Summary

The Cocuite gas field, located on-shore Mexico, is producing since the 1960’s from 4 main reservoir levels with a steadily declining production rate. The structural interpretation and geological model indicate the presence of substantial gas pockets trapped close to the existing wells. These gas pockets are basically un-drained the already drilled boreholes. Detailed amplitude studies were conducted on pre-stack and post-stack seismic data in order to validate this prediction and to enhance the recovery from the Cocuite gas field.

100km² of the larger Cocuite 3D seismic dataset were initially reprocessed. This included a full Kirchhoff pre-stack time migration, detailed velocity analysis and special noise attenuation. The zero-phased time migrated CDP gathers were stacked and inverted to acoustic impedance applying a model-driven algorithm. The same CDP gathers formed input for an AVO analysis, which extracted “intercept times gradient” and “fluid-factor” attributes from the dataset. 1D AVO modelling helps in understanding the complexity of the AVO and acoustic impedance results. In addition, a large number of existing wells were calibrated to the AVO response and this ensured a good comprehension of the AVO signatures at each reservoir level.

The well calibration shows that there is a good differentiation between the various fluids in the reservoirs. It provides a sound basis to interpret AVO and impedance anomalies away from the well control. Structural interpretation, together with anomalous AVO behaviour and a drop in acoustic impedance are extremely helpful for further well planning and to define new attractive locations at the four gas levels. A new drilling campaign was designed based on the inversion and AVO results. The multi amplitude approach has reduced the drilling risk considerably, as has been proven by the successful production wells drilled since.

Introduction

The first Cocuite wells were drilled in 1962 on amplitude anomalies without any specific pre-stack and post-stack amplitude studies. Gas was discovered in the Lower Pliocene, the Upper Miocene and the Middle Miocene clastics. The declining production rate and the increasing demand for gas has brought the need to re-investigate the exploitation of existing gas fields in Mexico. Conventional interpretation is now supported by additional data and integrated studies are conducted on a routine basis. The results of complementary inversion and AVO amplitude studies increase the confidence for the positive
outcome of new drilling proposals, with locations that are truly optimised from a reservoir characterisation point of view.

**Acoustic inversion and AVO analysis**

Newly acquired seismic data serves as input for the high resolution amplitude studies. The processing sequence includes a full Kirchhoff pre-stack time migration (cf. Sheriff and Geldart 1983). Dedicated seismic processing ensured noise attenuation without destroying the amplitude values (Da Silva et al., in prep.). The time migrated stack was input into the TDROV™ software package, that adopts a model-driven inversion approach (Duboz et al. 1998, Veeken and Da Silva, in prep). The seismic traces were inverted to acoustic impedance using an automated micro-layer concept and a “simulated annealing” technique (cf. Veeken et al. 2002). The micro-layers together with the cross and inline subdivision create a grid cell volume for storing constant AI values. These values are perturbed, synthetics computed and the difference with the real seismic trace is established. A Cost function is used to determine the regional minimum in difference and the corresponding AI model is retained as solution.

In parallel to the inversion, possible changes in amplitude with offset (AVO) were investigated. Cocuite-402 and Cocuite-403 intersect a gas and water-bearing reservoir at the G-sand level (Upper Miocene). A reliable set of petrophysical logs is available in both wells. The G-sand was used for generating synthetic 1D AVO models. A shear sonic was calculated using Gassmann’s equation (cf. Krief et al. 1990) over the interval of interest. Information is hereby needed on the lithology, porosity, water saturation, velocity and density. A simple linear Vp - Vs relationship was applied over the remaining geologic sequence. The synthetic modelling indicates that AVO is able to differentiate between gas and water filled sand. Therefore, an AVO analysis was performed over the same seismic cube as for the inversion. The standard “gradient-times-intercept” (= product-stack) and “fluid-factor” attributes were calculated (Figure 1).

**Results and Conclusions**

The synthetic AVO modelling shows a clear difference between a water-wet and hydrocarbon saturated G-sand. In the case of water, no increase in amplitude with offset is present at the top reservoir level (Figure 2). Gas sands display positive “product-stack” anomalies. In both scenarios, the acoustic impedance drops. However, the drop in acoustic impedance is twice as large at the top of a gas sand than at a water-wet reservoir. These findings provided enough confidence to utilise the inversion results together with the AVO response for designing new attractive drilling locations.

Acoustic impedance layer maps were generated (Figure 3). The “product-stack” AVO attribute was input into an interpretation workstation and AVO maps were produced. Equal investigation windows permits direct comparison of seismic amplitude and AVO maps.

The exploration risk decreases substantially over the Cocuite gas field when combining low acoustic impedance areas with high amplitude zones and large positive “product-stack” anomalies. New drilling locations have been designed according to these three criteria and in the year 2002 an extensive drilling program was planned for all four reservoir levels.
The calibration of gas- and water-wet wells with the acoustic impedance and the AVO response shows very distinctive signatures at the gas reservoirs. As a follow-up of the project, the study area has been increased and the rest of the 3D seismic cube is analysed in a similar way. The effectiveness and benefits of this integrated study approach has been demonstrated by the drilling of successful production wells.

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References
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Figure 1 ‘Gradient-times-intercept’ section across the COCT-402 well. The M-sand produces steadily, while the G-sand reservoir suffered from early water break-through.
Figure 2  1D synthetic modeling for the gas (COCT-402) and water case (COCT-403).

Figure 3  Acoustic impedance layer map for top of G-sand reservoir. The low impedance anomaly corresponds with the presence of gas.