PS A Seismic Method for Estimating Subsurface Vp/Vs Ratio Based on Converted Waves: A Case Study From Arabian Gulf*

Haoran Guo[1], Yuefeng Sun[2], and Zhifeng Wan[3]

Search and Discovery Article #42077 (2017)**
Posted May 15, 2017

*Adapted from poster presentation given at AAPG 2017 Annual Convention and Exhibition, Houston, Texas, April 2-5, 2017

[1]Department of Geology and Geophysics, Texas A&M University College Station, College Station, Texas, United States (guohaoran@tamu.edu)
[2]Department of Geology and Geophysics, Texas A&M University College Station, College Station, Texas, United States
[3]School of Marine Sciences, Sun Yat-sen University, Guangzhou, China

Abstract

Vp/Vs ratio is a critical property for geologist to identify subsurface rocks better. Because elastic properties of rocks, such as Young's modulus and Poisson's Ratio, can be calculated on the basis of P and S wave velocity ratio. It can indicate the kind of rock and fluids, the sand/shale lithologic boundary, and identify conglomerate and anhydrate/dolomite. This study proposes a seismic method to estimate Vp/Vs values for some subsurface reflectors and get a more accurate subsurface image, using the seismic converted-wave data. In previous studies, geophysicists assume the curved trace of converted wave is aligned vertically in one stacking bin, calculated by an approximate Vp/Vs value. For the deep part of the image space, Common Conversion Point (CCP) image trace is almost vertical, but the upper part is father away from the vertical trace. The image error increases as a reflector goes closer to the water bottom. Inaccurate P-wave and S-wave velocity ratios and subsurface imaging produce an

effect on interpreting geologic structures. In this study, the Vp/Vs value related to a subsurface layer can be estimated. The field data used for this study are 4C Ocean Bottom Cable (OBC) data, acquired by two 2D test lines around the Umm Al Lulu offshore fields of the U.A.E.. The ray paths of converted waves are asymmetric, so locating converted points is an important step to process converted waves. In this study, one Vp/Vs value was tested at a time. The theory proposed is that the Vp/Vs ratio determines the location of converted points. Because the asymmetric feature of converted waves, if Vp/Vs is incorrect, the records from positive and negative offsets represent different subsurface points. There will be no correlation between the positive- and negative-offsets stacking results. However, if Vp/Vs is close to the rock properties in some subsurface layers, there will be a strong correlation in specific times. This seismic approach can estimate Vp/Vs values for different depths. A set of Vp/Vs values was tested by processing seismic data to get positive- and negative-offsets stacking results, and then doing correlation between these stacks. By correlating events in different depth for each Vp/Vs ratio, some reflection events are enhanced in certain value, which means this Vp/Vs represents the rock properties at this depth. Then the best-correlated part of each stacking can be combined to get a more accurate converted-wave result about subsurface structures.

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Haoran Guo[1], Yuefeng Sun[1], Zhifeng Wan[1, 2]

1: Department of Geology & Geophysics, Texas A&M University, 2: School of Marine Sciences, Sun Yat-sen University.

OBJECTIVE

Vp/Vs ratio is a critical property for geologist to identify subsurface rocks better. Geophysicists assume the curved trace of converted wave is aligned vertically in one stacking bin, calculated by an approximate Vp/Vs value. For the deep part of the image space, Common Conversion Point (CCP) image trace is almost vertical, but the upper part is father away from the vertical trace. The image error increases as a reflector goes closer to the water bottom. Inaccurate Vp/Vs ratios and subsurface imaging produce an effect on interpreting geologic structures. This study proposes a seismic method to estimate Vp/Vs values for some subsurface reflectors and get a more accurate subsurface image, using the seismic converted-wave data.

METHOD

The field data used for this study are 4C Ocean Bottom Cable (OBC) data, acquired by two 2D test lines in U.A.E.. The ray paths of converted waves are asymmetric, so locating CCP points is very important in the converted wave processing flow. The theory proposed is that the Vp/Vs ratio determines the location of converted points. Because the asymmetric feature of converted waves, if Vp/Vs is incorrect, the records from positive and negative offsets represent different subsurface points. There will be no correlation between the positive- and negative-offsets stacking results. However, if Vp/Vs is close to the rock properties in some subsurface layers, there will be a strong correlation.

RESULTS

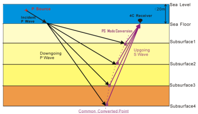

Figure 1: Raypaths illustrate the converted PP-S waveform.

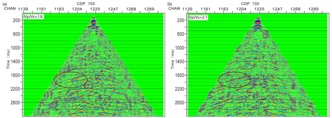

Figure 3: Portions of the CCP 700 record, based on: (a) Vp/Vs=1.8; (b) Vp/Vs=2.1. Red circles illustrate the characteristics of reflection events are different, because of the various CCP coordinates, calculated by different Vp/Vs ratios.

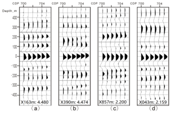

Figure 5: Cross-correlations from CDP 700 to 705 at different depths between positive- and negative - offsets stacks when the Vp/Vs ratio is 2.0.

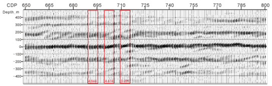

Figure 6: Cross-correlation from CDP 650 to 800 at the X390m depth between positive- and negative- offsets stacks when the Vp/Vs ratio equals to 2.0. Various cross-correlation amplitudes (e.g. the red rectangles) along the CCP line show that the Vp/Vs ratio changes horizontally in the space.

	CDP 700-705					
Depth(m)	1.8	1.9	1.95	2	2.1	Log Vp/Vs
X163	3.172	3.737	4.171	4.480	3.571	1.970-2.108
X390	4.149	4.405	4.460	4.474	3.417	1.982-2.013
X693	2.177	2.256	2.260	2.178	1.774	1.941-1.957
X857	2.109	2.143	2.162	2.220	2.129	1.991-2.009
X043	2.360	2.186	2.144	2.159	2.108	1.793-1.818

Table 1: Amplitudes of cross-correlations between positive- and negative- offsets stacks from CDP700 to CDP705 at different depth when the Vp/Vs value equals to 1.8, 1.9, 1.95, 2.0 and 2.1, separately. The red words show the strongest cross-correlations at the specific depth. And the last column presents the Vp/Vs ranges from the well log data at different depths. For example, at the X390m depth, the cross-correlation is the strongest when Vp/Vs=2.0, which means this Vp/Vs value matches the real geological properties at that depth. It is verified by the measured well log data, which show the Vp/Vs range is from 1.982 to 2.013.

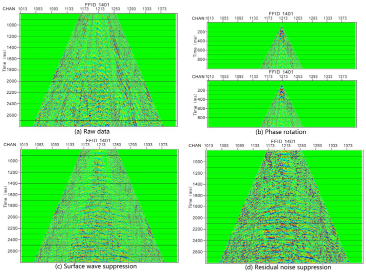

Figure 2: Preprocessing sequences in X component: (a) the raw shot record; (b) before and after phase rotation in positive offsets; (c) after removing surface waves; (d) after removing residual noises.

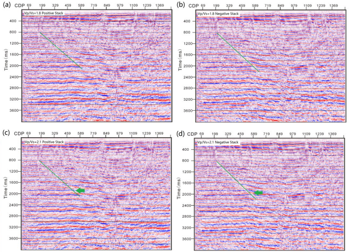

Figure 4: Portions of stacking results: (a) positive-offsets stack when Vp/Vs=1.8; (b) negative-offsets stack when Vp/Vs=1.8; (c) positive-offsets stack when Vp/Vs=2.1; (d) negative-offsets stack when Vp/Vs=2.1. Geological structures (e.g. the green fault) are in different locations, when using different Vp/Vs ratios to obtain CCP coordinates.

CONCLUSION

A set of Vp/Vs values was tested by processing seismic data to get positive- and negative-offsets stacking results, and then doing correlation between these stacks. By correlating events in different times for each Vp/Vs ratio, some reflection events are enhanced in certain value, which means this Vp/Vs represents the rock properties at this depth.

Author Contact: Haoran Guo (guohaoran@tamu.edu)