



IG. 1-25. Three zero-phase wavelets (top row) and their respective amplitude spectra (bottom row). (a) The eeply defined slopes of the passband cause ripples in the wavelet and the actual amplitude spectrum. (b) A oderate and (c) gentle slope help eliminate the ripples. Refer to the text for a discussion of points A, B, C, and D.

Parameters of Band-pass:

There are two parameters of band-pass filter,

1.Low-pass Filter:

An ideal low-pass filter is a function whose response is of Constant amplitude for all frequencies up to a fixed cut-off frequency and zero for all frequency above cut-off frequency.

2.High-pass filter:

This filter passes all frequency component above a given cut-off frequency. The amplitude response is constant for the part of the spectrum above cut-off frequency and zero below it.

Uses of Band-pass filtering in data processing:

Band-pass filtering is performed at various stages in seismic data processing.

1. Before deconvolution band pass filtering is usually applied to suppress remaining ground roll energy and high frequency ambient noise that otherwise would contaminate signal autocorrelation.

2. Narrow band-pass filtering may be performed before cross correlation traces in a CMP gather with a pilot trace for use in estimating residual static's shifts.

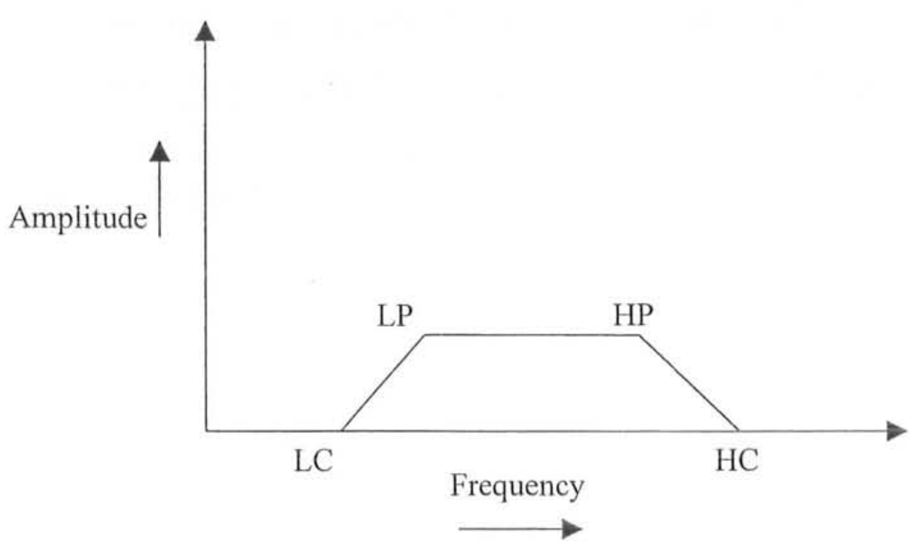
3. Band-pass filtering can also be performed before computing cross correlation during construction of velocity spectrum for improved velocity picking. (Yilmaz, 1987).

Types of Band-pass Filters:

1. Trapezoid band-pass filter:

A wavelet is designed from a basic trapezoid band-pass Filter defined by the four corner points. The filter rejects everything below frequency1 (low-cut) and above frequency4 (high-cut).

The filter is linear between frequency 1 and frequency 2 (LP-low-pass), and frequency 3(HP-high-pass) and frequency 4.Between frequency 2 and 3 it is flat and passes all frequencies.



2. Butter-worth Filters:

The Butter-worth characteristics provide a very flat amplitude response in the pass-band. The face response is not linear and face shift of signals passing through the filter varies nonlinearly with frequency.

Filters with Butter-worth response are normally used when all frequencies in the pass-band must have the same gain. The Butter-worth response is often referred as maximally flat response. (Floyd, 1996).

Butter-worth low-pass filters (LPF) are designed to have amplitude response characteristics that is as flat as possible at low frequencies and that is monotonically decreasing with increasing frequency. (Rorabaugh, 1993).

Band width and Vertical Resolution:

Frequency filtering is intimately tied to vertical (temporal) resolution of seismic data. In seismic data processing both high and low frequencies are needed to increase temporal resolution and is controlled by spectral bandwidth.

Consider the filter operators in the figure below. Both have same effective bandwidth (difference between the high-cut and low-cut frequencies); therefore, the envelopes of two operators are identical. The great ringyness of the second operator (fig.b) results from its lower bandwidth ratio (the ratio of the high-cut to low-cut frequency). (Yilmaz, 1987).

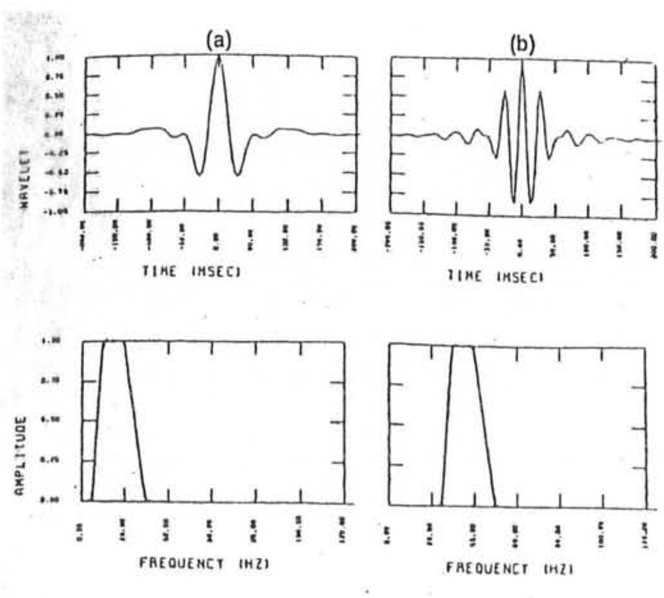


FIG. 1-27. Two wavelets (top row) with the same bandwidth (bottom row); the passband of the left wavelet is centered at 15 Hz, while that of the right wavelet is centered at 35 Hz. Both wavelets have ripples, although one is low and the other is high frequency in character. Just having low or high frequencies does not suffice; both are needed to increase temporal resolution.

In fact resolution relates to how close two points can be, yet still be distinguished. The both vertical and horizontal resolutions are controlled by spectral bandwidth. The yardstick for vertical resolution is the dominant wavelength, which is wave velocity divided by dominant frequency.

Vertical resolution is concern when discontinuities are inferred along a reflection horizon because of faults

TVF(Time Variant Filtering):

Time variant filtering consists of various defined Band-pass filters and their bandwidth varies with time or depth. It means that different parts of the seismic trace will require different filtering operators at different times. TVF typically are applied on stacked data.

Conclusion

CONCLUSION

The given seismic section contains high frequency noise components disturbing the waveforms constituting reflectors, shown in the figure.1. The amplitude spectrum of this seismic section is demonstrated in fig.2.This shows that the seismic energy is concentrated in frequency range 10 to 70Hz.

To observe the effectiveness of Band Pass filtering the seismic section is passed through filter of bandwidth 10 to 35Hz.The filtered seismic version is presented in fig.3. The amplitude spectrum of this filtered version is shown in fig.4.Some leakage of energy takes place and can be observed in the reject zone. This effect is known as Gibbs effect and is more evident in amplitude spectrum (fig.4.). The Gibbs effect is produced due to sudden truncation of frequencies or steep slope of band pass filter causing over shooting and ripples.

The time section is also convolved with a band pass filter having bandwidth 40-90Hz.This shows the high frequency components about 45Hz in the seismic section fig.5a, which are more prominent in its amplitude spectrum in fig.5b.Applying band pass of bandwidth 10-50Hz on the original data produces result that is illustrated in fig.6.

The section convolved with BP 10-35 Hz causes higher frequency about 45Hz bearing reflectors in upper parts (200-800 msec) to be filtered out completely but tremendously improves reflections appearing in the lower parts (1250-1700 msec). The reflectors in the middle parts are differently affected, the reflector at 950 msec appears to be improved but the sequence of reflectors at times 1100-1200 msec seems to have undergone shape distortion resulting in the decrease of temporal resolution.

The section convolved with BP 10-50 does not have much effect on the overall reflection character. So this filter improves the wavelet shape. The amplitude spectrum of the filtered section shows leakages above 50 Hz (fig.7) but their amplitudes are small and Gibbs effect is less prominent.

5 AMP: 1 Display of w85-8.sgy o.D

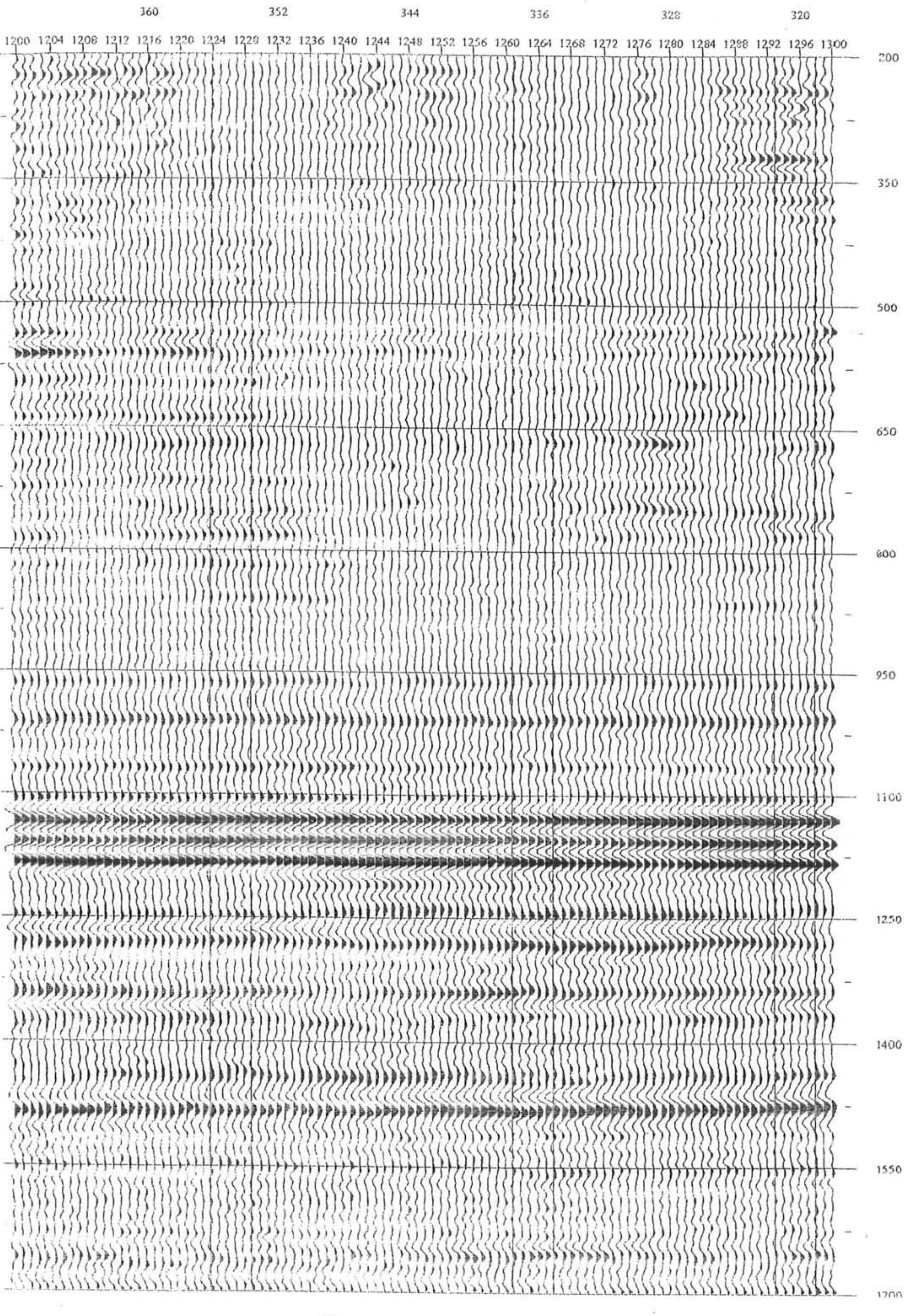


Fig-1

5 AMP: 1

Amplitude Spectrum of moon.bin

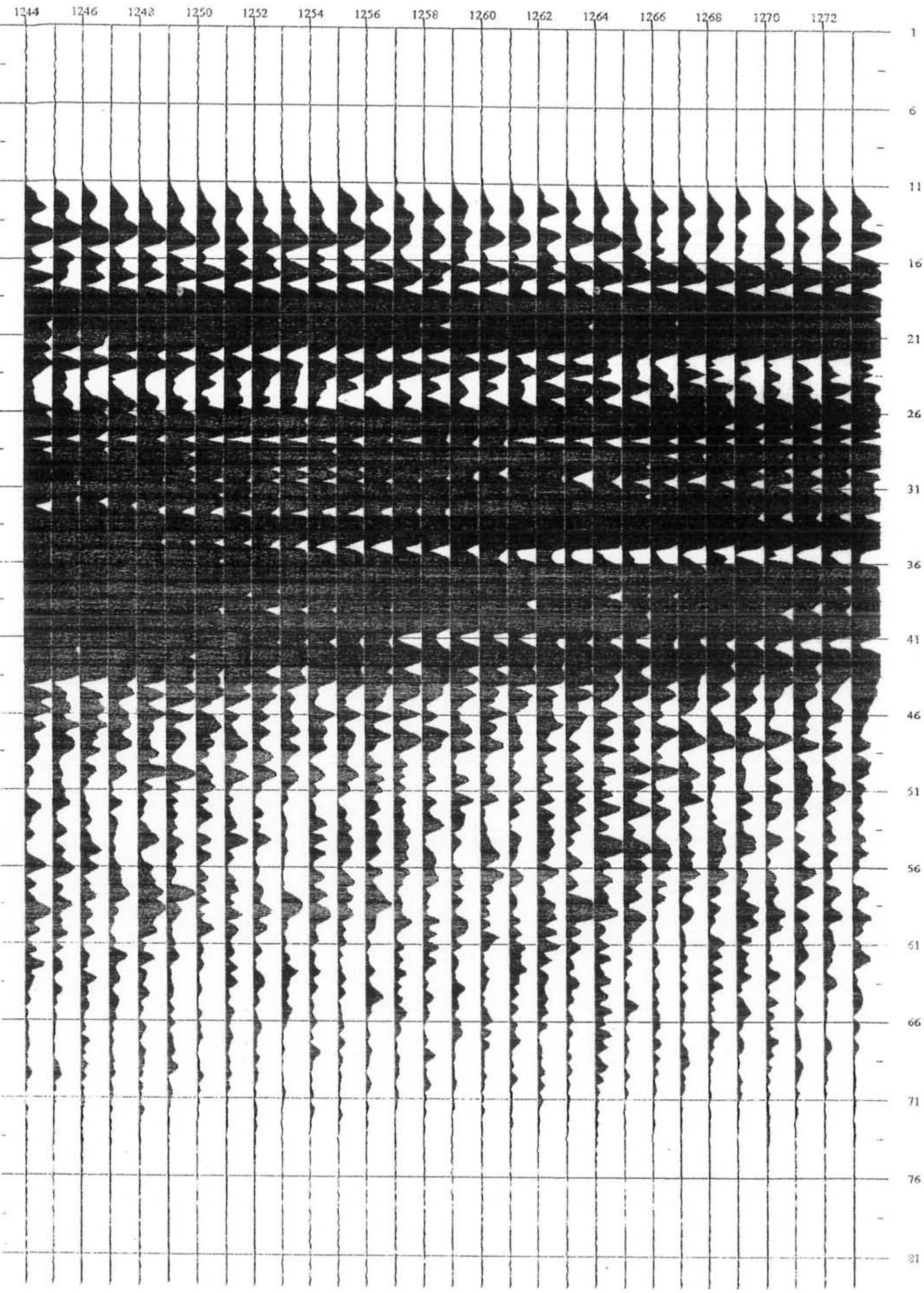


Fig-2

5 AMP. 1

w85-8.sgy convolved with BP filter 10 - 35 Hz

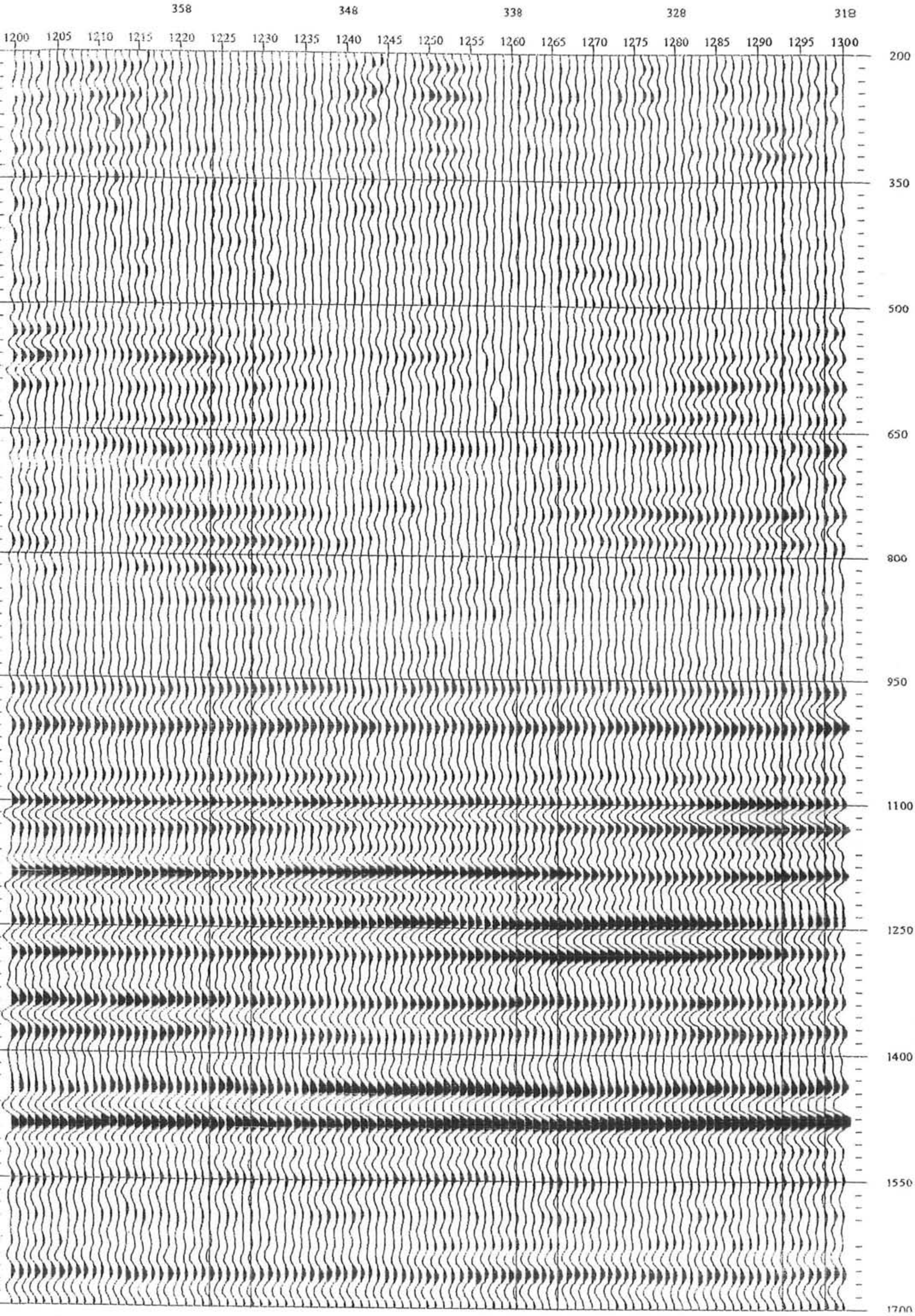


Fig-3

5 AMP 1

Amplitude Spectrum of w85-8.sgy

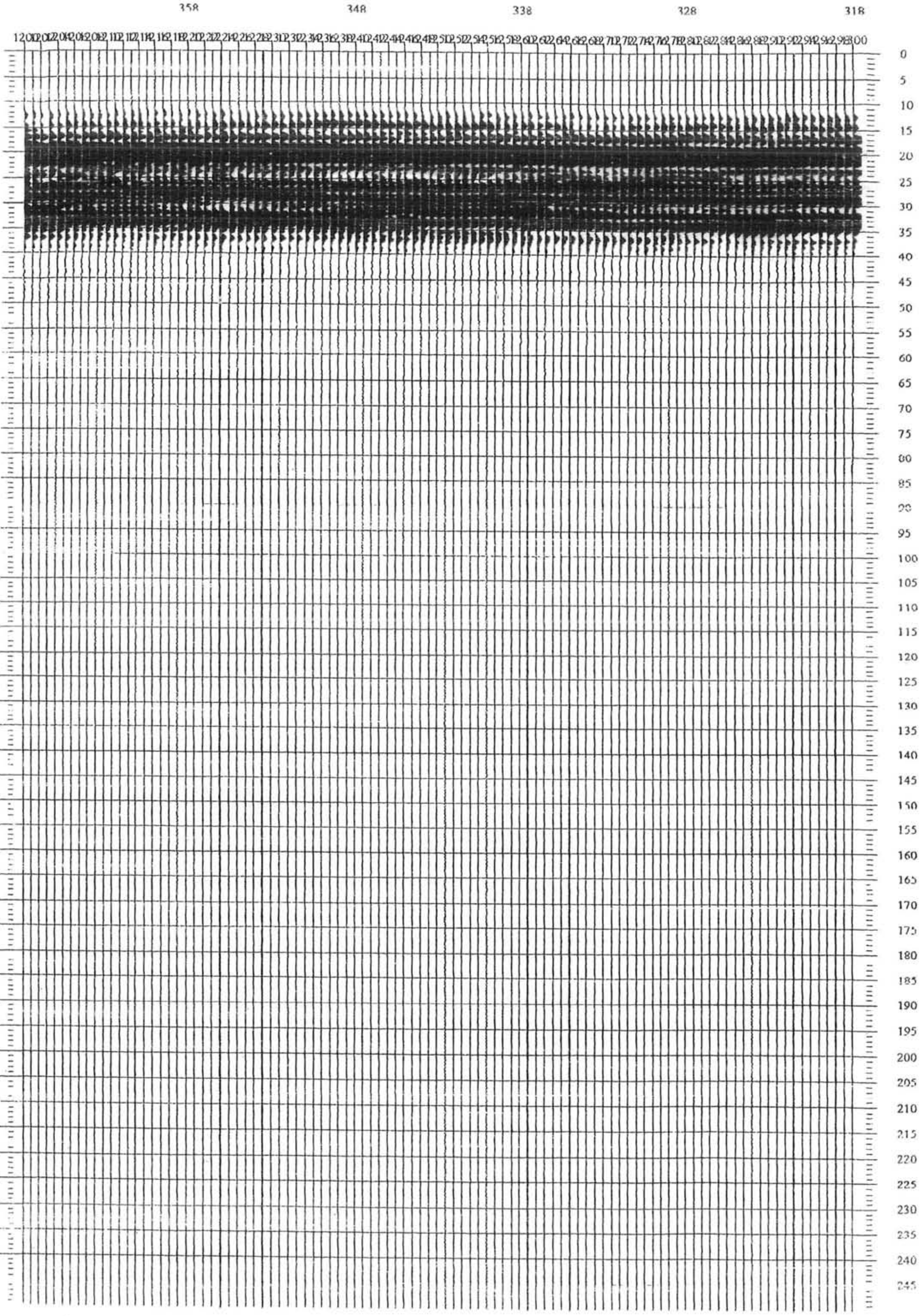


Fig.4

w85-8.sgy convolved with BP filter 40 - 90 Hz

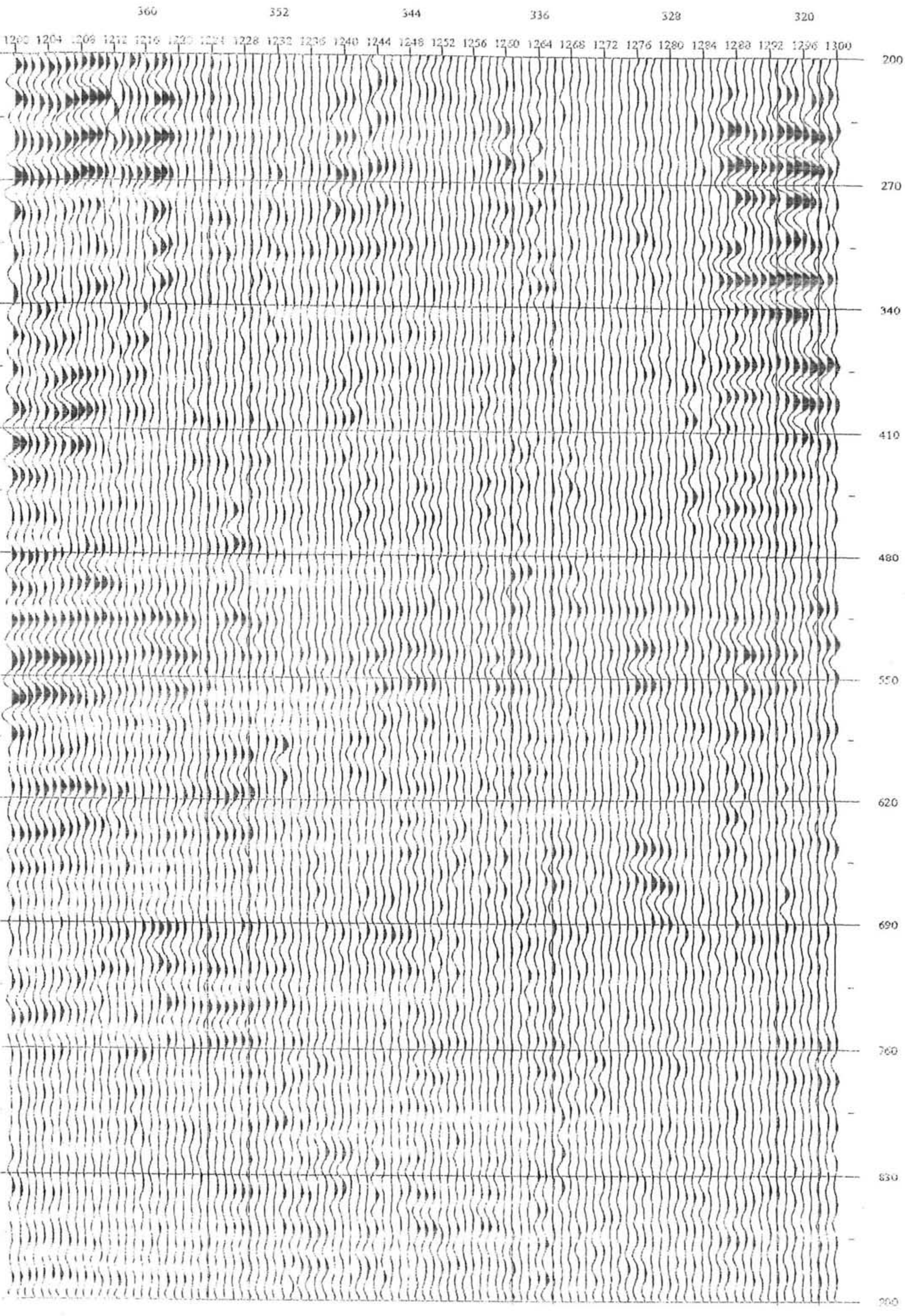


Fig-5a

AMP: 1

Amplitude Spectrum of moon.bin

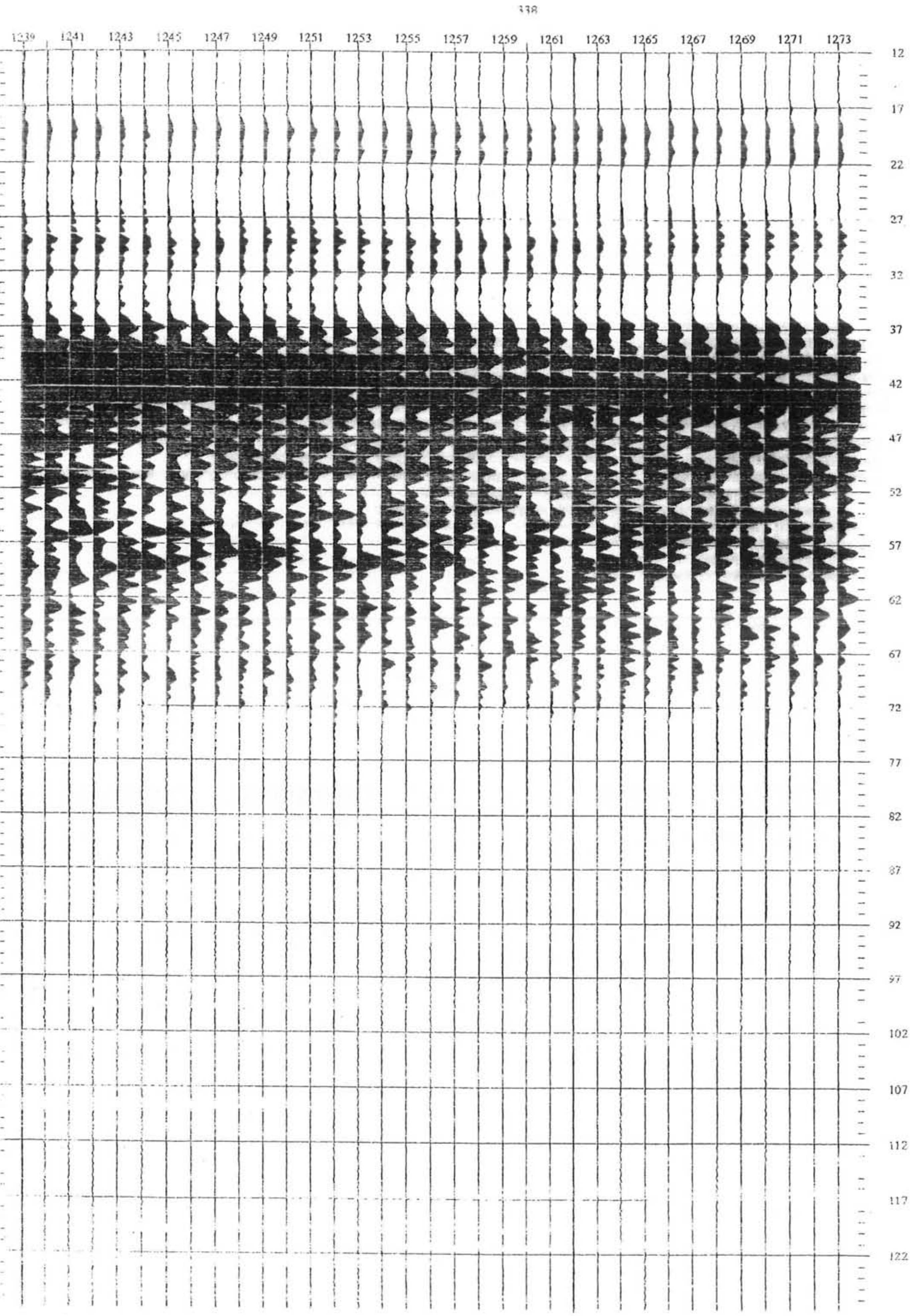


Fig.5b

5 AMP: 1

w85-8.sgy convolved with BP filter 10 - 50 Hz

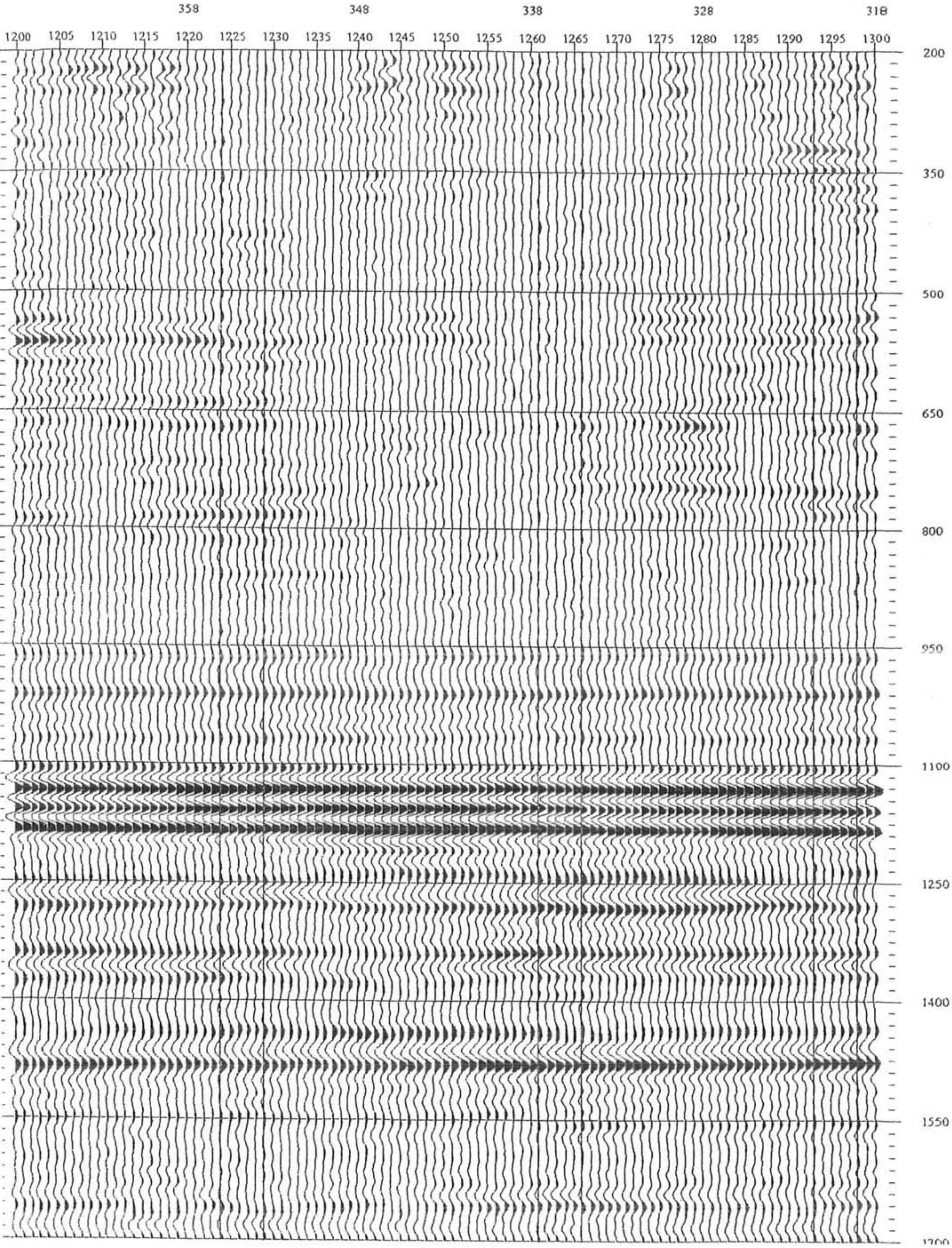


Fig.6.

5 AMP: 1

Amplitude Spectrum of w85-8.sgy

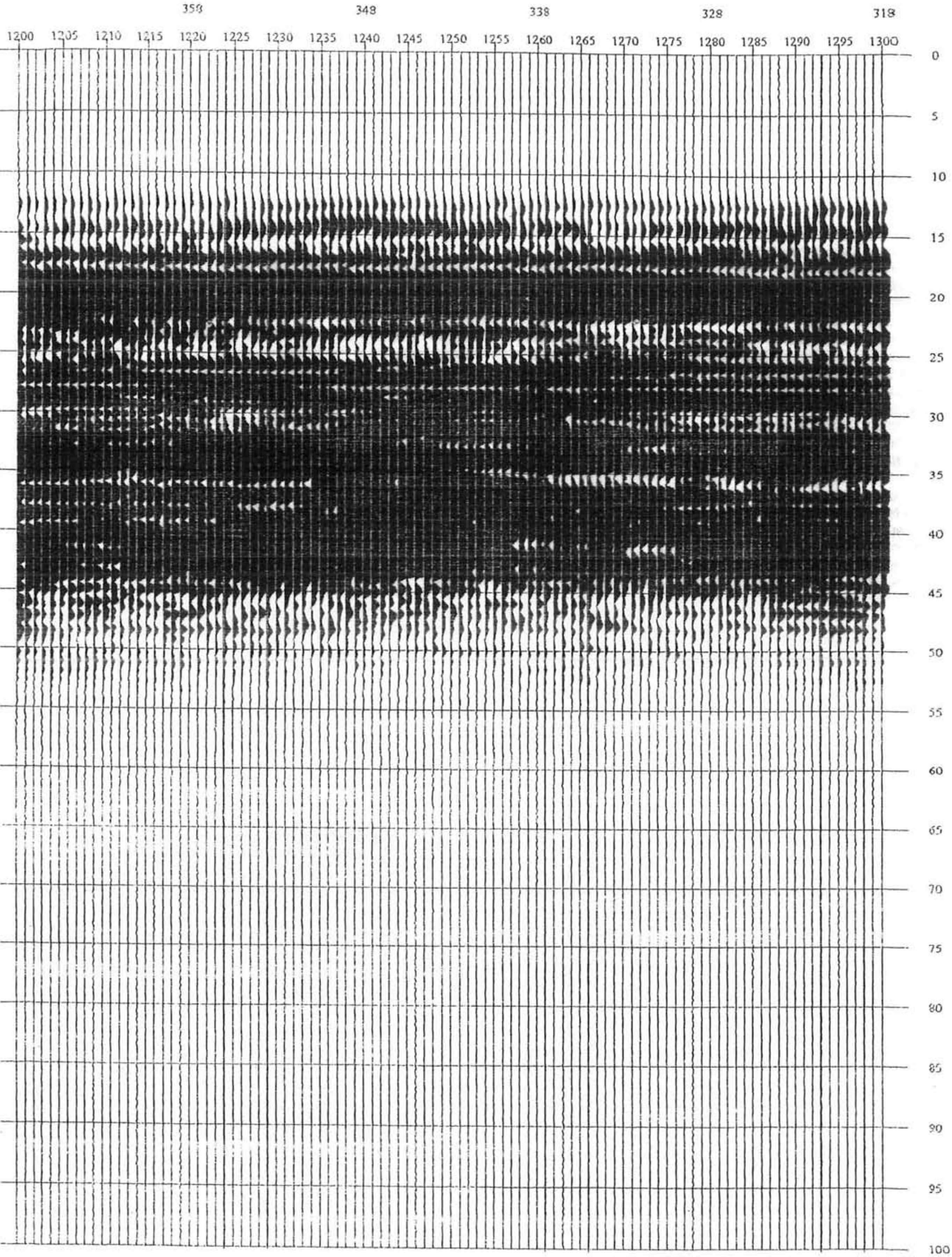


Fig. 7.

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