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Brine-methane Substitution: The Seismic Response of Coalbeds

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Summary

Based on data from the Mannville coals in the Corbett Field, Alberta, Canada, we provide a numerical evaluation of the seismic response generated by the substitution of brine by a combination of brine and methane. For the development of this project, we perform a fluid simulation and a Gassmann fluid substitution to generate synthetic seismograms to establish the suitability of seismic to monitor coalbed methane production.

Introduction

Coalbed methane (CBM) is an unconventional resource that has lately received the attention of the world due to its potential to become an important source of natural gas (Shi and Durucan, 2005). The production of the CBM takes place when a reduction of the pressure at a reservoir level causes desorption of the methane from the matrix. In the presence of coalbeds with high water content, the process begins with water production that will bring as a consequence the pressure reduction required for the methane desorption (Clarkson and Bustin, 2010).

In this study we model a 10m and a 20m coalbed to evaluate the changes in the seismic response caused by the substitution of brine by methane; beginning with the initial production state, and then with a later stage after methane desorption starts. For the development of this project we selected coal data from two coalbeds of the Mannville Group in the Corbett Field, Alberta, Canada.

Method

We select the Corbett Field in Alberta, Canada as the area of study. In this field, the targets are two coalbeds, the Main and Lower seams of the Mannville Group (Cockbill, 2008). We use well log data from the well 100-03-22-062-06W500, located in the NE of the Corbett Field, to model a 10m and a 20m coal seam. For the development of the project we complete a fluid simulation and a fluid substitution in order to generate the synthetic seismograms associated to two different stages of the reservoir.

We perform fluid simulation for a homogeneous coal seam using a tank model which assumes that there is no variation of the reservoir properties in any direction, and that averages of these properties represent a good approximation of the reservoir conditions (Odeh, 1969). The fluid simulation includes the construction of the Langmuir isotherm to model the methane adsorption/desorption in the coalbed (Robertson, 2008), and we estimate the change in the coal matrix during depletion using a production forecast and the Palmer and Mansoori permeability model (Palmer and Mansoori, 1998).

The fluid simulation provides an estimation of methane and water saturation, changes in porosity during production, and the pressure decrease in an 8 years period; to provide the required scenario to complete the fluid substitution

The fluid substitution is performed using a general form of the Gassmann equation and following the workflow presented by Smith et al. (2003) and Kumar (2006) in their tutorials for the application of the Gassmann equation (Gassmann, 1951). This technique allows us to estimate changes in the seismic velocities and density that occur as a consequence of variations in the fluids saturation (Kumar, 2006); based on the real conditions of the reservoir at the moment in which the well data was measured (Dvorkin et al., 2007).

For the Gassmann fluid substitution, we assume a pore fluid of 100% brine as the initial condition and calculate physical properties of the coal associated with this stage. Finally, based on the results obtained for the initial state, we calculate the seismic properties of coal saturated with 82% of brine and 18% of methane.

The synthetic seismograms give an idea of the character of the seismic response of the coalbeds saturated with 100% brine and with 82% of brine and 18% of methane. We generate synthetic seismograms for the initial and final state using a 30HZ ricker wavelet.

Examples

Figure 1 presents the synthetic seismograms for a 10m coalbed before and after fluid substitution. In the synthetic seismograms, the amplitude trough at a depth of 980m coincides with the top of the coalbed while the peak at around 990m can be associated with its base. In this case, there is no evidence of variation of the amplitude versus offset (AVO).

In synthetic seismograms in Figure 1a the fluid present in the coalbed is 100% brine and the top and the base of the coalbed can be easily identified as the strongest reflections in the seismograms. Figure 1b shows the synthetic seismograms for the coalbed saturated brine and methane. The replacement of brine by methane using Gassmann fluid substitution (Gassmann, 1951) caused a change in the character of the wavelet, presenting an amplitude increasing and a phase shift.

The depth domain synthetic seismogram for the 20m coal seam that was generated with a 30Hz Ricker wavelet is displayed in Figure 2. Before fluid substitution (FIG. 2a), at approximately 980m appears the reflection of the top of the coalbed while the one related to the base is close to a depth of 1000m. A decrease of the amplitude with the offset is also observed. With 82% of brine and 18% of methane in the pore space (FIG. 2b), the character of the wavelet completely change presenting a lightly increase of the amplitude of the reflections and a shift in the phase. The AVO response becomes less obvious after substituting brine by methane

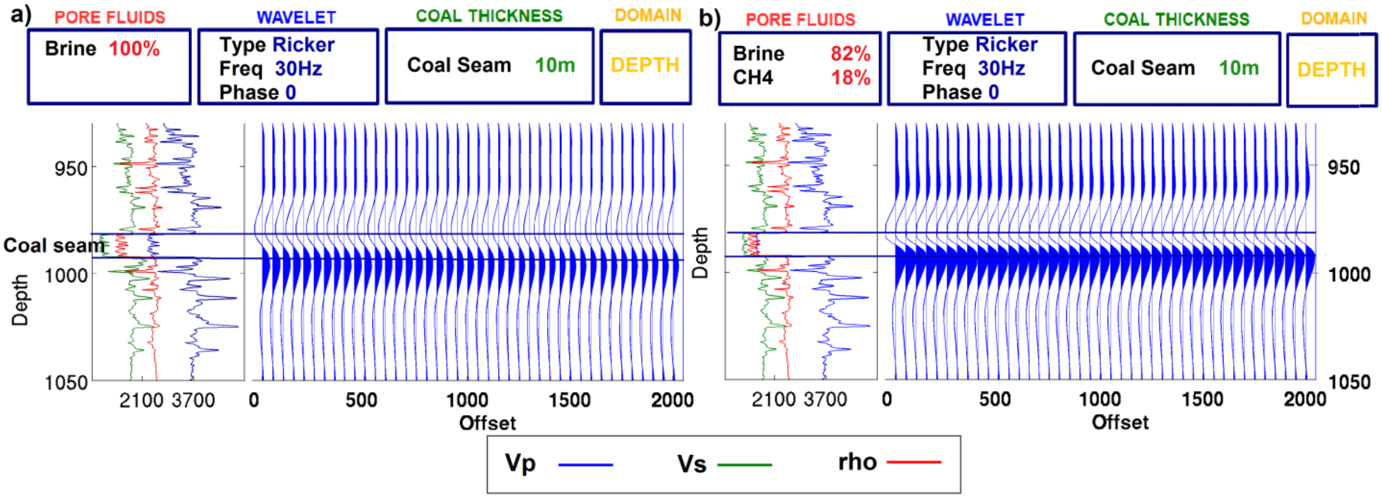

Figure 1: Synthetic seismograms for a 10m coalbed, generated with a 30Hz zero phase Ricker wavelet. a) coalbeds are saturated with 100% brine; b) coalbeds are saturated with 82% brine and 18% methane

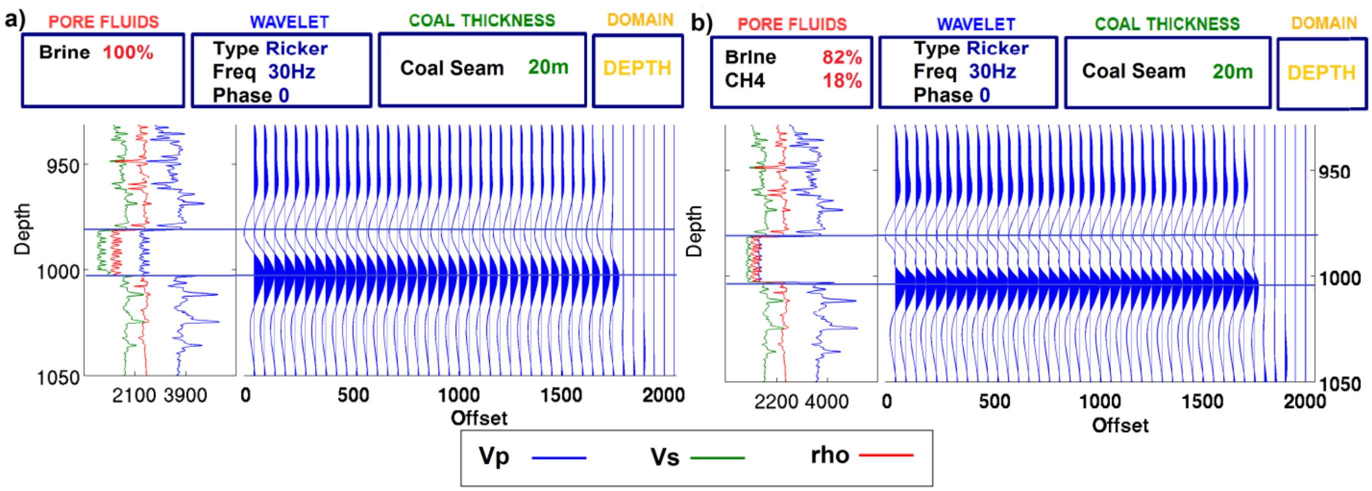

Figure 2: Synthetic seismograms for a 20m coalbed, generated with a 30Hz zero phase Ricker wavelet. a) coalbeds are saturated with 100% brine; b) coalbeds are saturated with 82% brine and 18% methane

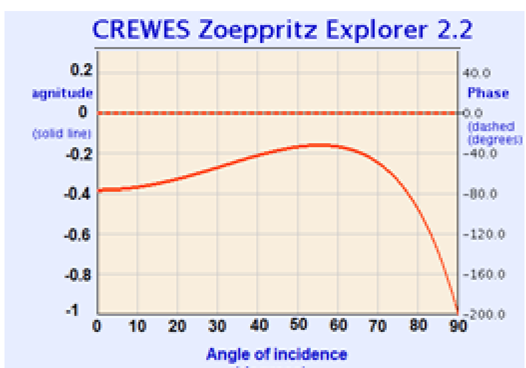

Figure 3: Variations of the reflection coefficients with the incidence angle using the Zoeppritz equation.

We also use the Zoeppritz equation to evaluate the variations of the reflection coefficients with the incidence angle and the results are presented in Figure 3. From this graph, it can be interpreted that there is not a critical angle over which the reflection coefficient becomes or approximates to zero. For incidence angles between 0° and 55° the amplitude will tend to slowly decrease and for incidence angles over that range the amplitude will have a representative increase. Another important observation is that the reflection coefficients have a negative range indicating that in this case the top of the coalbed will be always a trough which coincides with the observation in synthetic seismograms generated

Conclusions

The evaluation of the synthetic seismograms for different coal seams thicknesses gives an idea of the changes that we can expect depending on the fluid in the pore space of the coalbed. In the Case 1, we evaluate a 10m coalbed and we identify the top and the base of the coal seam with the 30Hz Ricker wavelet and there was no evidence of an AVO response. The fluid substitution caused a change in the character of the wavelet, by showing an increase in the amplitude and a phase shift.

For a 20m coalbed case, we identify a decrease of the amplitude with the offset. After the substitution of 100% brine by a mix of brine and methane, the changes in amplitude and phase were more accentuated than in the first case (10m coalbed). The AVO response was less evident after fluid substitution.

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