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North American Explorationists Meeting

by Kevin B. Hill Hill Geophysical Consulting, Shreveport, LA William R. Meaney Anderson Oil and Gas, Shreveport, LA

Grayson Field, Jurassic Smackover Reservoir, Columbia County, AR

A Case Study Using Leading Edge Reservoir Characterization Seismic Processing of 3D Seismic Data

The discovery well at Grayson Field, Columbia County, Arkansas, was drilled on a four-way dip closure defined by three 2D seismic lines. Investors were hoping to find a maximum of 100 feet of pay. After the discovery of 158 feet of pay at 8000 feet (measured depth) in the Jurassic Smackover limestone in January 1993, the participants decided that a 3D seismic program was needed. The objective of the 3D seismic program was to define the structural and stratigraphic limits of the new field.

Specific processing and interpretive tools will be illustrated with many different seismic displays. Evidence will be presented that 1) relative amplitude of the Smackover reflector does not define the reservoir's stratigraphic parameters, 2) attributes of the acoustic impedance data (inversion) show good statistical correlation to key reservoir parameters, 3) AVO shows a hydrocarbon indicator over the reservoir, and 4) reservoir characterization data (petrophysical volumes generated with Hampson-Russell Emerge software) generated with the 3D seismic data delineates the production.



In July 1995, gas injection was begun in the field. In February 1998, a water flood program replaced the gas injection. In-fill drilling was needed to optimize the production. 3D seismic data was needed for this work, but the resolution of the reservoir was not really clear enough on the original processing. Reprocessing of the data set with "state-of-the-art" parameters such as detailed editing of each shot record, pre-stack time migration, and post-stack inversion (acoustic



Smackover structure map with location of Smackover fields in Columbia County, Arkansas. Map courtesy of Geological Consulting Services. © GCS 2002.

Grayson Field

Productive area: 800 acres Oil in place: 41,500,000 BO EUR 21,000,000 BO Cum Prod (9/30/02) 9,353,580 BO Avg. Prod (9/02) 3834.3 BOPD

Barlow Branch Field Productive area: 320 acres Oil in place: 1,500,000 B0 Cum Prod (1990) 242,575 B0 Plugged out in 1990 impedance), AVO, and petrophysical cubes was needed. The full integration of the entire suite of logs from every well in the area into the poststack processing of the 3D data yielded multiple data volumes. The bandwidth of the reprocessed data is 15—90 hertz, with a dominant frequency of 43 hertz. With the broad > continued on page 15

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bandwidth and integration of the well log information, the new data volumes show the stratigraphic components of the reservoir very clearly.

The tuning thickness of the wavelet at the Smackover level is 9 milliseconds (approximately 54 feet). Identification of the upper and lower pay intervals is very difficult because the upper zone is thinner than the tuning. The two pay zones appear to merge into one thick, high-amplitude seismic event. The sonic



North-south dip line from 3D seismic data showing water saturation data volume calculated with Archie's equation.

and density logs from the wells were used to calibrate and generate an acoustic impedance data volume. This multi-linear regression technique yields a data volume that better defines the two layers within the reservoir. The acoustic impedance (velocity) of the upper 100 feet of the Smackover was evaluated with different attributes to see if there was a correlation to the overall reservoir. Cross-plots of certain seismic attributes exhibit a good statistical fit with the reservoir's porosity and pore-volume maps generated from well information. The Grayson field Smackover reservoir is a low-velocity zone encased within high-velocity rocks. This is a classic Type III AVO case. >

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The average of the top 100 ft. of the Smackover indicates that there may be some low velocity areas on the west end of the structure. However, low velocity was only indicative of porosity and the permeability was virtually absent on the western end. Only Grayson field is seen on this map. The oil wells in the upper right corner are Barlow Branch field.



Comparison of "porosity" 3D seismic data volume (top) and "water saturation" 3D seismic data volume (bottom). The "water saturation" volume properly defines the stratigraphic limits of the reservoir.

A positive AVO P*G (primary times gradient) response is seen at the producing wells, whereas no AVO P*G response is observed in the non-producing areas.

The difficulty of identifying the thin upper pay interval was overcome by making deep induction and gas effect "seismic" volumes that could be used in conjunction with the relative amplitude, AVO, and acoustic impedance volumes. The seismic data quality was very good and a sufficient population of well bores, with the target attributes, was available. Hampson-Russell Emerge software was used for the reservoir characterization data generation. This is an artificial neural network algorithm that successfully computed the deep induction, density porosity, and neutron porosity volumes.

Cross-plotting the density porosity and neutron porosity data volumes generated a gas effect "seismic" volume. The results of this data volume were outstanding. The thick pay interval at Grayson field as well as a thin stratigraphic pay at Barlow Branch



Relative amplitude of the top Smackover reflector with subsurface and seismic depth contour overlay. Arb line represents the seismic line seen on page 15.



"Gas effect" calculated by taking the density porosity 3D seismic volume minus the neutron porosity 3D seismic volume.

field stood out extremely well.

The hydrocarbon saturation and water saturation can be calculated using Archie's equation with the "seismic" deep induction and density volumes. The data show the upper and main pay intervals as well as a possible separate deeper zone. The deeper zone has produced in two wells, and it was originally thought to be connected to the main pay zone. However, the new processing shows this zone to be separated from the main pay zone by at least 15 feet throughout the field. Further evaluation of this interval is ongoing.

The acoustic impedance data show low velocity (porosity) extending outside of the known producing limits of the field whereas the oil and water saturation volumes show the definitive limits of the pay interval. The oil and water saturation volumes also more clearly define the separation of the three different pay zones within the reservoir.

Conclusion

3D seismic data played a significant role in the development of Grayson field. The 3D seismic data allowed Petro-Chem Operating Company to drill the best structural locations within the field. Reprocessing the 3D seismic data brought out the stratigraphic nuances of the field. The relative amplitude strength of the top Smackover reflector does not define any reservoir parameters. The acoustic impedance data volume shows a good statistical correlation to the gross reservoir parameters of the upper 100 feet of the Smackover. Multi-attribute inversion using an artificial neural network algorithm (Emerge) successfully computed the deep induction, density porosity, and neutron porosity volumes. "Seismic" volumes of gas effect, water saturation, and hydrocarbon saturation clearly delineate the reservoir. New wells drilled using these 3D seismic volumes greatly increased the production rate and ultimate recoverable reserves in the field. Recent drilling proves that the 3D seismic effort and expense were well worth the money.

Biographical Sketches

KEVIN B. HILL is the president of Hill Geophysical Consulting in Shreveport, Louisiana. He has more than 25 years of Gulf Coast and international experience in exploration and production geophysics and geology.

Mr. Hill specializes in integrating state-of-the-art geophysical technologies with geology and has designed and interpreted numerous 2D and 3D seismic surveys in the Jurassic, Cretaceous, and Tertiary plays of the Gulf Coast basins in Texas, >

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Louisiana, Arkansas, Mississippi, and Alabama. His international work includes interpretation of over 2,000 km of seismic in a Latin American offshore Tertiary basin, Australia, Canada, Bahrain, and a large 3D transition shoot in Trinidad.



He was involved in the original design of the Kingdom PC-based 3D seismic workstation software. He teaches courses on using Seismic Micro-Technology, Inc. Kingdom software at schools around the world.

Hill received a BS in geology in 1977 from Louisiana State University, Baton Rouge, LA. Prior to becoming a consultant in 1987, he worked as Senior Exploration Geophysicist for Sonat Exploration in Shreveport, LA; Regional Exploration Geophysicist for Forest Oil Corporation in Lafayette, LA, and Jackson MS; and as a Senior Geophysicist for Cities Service Company in Tulsa, OK, and Jackson, MS. Hill has authored and presented numerous technical papers at Gulf Coast professional society meetings. In 2000 he received the Third Place Excellence of Presentation Award at the 50th GCAGS convention. At the 51st GCAGS convention, in 2001, he received the First Place Excellence of Presentation award and the A. I. Levorsen Award.

Mr. Hill is a member of the AAPG, Shreveport Geological Society, SEG, and is a Commandeur in the Confrerie des Chevaliers du Tastevin.

WILLIAM R. MEANEY is the exploration geologist with Anderson Oil and Gas, Inc. in Shreveport, Louisiana. He has worked with Anderson for over 11 years and has almost 30 years of oil and gas experience.

Bill received a BA in geology in 1970



from Vanderbilt University, Nashville, Tennessee, and an MS in geology in 1973 from Louisiana State University in Baton Rouge, Louisiana.

He has worked as a geologist for Marathon Oil Company, Hunt Energy Corp., Fortune Gas and Oil, for O. B. Mobley, Jr. and Hurley Petroleum. He was associated with the discovery and development of Clear Branch Field in Jackson Parish, Louisiana, while employed with Hunt Energy.

Bill's love for the Smackover was whetted with the 1980 discovery of Corney Bayou field in Union Parish, Louisiana; however, the ensuing years proved the elusiveness of this storied target.

In May 1991 he went to work for Anderson Oil and Gas. Inc. The first deal he reviewed and recommended to Anderson ultimately led to the discovery of Grayson field, of which Anderson is the largest working interest owner.

Bill is a member of the AAPG, AAPG Division of Professional Affairs, Shreveport Geological Society, and HGS. He is a past president of the Shreveport Geological Society and has been active in the Gulf Coast Association of Geological Societies, most recently serving as GCAGS Vice Chairman and Awards Chairman of the 2001 GCAGS annual convention. Bill currently serves on AAPG's Core and Sample Preservation Committee and Membership Committee.