SEISMIC VERSUS SONIC REVISITED

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ABSTRACT

The sonic log enables all features along the depth scale can be correlated with all features in the time scale as found in the seismic section. However, this sonic log must be corrected to the time-depth curve obtained from the check shot survey. The problem arises when some zones around the borehole such as the invaded zones or the flushed zones exhibit dispersive properties. This dispersive properties causes discrepancies between integrated sonic transit time and the time-depth curve. As a result, the synthetic seismogram generated from the sonic log will not match with the corresponding seismic section. To solve this problem, a practical method for correcting the discrepancies is presented in this paper. Although the method is inspired by paper published in the seventies, but the way to approach the problem is different. This problem looks simple, but its effect on mapping top and bottom of the reservoir is important. An example of implementation from the real field is also given.

Keywords : seismic, sonic log, check shot survey, discrepancies.

I. INTRODUCTION

Sonic log is the "bridge" which connects well log data in the depth domain to seismic data in the time domain. With the aid of sonic log every intresting features found along the borehole can be correlated to specific signals in the seismic section. This will make its lateral extension can be followed precisely.

Sonic log records the transit time of the sonic waves across a specific interval. Because the transit time is the reciprocal of the velocity, so this data will enable one to convert every depth interval along the borehole to compose an integrated transit time from the beginning of the log run to the end of the log run. To tie the integrated transit time to seismic section, one needs time-depth curve (T-D curve) from the check shot survey. Tying the top of the log run to the T-D curve is not a problem, but tying an interval in the sonic log to the same interval in the check shot survey usually invites problems. As a result, the synthetic seismogram generated using this kind of sonic log will not match with the seismic section, which is usually considered as miss tying. This is due to the discrepancies between sonic log and seismic velocities

This paper deals with a description of the factors affecting this dicrepancies and propose its possible solution. This kind of problem has been known for along time (Goetz, et al., 1979) but very little attention has been paid to solve it which in turn causes confusion in practical seismic interpretation. Before entering into the core problem, we will review briefly the basic principles of the sonic log and the check shot survey. The discussion is still limited to the conventional sonic log which is widely used in the oil industry. The full waveform acoustic log (Mari, et al., 1984) will not be discussed here.

II. BASIC PRINCIPLE OF SONIC LOG AND CHECK SHOT SURVEY

A. *The sonic log*

The use of sonic log which is also referred to as acoustic well logging to determine the compressional waves velocity of a formation has been introduced long time ago (Summers and Broading, 1952; Vogel, 1952). However, the full waveform sonic log which records the propagation velocities of different types of elastic waves has been introduced to the industry more recently (Astbury and Worthington, 1986).

The principles of sonic log measurement is as follows (see Figure 1).

The transmitter T emits an acoustic signal to the borehole wall. This acoustic waves propagate downward along the fluid (mud) or the borehole wall and detected by the sonic receivers R1 and R2. In the single source and dual–receiver acoustic device, the difference in travel time of the sonic waves received by receiver-1 and receiver-2 reflects the transit time at an interval proportional to the distance of both reecivers. Since this probe moves upward or downward, this interval will cover different layers crossing the borehole.

B. *The check shot survey*

The check shot survey is the synonim of well velocity survey. It is a survey along a borehole with an objective to measure the velocity as a function of depth around the borehole. The principles of the check shot survey measurement is as follows (see Figure 2-a).

At the beginning a geophone is placed at a certain depth along the borehole, and a shot is fired from a certain distance (away from the well), the wave traveling from the shot to the geophone is recorded in the recording truck. Since shot point (source) distance to the well and the depth of the geophone are known, so it is possible to measure the travel time from the shot point to the geophone's position. This value contributes one point in the Time-Distance curve (see Figure 2-b). The next step is to move the geophone's position upward or downward, then the shot is fired again. This geophone's position is usually determined by wellsite geologist. Using the same procedure mentioned before one will obtain another point in the T-D curve. With 5 geophone's positions along the borehole and with a specific geological condition one may obtain T-D curve similar to Fig-

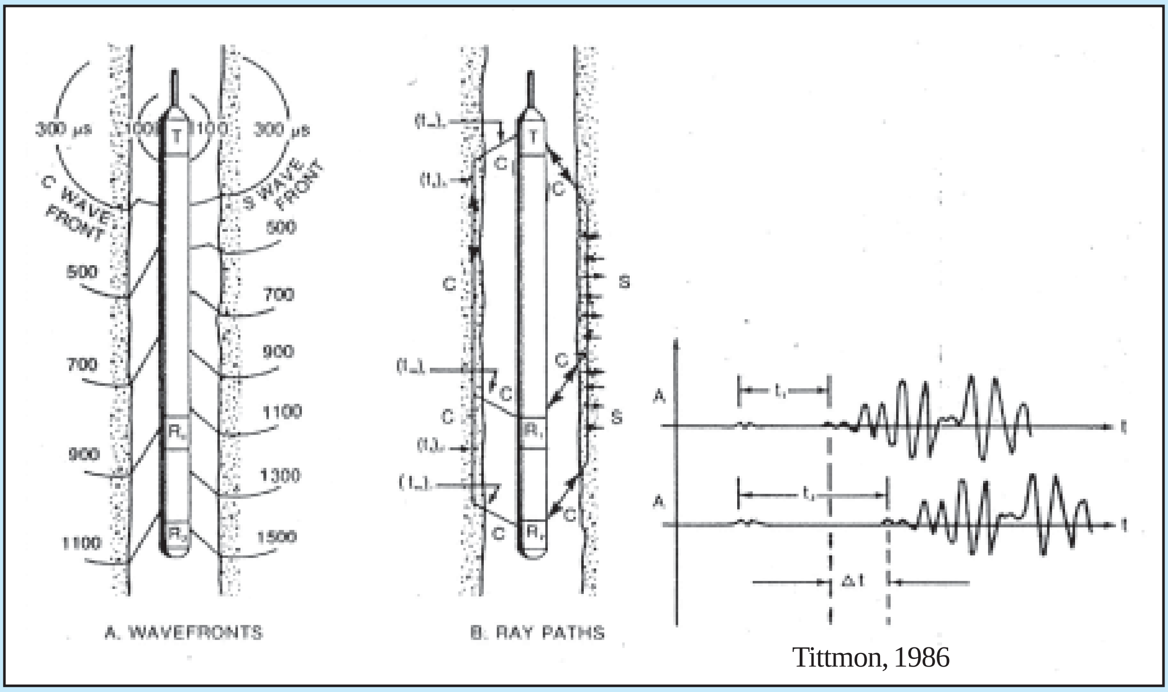

Figure 1
The principle of sonic log measurement : a sonic probe contains a transmitter (T) and two receivers (R1 and R2). The source (T), emits sonic waves to the wellbore which will propagate along the borehole wall. The different in arrival times between receiver R1 and R2 represents the sonic transit time in an interval (distance) separating R1 and R2.
Once this transit time is recorded, the probe is towed upward gradually

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ure 2-b. The abscissa in this diagram represents the one way travel time, while the ordinate represents the depth. The T-D curve is usually a polynomial.

Although the T-D curve is so simple, its role in seismic exploration is very important. It enables the geologists and geophysicists to correlate any interesting features found along the borehole (in the depth domain) to the seismic section (in the time domain) and vice versa.

Nowadays, the check shot survey is sometimes replaced by VSP (Vertical Seismic Profiles). The difference between check shot survey and VSP is that in check shot survey the interval between geophone's is rare, their positions are determined by the geological conditions, while in VSP the interval is closer and regularly spaced. In check shot survey there are only several geophone's position, while in VSP there are tens geophone's position.

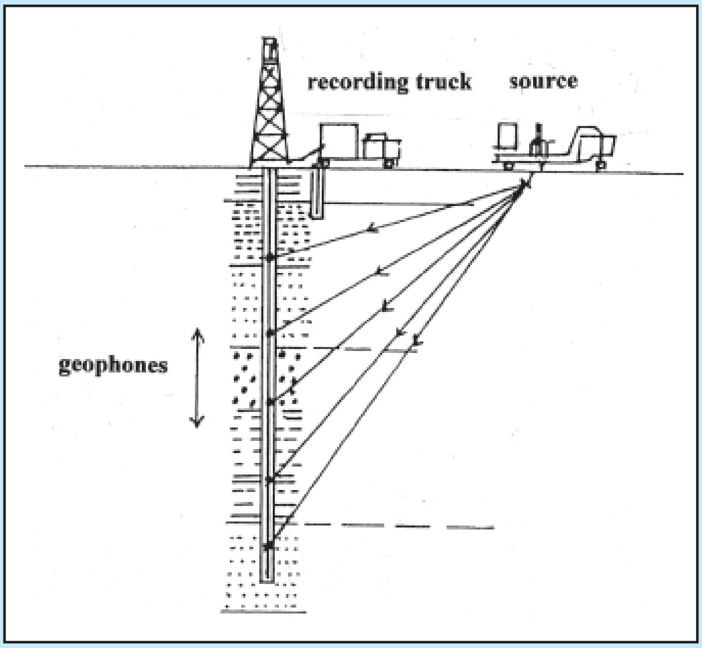

Figure 2-a
The principle of check shot survey or well velocity survey measurement

III. DISCREPANCIES BETWEEN SONIC LOG AND SEISMIC VELOCITIES

A. *The effect of discrepancies*

The existence of discrepancies can be observed if one tries to overlay the T-D curve from check shot survey or VSP to the integrated transit time obtained from sonic log. In this case, both curves will not match in some places (see Figure 3). Integrated transit time is obtained by calculating the transit time in every interval along the borehole's depth, then summing up from the top of the log run down to the bottom of the log.

If this happens, there will be difficulties to match synthetic seismograms to the seismic section. The peak and trough of its wavelet in the zone of interest will be shifted considerably. As a result, this kind of well to seismic tie will not be accepted in standard routine seis-

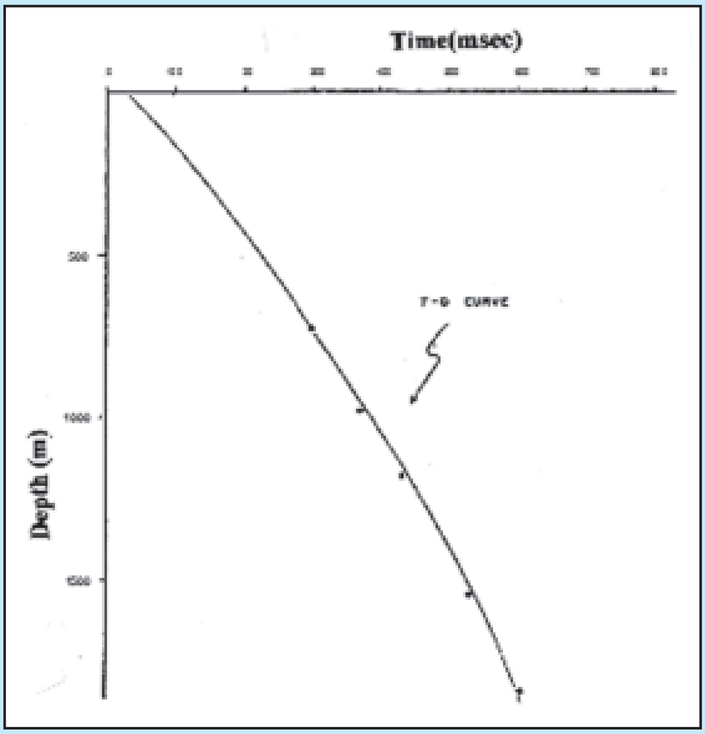

Figure 2-b
The time-depth curve obtained from check shot survey

mic interpretation, especially for seismically guided reservoir characterization. It is well known that in shales or poorly cemented formations of high porosity the sonic log tend to give high transit time.

The difference between the total integrated transit time from sonic log to the vertical travel time from well velocity survey is called the drift. This drift can be observed much more clearly by plotting drift values versus depth along the borehole. Figure 4 is the schematic diagram of the drift (Boyer and Mari,1997).

B. *The possible solution*

To achieve the solution of the problem, one should decide the “base line” of the velocity for this purpose. Since the data which must be tied to the well is the seismic data, so the base line of the velocity is the velocity of the seismic wave. This means that the time-depth curve from the check shot survey must be used to correct the integrated transit time obtained from the sonic log.

There are two well known methods which can be used to correct the effect of discrepencies between the sonic log and seismic velocity, i.e., the block shift method and the minimum delta t method. The block shift method is demonstrated by the schematic diagram given in Figure 5, while the minimum delta t method is demonstrated by the schematic diagram illustrated in Figure 6.

IV. EXAMPLE FROM THE REAL DATA

An example from the real well data was taken from well PT-21 in North Sumatra basin, but for the sake of industrial secrecy, the complete information will not be exposed. The point which will be displayed is just the effect of correcting discrepancies to the sonic log, how big it is and which part of the zones along the borehole which needs correction ?

Figure 7a is the discrepancies between sonic log and seismic and when adjustment were carried out in order to match both curves were, the effect on sonic log is quite considerable, as can be seen in Figure 7b.

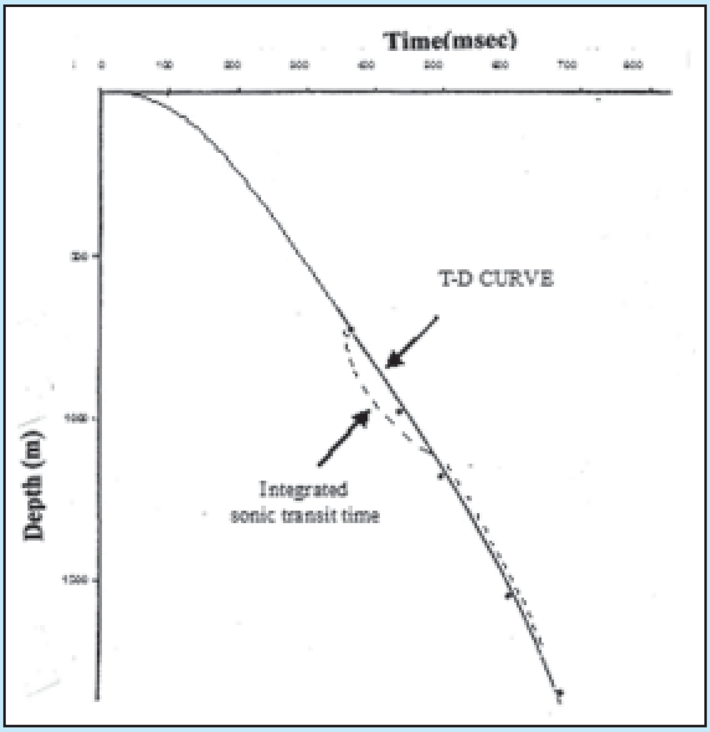

Figure 3
Discrepancies between sonic log and seismic velocities

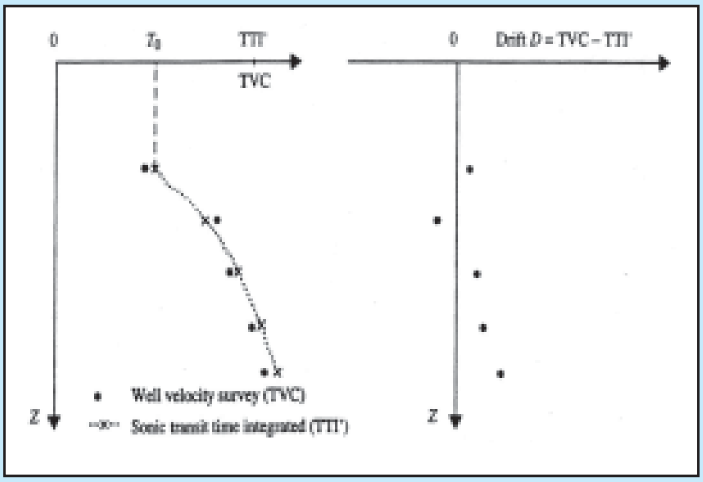

Figure 4
The drift demonstrating the existence of discrepancies between sonic log and seismic velocity

The correction must be done in such away so that by changing the value of the sonic transit time, both curves i.e., the integrated sonic transit time and the T-D curve co-incide.

The effect of eliminating the dis-crepancies between the sonic log and the check shot survey is the perfect matching between synthetic seismogram and the seismic section.This is an ideal case which is expected to occur by the seismic interpreter and seismic analyst dur-ing the seismically guided reservoir characterization (Figure 8).

V. ANALYSIS AND DISCUSSION

The following are the desriptions of possible causes of the discrepancies between sonic log and check shot survey:

Sonic and density logs have a shallow depth of investigation around the borehole in the flushed zone where mud has driven out the formation water and part of hydro-carbons (Boyer and Mari, 1997). The flushed zones or invaded zones are generally not very sensitive (a few tens meters in the most), while the seismic waves used by the check shot survey mainly propa-gates through the uninvaded or vir-gin formation before reaching the receiver (Boyer and Mari, 1997).

The velocity and density char-acteristics of the medium depend on the fluids (mud, formation water and hydrocarbons).and their saturation. These fluid characteristics are therefore related to the geological media investigated by the survey.

The seismic wave path used in the check shot survey can be rela-tively far from the well depending upon the well-shot point configura-

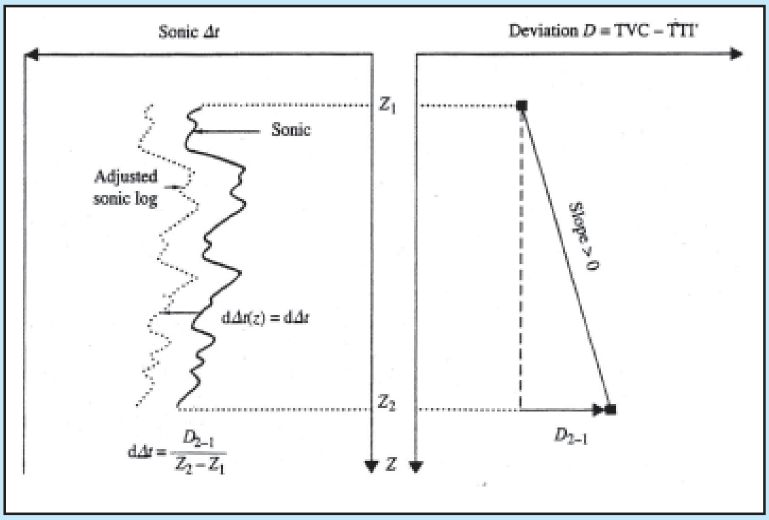

Figure 5
Schematic diagram of the block shift method for callibrating sonic log. In this method, the correction is distributed uniformly over the whole interval between two inflection points using a constant value. (Boyer and Mari, 1997)

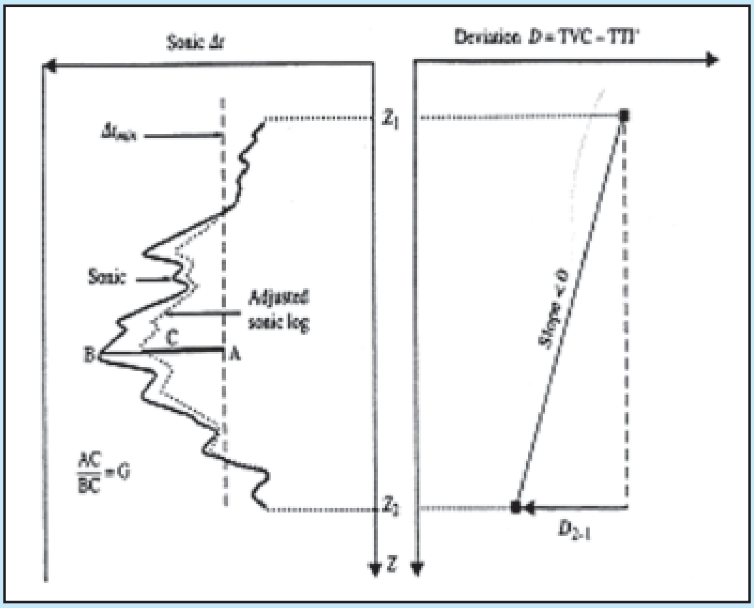

Figure 6
Schematic diagram of the minimum delta t method for callibrating sonic log. In this method the corretion is proportional to the delta t value itself, if its value is above the cut off , but no correction is applied if the value below the cut off. (Boyer and Mari, 1997)

tion. At this distance lateral facies variation may occur. This lateral facies variations are usually accompanied by changes in elasticity and lithology.

In the case of the check shot survey, the measurement of travel time is direct from the source to the receiver, while in the seismic log, the integrated transit time is calculated by summing the transit time of all measured intervals along the borehole, so that any small errors on transit time measurement will accumulate progressively over the depth of the logs.

Another cause of discrepancies may come from the dispersion effect. If this happens the low frequencies component of the seismic waves will travel slower than their high frequency component. Since the dominant frequency of the seismic wavelet is different to the dominant frequency of the sonic log, so both wavelet will not travel at the same velocity. The relationship is given by the following formula (Futterman, 1962; Boyer and Mari, 1997) :

$$\frac{V(\omega_1)}{V(\omega_2)} = 1 + \frac{1}{\pi Q} Ln\left(\frac{\omega_1}{\omega_2}\right)$$

where $\omega = 2\pi f$ (1)

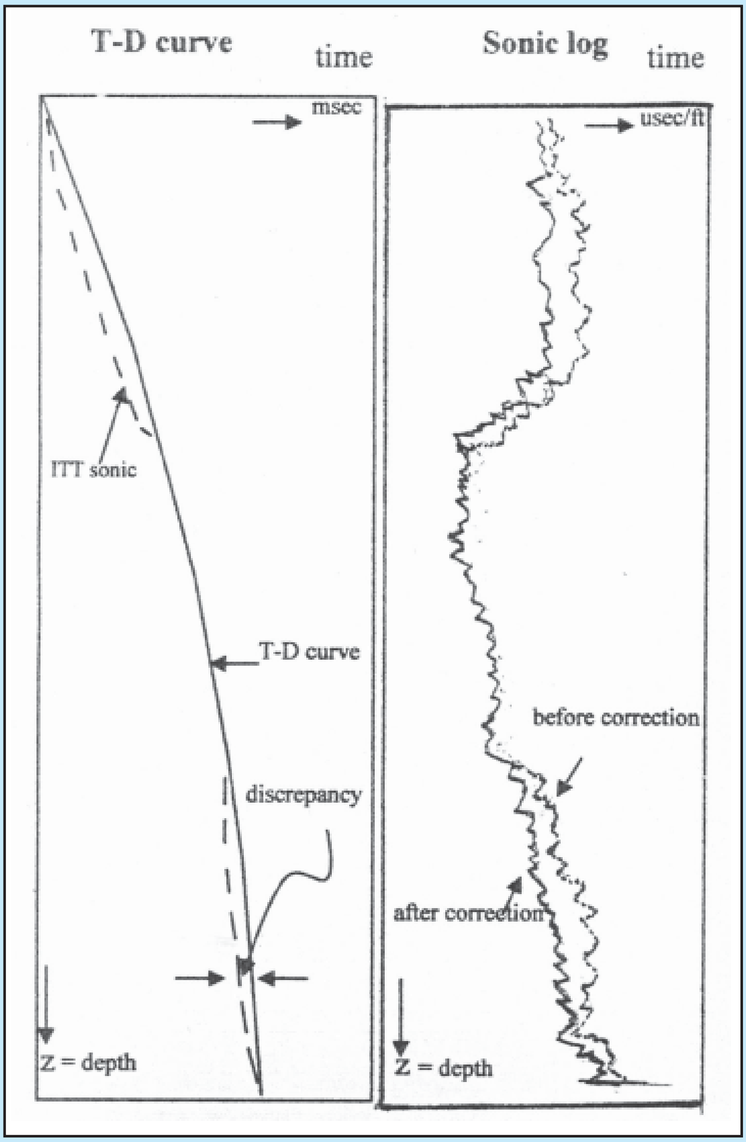

Figure 7-a
The discrepancies between sonic integrated transit time (dotted line) and the time-depth curve obtained from the check shot survey (solid line)

Figure 7-b
The effect of eliminating the discrepancies causes the shifting of sonic transit time to the corrected position. One may use the block shift method as well as the minimum delta t method in this case

The check shot survey uses the seismic waves at frequencies between 10-150 Hz, while the sonic log uses acoustic waves at frequencies between 1-20 kHz, so it is reasonable that their velocities are different. As an example, for medium which exhibits very little attenuation such as carbonate Q = 100, while for attenuating medium such as shale, Q = 30. Q is the quality factor of the medium, it is directly proportional to the dominant ferquency of the seismic wavelet and inversely proportional to the velocity of the medium multiplied by attenuation factor of the medium. The following relation is usually accepted to relate factors affecting Q.

$$Q = \frac{\pi f}{\alpha v} \qquad (2)$$

where π = 3.14159, f and V have been mentioned above.

Sonic velocity and seismic velocity do not always agree. This is because they travel in different medium. The medium where the sonic waves travel is the invaded zones which is located a few decimeters from the borehole wall, while the medium where the seismic waves travel mostly is located in the virgin zones. Besides, they operate at different frequencies, seismic wave has the frequencies between 10 - 100 Hz, while the sonic log operates arround 20.000 Hz.

The effect of drift correction not only does shifting the sonic velues to the appropriate positions but also refine the amplitude of the synthetic seismogram. The synthetic seismogram as was known, is usually generated by convolving the reflection coefficients with the seismic wavelet. The change in the sonic values will directly affect the change of the velocities and the change in the velocities means the change in the reflection coefficients. Then finally, means the change of the amplitudes in the synthetic seismogram.

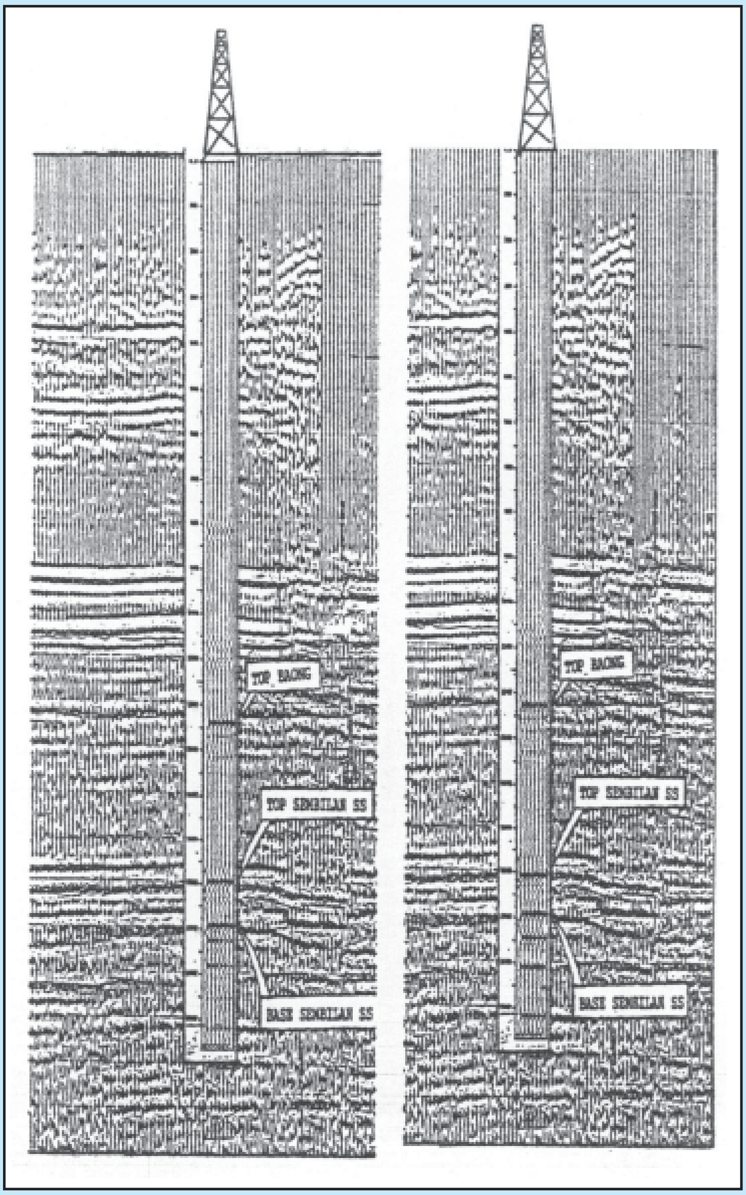

Figure 8
Left : seismic section vs. synthetic seismogram before drift correction
Right: seismic section vs. synthetic seismogram after drift correction.

VI. CONCLUSION

The invaded zones usually have dispersive properties. In this case, the velocity of the waves depend on the frequency. This is why discrepancies occur between sonic velocity and seismic velocity. If this discrepancies are not corrected, the well-seismic tie will be difficult, which in turn causes miss match between the synthetic seismogram and the corresponding seismic section. This is a condition where the picking horizons during seismic interpretation cannot be accepted. The minimum delta t method is more appropriate to correct the discrepancies between sonic log and seismic velocity, whereas the block shift method is more practical for this purpose.The drift correction causes the refinement of the amplitudes in the synthetic seismogram.

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