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Uses of reflector amplitude of seismic acoustic impedance logs as an aid in deducing lithological content of the geological formations

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Abstract - Seismic data of two across lines have been processed. The processing sequence implied a suggested parameters that have least effects on original wavelet attributes (e.g., the amplitude and shape). This processing procedure is a legitimate enough for studying the lithological consists of geological formations as well as hydrocarbon contents. A total of 47 wiggle traces (i.e., 19 wiggle traces from line one and 28 wiggle traces from line two) have been aligned side by side according to their CDP number. The data were limited to time window of 1000-2000 m sec. Reflector amplitudes were manually picked/estimated along the all seismic wiggle traces. The picked amplitude values were plotted as contour maps. Contour maps provided preliminary indications of lithological variation from soft to hard physical properties within the formation where seismic line crosses. A number of contour lines closures in line one were noticed. These closures may be an indication of variation in the lithological consistent and hydrocarbon trap. More contour lines closures were existed in the second line. Some of them were new and the other were extension to the closure in the first line. These closures/features can be a horizontal extension to the same facies.

Keywords: Seismic wiggle trace, acoustic impedance, stratigraphy, data processing, well legs.

Introduction

The study and interpretation of seismic attributes give some qualitative information on the geometry and the physical parameters of the subsurface. It has been noted that the amplitude content of the seismic data is the principle factor for physical parameter determination, such as the acoustic impedance, reflection coefficients, velocities and absorption, etc. (Sheriff, 1982). The amplitude of seismic wave reflected from an interface between two materials is governed by the reflection coefficients (R). That is defined as the following (Dobrin, 1988):

$$R = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1} \quad \text{.......................} (1) \quad \text{or}$$

$$Rc = (I_2 - I_1) \cdot (I_2 - I_1)^{-1} \qquad \text{(John Milson, 2003)}$$

Were $\rho_1 V_1$ is the acoustic impedance of the first layer and $\rho_2 V_2$ is the acoustic impedance of the second layer. Acoustic impedance is evident that the reflection coefficient and hence the reflection amplitude depend on the contrast in acoustic impedance across the reflecting interface. Bala (1996) illustrated that any lateral changes in the velocity or density of one or both the materials separated by the interface should cause the amplitude of the reflection from this boundary.

Theoretical Background:

Reflection amplitude:

The geologic sequences consist of variable types of lithological contents as lithological stratigraphy. Every strata has unique acoustic impedance, the magnitude of incidence wave reflection at the interface that separate two layers different in their acoustic impedance depended on the magnitude difference in their acoustic impedance.

The amplitude of reflection considers the primary reflection and first multiples reflection. The summation of the two reflections is the reflection amplitude (James, 1985). The amplitude versus offset (AVO) contains information about the elastic and density parameters of the reflection media. There are several factors which contribute to (AVO) effects in seismic signature. The main factors are the reflection and transmission coefficient, spherical spreading, an elastic attenuation, and sources and receiver directivities (Johansen, 1995; Ibrahim, 2001).

Acoustic Impedance:

Kleyn (1983) defined the acoustic impedance that is acoustic wave (compressional) passing in the materials causes particles movement and give them a certain velocity. The equation that compounds the directed pressure (P) at (Z) axis, and particle velocity (J) is that of:

P = JZ ....(2) (Kleyn, 1983)

If (L) is the unit distance in time (T) and directed pressure force on material is ML/T^2 . At unit area (L^2) we will get:

$$\frac{MLT^{-2}}{L^2} = Z\left(\frac{L}{T}\right) \quad ....(3)$$

Consequently any formation character in the (Z) direction will be:

$$Z = \left[\frac{\frac{ML}{L^2} \cdot \frac{1}{T^2}}{\frac{L}{T}}\right] = \left[\frac{M}{L^3}\right]\left[\frac{L}{T}\right] \quad ....(4)$$

Density Velocity

Hence the formation character results from the density are multiplied by velocity. If we want to estimate (Z) value of the material properties we will suppose that the influence of surface area in the pressure (P) is (δA) to that portion of material along (Z) direction and we can write equation of wave movement:

$$\frac{\partial \rho}{\partial Z} = \delta A \Delta Z = \rho \delta A \Delta Z \frac{\partial J}{\partial T} \quad \text{..................(5)}$$

Where ρ is the density in gm/cm^3 , ΔZ is the thickness in cm .

The above relationship is the wave equation and to solve it we must suppose that:

$$P = P_{\circ} e^{i(z-vt)}$$

$$J = J_{\circ} e^{i(z-vt)}$$

By differential integration of the equation we will get:

$$iP_{\circ} = iPVJ_{\circ} \quad \text{...............(6)}$$

Hence the acoustic impedance is a result of multiplying the density and velocity data (Ellis, 1987). Al-Sady (1982), Dobrin (1988), and Ibrahim (2001) gave an elaborated definition of acoustic impedance logs that is graphically plot of ρV values as a function of depth or two way time. In other words, the acoustic impedance logs is the summation of the successive reflection coefficients and it gives an indicative knowledge of the lithology of geological formation.

Seismic data processing:

Al-Kashan (2002) studied the effects of seismic data processing parameters on the amplitude and shape of the original seismic wavelet. He suggested many processing parameters that have less effect on the original attributes of the seismic wavelet. Absolute processing effects on the original wavelet cannot be omitted from the final seismic profiles because applying them is a necessity in increasing signal to noise ratio on seismic sections. The most effect of seismic data processing is diminishing the small changes that are lithological content indication. Also, he showed how we can choose the effective parameters such as band pass filter and spike deconvolution. His procedure was built on partial matching principle between the trace of acoustic impedance log which is a derivative of multiplying the values of velocity log and density log values. In order to have a good matching, well location should be close to the seismic line. Thus, a well processed seismic trace will represent the site of that well on the line (Banik, 1985; Simmons, 1996).

The processing parameters that directly deal with the wavelet amplitude are Automatic Gate Control (AGC), so that their effect were minimized by applying two large time gates, the first is (0-1000) msec and the second (2000-4000) msec, and completely neglect balance processing program (Trace Equalization). The present data were processed based on the above suggested parameters (Al-Kashan, 2002). As this processing procedure was followed, the resulted seismic section was represented as an acoustic impedance section and individual traces presented an acoustic impedance log.

Results

One of the reflectors was defined by using synthetic seismograms. It was given an informal name as (F) reflector. Its continuity has been followed along the two lines sections (L1, L2). The reflector arrival times were picked 19 CDPs belong to L1 and 28 CDPs belong to L2. Every CDP data was displayed as a single seismic wiggle trace in a zoomed time window (1000-2000) msec. The selection of the time window depend upon interpreter point of view, the expected reflector depth. Seismic wavelet behavior (i.e., shape and amplitude) of (F) reflector was determined according to the picked time for all reflector traces of the two seismic lines (L1, L2). And these CDPs traces were put side by side based on their number sequence in the seismic lines. In this display format, it became easier to follow and study the lateral changes in the formation lithological content along the section by observing the change in the amplitude and the shape of the seismic wavelet. It is more important to mention that any individual trace represent several stacked traces. Stack give better results in comparison with single or little traces to be stack, in general. Hendickson (1999) proved that the strength of wavelet signal will increase when increasing the coverage (number of stacked traces). The obtained seismic wiggle traces explain the reflector amplitude changes with time. Figure (1) illustrates the 19 seismic traces of L1 and Figure (2) shows the 28 traces belong to L2.

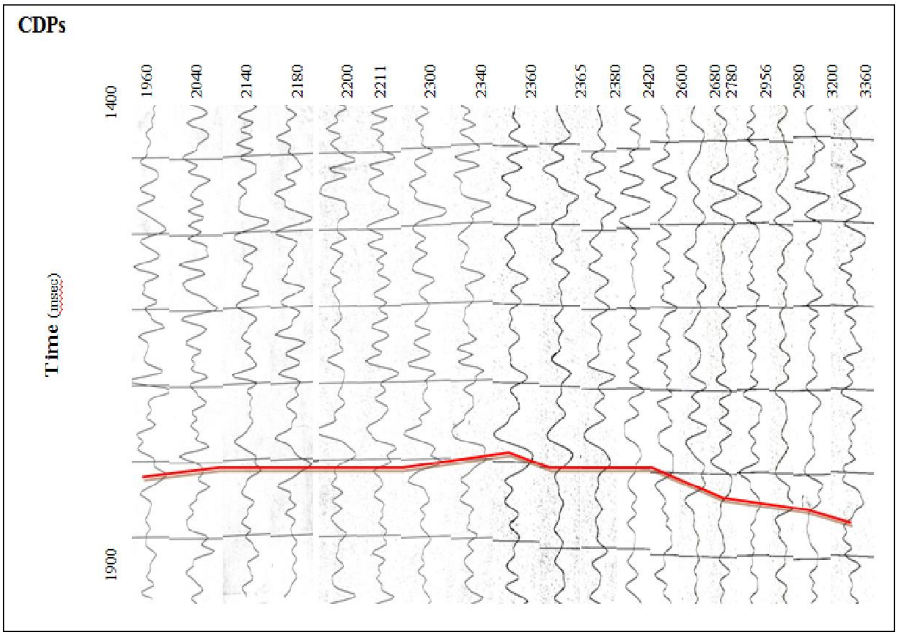

Figure 1. Wiggle traces of 19 CDPs belonging to line L1 showing the studied reflector. The red line represents the picked reflector.

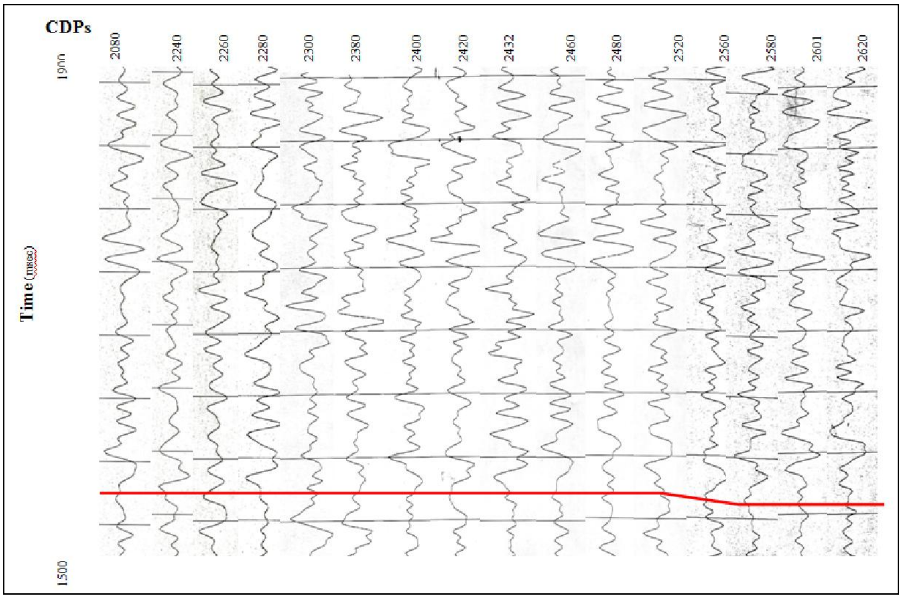

Figure 2a. Wiggle traces of 19 CDPs belonging to line L2 showing the studied reflector. The red line represents the picked reflector.

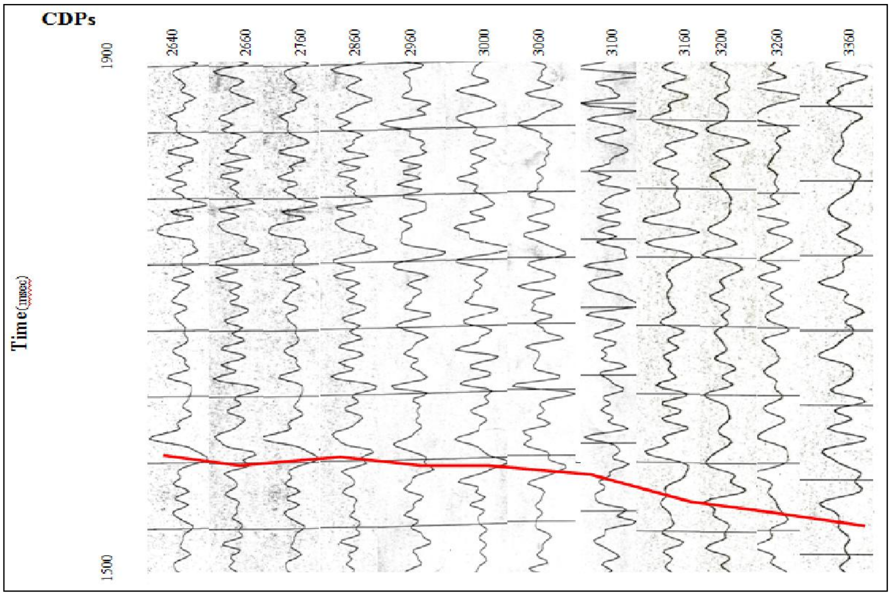

Figure 2b. Wiggle traces of 19 CDPs belonging to line L2 showing the studied reflector. The red line represents the picked reflector.

Reflector amplitude has been manually estimated on every single trace. There was high amplitude in some positions and low in other places. This fluctuation in the reflector amplitude may reflect the lateral physical properties changes. The amplitude variable was plotted for each line as a contour map. The x axis represents the horizontal distance which is CDPs sequence. The y axis shows the two way travel time scale (Figures 3 and 4).

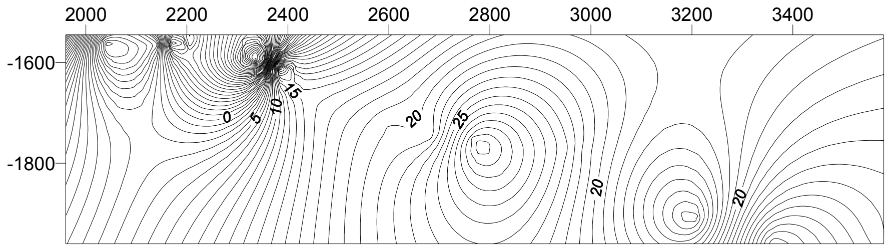

Figure 3. Contour map of the Amplitude variable of the studied Reflector belonging to line L1.

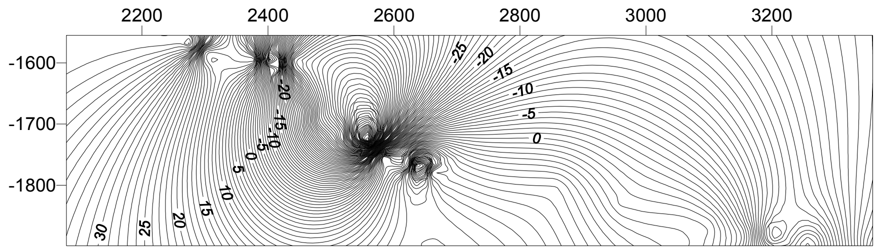

Figure 4. Contour map of the Amplitude variable of the studied Reflector belonging to line L2.

Discussion

After securing optimum seismic data processing procedure that served toward stratigraphic interpretation purposes and preserving the shape and amplitude of original wavelet, seismic sections become more reasonable for studying the small lateral variations within the geological formations. However, the current available processing capabilities in Iraq are more suitable for structural studies. And it would be perilous for stratigraphic interpretation because they may give us a good reflector continuation, but far from real. Consequently, a legitimate stratigraphic feature studies are no longer exists on such processed seismic profiles. As a substitute, the current study try to preserve the stratigraphic phenomena by converting the seismic wiggle traces to seismic acoustic impedance log. Processing parameters play a significant role in this terminology. The try and error matching between the seismic wiggles and well logs wiggle in order to turn a seismic wiggle traces to an acoustic impedance log.

The acoustic impedance log is an indication of density and velocity. After a good seismic acoustic impedance logs were obtained, the stratigraphic phenomenon and faicies would be a worthwhile. Changing in the shape and amplitude of seismic wavelet with horizontal distance (CDPs) may be reflected by stratigraphic features.

This study focused on one of the reflectors, as a methodological approach, by estimating its amplitudes at 19 CDPs. Then the amplitude values were plotted as contour map for the first line (Figure 3).

The contour map showed that there were three contour line closers, that may be refer to three main lithofaicies found in the geological formation, one of them between the others at 2800 and in time 1800 msec represents a porous lithofaicies that should contain a hydrocarbon accumulations. This conclusion supported by well primary report data. The second contour map (Figure 4), is representing amplitude variable with time domain for 24 wiggle traces of the second seismic line, showed only one contour line closer, and the rest of the lines are spread equally.

This remark infer that there were two main facies appears in the seismic line. The contour lines closer represents impermeable compacted lithofaicies. The other faicies are horizontal extensions of porous thin bed that is existed on the first seismic line. So that from the two contour maps we can presume a suitable stratigraphic-geological model.

Conclusions

1. After the assurance that processing flowchart has been applied correctly and there is no harm to the original seismic signal, one can depend on the seismic trace shape which is unique for any formation lithology that represent physical properties (e.g., velocity, density, and hydrocarbon accumulations).
2. Contour maps of amplitude variable showed that the contour line closers at specific positions may reflect the change in reflector amplitude along seismic section. This is a more details way to conclude the lithologic consistent of any reflector intended to be studied. Thus, physical properties or abnormal features are easily to be deciphered. And contour line closers may give an indication of the hydrocarbon accumulations in specific litho-facies. These results help us to produce a geological model supported by direct data such as well log data.
3. These types of contour maps simplify detecting and studying the lithofacies along seismic sections.

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استخدام سعة العواكس لمجسات الممانعة الصوتية الزلزالية كمساعد في استنتاج المحتوى الصخاري للتكاوين الجيولوجية

علي زباري المياحي

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المستخلص - عُولجت المعلومات لخطين زلزاليين وذلك بإتباع خطوات وضوابط معالجة ذات اقل تأثير على ملامح المويجة الزلزالية الأصلية (مثل السعة والشكل). الطريقة المتبعة للمعالجة كانت كافية قدر الامكان لدراسة التركيب الصخاري للتكاوين الجيولوجية فضلاً عن المحتوى الهيدروكاربوني. العدد الكلي للآثار الزلزالية المفردة التي وُضعت جنباً الى جنب هو 47 (19 اثر عائد الى الخط الاول و 28 للخط الثاني) وحسب تسلسل النقطة العمقية المشتركة الـ (CDP). حُددت المعلومات بنافذة زمنية 1000-2000 ملي ثانية. لقد اُلتُقِطَتْ وحُدِدَتْ سعات العاكس يدوياً لكل الاثار الزلزالية. رُسمت السعات الملتقطة كخرائط كنتورية. بيّنَتْ الخرائط الكنتورية التغيرات في الصخارية اولياً من الطبيعة الرخوة الى الصلبة ضمن التكوين حيث يمر الخط الزلزالي. لُوحِظتْ عدد من الانغلاقات في الخطوط الكنتورية. هذه الانغلاقات ممكن ان تكون مؤشر على التغيرات في المحتوى الصخاري والمصائد الطباقية. وانغلاقات كنتورية اضافية تواجدت في الخط الثاني. بعضها جديد والبعض الاخر كان امتداد للانغلاقات في الخط الاول. هذه الانغلاقات/الملامح يمكن ان تكون امتداد افقي لنفس السحنات.