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PREDICTION AND APPLICATION OF SEISMIC QUALITY FACTOR (Q) IN SOUTHERN TURKEY

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ABSTRACT

Attenuation of seismic waves is a diagnostic parameter to predict petrophysical properties of rocks such as porosity, permeability and fluid saturation. But prediction of attenuation related quality factor (Q) is extremely difficult. There have been a number of methods proposed to compute Q. The algorithm employed in this study is based on spectral-ratio method which uses the slope of the log-amplitude spectrum, derived from seismic data.

It has been observed that after application of inverse Q filtering before stack the resolution of the seismic traces increases and reflections become more distinct. Results of the Q measurements indicate that in limestones, Q increases (attenuation decreases), but as opposed to sandstones Q decreases (attenuation increases). In addition, it has been observed that estimation of Q from seismic data and applying inverse Q filtering can create additional perspective for interpreters.

Keywords : Quality Factor, Q, Attenuation, Southern Turkey

1. INTRODUCTION

One of the major goals in seismic interpretation is to determine rock properties. Many parameters are necessary to make complete interpretation of seismic data such as acoustic impedance, velocity, poisson ratio, and so on. Incorporating seismic absorption into this process may help rock properties better delineated. For instance, absorption is very sensitive to clay (Klimentos and McCann, 1990). Real absorption values are hardly measured but can only be predicted. Elastic absorption in rocks is related to porosity, saturation, fluid type and overburden pressure (Toksöz et all, 1979, Winkler and Nur, 1979, Johnson and Toksöz, 1980). Attenuation is another parameter to shed ligth on lithology. Attenuation-based experiments in labs and in-situ correlate with lithology.

Generally, frequency in seismic recording decreases with time due to frequency dependent losses within the earth. The wave energy is changed by rock properties while waves travel down to the earth. This is called absorption (Kennett et all, Hardage 1983).

Anelastic absorbtion is a transformation of seismic energy into heat. It can be described by the absorbtion coefficient α or the seismic quality factor Q. The exponential decay of amplitude with distance given by;

$$A = A_0 e^{\alpha z}. \tag{1}$$

The spatial attenuation factor for a wave propagating in the z direction is written as $exp\ (-\alpha z)$ where α is the absorption coefficient and,

$$\alpha = \frac{|w|}{2cQ} \tag{2}$$

where $|w|$ is the absolute value of the angular frequency and c is the phase velocity. Q is the quality factor and it can be written as;

$$\frac{2\pi}{Q} = \frac{\Delta E}{E} \tag{3}$$

where ΔE is the energy dissipation per cycle and E is the peak energy stored in the cycle.

Q can be computed by using different methods such as Rise Time Method and Spectral Ratio Method. There are a few publications on contrasting of different methods, and Q calculations are mostly based on some well known methods (Newman and Worthington 1982, Jannsen, Voss and Theilen 1985, Tarif and Bourbie 1987, Badri and Mooney 1987, Tonn 1988, 1989, 1991).

Tonn (1991) studied ten methods of attenuation determination and compared them. These are called amplitude decay, analytical signal, wavelet modeling, frequency modeling, phase modeling, rise time, pulse amplitude, matching technique, spectral modeling and spectral-ratio modeling. Researches have shown that each method has its merits and demerits and ended up with observations that geological units and acquisition parameters are the main effects on Q quality. Therefore, each method has been chosen based on these factors.

In this study, predicted Q values using spectral ratio method have been applied to stack sections.

2. GEOLOGICAL SETTING

The study area is located in the western part of the southeastern Anatolia, Turkey. The location map of the study area is shown in Figure 1. This area geologically is a part of the Arabian plate. The Southeastern Turkey is the main hydrocarbon bearing basin of Turkey. Generalised stratigrafic columnar section of Western SE Anatolia is shown in Figure 2.

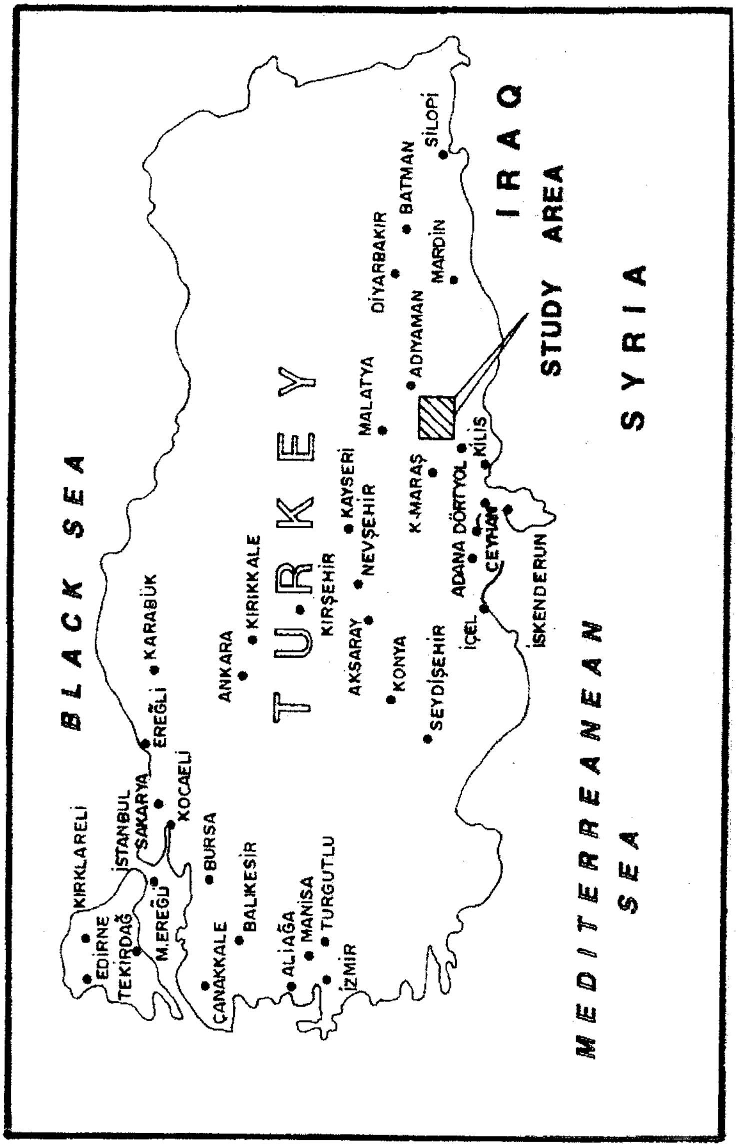

FIG.1. Location map of the study area in Turkey.

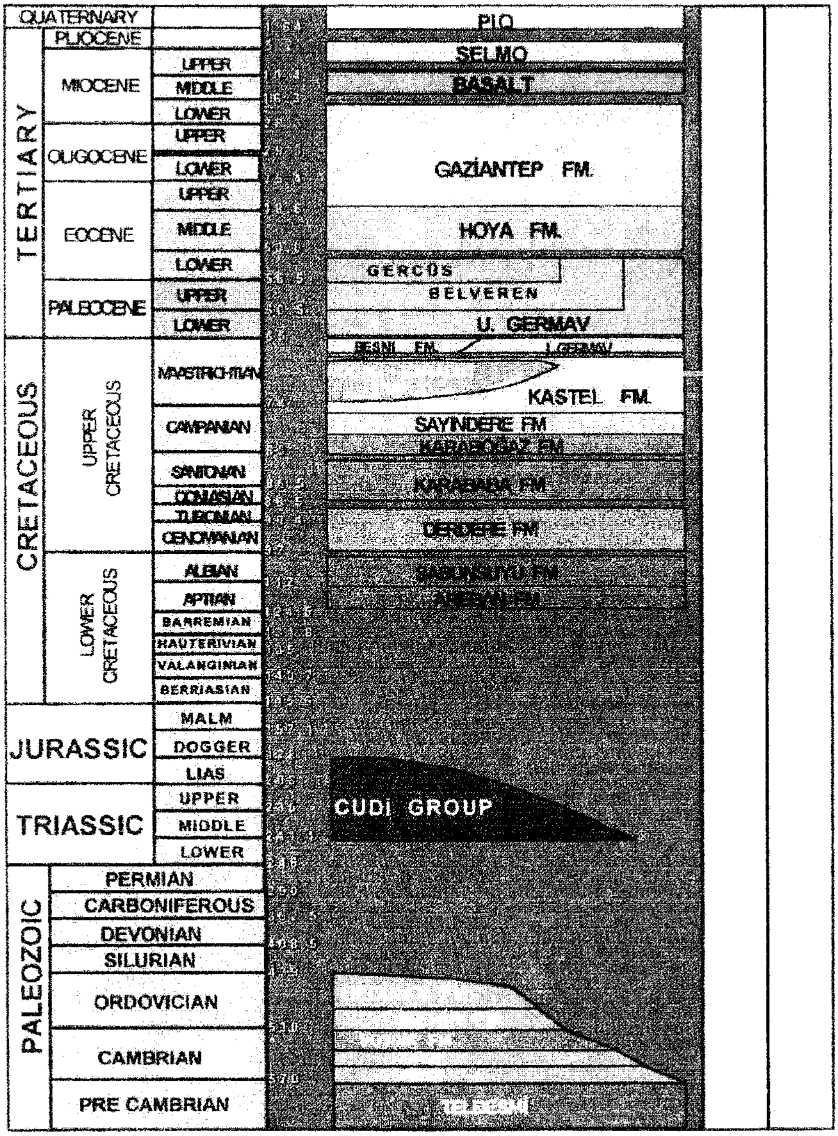

FIG.2. Generalised stratigrafic columnar section of Western SE Anatolia.

3. DATA AND METHODOLOGY

The spectral ratio methods described by Bath (1974) and Babbel (1984) are the best known methods for Q computation. These spectral-ratio methods are divided into three sub-methods called the frequency-ratio method, the station-ratio method, and the amplitude-ratio method . The frequency-ratio method is used for analyzing different frequencies at a single station. The station-ratio method uses different frequencies at more than one station. The amplitude ratio method compares amplitudes at different times. Attenuation can also be predicted using VSP first arrivals and reflections because they have high signal/noise ratio. First arrivals (down going waves) are mostly used in this method (Kenneth et all, 1980).

In this study, first the amplitude spectrum at specified depths were computed using the Fourier transform. The corresponding amplitude spectra A_1 and A_2 are shown in Figure 3. Second, the ratio of A_1 and A_2 at each frequency was computed and then they were plotted as a logorithmic function of these ratios versus frequency. Based on this graph, regression analysis was carried out to compute the negative slope based on $-2\pi \frac{T_2 - T_1}{Q}$ where T_1 and T_2 are different time ranges on the seismic trace and Q refers to the absorbtion occuring over the time range (Anstey 1977).

This method has been used both in laboratoaries (Toksöz et al., 1979) and field data analysis succesfully (Ganley and Kanasewish 1980, Huge 1981, Bulch et al., 1982).

A seismic profile was used for Q estimation as an actual application of the algorithm mentioned above. The seismic profile was located in the Keysun-Kizilin field as depicted in Figure 1. The data were acquired by Türkiye Petrolleri A.O. (TPAO) (Turkish National Oil Company) in 1998 with 240-channel recording system, 25 m. group interval, 50 m shot interval, 2 ms sample rate. Dynamite was

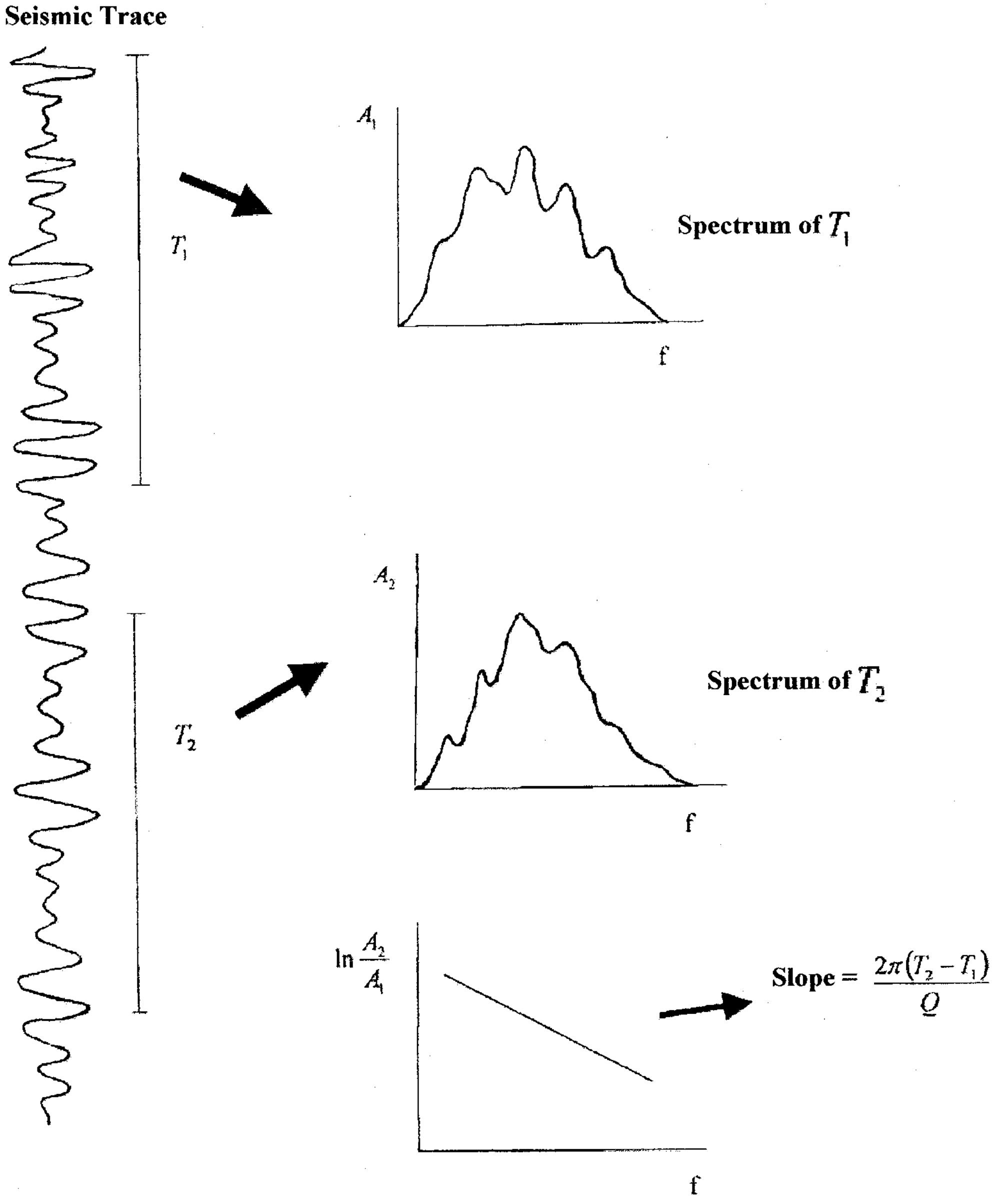

FIG.3. Spectral-ratio method from Anstey, 1977. The ratio of A_1 and A_2 at each frequency was computed and then they were plotted as a logarithmic function of these ratios versus frequency. Based on this graph, regression analysis was carried out to compute the negative slope based on the formula.

used as source during the acquisition. There are two wells located on the seismic profile which were drilled by TPAO.

4. OBSERVATION OF Q DIVERSITY ON REAL DATA

The seismic data used for this study were demultiplexed and bad traces were edited. Since true amplitudes are necessary for Q computation, conventional processing steps were not applied. The basic sequence applied to the data are; spherical divergence, velocity analysis, NMO correction, mute application, residual static correction and Butterworth filter (8-72 Hz.) prior to final stack and migration. Spectrum analysis was done after migration on CDP 1010. For this purpose, the amplitude spectrum was plotted for every 512 ms. stack window. The ratio of first stack window to the second has been cross-plotted with respect to frequency. After regression analysis of this plot, Q compansation has been calculated using the following formula;

$$Slope = -2\pi \frac{T_2 - T_1}{Q} \tag{4}$$

In Figure 4, between 1024 ms.-512 ms. time ranges Q was found to be 61. By using the same method in Figure 5, Q was found to be 88 (between 1536-1024 ms. time ranges), and in Figure 6, Q is 70 (between 2048-1536 ms. time ranges) and in Figure 7, Q is 104 (between 2560-2048 ms. time ranges). These Q values have been used in QCOMP program (Paradigm Trademark), and they were used for pre-stack inverse Q filtering.

On the other hand, since Q filters effect the amplitude and phase of seismic data, after sorting, inverse Q filtering was applied to the all sequence of processing, such as velocity analysis, mute, residual static and so on. Until this point, Q values obtained at CDP 1010, which is the well location, have been applied to the whole section.

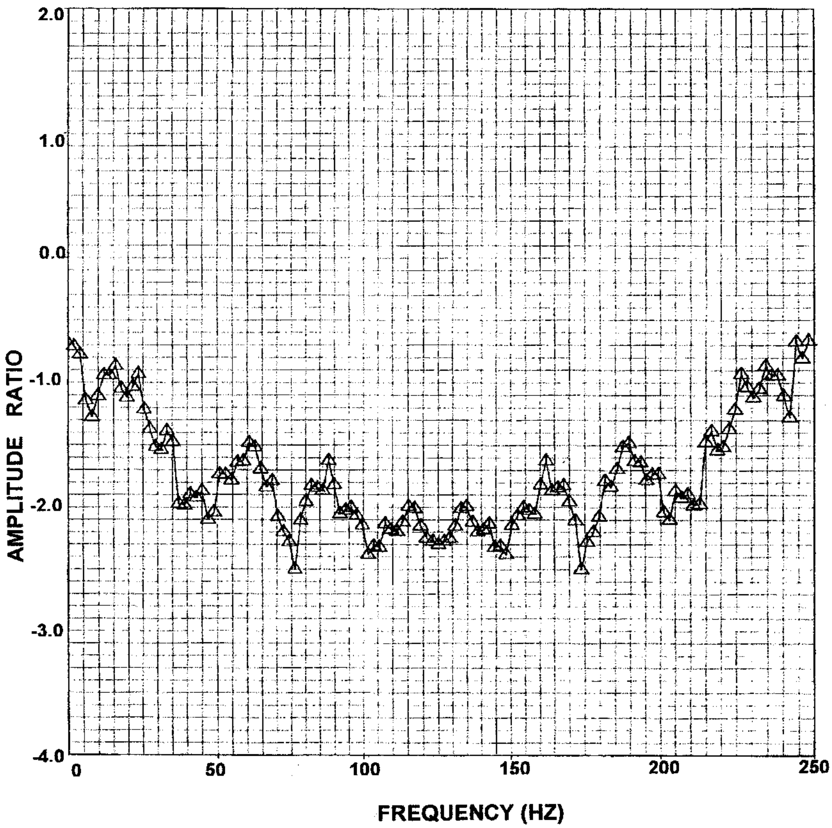

FIG.4. The amplitude ratio versus frequency plot taken from 512-1024 ms.time ranges. Based on this graph and the formula Q was found to be 61.

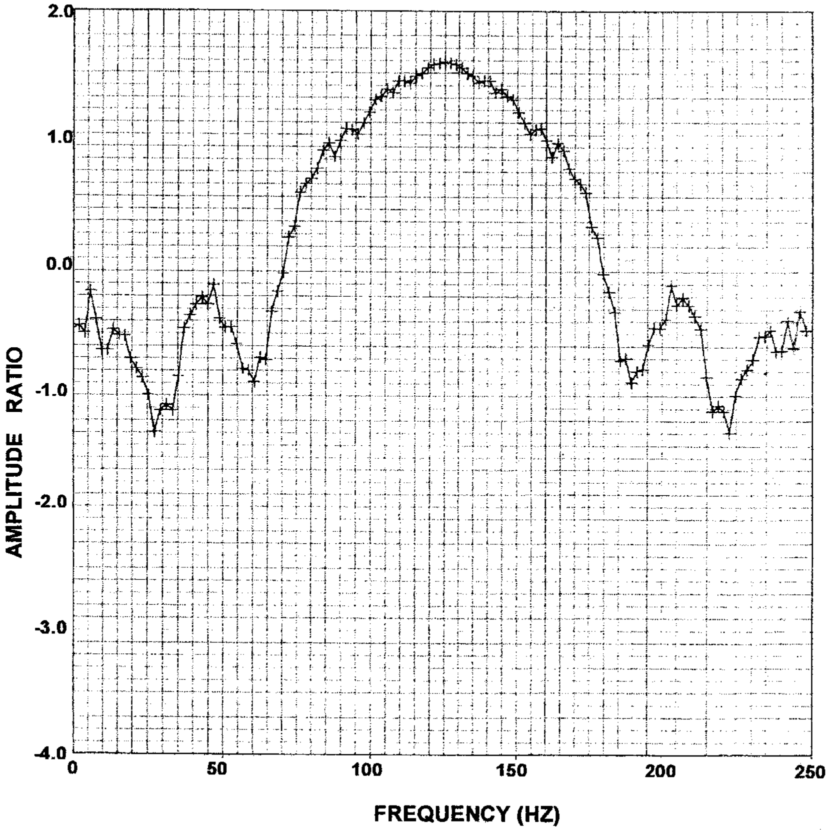

FIG.5. The amplitude ratio versus frequency plot taken from 1024-1536 ms.time ranges. Based on this graph and the formula Q was found to be 88.

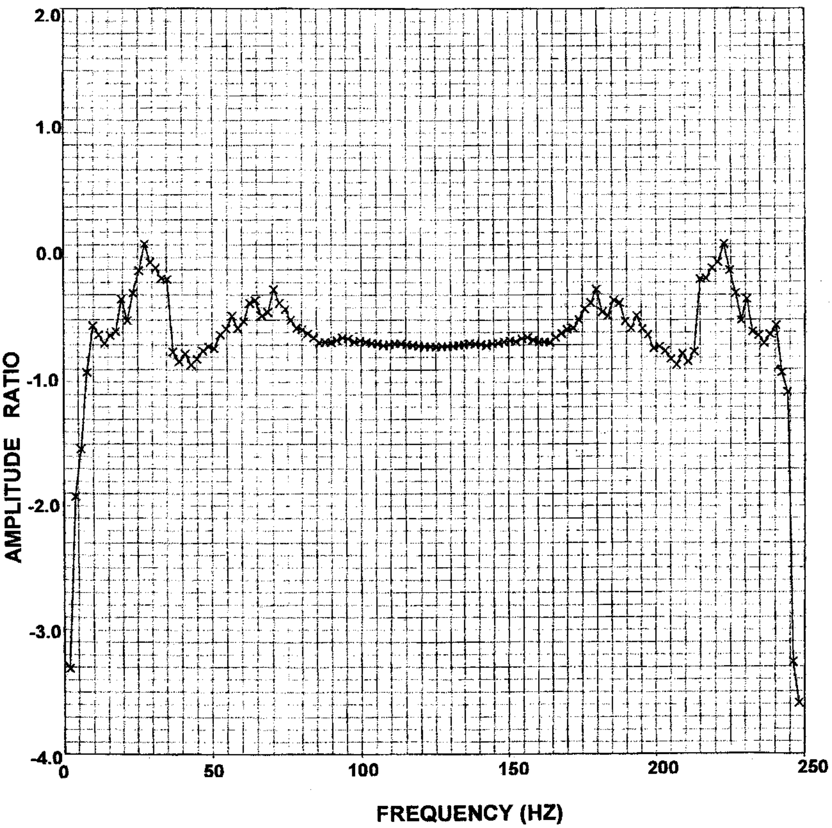

FIG.6. The amplitude ratio versus frequency plot taken from 1536-2048 ms.time ranges. Based on this graph and the formula Q was found to be 70.

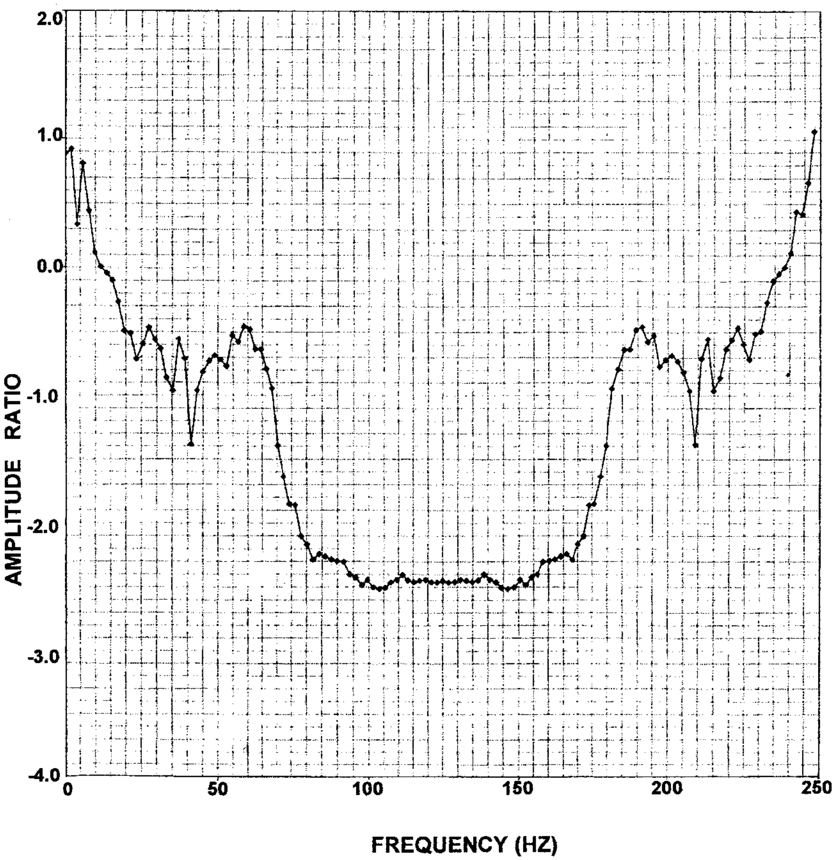

FIG.7. The amplitude ratio versus frequency plot taken from 2048-2560 ms.time ranges. Based on this graph and the formula Q was found to be 104.

The seismic section processed conventionally is shown in Figure 8. In order to see the effect of inverse Q filtering, Q values applied to the conventionally processed data. The result is shown in Figure 9. And then the migration was applied on this stacked data which is shown Figure 10, and the other migration, applied after stacked with inverse Q filtered data is shown Figure 11.

Up to this point, only Q values obtained from the vicinity of the well was applied to the whole section. (These values are 61,88,70,104). We analysed whether the Q's from the four different CDP's agree with above values. For this, we chose the traces that represent different parts of the section from CDP's 1055,1380,1560 and compare them with those obtained from the vicinity of the well.Table 1 shows this comparision.

One can easily that these values are in good agreement with each other except CDP 1380, Q=55 values. To understand why this differs from others, we studied the logs of the well. To see the characteristics of the formation, the time section was converted to the depth section (the times corresponded to the depths of 920 m., 2005 m., 3020 m. are 512 msn, 1024 msn. and 1530 msn, respectively).

In general, the lithology consists of limestone and there is no porosity indications in the logs for CDP 1380. However, where the Q value is 55 the logs indicate porosity. It is well known that the porous media absorbs the energy, considerably.

It is easily observed that Q values at the same time are very close to each other. Log interpretation has been used for petrophysical information such as porosity, fluid type, and so on.

For this purpose, Gamma Ray, Sonic, Neutron-Density logs have been interpreted for petrophysical properties of the rocks in the stratigraphy. Run 1 contains only Gamma Ray and Sonic logs. As mentioned above in the seismic section, the intervals that obtained for Q values converted to depth.

The petrophysics results can be summarized as;

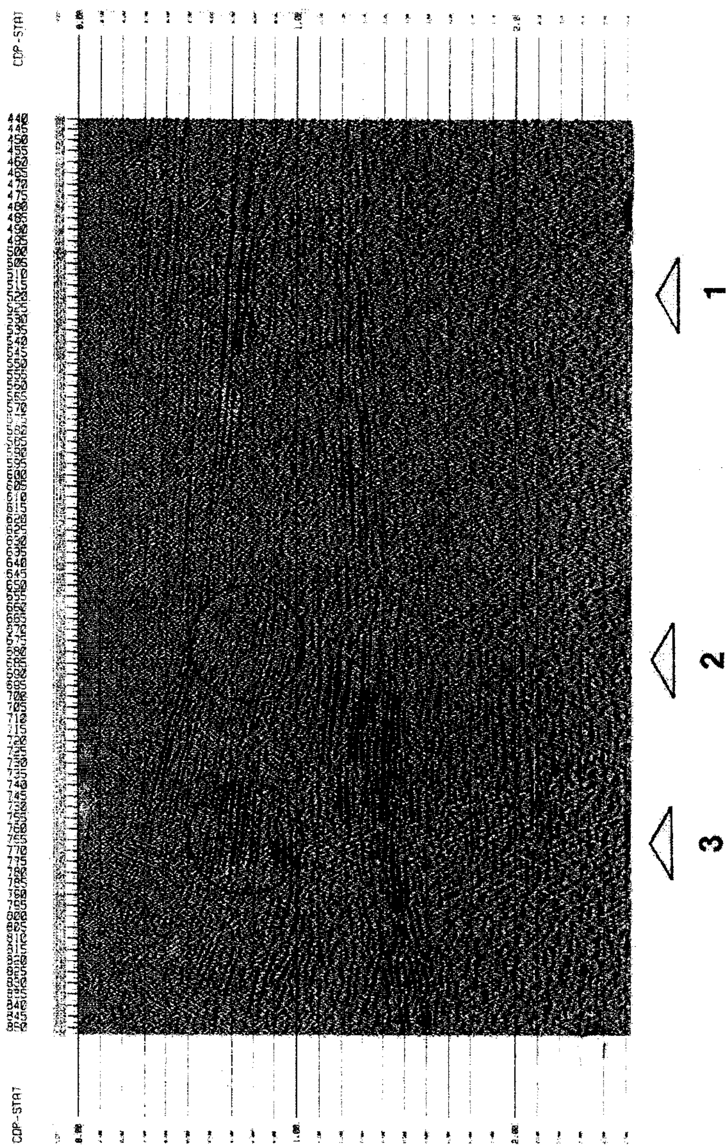

FIG.8. Conventionally. Processed seismic stack section.

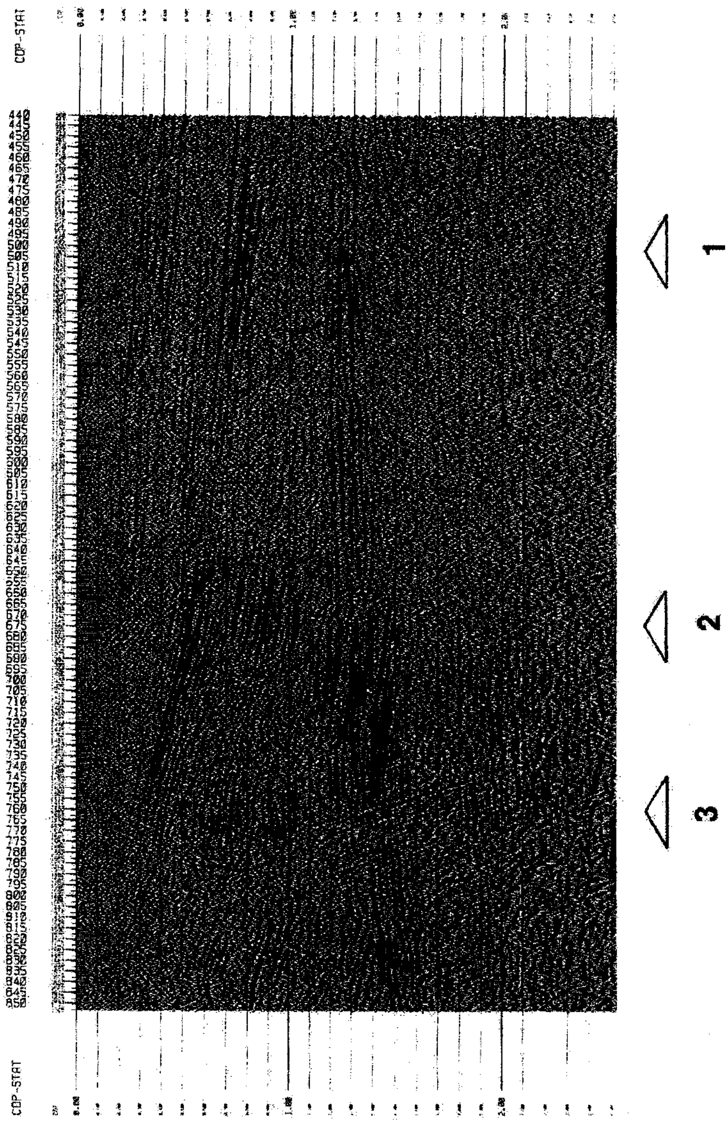

FIG.9. Inverse Q filtering applied to the seismic stack section.

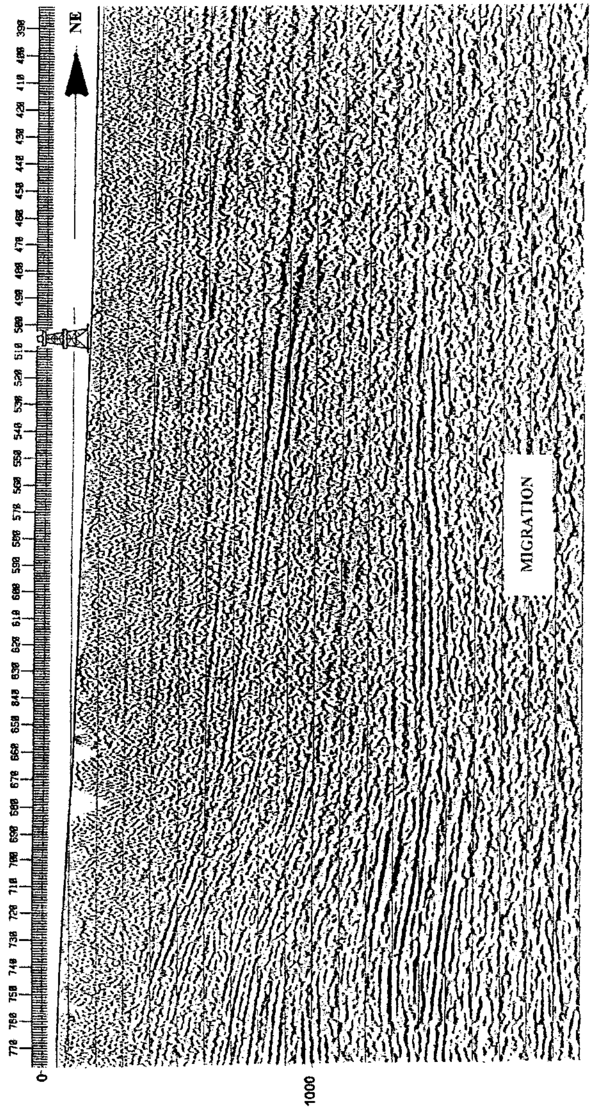

FIG.10. Migration applied to the conventionally processed seismic stack section.

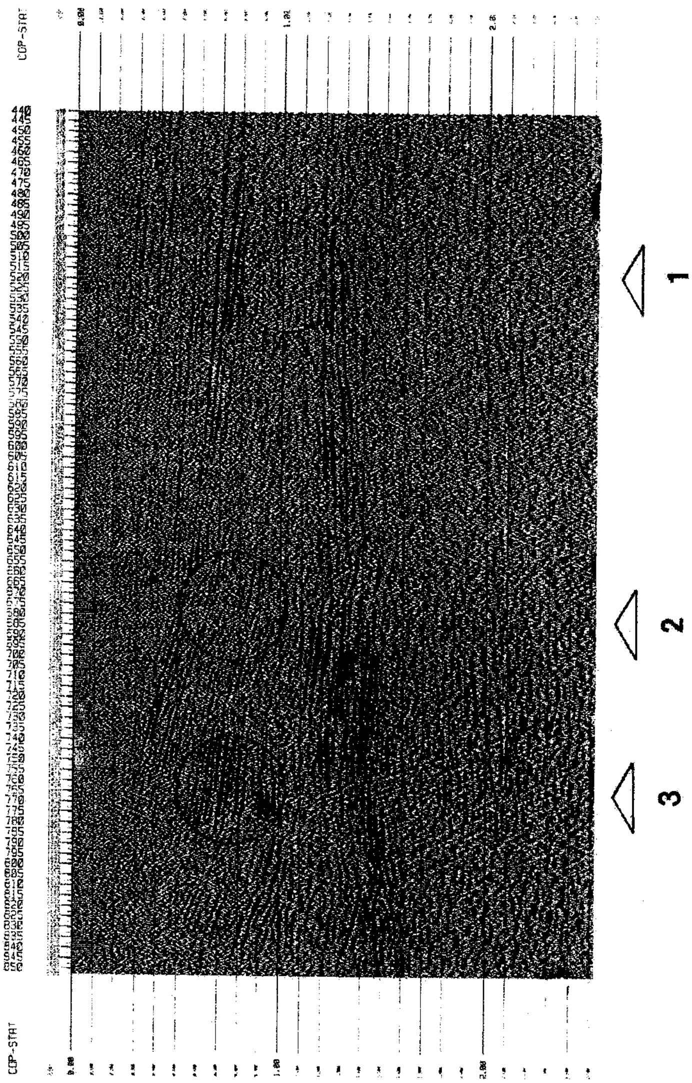

FIG.11. Migration applied to the seismic stack section processed with inverse Q filtering.

TABLE

	$Q_1 = \frac{A_{1024ms}}{A_{512ms}}$	$Q_2 = \frac{A_{1536ms}}{A_{1024ms}}$	$Q_3 = \frac{A_{2048ms}}{A_{1536ms}}$	$Q_4 = \frac{A_{2560ms}}{A_{2048ms}}$
CDP 1010	**61**	**88**	**70**	**104**
CDP 1055	**48**	**93**	**85**	**187**
CDP 1380	**37**	**80**	**55**	**112**
CDP 1560	**45**	**80**	**80**	**125**

TABLE 1. The comparision Q values from different parts of the section from CDP's 1010, 1055,1380 and 1560.

At 1842 m, the lithology consist of clay-limestone, no stain, no porosity.

At 1944 m, lithology, limestone and chert, no stain, no porosity

At 1951m, limestone, and stain between 1952m and 1980m. Porosity is 7% between 1952 and 1956, also 1966 and 1972.

At 1987, lithology is limestone and chert, no stain, porosity is 3% 1987-1990, 2 to 9 % in between 1995 and 2003, fracture between 1990 and 2001.

At 2043, lithology clay limestone. No hydrocarbon.

At 2055, limestone, asphaltine stain, below oil water contact.

5. DISCUSSION

Before this study, the limestone in the stratigraphy could not been identified by using seismic profiles and the well information. Geological and geophysical adverse effects were searched to identify the cause of the resolution problem. The main reason was related to the seismic data processing. Then, every step of the processing algorithm was examined again for this seismic section such as velocity analysis, mute, and so on. But working on parameters on residual static, velocity analysis and mute did not increase the resolution for the seismic section. Therefore, Q filter was added to the processing algorithm. The Q filter effect can be observed in Figures 12 and 13. They are the enlarged versions of the improved parts. Figure 14 and 15 show the lithology taken from the well and the portions of the migrated section with and without inverse Q filter respectively. The improvement of the resolution of the stack sections can seen easily. The interpretations of the seismic sections with Q filter and without Q filter are as follows.

From Figures 8 and 9;

a) Q filter section has little improvement on the layers of group 1.

b) The layers of group 2 are correlated to the group 1 after processing with Q filter.

c) The group 2 correlates with the group 3, clearly. Lithology in the groups 2 and 3 is shale and sandstone alternation. Absorption in the shale and sandstone alternation is high. After applying Q filter to the seismic data, we have got improvement in resolution.

From Figures 12 and 13;

The horizontal resolution in migration-applied seismic stack section processed with inverse Q filtering (Figure 13) is better than the migration without inverse Q filtering (Figure 12). This, obviously identifies the stratigraphy much more clearly.

From Figures 14 and 15;

The red colored level is clear and continious. This is because Sayindere Formation consists of limestone with clay and it's velocity is low.

The yellow and blue colored levels are also clear.

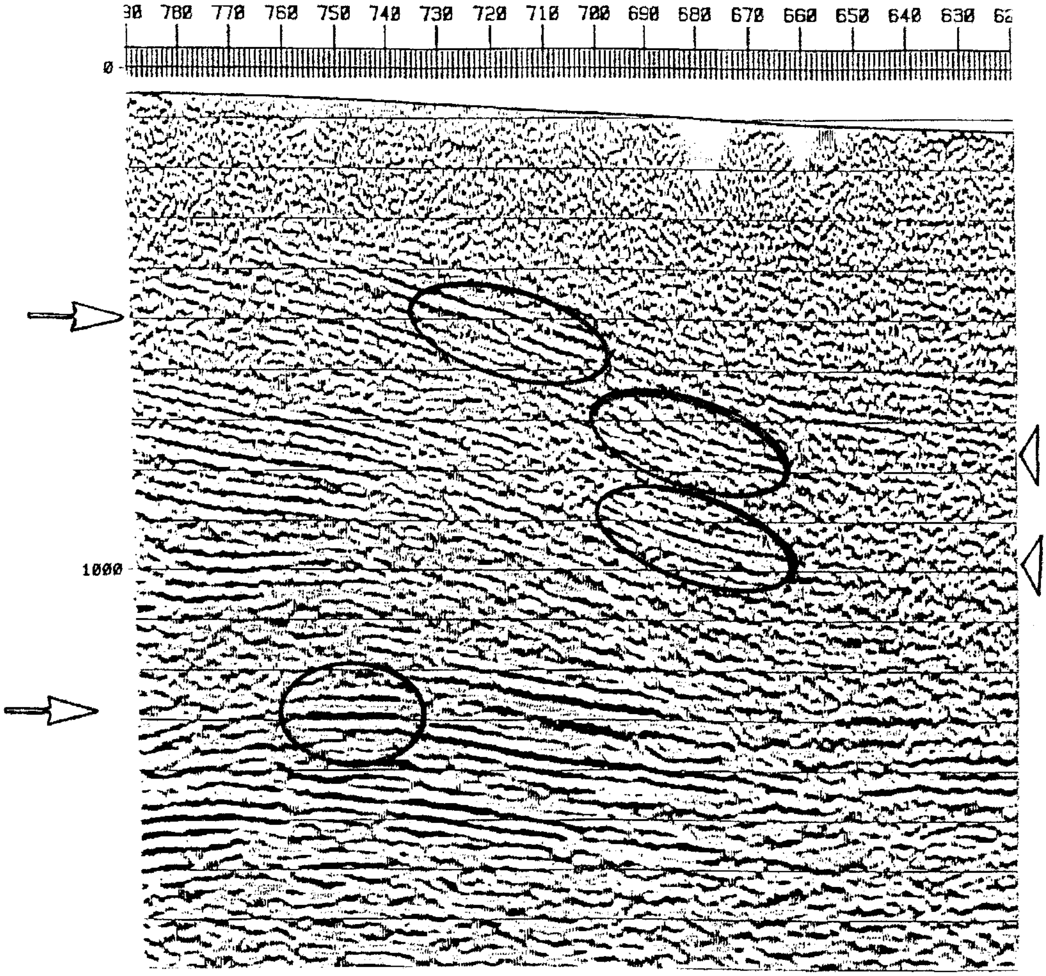

FIG.12. The enlarged versions of the Fig.10.

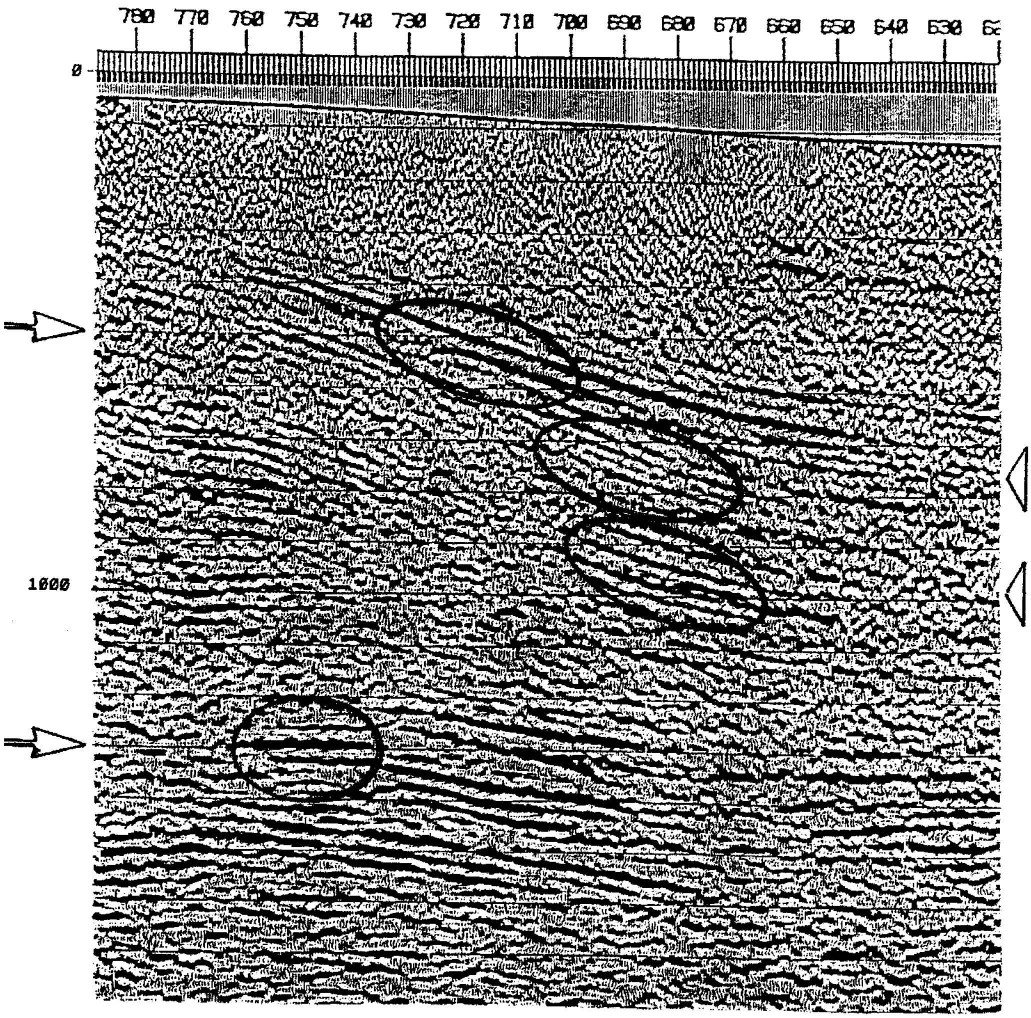

FIG.13. The enlarged versions of the Fig.11.

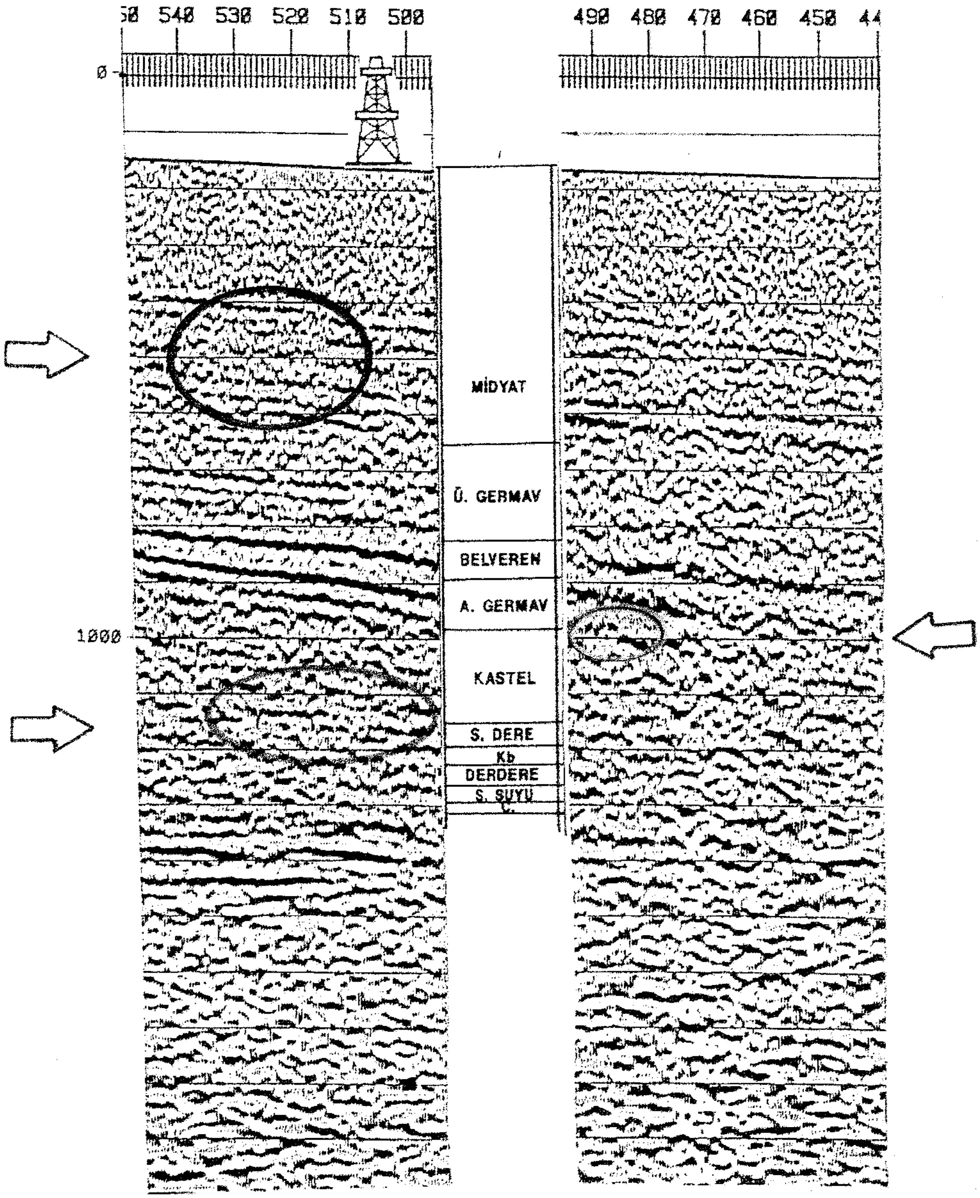

FIG.14. The lithology taken from the well and the portions of the migration section without inverse Q filtering.

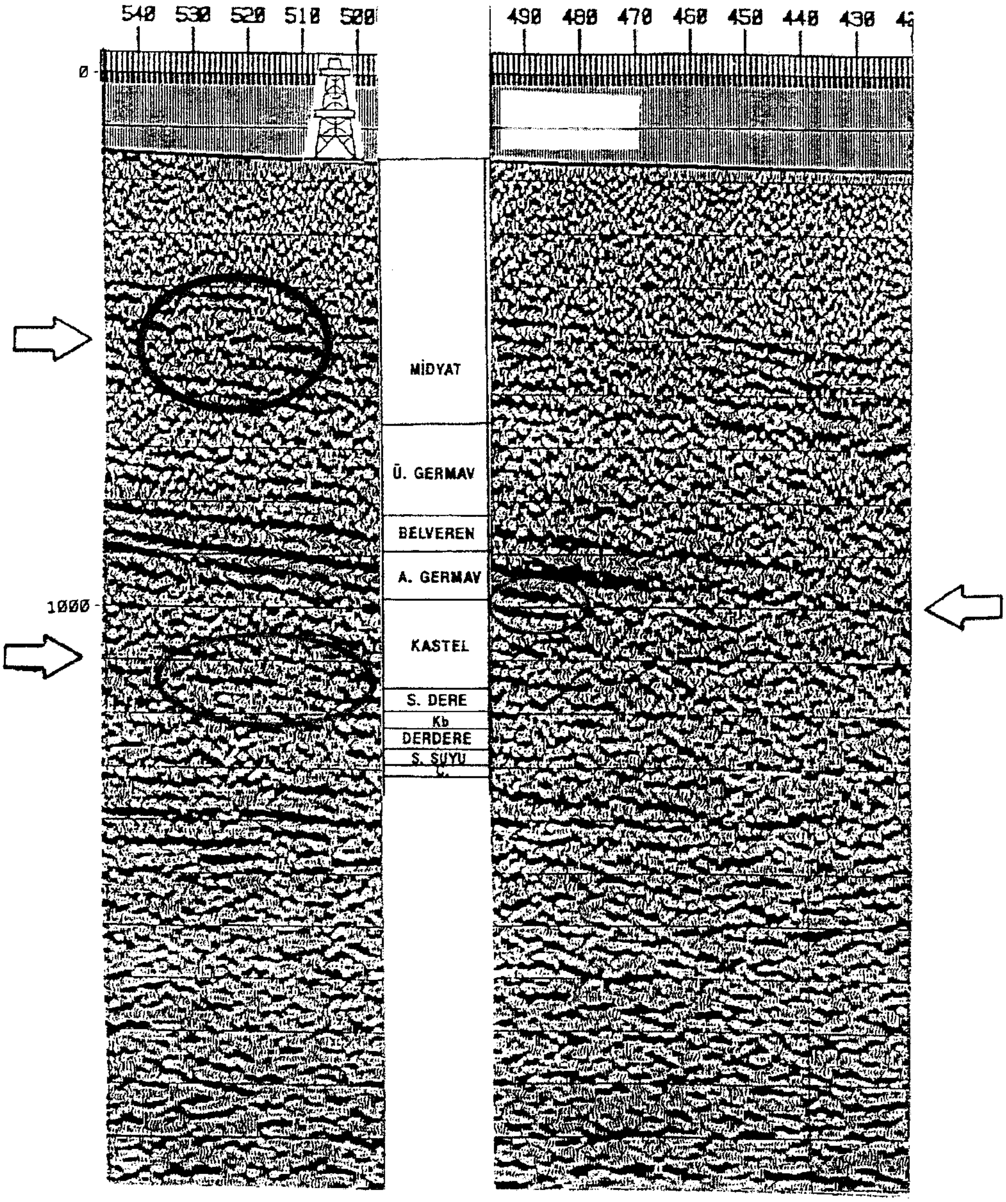

FIG.15. The lithology taken from the well and the portions of the migration section with inverse Q filtering.

6. CONCLUSION RECOMMENDATION

The attenuation of seismic energy is the result of wave propagation. Attenuation affects the frequency dependent amplitude and phase of the recorded reflection and in turn affects signal/noise ratio.

Amplitude and phase distortion and seismic and sonic time can be recovered by inverse Q filter. Inverse Q filter is useful after conventional statistical convolution. Inverse Q filter is revealing to be a method of recovering phase distortion and waveform distortion after spiking deconvolution.

In application, Q has been computed from log-amplitude spectrum by using written codes. After this, QCOMP programme has been used to apply Q filtering. This software corrects phase distortions, but it does not correct amplitude.

In this study it is observed that the inverse Q filtering works very well for intervals which contain sandstone, shale and marn, but it does not work for limestone. One well information has been used for getting petrophysical properties of the rocks in the area. If there were more than one well information, this application would have been more useful in interpretation.

Another programme may be requiring both correct amplitude and phase distortion during seismic data processing.

Q filtering didn't work for some parts of the seismic sections. It must be studied further if this is related to QCOMP program.

7. ACKNOWLEDGMENT

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