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ATTENUATION AND REFLECTIVITY OF SEISMIC WAVES IN EVAPORITE SUCCESSION AT RAS FANAR AREA, GULF OF SUEZ

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ABSTRACT

This work is carried out to study the effects of the quality and thickness of rocks forming the Zeit, South Gharib and Belayim Formations on the seismic wave propagation in Ras Fanar area.

The seismic quality factor (Q) of rocks has been determined to study the influence of these formations on the seismic waves characteristics. The reflection and transmission coefficients are analyzed and accordingly the amplitudes and phases of the frequency dependance reflection coefficient at different angles of incidence upon sequence of these formations have been computed and examined. From this study the influence of Zeit, South Gharib and Belayim Formations on the dynamical characteristic of the reflected wave is investigated.

INTRODUCTION

The study area is located west of Ras Gharib Oil field in the offshore western side of the Gulf Of Suez between Longitudes 33° 03′ N and 33° 09′ N and Latitudes 28° 20′ E and 28° 25′ E (Fig. 1).

The drilled wells in the study area (Fig. 2) exhibit a number of unconformities between Middle Miocene Formations and the underlaying Pre- Miocene Formations. The penetrated Miocene Rock Units in the study area are successfully upward as follows : Belayim,

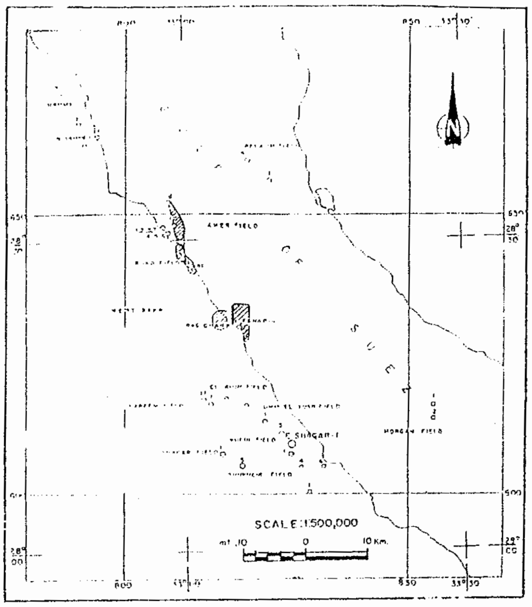


Fig. 1. Location map of the study area.

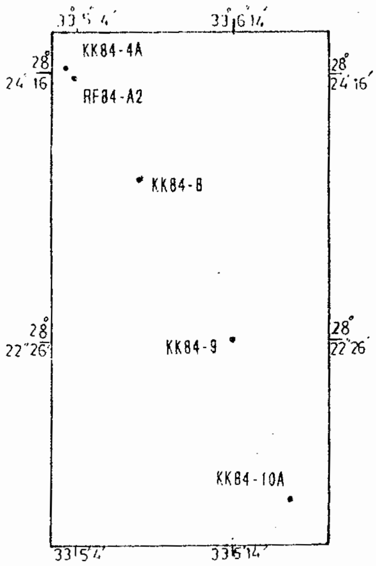


Fig. 2. Location map for the study wells.

South Gharib and Zeit Formations.

Futterman (1962), showed that a causal wave (i.e one generated by a sudden release of energy) traveling in a medium that attenuates the energy as the travel time increases, theoretically must be effected by dispersion. This is, of course because the velocity of wave components is a function of their frequency.

The reexaminations carried out by Waters (1987), for the original data taken by Mc Donal *et al.* (1958), Wuenschel (1965), and Kjartansson (1979), show that there was almost an effect fit with a dispersive, constant Q model, where the symbol Q is often used to denote the quality of a rocks for seismic wave propagation or seismic quality factor for rocks .

In this study, the seismic quality factor (Q) has been determined and used to study the effect of frequency dependence attenuation of Zeit, South Gharib and Belayim Formations on seismic waves.

The reflection and transmission coefficients of these formations has been analyzed using the acoustic impedance of the succession, together with thicknesses of these formations at different wells. Then amplitudes and phases of the frequency dependance reflection coefficient have been computed and examined at different angles of incidence of seismic wave upon sequences of these formations.

I. THEORETICAL CONSIDERATION OF SEISMIC WAVE ATTENUATION

The relationship between the value of seismic quality factor or quality of rock for seismic wave propagation (Q) and velocity for this rock (V) is given by Waters (1987) as :

$$1/Q = C/V^2 \quad \text{...} \quad 1$$

where $C = 10^6$

The seismic quality factor of Zeit, South Gharib and Belayim rocks are determined at different wells and have been calculated using interval velocity of these formations (Fig, 3) and represent in maps (Figs. 4a, 4b and 4c). These factors are used to determined the attenuation coefficient (α) of these formation at different frequencies using Waters Formula (1987)

$$\alpha = \pi f / Q V \quad \text{...} \quad 2$$

The attenuation coefficient distribution maps for Zeit, South Gharib and Belayim Formations at frequencies (10 Hz, 20 Hz and 30 Hz) are represented in figures (5-7). These maps can be described as follows :

1. The attenuation coefficient distribution maps of Zeit Formation (Figs. 5a, 5b & 5c) show increasing of attenuation coefficient values towards southeastern part of the area (well KK48-10A) and decreasing towards the northestern part of the area (wells RF-2 and KK 84-4A)

2. The attenuation coefficient distribution maps of South Gharib Formation (Figs. 6a, 6b &6c) exhibit considerable high values of the attenuation coefficient occupying the area around well KK 84-8. These values are decreased towards the northwestern and southeastern parts of the area.

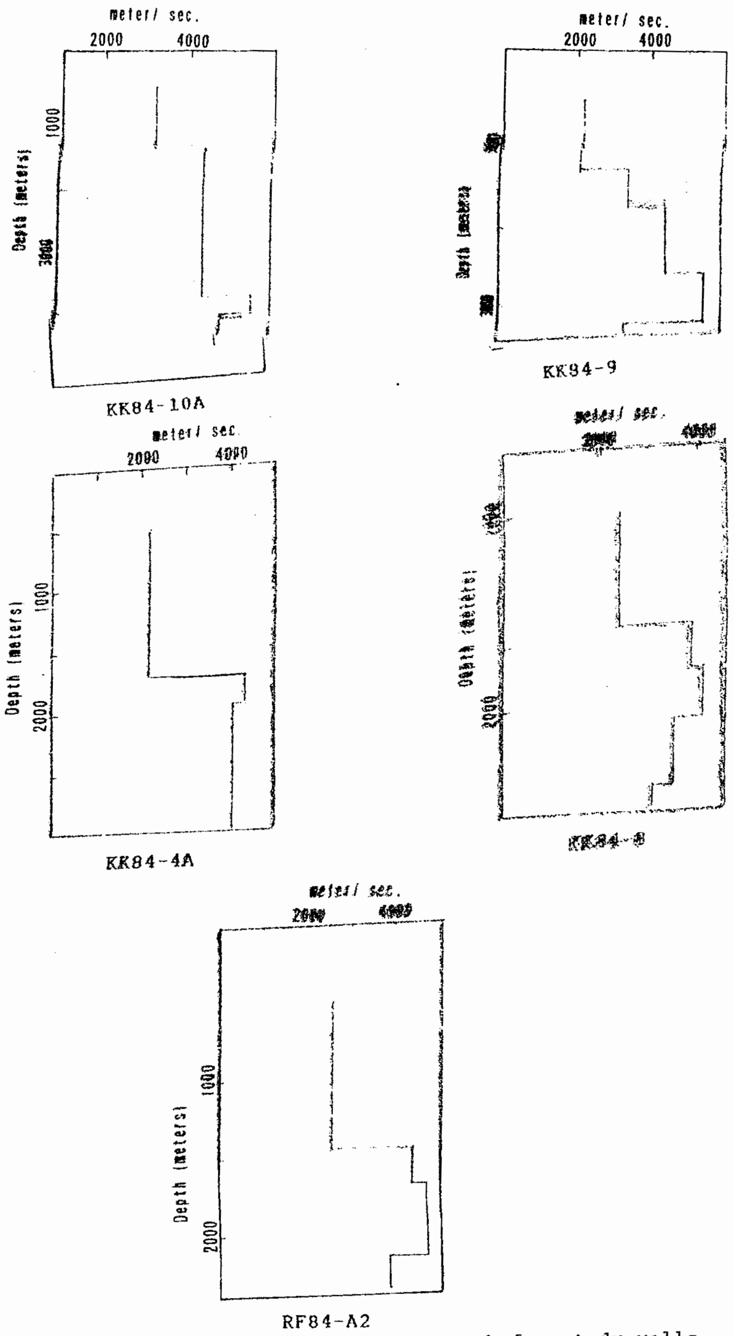


Fig .3. Interval velocity versuse depth for study wells

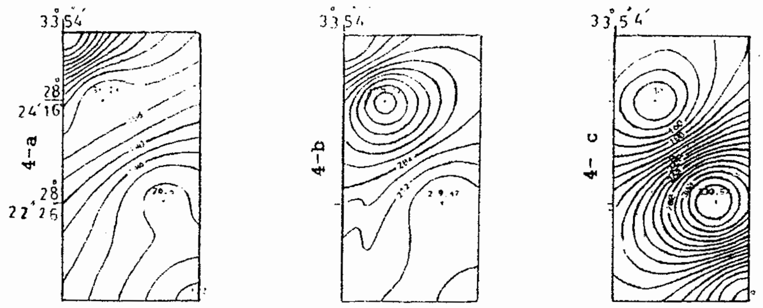


Fig. 4. Seismic quality factor maps (Q) for a- Zeit Formation b- South Gharib Formation c- Belayim Formation.

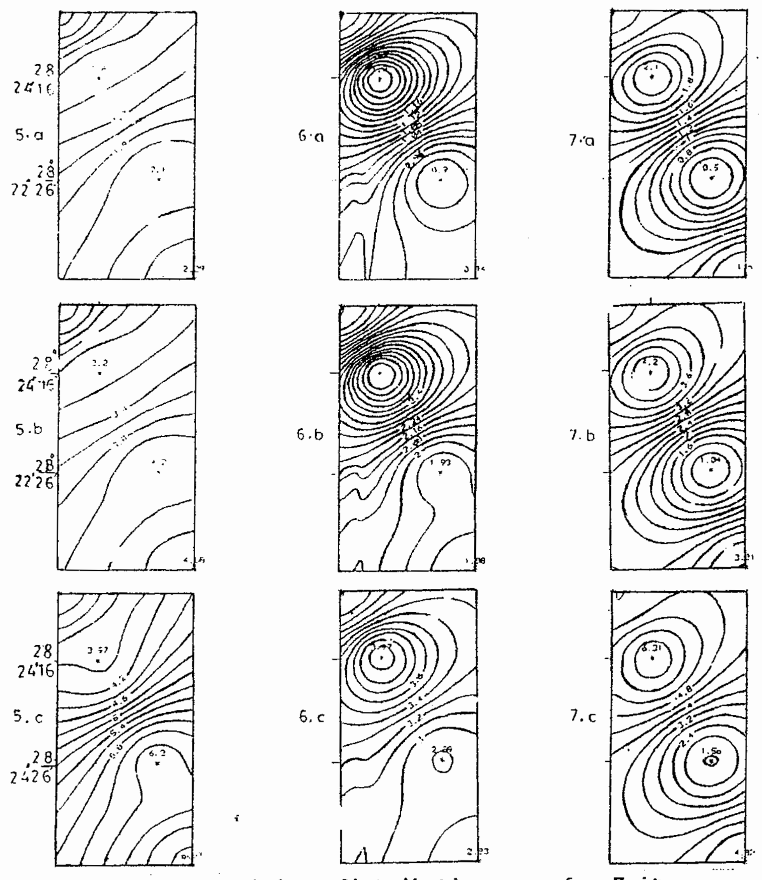


Fig. 5. Attenuation coefficient distribution maps for Zeit Formation at frequencies a-10 Hz b-20 Hz c-30 Hz

Fig. 6. Attenuation coefficient distribution maps for South Gharib Formation at frequencies a-10 Hz b-20 Hz c-30 Hz

Fig. 7. Attenuation coefficient distribution maps for Belayim Formation at frequencies a-10 Hz b-20 Hz c-30 Hz

3. The attenuation coefficient distribution maps of Belayim Formation (Figs. 7a, 7b &7c) show high anomaly values around well KK 84-8 and low anomaly values around well KK 48-9.

Comparison between the results of these maps and isolith facies maps of the above mentioned formations (Figs 8-10) indicates increase of attenuation coefficient with decreasing the evaporite percentage in Zeit and South Gharib Formations, and the attenuation coefficient values of Belayim Formation are smaller than its overlaying studied formations, this can be returned to the rock constituent of Belayim Formation is mainly limestone and dolomite.

II. REFLECTIVITY STUDIES

A. Reflection and Transmission Coefficients

For normal incidence of seismic wave the reflection coefficient (R) is represented by O'Doherty and Anstey (1971) and Sheriff (1980) by the following equation :

$$R = (\rho_2 v_2 - \rho_1 v_1) / (\rho_2 v_2 - + \rho_1 v_1) \quad ....3$$

Where ρ_1, ρ_2, v_1 and v_2 are the densities and seismic wave velocities of the upper and lower medium respectively. This equation can be expressed as :

$$R = (I_2 - I_1) / (I_2 + I_1) \quad .... 4$$

Where " I" acoustic impedance is the product of density and seismic wave velocity.

The two-way transmission coefficient (T) for normal incidence wave is given by O`Doherty and Anstey (1971) as :

$$T = 4 (\rho_1 v_1 \rho_2 v_2) / (\rho_1 v_1 + \rho_2 v_2)^2 \qquad 5$$

$$T = 4 (I_1 I_2) / (I_1 + I_2)^2 \qquad 6$$

To generalize the reflection and transmission coefficients for angles of incidence (i)

$$R_i = (I_2 \cos r - I_1 \cos i) / (I_2 \cos r + I_1 \cos i) \qquad 7$$

and

$$T_i = I - R_i^2$$

Where i is the angles of incidence and r is the angles of refraction of the transmitted P wave. These two angles are related by Snell's law :

$$(\sin i / \sin r) = (V_1 / V_2) \qquad 8$$

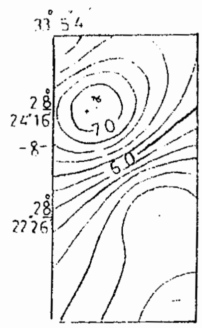
The calculated values of the acoustic impedance, reflection and transmission coefficient for Zeit , South Gharib and Belayim Formations are demonstrated in table 1 and Figures 11 (a, b & c) and 12 (a, b & c). These illustration reveal the following :

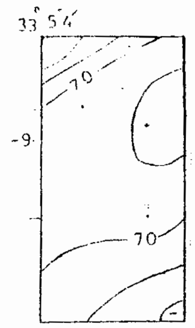
1. The map of Zeit Formation (Fig. 11a) shows high positive reflection coefficient values in the northwestern part of the area which decrease towards the southeasten part .

2. The reflection coefficient map of South Gharib Formation (Fig. 11 b) exhibits increasing values towards well RF-A2 in the northwestern part of the area and towards well KK84-9.

Table 1. Represents velocities, densities, and reflection and transmission coefficients at different angles of incidence.

Formation	Velocity	Density	R.c i=0	R.c i=10	R.c i=20	R.c i=30	T i=0	T i=10	T i=20	T i=30
Well:KK84-9										
Post Zeit	2177.03	2.5								
Zeit	3483.25	2.45	.221	.209	.165	.041	.778	.79	.83	.95
South Gharib	4515.33	2.55	.148	.143	.125	.08	.85	.85	.87	.91
Belayim	5541.54	2.65	.121	.117	.103	.07	.87	.88	.89	.92
Matulla										
Well: KK:84-8										
Post Zeit	2344.5	2.5								
Zeit	3809.81	2.45	.228	.216	.169	.03	.771	.78	.83	.96
South Gharib	4063.8	2.55	.052	.051	.047	.04	.94	.948	.95	.95
Belayim	3483.259	2.3	-.127	-.125	-.119	-.107	1.12	1.12	1.11	1.07
Esna	3047.85	2.4								
Well: RF-A2										
Post Zeit	2539.87	2.5								
Zeit	4354.07	2.45	.25	.23	.18	-.0004	.74	.76	.81	1
South Gharib	4689	2.55	.05	.055	.051	.043	.94	.94	.94	.95
Belayim	3809.81	2.45	-.123	-.12	-.11	-.09	1.12	1.12	1.11	1.09
Well: KK84-10										
Post Zeit	2177.03	2.5								
Zeit & south Gharib	3386.5	2.45	.207	.196	.157	.05	.79	.8	.84	.94
Belayim	3809.081	2.325	-.0437	-.041	-.034	-.02	.92	.93	.95	1
Nubia B	4354	2.45								
Well KK84-4A										
Post Zeit	2177.03	2.5								
South Gharib	4354.07	2.55	.34	.32	.22	-.97	.65	.67	.77	1.9
Belayim	4063.8	2.45	-.054	-.053	-.05	-.04	1.05	1.05	1.05	1.04
Basal Bed	4060	2.43								





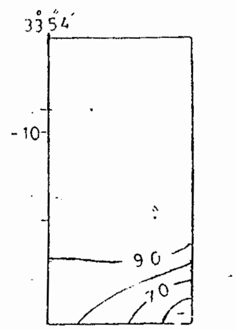
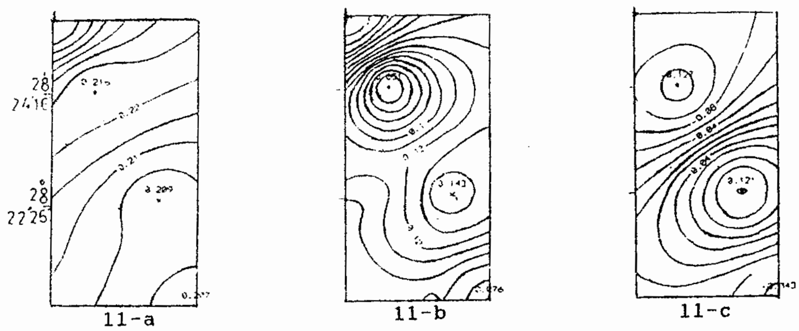
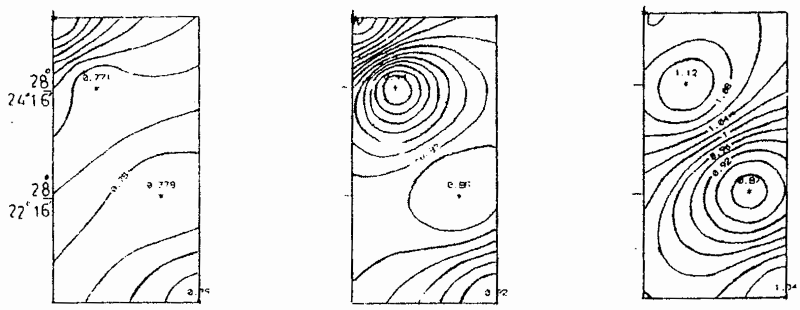


Fig. 8. Evaporites precentage map of Zeit Formation
Fig. 9. Evaporites precentage map of South Gharib Formation
Fig. 10. Limestone and dolomite Precentage map of Belayim Formation



11-a 11-b 11-c

Fig. 11. Reflection coefficient map of a- Zeit Formation
B- South Gharib c- Belayim Formation.



12-a 12-b 12-c

Fig. 12. Transmission coefficient map of a- Zeit Formation
B- South Gharib c- Belayim Formation.

3. The reflection coefficient map of Belayim Formation (Fig. II c) shows positive anomaly around well KK84-8 and negative anomaly around well KK84-9. This can be returned to the drastic variation in the acoustic impedance of Belayim Formation values in the area which is results of obvious change in its facies.

4. The two- way transmission coefficient maps of these formations (Fig. 12 a - 12 c) inicated the increase of transmission coefficient values with depths.

B. Amplitudes and Phases of Seismic Wave Studies

The acoustic impedances (I) and thickness of Zeit, South Gharib and Belayim Formations have been used to computed the amplitudes (R_{amp}) and phases (R_{ph}) of the frequency dependance reflection coefficient at different angles of incidence upon sequence of these formations. According to El Hefnawy (1983), the amplitudes and phases of the plane seismic wave, generated and inserted normally to the sequences of a certain formations can be introducted as :

$$R_{amp} = \frac{(-1 + m_1 m_2)^2 \cos^2 (K_c h_c) + (m_1 - m_2)^2 \sin^2 (K_c h_c)^{\frac{1}{2}}}{(1 + m_1 m_2)^2 \cos^2 (K_c h_c) + (m_1 + m_2)^2 \sin^2 (K_c h_c)} \quad ....9$$

and

$$R_{ph} = \tan^{-1} \frac{(m_1 - m_2) \sin (K_c h_c)}{(1 + m_1 m_2) \cos (K_c h_c)} - \tan^{-1} \frac{(m_1 + m_2) \sin (K_c h_c)}{(1 + m_1 m_2) \cos (K_c h_c)} \quad ..10$$

Where K_c is wave number in the considered formation ($K = 2\pi f / v_c$) f and v_c are the frequency and interval velocity of the formation.

h_c is the thickness of the considered formation
m1 and m2 are defined as :

$$m_1 = \rho_c v_c / \rho_o v_o$$

and $$m_2 = \rho_u v_u / \rho_c v_c$$

Where ρ_c, ρ_o, ρ_u and V_c, V_o and V_u are the densities and velocities of these concerned formation respectively. (see Fig. 12 d) For different angles of incidence, the m1 and m2 can be modified and then express as :

$$m_1 = (\rho_c v_c / \cos r_c) \ / \ (\rho_o v_o \cos i)$$
$$m_2 = (\rho_u v_u \ \cos r_u) \ / \ (\rho_c v_c \cos r_c)$$

Where i is angles of incidence, r_c and r_u are the reflected angles of transmitted p waves.

Figs. 13-18 ilustrate the amplitude and phase spectra of the reflection coefficient at normal and inclined (10, 20 and 30) incidence of plane seismic wave for Zeit , South Gharib and Belayim Formations in RF-A2, KK84-8, KK84-9, KK84-10 A and KK84-4A Wells. The series of alternate maxima and minima of amplitudes and phases are affected by the angle of incidence as well as the thickness of different formations, where, as the angles of incidence decrease the amplitudes values along these series are increased and they reach maximum value when seismic waves inserted normally, Also it can be noticed that the decreasing of thickness of the studies formation causes broaden in ocillation cycles.

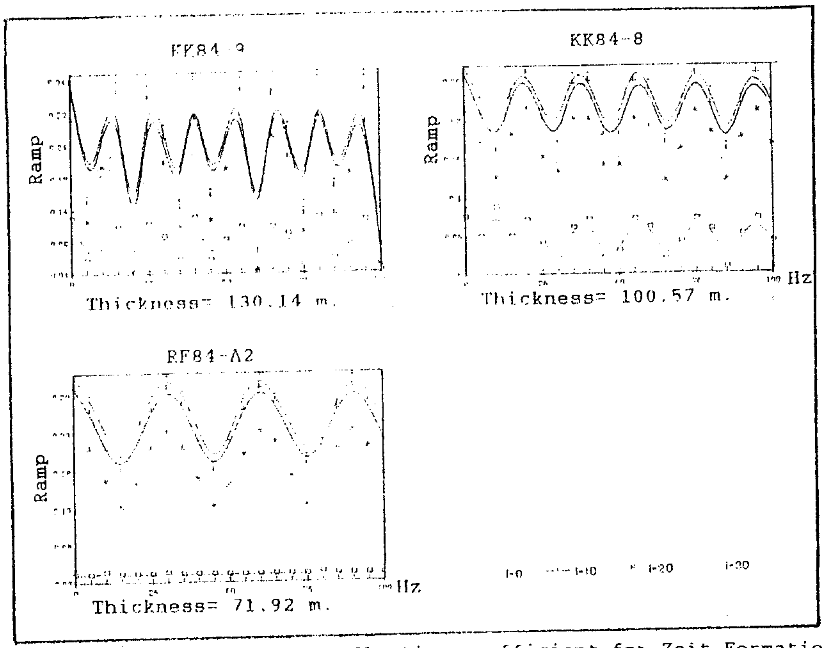


Fig. 13. Amplitude of the reflection coefficient for Zeit Formation at different wells.

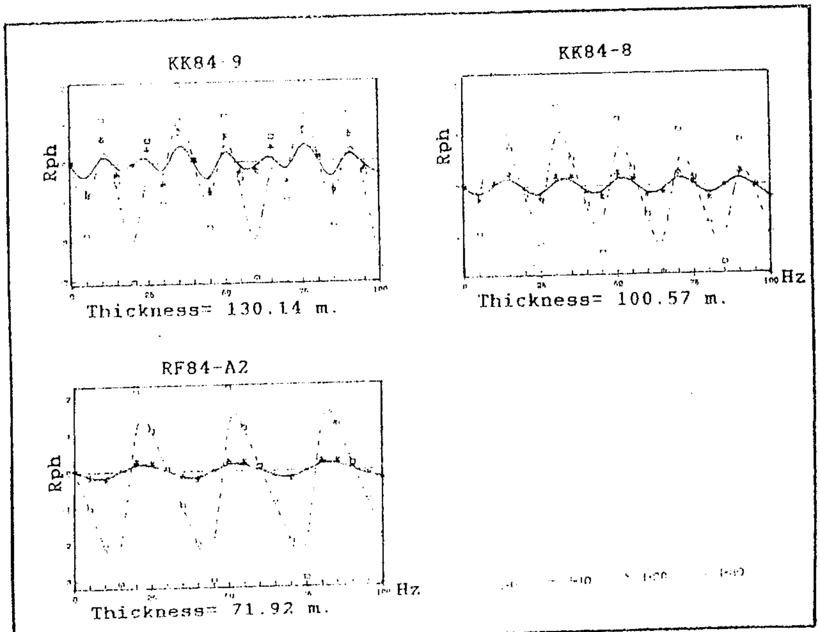


Fig. 14. Phases of the reflection coefficient for Zeit Formation at different wells.

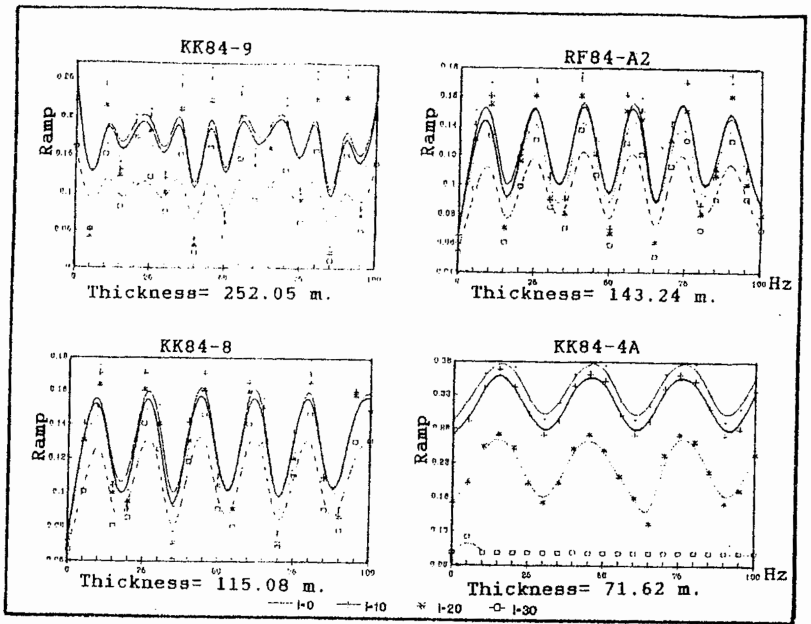


Fig. 15. Amplitude of the reflection coefficient for South Gharib Formation at different wells

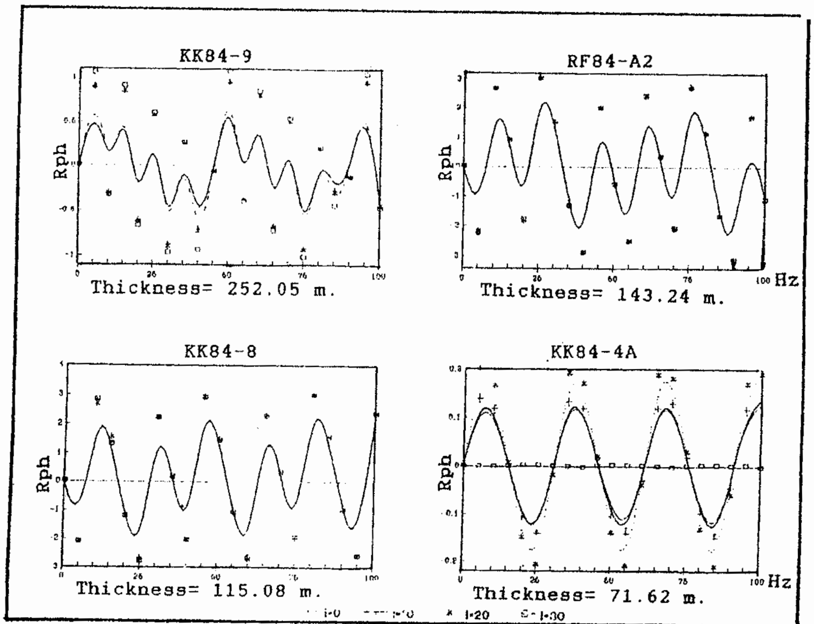


Fig. Phases of the reflection coefficient for South Gharib Formation at different wells

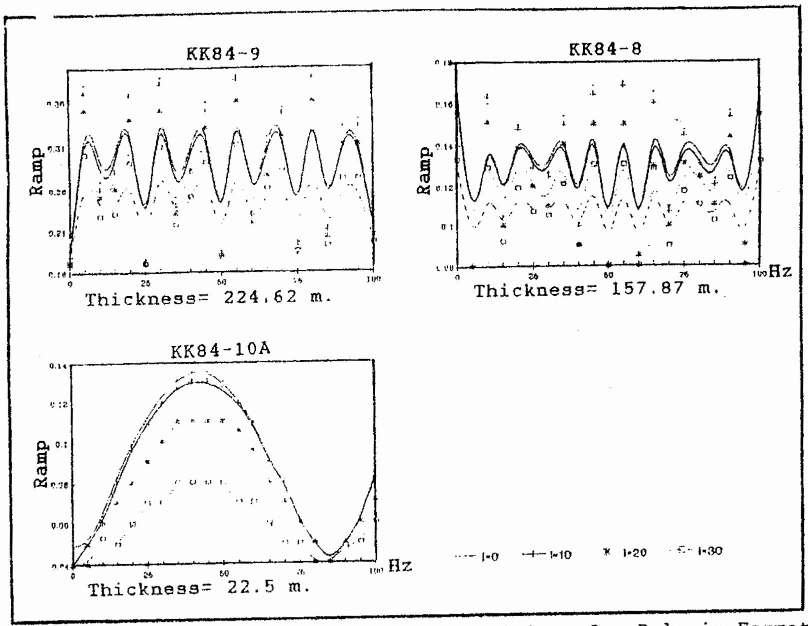


Fig. 17. Amplitude of the reflection coefficient for Belayim Formation at different wells.

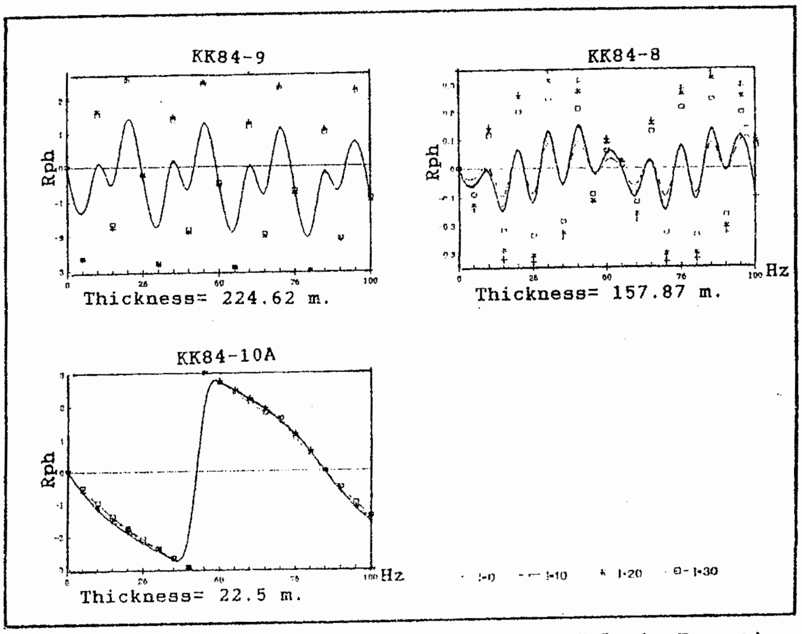


Fig. 18. Phases of the reflection coefficient for Belayim Formation at different wells.

CONCLUSIONS

The seismic quality factor (Q) of the rocks has been determined to study the influence of Zeit, South Gharib and Belayim Formations on the attenuation of the seismic waves at different frequencies.

This study indicates an increase of attenuation coefficient with the decrease of the evaporite percentage in Zeit and South Gharib Formations. Also the attenuation coefficient of Belayim Formation has small values in comparison with the overlaying formations. This can be returned to rock constituent of Belayim Formation which consists mainly of limestone and dolomite.

Both reflection and transmission coefficient are analyzed and used to compute and examine the amplitudes and phases of the frequency dependance reflection coefficient at different angles of incidence of seismic wave upon sequences of the above mentioned formations. This study reveals that the series of alternating maxima and minima of the amplitudes and phases are effected by angles of incidence of seismic wave and thicknesses of the studied formations.

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الإضمحلال والإنعكاسية للموجات الهزية في تتابع المتبخرات بمنطقة رأس فنار – خليج السويس

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هذا البحث يرتكز علي دراسة الأثار الناشئة عن نوعية وسمك الصخور لتكوينات زيت وجنوب غارب وبلاعيم علي إنتشار الموجات الهزية بمنطقة رأس فنار . ولهذا تم تحديد معامل النوعية الهزية (Q) للصخور وتحليل المعاملات الإنعكاسية والإنفاذ . وهكذا تم حساب وإختبار السعة والطور للترددات المعتمدة علي المعاملات الإنعكاسية للموجات الهزية الساقطة بزوايا مختلفة علي تعاقب هذه التكوينات.

ومن هذه الدراسة أمكن إستنتاج تأثيرات هذه التكوينات علي الخواص الديناميكية للموجات المنعكسة .