CORRELATION OF SYNTHETICS WITH SURFACE SEISMIC UNDER DIFFERENT GEOLOGICAL SETTINGS: A CASE STUDY FROM INDUS BASIN PAKISTAN

BY

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Abstract: *Synthetic seismogram is one of the most important techniques for incorporating surface seismic and well data. During its construction reflectivity series is convolved with a seismic wavelet. It is an industrial exercise to use some wavelets and neglect all the other during construction of synthetic seismogram. The present study aims to investigate the response of all the available wavelets by constructing synthetics using seismic and well data of different geological settings in the most prolific hydrocarbon producing Indus Basin of Pakistan. These settings involve extensional (Kandra and Khipro) and compressional (Meyal) regimes. A total of eight seismic wavelets are used for the generation of synthetic seismogram in search of best match with the seismic data. The results suggest that in most of the cases the extracted wavelet from seismic data provides the best match. The results also suggest that polarity of the seismic data can also be determined with such kind of analysis.*

INTRODUCTION

Seismic and well log data are acquired in exploring oil and gas reservoirs for decades. Seismic data with low resolution reservoir coverage and wireline log data with high resolution reservoir coverage has played a vital role in petroleum industry. Barkved et al., 2004 reported that efforts are accomplished in all direction to improve the resolution of seismic data to a comparable level with high resolution log data. However, Christie et al., 1995 indicated that high resolution and full reservoir coverage at the same time in a single set of data has not been possible until now. Experiments are also performed to integrate high resolution well log data with seismic domain aimed at better linkage and correlation between both set of data for high resolution and full coverage of reservoir. Synthetic seismograms act as a bridge between seismic and well data. Derived synthetic seismograms from well log data having high resolution are an extensively valuable way to tie seismic time section to well log depth and the technique is more often use in the hydrocarbon exploration and development (Henry, 2000; Huyen et al., 2010; Deshenenkov *et al*., 2011; Goldberg, 1997). In hydrocarbon exploration, different map is generated using seismic, well log and core data that depict subsurface geological information. Seismic section must be correlated to nearby wells for finding precise subsurface geological information (Henry, 2000). Moreover, information about seismic processing and interpretation can also be obtained from synthetic seismogram ties and their associated well-based wavelet extractions (Box et al., 2004).

Synthetics vary in character with seismic data, and to establish a tie between them requires stretching or squeezing. Amount of stretch can be calculated by using check shots which also help in establishing the time-depth relationships (Box and Lowrey 2003; White and Hu, 1998; Allouche et al., 2009). Careful log editing and smoothing also play a vital role during construction of synthetics (Duchesne and Gaillot, 2011, Ziolkowski et al, 1998, Edgar and Baan, 2011).

Petroleum industry employs commercially available software to generate synthetic seismograms. SMT Kingdom (TM) software provides user a choice up to seven types of standardized wavelets and its parameters. These wavelets are Ormsby, O'Brien, Klauder, Butteworth, Minimum phase, Gaussian and Ricker. Moreover, the SMT Kingdom (TM) software also gives user choice to extract wavelet from seismic section. In petroleum industry, it is normal practice to generate synthetic using Klauder, Ricker or extracted wavelets.

In the proposed research work, attempts are made to find the best matching between synthetics seismogram (generated using above mentioned eight types of wavelets) and seismic section belonging to different geological settings of Indus Basin of Pakistan. In order to achieve objective, the flow chart of generating and correlating synthetic seismogram with seismic section is depicted in Fig. 1.

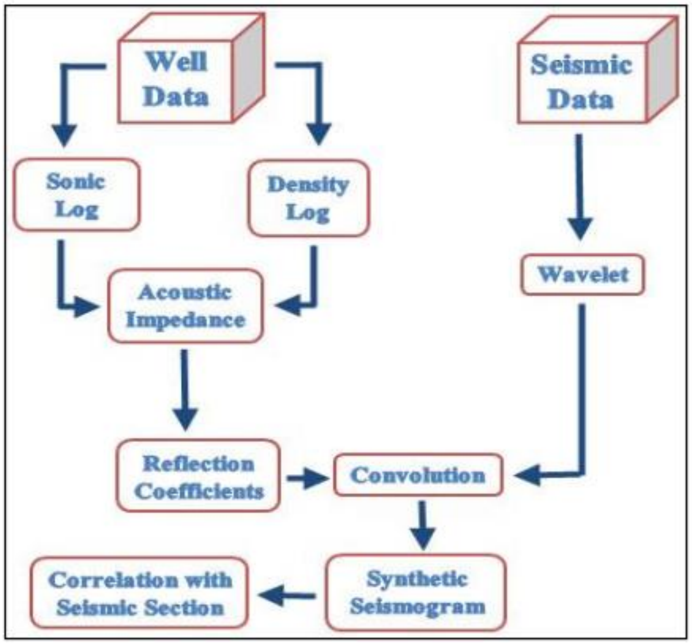

Fig. 1 Synthetic generation flow chart

This research work is mainly carried out in the Indus basin which is one of the most important oil and gas producing basin of Pakistan. The Indus basin is divided into sub basins, such as Upper Indus basin, central Indus basin and lower Indus basin. 3 case studies (areas) from each sub basin of Indus basin have been selected for this research work as depicted in Fig. 2.

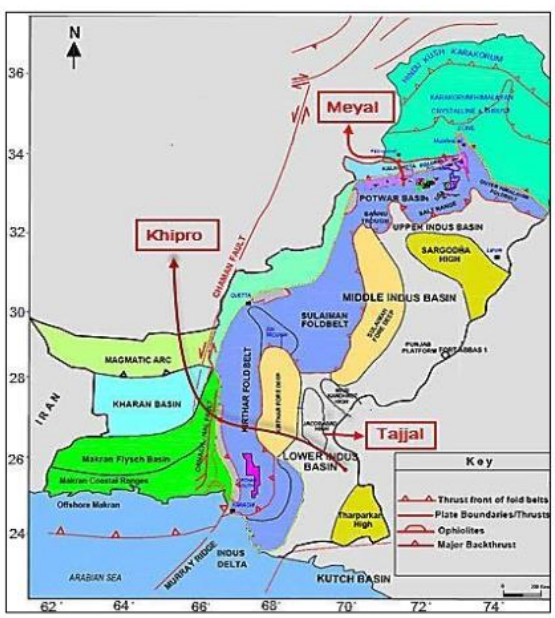

Fig. 2 Map showing the Middle Indus basin (Kazmi & Snee, 1989).

The case study 1 is located in upper Indus basin, which is essentially a complex tectonic and geological setting, where major structures are thrust and reverse faults (Kazmi and Jan, 1997). However, the case study 2 belongs to central Indus basin which comprises of punjab plateform, sulaiman depression and Fold Belt (Kadri, 1995). Furthermore, the case study 3 belongs to lower Indus basin where mostly normal faults are prevailing in the form of horst and grabben structures (Kadri, 1995; Kazmi and Jan, 1997).

MATERIALS AND METHODS

SMT Kingdom (TM) seismic interpretation software was used for the generation and comparison of synthetic seismograms. The detail of seismic lines, wells and locations used for comparison of synthetic seismograms are given in Table 1. Seismic line # S97-MYL-09 and well log data of Meyal-17 of upper Indus basin was selected to construct synthetic seismograms using eight different wavelets. Similar procedure was repeated for central Indus basin where seismic line # GP07-KDR-05 and log data of Kandra-02 was utilized to generate synthetic seismograms using eight different wavelets. Alike was performed again for lower Indus basin using seismic line # G2003-KH-44 and well log data of Siraj South-01 to generate synthetic seismogram using eight different wavelets.

Table 1. Data used for synthetic generation.

Line name	Well Name	Area	Basin
S97-MYL-09	Meyal-17	Meyal	Upper Indus basin
GP07-KDR-05	Kandra-2	Kandra	Central Indus basin
G2003KH-44	Siraj-South-01	Khipro	Lower Indus basin

The compensated sonic logs and formation density logs of Meyal-17, Siraj South-01, Kandra-02 and Kadawari-01 represent the basic source of velocities and densities respectively. Furthermore, composite logs of these wells are accessible to describe the lithologies of rock units, stratigraphy and depth of formation tops. From velocity and density logs, acoustic impedance logs can be generated which yield reflectivity series. The reflectivity series can be convolved with seismic wavelet for the generation of synthetic seismogram as shown in Fig.1.

For the generation of synthetic seismogram, selection of the wavelet is the most important step (Ping, 2006). In fact, matching of synthetic traces with original seismic trace is dependent upon wavelet with which reflectivity series is convolved to generate synthetic traces. The details about the characteristics of wavelets illustrating their shape and frequency spectrum available in SMT Kingdom (TM) seismic interpretation software can be obtained from Ryan (1994). In addition, wavelet can also be extracted from original seismic data and can be used for generation of synthetic seismogram.

RESULTS AND DISCUSSION

Case study 1: Wavelet Response in upper Indus basin (Meyal Area)

Seismic line S97-MYL-09 and well data of Meyal-17 are selected from upper Indus basin to construct various synthetic seismograms for comparison. Tectonically, Meyal is considered as an active compressional regime and is characterized by thrust/reverse faults and anticlinal structures (Kadri, 1995). Fig. 3 and 4 show the synthetic seismograms prepared using eight different wavelets along with their tie on the well location with the seismic section. Five seismic horizons of interest Kohat formation, Chorgali formation, Skesar formation, Patala formation and one reflector of Triassic age is highlighted on the seismic section for synthetic seismogram tie. Fig 3a (butterworth) shows the match of only two horizons while the Fig.3c (gaussian) and Fig. 3d (klauder) shows many uncertainties in matching results. Fig. 4a (minimum phase) and Fig.4b (Obrien) represent a lot of deviation for seismic horizons from their actual position. Similar results can be seen in Fig.4c (ormsby) and Fig.4d (ricker) are unable to produce the exact match. Fig. 3b (extracted) shows the best match with the seismic data. The peaks of the synthetic in all the cases presented above lie exactly over the trough of the seismic section and vice versa. Hence, the seismic section and synthetic seismogram have different polarity and phase. Except for the extracted wavelet, all the synthetics prepared using other wavelets show a great uncertainty in matching results. This may be attributed to the loss of frequency content due to the presence of many faults and fractures.

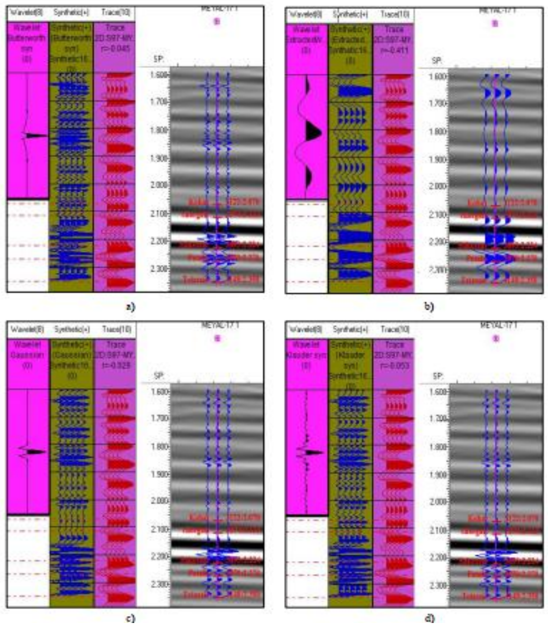

Fig. 3 Synthetic seismogram generated by using Butterworth (a), Extracted (b), Gaussian (c) and Klauder wavelet (d) for Meyal area, upper Indus basin.

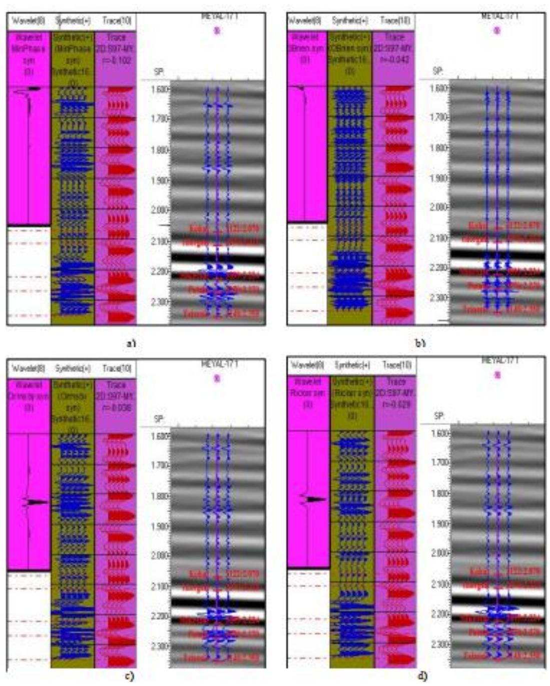

Fig. 4 Synthetic seismogram generated by Minimum phase (a), Obrien (b), Ormsby (c) and Ricker wavelet (d) for Meyal area, upper Indus basin.

Case Study 2: Wavelet Response in Central Indus Basin (Kandra Area)

Seismic line GP07-KDR-05 and well data of Kandra-02 (Central Indus Basin) are used to generate seismograms as shown in Fig.5 & Fig.6. With the help of well tops and time-depth relation only two reflectors; Sui shale and Sui main limestone are highlighted on the seismic section due to shallow depth (660 m) of Kandra-02 well. It can be observed clearly from Fig.5 and Fig.6 that for all zero phase wavelets i.e., Butterworth (Fig. 5a), Extracted (Fig. 5b), Gaussian (Fig. 5c), Klauder (Fig. 5d), Ormsby (Fig. 6c) and Ricker (Fig. 6d) provide reasonable matching results. There is a very low of probability of obtaining good match of synthetics with minimum phase wavelets (Fig. 6a, 6b). Apart from extracted wavelet all the other synthetics prepared by zero phase wavelets do not fall at the exact locations on the seismic sections. Synthetics generated with Butterworth (Fig.5a), Gaussian (Fig. 5c), Klauder (Fig.5d) and Ricker wavelets provide a match just below the exact location while Ormsby wavelet (Fig.6c) yields the match above from the exact time-depth location. It can also be seen (Fig.6b) that the peaks of the synthetic seismogram overlays the troughs of the seismic section and vice versa.

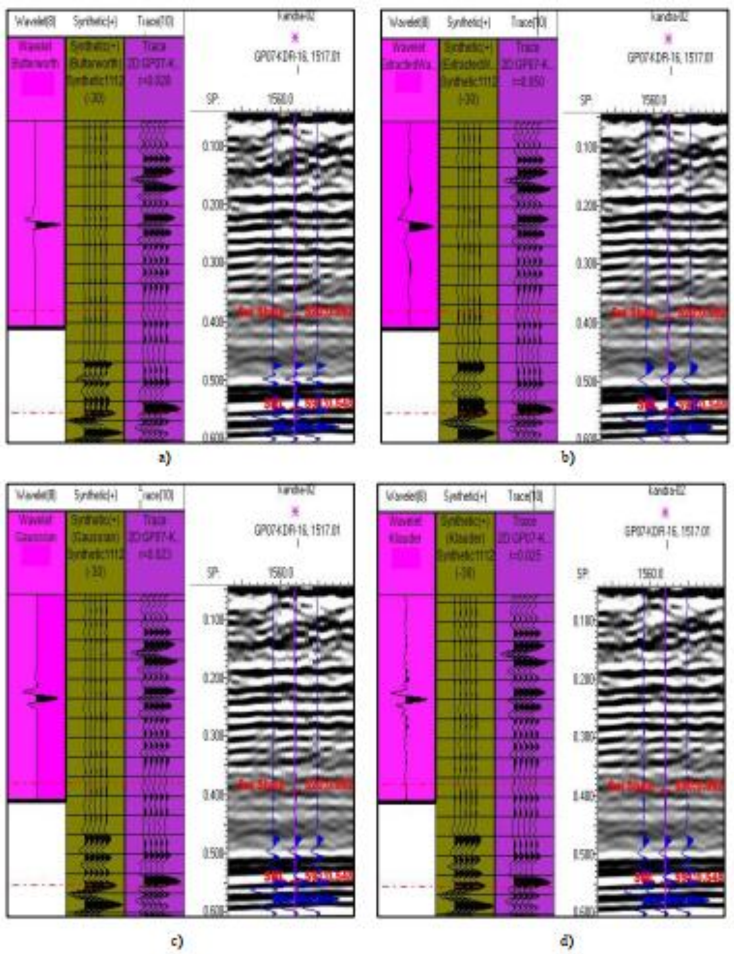

Fig. 5 Synthetic seismogram generated by using Butterworth (a), Extracted (b), Gaussian (c) and Klauder wavelet (d) for Kandra area, central Indus basin.

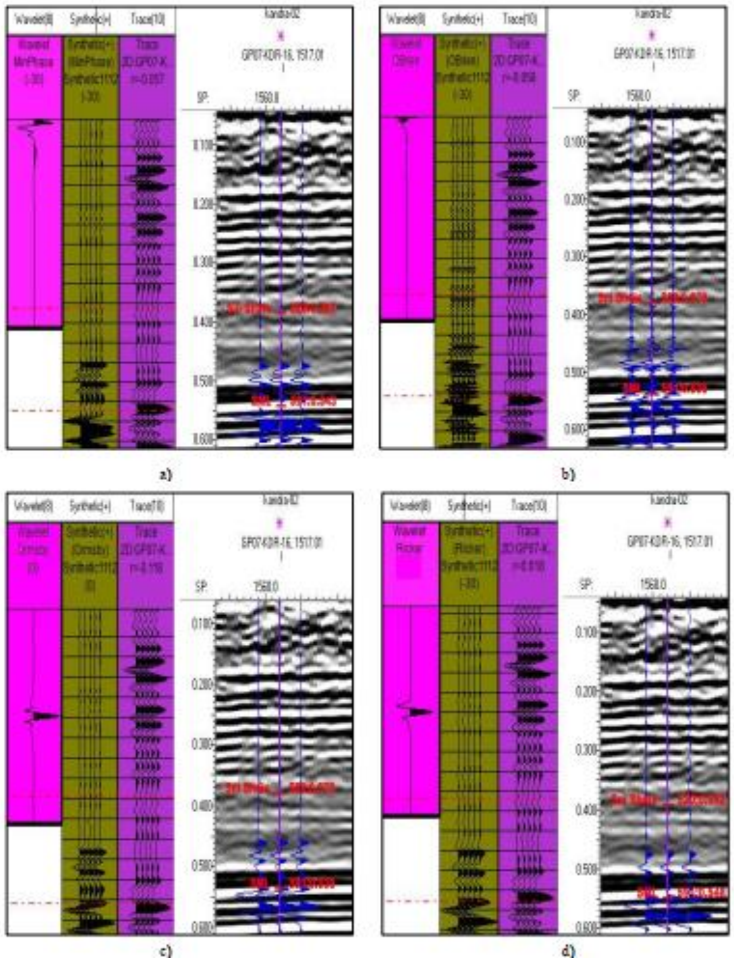

Fig. 6 Synthetic seimogram generated by Minimum phase (a), Obrien (b), Ormsby (c) and Ricker wavelet (d) for Kandra area, central Indus basin.

Case Study 3: Wavelet Response in Lower Indus Basin (Khipro Area)

Khipro block is the part of Thar Platform which is a westward sloping monocline and controlled by its basement topography. It is bounded by the Indian Shield to East, Sukkur Rift to North and it merges into Karachi and Kirthar trough to West and Sindh monocline to South (Kadri, 1995). The structures are due to the result of normal faulting on West dipping Indus Plain and this fault plane act as migrating paths for hydrocarbons from underlying source sequence. Basal Sands (producing reservoir) are bounded on the East and West by extensional faults dipping to the West and East and trending NW-SE (Kadri, 1995). By using well data of Siraj South-01 and SEG-Y data of G2003KH-44 (Central Indus basin) number of synthetics are prepared (Fig.7 & Fig.8).

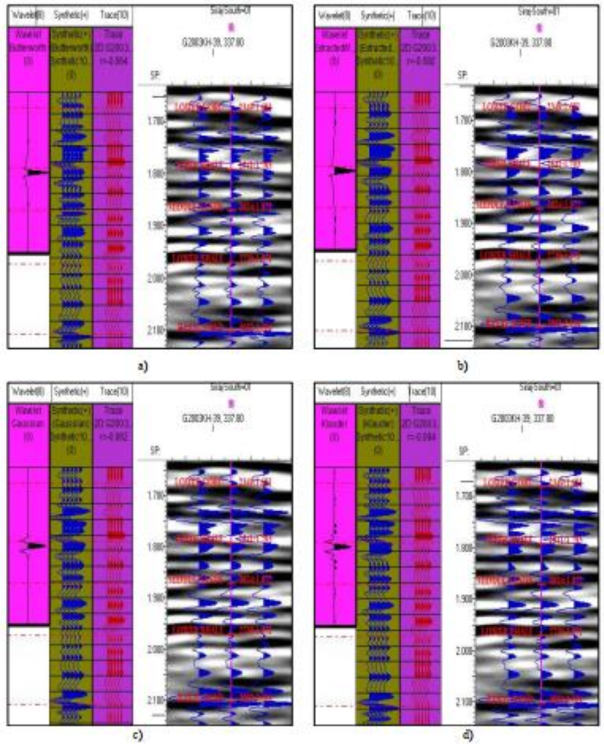

Fig. 7 Synthetic seismogram generated by using Butterworth (a), Extracted (b), Gaussian(c) and Klauder wavelet (d) for Khipro area, lower Indus basin.

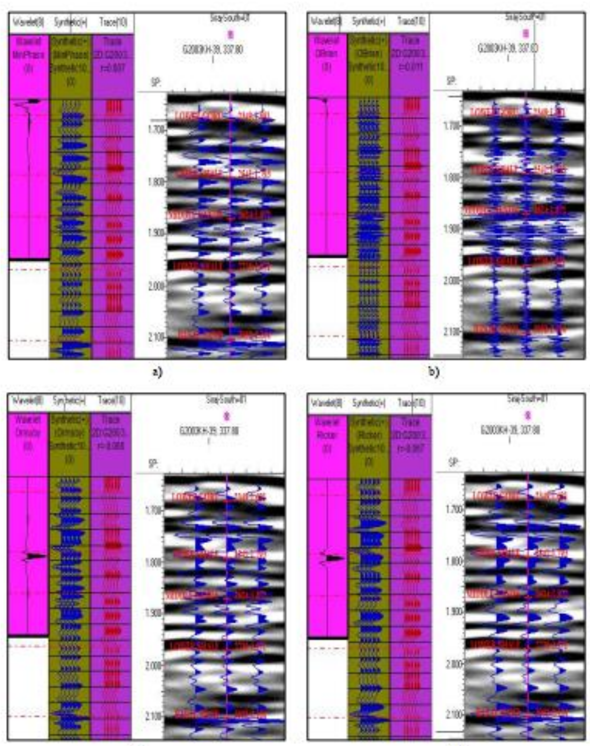

Fig. 8 Synthetic seismograms generated by using Minimum phase (a), Obrien (b), Ormsby (c) and Ricker wavelet (d) for Khipro area, lower Indus basin.

Five seismic horizons of interest are also shown on the seismic section at their corresponding time and depth. All the zero phase wavelets Fig.7a (butterworth), Fig.7b (extracted), Fig.7c (gaussian), Fig.7d (obrien) Fig.8c (ormsby) and Fig.8d (ricker) show similar kind of behavior on matching. But Fig.8a (minimum phase) and Fig.8b (obrien) are showing very low probability of synthetic matching and its tie. Among the entire zero phase wavelets, the extracted wavelet as shown in Fig.8b provides the best match as peaks are matching with peaks and troughs are matching with troughs. So, it implies that one can predict the phase of the seismic data i.e. zero phases.

CONCLUSIONS

Comparison of synthetic seismogram and seismic data using different seismic wavelets under different geological settings reveal that synthetic traces obtained using zero phase (Ormsby, Klauder, Butteworth, Extracted, Gaussian and Ricker) wavelets often provide the best match. The synthetic match in Meyal and Kandra areas suggest that the seismic traces having reverse polarity give the best results, while that was opposite for Khipro area. In most of the geological settings, the synthetic traces generated by using extracted wavelets (wavelets extracted from seismic data) are providing the best matching with the seismic data.
This study also suggests that considering the seismic data as zero phase always can lead to false interpretation as evident from Meyal and Kandra areas having different geological settings. In other words, such kind of study helps to accurately determine the polarity of the seismic data improving the quality of seismic interpretation.

REFERENCES

Allouche, H., Thore, P., and Monnerie, T., 2009, Towards a better seismic to well tie in complex media. In: SEG Technical Program Expanded Abstracts, 1870-1874.

Barkved, O., Bartman, B., Compani, B., et al., 2004, The Many Facets of Multicomponent Seismic Data, Oilfield Review, pp 42-56.

Bartel, T., Krastel, S., and Spiess, V., 2007, Correlation of high-resolution seismic data with ODP Leg 208 borehole measurements. In: Kroon D, Zachos J C, Richter C. *Proc. ODP, Sci. Results,* 208, 1–27.

Box, R., and Lowrey, P., 2003, reconciling sonic logs with check-shot surveys: Stretching synthetic seismograms. The Leading Edge, 22(6): 510–517.

Box, R., Maxwell. L., Loren, D., 2004, Excellent synthetic seismograms through the use of edited logs: Lake Borgne Area, Louisiana, U.S. The Leading Edge, 23(3), 218–223.

Bui, H., Ng, D., Hwa, P., Becker, D., Zhou, Z., and Smith, M., 2010, Well-to-seismic mistie: A valuable indicator of seismic anisotropy for subsalt velocity model update. A case study in a deviated subsalt well in the deep-water Gulf of Mexico. In: SEG Annual Meeting. Society of Exploration Geophysicists.

Duchesne, M.J., and Gaillot, P., 2011, Did you smooth your well logs the right way for seismic interpretation? Journal of Geophysics and Engineering, 8(4), 514.

Edgar, J.A., and Baan. M., 2011, How reliable is statistical wavelet estimation? Geophysics, 76(4), V59-V68.

Goldberg, D., 1997, The role of downhole measurements in marine geology and geophysics. Reviews of Geophysics, 35(3), 315-342.

Henry, S., 2000, Pitfalls in synthetics. The Leading Edge, 19(6): 604–606.

Kadri, I.B., 1995, Petroleum Geology of Pakistan: Pakistan Petroleum Ltd, 262-292.

Kazmi, A.H., and Jan, M.Q., 1997, Geology and Tectonics of Pakistan: Graphic Publishers, Karachi, Pakistan, 483-500.

Kelly, K.R., Ward, R.W., Treitel. S., and Alford, R.M., 1976, Synthetic seismograms: a finitedifference approach. Geophysics, 41(1), 2-27.

Nathalie, L., and Pierre. D., 2000, Well to seismic calibration: a multi-well analysis to extract one single wavelet. Retrieved 15.06.2011 from (Seismic calibration) http://www.beicip.com/index.php/eng/news/publications/2000_2002

Ping, A., 2006, Application of multi-wavelet seismic trace decomposition and reconstruction to seismic data interpretation and reservoir characterization. In: SEG Annual Meeting. Society of Exploration Geophysicists.pp

Ryan, H., 1994, Ricker, Ormsby, Klander, Butterwoth-A Choice of wavelets. CSEG Recorder, 8-9.

White, R., and Hu. T., 1998, How accurate can a well tie be? The Leading Edge, 17(8), 1065–1071.

Ziolkowski, A., Underhill, J.R., and Johnston, R.G., 1998, Wavelets, well ties and the search for subtle stratigraphic traps. Geophysics, 63(1), 297-313.