



CHALLENGES IN AN UNCONVENTIONAL RESERVOIR

More than seventy percent of the world's undiscovered reserves are reportedly held in unconventional reservoirs. As such, these fracture dependent plays are becoming the focus of E&P companies globally. Higher risk in these plays hampers success. ION has made advances in acquisition, processing, and interpretation techniques to address unconventional reservoirs and help E&P companies lower this risk.

FRACTURED RESERVOIR CASE STUDY

The second largest oil and gas company in China, Sinopec, is focused on the challenge of producing its sizable domestic unconventional resource base. One of the main areas of production for Sinopec is the Sichuan Province. While the area is a known gas-producing region, the productivity of individual wells can vary significantly, even within the same field and geologic horizon. This variability is often due to natural fracturing within the reservoir rocks; increased fracturing generally correlates with higher well productivity.

In order for Sinopec to efficiently produce its domestic tight gas reserves, they had to find new technology that would help them better image the natural fractures. They not only needed to find areas of high fracture density, but also determine fracture orientations so that they could intersect as many open fractures as possible with horizontal drilling for optimized production. After performing independent tests and modeling, Sinopec concluded that using full-wave could help them drill optimal wells. It was at this point that Sinopec and ION began a partnership to tackle the basin challenges together.

THE PLAN

Sinopec and ION embarked on a full-wave project that spanned acquisition, processing, interpretation and well location selection. The project leveraged VectorSeis®, ION's award-winning digital 3C sensor, to acquire the 3D full-wave survey for accurate p-wave and converted wave. It also included full-wave processing by ION's GX Technology imaging division, with a focus on fracture imaging and

interpretation of the full-wave data by ION's Reservoir Solutions Team.

FULL-WAVE ACQUISITION

The acquisition of the seismic data was a crucial step in the project. To capture the information necessary for fracture imaging, the survey had to be a well sampled, wide-azimuth design acquired with single point multi-component receivers. Sinopec chose ION's VectorSeis receiver to acquire the survey over the XinChang field in the Sichuan Basin. The survey was almost 530 sq. km. and has full-azimuth sampling beyond the 6000m offset.

PROCESSING FOR FRACTURES

Anisotropy in hard rocks leaves very distinct patterns in seismic data. At first these patterns appear destructive, but when processed correctly the result is not only high resolution data, but extractable fault and fracture information. As seismic waves travel through anisotropic (fractured) rocks, velocity changes are introduced in the wave fronts. By measuring and correcting for these velocity differences, it becomes possible to put together a picture of fracture density. In the case of converted waves, not only does the wave field exhibit a velocity difference as it crosses fractured zones, it actually splits into two different wave fronts, one fast and one slow. The fast wave front travels parallel to the fractures and the slow wave front travels across the fractures.

Because VectorSeis accurately captures the difference in the fast and slow wave fronts, it is possible to predict fracture density and fracture orientation. This kind of information is crucial in optimizing production in fractured reservoirs. In the case of XinChang, both p-wave and c-wave data were processed for fractures, however; most of the focus was placed on the c-waves because of the accuracy with which the shear-wave splitting phenomena can determine fracture orientation and density.



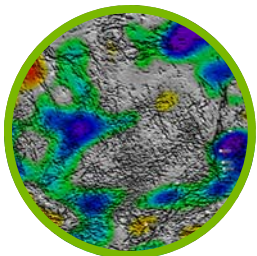
INTERPRETATION

ION's Reservoir Solutions Team performed a variety of work during the interpretation of the XinChang data. The team carried out field visits for outcrop mapping, analyzed well cores, logs and legacy seismic data. These studies not only allowed them to become familiar with the regional geology, but also helped them understand regional stress fields so that they could determine which of the key fracture sets were likely to be open and fluid filled.

In order to find fractured zones, the team used data volumes generated by the shear-splitting attributes to locate areas with single direction fractures and areas of dual direction fractures. The team's goal for the shear data was to image fractures, but they also found that the recorded shear information provided a clear picture of the lithology. This lithology information allowed them to target fractured locations near the organically rich shale source rocks.

PULLING IT ALL TOGETHER FOR WELL LOCATIONS

To choose the best well locations, the team integrated lithology, stratigraphy, structure, curvature and fracture information and verified their theories with existing well production. Having established good correlations with the new seismic attributes and well production, they were ready to recommend the most efficient well locations and designs. In areas where they knew they had high density dual direction fractures they recommended vertical wells to minimize costs, and in areas where they had single direction fractures, horizontal wells were recommended so that as many parallel fracture sets as possible could be intersected. With



→OPTIMIZING WELL PLANS VECTORSEIS SOLUTIONS APPLIED

ION's Reservoir Solutions Team can help identify fracture orientations for optimized well planning.

these recommendations ION delivered the value of full-wave data in the form of optimized well productivity. Sixteen new well locations were chosen by joint teams from ION and Sinopec.

SUCCESS

Two of the first sixteen wells found were listed in the "most significant discoveries of 2007" in the January 2008 *AAPG Explorer*. With initial successes, Sinopec not only continued drilling but purchased 10,000 stations of VectorSeis so that they could apply these full-wave techniques over additional fields and exploration areas.

For detailed information about these surveys or to learn more about how ION can help you, please contact John Tinnin, john.tinnin@iongeo.com.