Sierra Chata Field, Argentina: Geophysical Discovery and Development of a Stratigraphic Trap

Kevin L. Woller* and William T. Louder#

*Mobil Technology Company, #Santa Fe Energy Resources

Drilling a seismic amplitude anomaly in the Cretaceous Mulichinco Sandstone discovered the Sierra Chata gas field in the Neuquen Basin, Argentina. This well followed several unsuccessful attempts to locate hydrocarbons in the block, including a well only 3 kilometers from the closest producing well in the field. Since that time, seismic data has played the major role in locating new wells, all 24 of which have been completed as producers.

Porosity developments in the Mulichinco Sandstone are the source of the amplitude anomalies. The development of porosity in the sandstone, which is related to diagenetic changes to the fluvial and estuarine deposited sediments, results in a significant increase in travel time. The contrast between porous and non-porous sandstone is great enough to give rise to seismic reflections. The correlation between porosity and seismic acoustic impedance is excellent, so that post-stack acoustic impedance inversion techniques can yield accurate estimates of the location and amount of porosity development.

The evolution from 2-D to 3-D seismic over the field has provided immense detail of the Mulichinco reservoir. Maps of reflection amplitude at the porous intervals show shapes that agree with the interpreted environment of deposition of the unit. Porosity transformed data obtained from the 3-D seismic depicts zones of high porosity which can be mapped in detail.

INTRODUCTION

The Chihuidos partnership, operated by Petrolera Santa Fe S.A., a subsidiary of Santa Fe Energy Resources, discovered the Sierra Chata field in 1993 with the Sierra Chata x-1 well. The Sierra Chata field is located in the Neuquen Basin in Argentina (Figure 1) on the eastern flank of the Chihuidos anticline. Seismic amplitude anomalies in the Mulichinco Sandstone played the key role in the location of the Sierra Chata x-1 well. Mobil Oil Company entered into the Chihuidos Block partnership in 1996. The excellent relationship between reservoir porosity and seismic reflections influenced Mobil's decision to join the partnership. Recently the level of geophysical contibution has increased by shooting a 250 sq km 3-D survey over the Sierra Chata field. The transition from 2-D to 3-D seismic has provided a new level of detail. With the use of seismic data, the Chihuidos group has placed twenty-four wells in the field, all of which are producers. We are currently undertaking work to generate a reservoir model based on the relationship obtained between seismic acoustic impedance and porosity derived from borehole data.

SETTING

The Neuquen basin is located in west-central Argentina, about 1100 km southwest of the city of Buenos Aires. The basin has mainly existed in a back-arc position to the Pacific plate subduction zone. Since late Cretaceous time, the basin has undergone significant structural modification, so that today there are structural highs in areas which were depocenters. There are several source rocks and reservoirs, making this a prime area for petroleum generation and trapping.

The Cretaceous Mulichinco Formation sandstone was deposited in fluvial and estuarine environments in the vicinity of Block CNQ-10. The sandstone is encased between the Quintuco formation, which is a carbonate rich shale, and the Lower Agrio Limestone. The field is located on the eastern flank of the Chihuidos anticline. Here the Mulichinco Formation ranges between 150-190 m (75-95 msec) thick (Figure 2).

Diagenetic changes to the Mulichinco sandstone resulted in porosity development in certain parts of the formation. Hydrocarbons have migrated into much of the formation and can be produced in commercial quantities in the more porous parts of the formation.

HISTORY

Sixteen wells were drilled in the Chihuidos Block CNQ-10 by various companies before the discovery of the Sierra Chata field in 1993. One of the wells, the Canadon Agua Salada dry hole drilled in 1983, is within 3 kilometers of the current producing area. The lack of structural separation between the Canadon Agua Salada well and the field indicates the trap is stratigraphic in nature. Twenty-four to sixty fold 2-D seismic was acquired in the block from 1981-1991 before the drilling of the discovery well, the Sierra Chata x-1. This well was the fourth in a program that had previously tested multiple targets in favorable structural positions. The Sierra Chata x-1 successfully drilled a Mulichinco seismic amplitude anomaly with no structural closure.

RELATIONSHIP BETWEEN POROSITY, ACOUSTIC IMPEDANCE AND REFLECTIONS

In the vicinity of the Sierra Chata field, the Mulichinco Formation is predominantly sandstone. Other lithologies such as shale generally do not affect porosity calculations. Therefore, there is a very direct relationship between porosity development, velocity, acoustic impedance and reflections. Figure 3 illustrates this relationship. The B, D and F zones are levels where porosity has developed. These same zones are depicted as lower acoustic impedance in Figure 3. The contrast between the porous and non-porous sandstone gives rise to large reflection coefficients in the center of this figure. Convolution of the reflection coefficients with a 20-80 Hz zero phase wavelet shows reflections as a result of the porosity development. The forward models match the seismic data very well. This gives us confidence that we can apply post-stack acoustic impedance inversion to get reasonable estimates of this rock property.

An additional step in the process is to further use the relationship between acoustic impedance and porosity. Figure 4 shows a cross-plot between effective porosity and the logarithm of acoustic impedance for several wells and several levels in the Mulichinco. The relationship is a straight line in this domain and doesn't have much scatter. This indicates that we can use our estimates of acoustic impedance from seismic inversion to further define the reservoir in porosity units.

INTERNAL REFLECTION PATTERNS

Sectional views of the Mulichinco reveal the discontinuous nature of the internal reflection patterns. These patterns are more evident in a flattened mode. Figure 5 shows the Mulichinco formation flattened at its base, the top of the Quintuco formation. The reflectors within the Mulichinco can be seen to undulate and intersect, suggesting a complex depositional sequence rather than a layer-cake stratification.

HORIZON AMPLITUDE MAPS

Much of the information in the seismic volume has to be dissected along interpreted boundaries to be properly understood. One way of doing this is to interpret horizons in a sectional view and link them together to form lateral 2-D surfaces. We did this for the Sierra Chata 3-D data and used the nominal layer names of A, B, C through I that were already in use by the geologists. Extraction of seismic amplitudes along these interpreted levels show patterns which can be interpreted as depositonal (Figures 6 and 7). We have drilled three wells on three new features defined by the 3-D data and they have been verified as producible porosity developments.

POROSITY TRANSFORMED DATA

Figure 8 shows an example of the seismic data transformed to porosity. In this black and white view, the higher porosity zones are indicated by darker shades between the interpreted levels. Now, instead of a sea of undulating reflections, specific zones of high porosity are defined. These porosity zones were recently confirmed with the drilling of four wells verifying three new features defined by the 3-D data.

CONCLUSIONS

Seismic techniques and interpretation have played a major role in finding and developing the Sierra Chata field. The transition from 2-D to 3-D seismic has provided greater detail of the Mulichinco Formation porosity zones. Porosity transformed data displays high porosity zones that, when mapped, defined new features that have been tested successfully by drilling.

ACKNOWLEDGEMENTS

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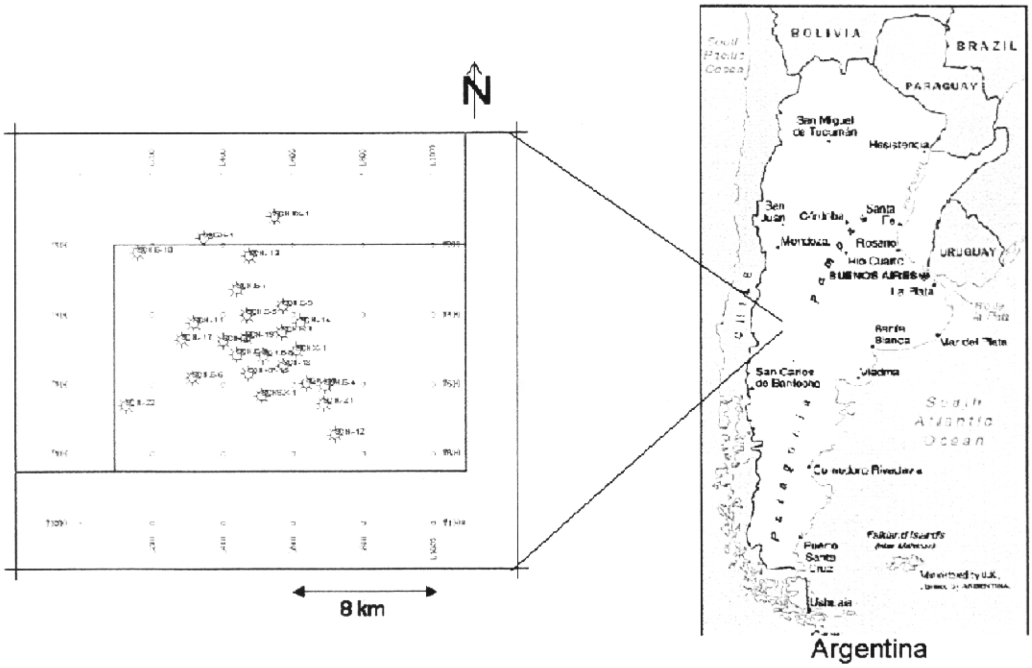

Figure 1: Sierra Chata Location Map

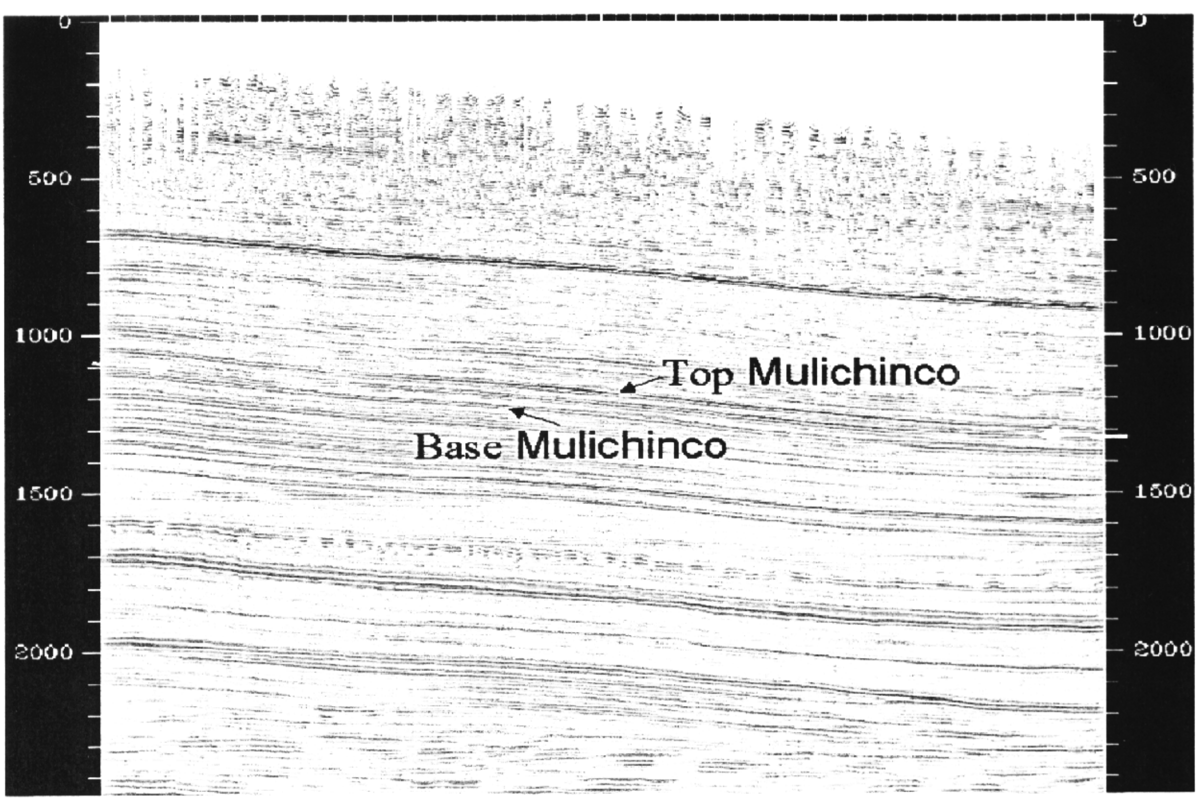

Figure 2: West-East Seismic Section

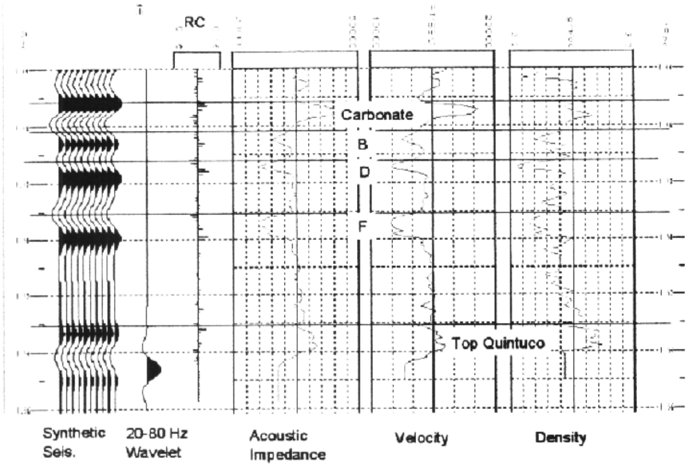

Figure 3: Sierra Chata Type Logs and Synthetic Seismogram

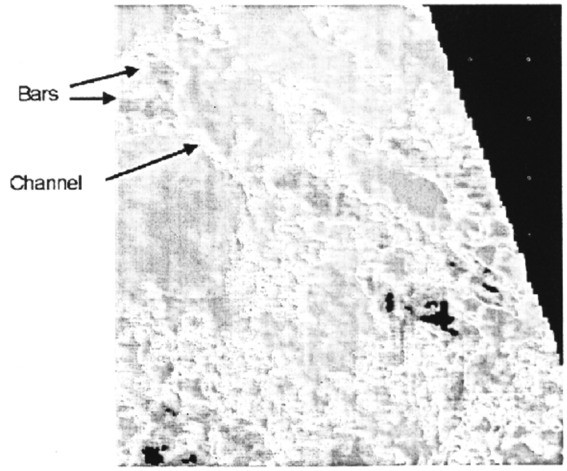

Figure 6: Mulichinco Horizon Amplitude Map 1

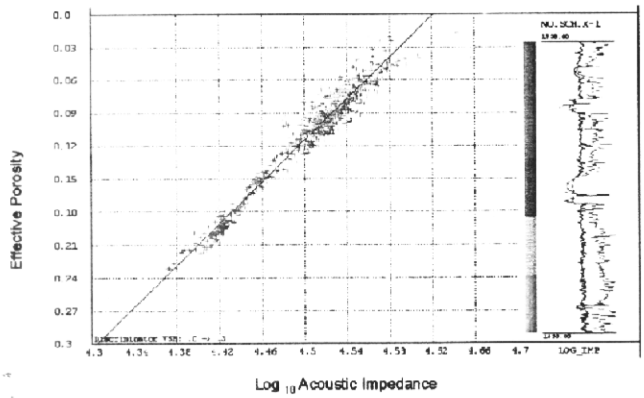

Figure 4: Effective Porosity vs Log $_{10}$ Acoustic Impedance

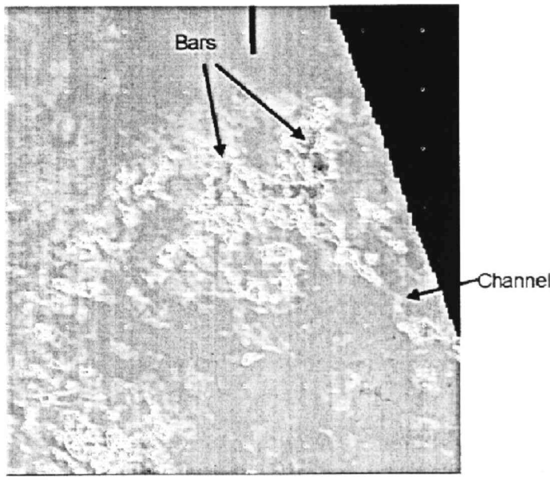

Figure 7: Mulichinco Horizon Amplitude Map 2

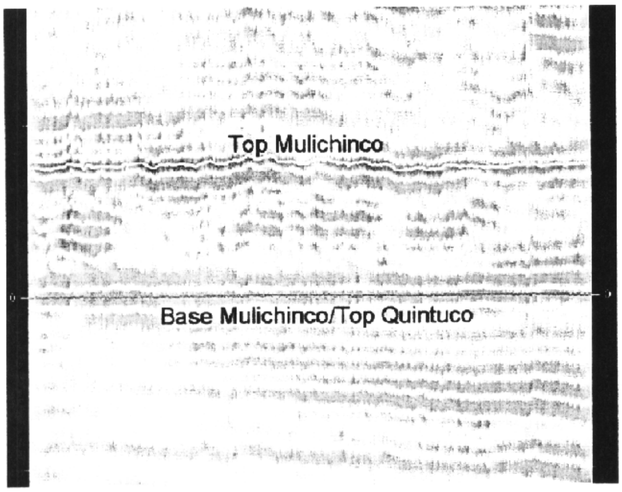

Figure 5: Seismic Data Flattened at Base Mulichinco

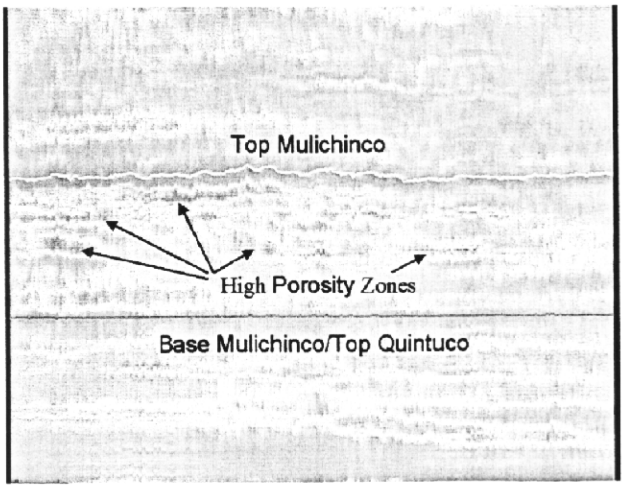

Figure 8: Porosity Section Flattened at Base Mulichinco