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Multicomponent interpretation in the Marcellus Shale

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Summary

The Devonian Appalachian Basin in the Northeast United States holds vast reserves of hydrocarbons. The Marcellus Formation is a black shale that contains one of the world's largest unconventional tight gas plays. In this paper, a three component 3D seismic dataset acquired in Northeast Pennsylvania, near the New York border, is used to analyze the Marcellus Formation. A general seismic interpretation and a more specific interval rock property analysis is performed. The mildly dipping, East-West trending thrust fault structure in the Marcellus and surrounding formations is explained. Interval Vp/Vs ratios are found for several of the important intervals in the Appalachian Basin, and potential sweet spots for hydrocarbon generation are speculated. A correlation between anisotropy and high Vp/Vs ratio was found.

Introduction

The Marcellus Shale is growing unconventional resource play in the Appalachian Basin, located in the northeast United States. The Marcellus Formation covers and area greater than 100 000 square miles (259 000 km2). The United States Department of Energy estimates a technically recoverable resource of 140 500 TCF, the production trend from the Marcellus Shale is shown in figure 1. The production to the beginning of 2013 was just under 8 BCF/day.The Marcellus Formation is a low porosity, low permeability natural gas bearing shale. The hydrocarbons are only economically produced using modern hydraulic fracturing techniques. A multicomponent 3D seismic dataset was provided by Geokinetics for use in this project. Multicomponent seismic is valuable in understanding unconventional reservoirs and several rock physics parameters can be estimated from the dataset. Important rock physics parameters in tight gas reservoirs include: porosity, lithology, permeability, anisotropy, pore fluids, elastic parameters and permeability. Understand these parameters can reduce drilling risk and allow for increased economic production in resource plays.

Theory and/or Method

Following the general stratigraphic understanding of the Paleozoic Appalachian Basin and the work done by Chaveste et al. (2013), a general seismic interpretation was completed. For the general seismic interpretation 6 main reflection events were picked: Tully Limestone, Marcellus shale top, Lower Marcellus Shale, Onondaga Limestone, Trenton Limestone, and the Basement reflection. All 6 events are present on the PP seismic data, however the converted wave 3D volumes are missing some of the reflections. On the fast shear wave section (PS1) all events are present with the exception of the basement reflection and on the slow shear wave section (PS2) the Trenton Limestone and the basement reflection are not present. Generally speaking, the reflections in the Appalachian Basin are gently dipping pervasive events, this character is seen in the Tully Limestone, Trenton Limestone and basement picks. However, the Marcellus top, Lower Marcellus and Onondaga Limestone have more complex structure. Time structure and amplitude maps were made for the present horizons on each of the 3D seismic volumes. The basement reflection displays mildly dipping structure towards the south. The events above the basement follow the same gently dipping structure, but the dip angle decreases with elevation, and around the depth of the Marcellus Formation structure changes. Amplitude maps of the Marcellus Formation top give a very good representation of the fault blocks, the fault planes can be mapped easily.

Examples

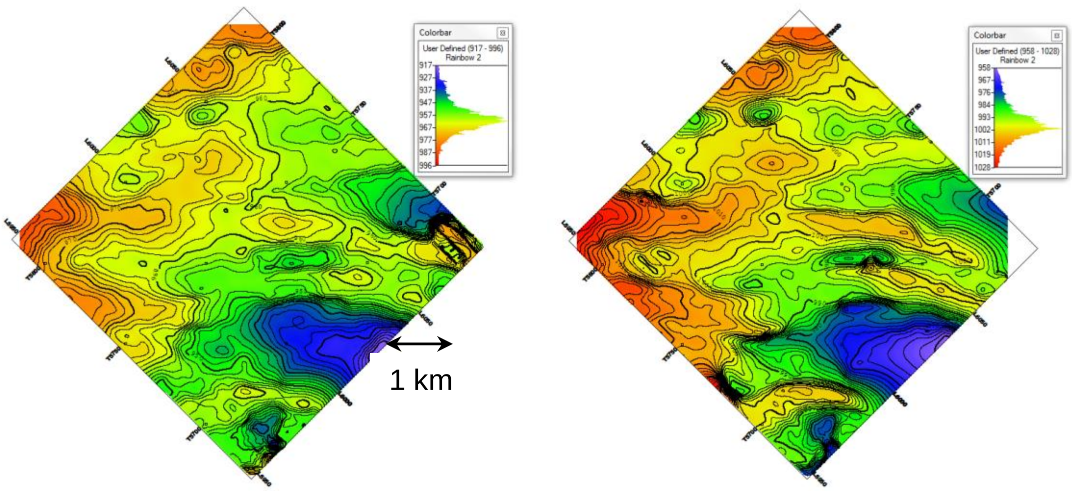

FIG. 1. (left) Marcellus top time structure, (right) Lower Marcellus time structure. The east-west trending features are fault blocks.

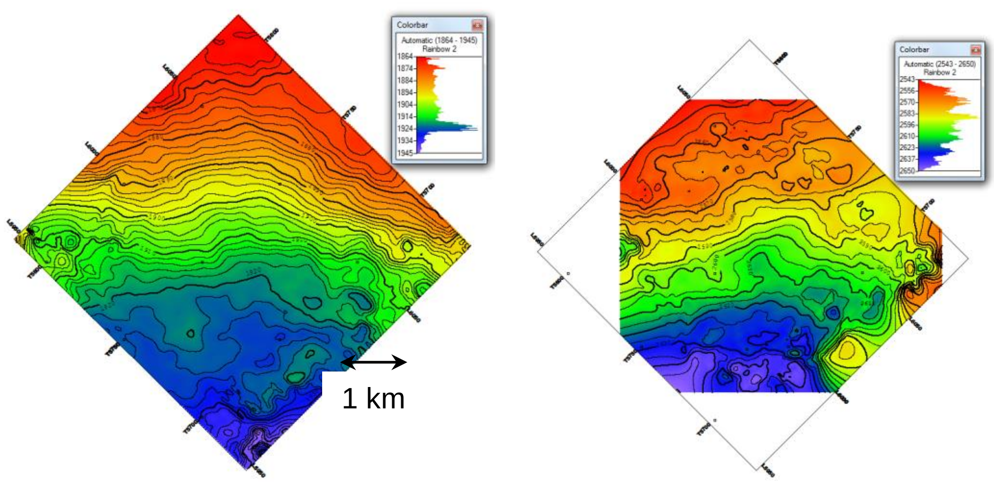

FIG. 2. Time structure for the Trenton Limestone for the PP (left) and PS1 (right) seismic data

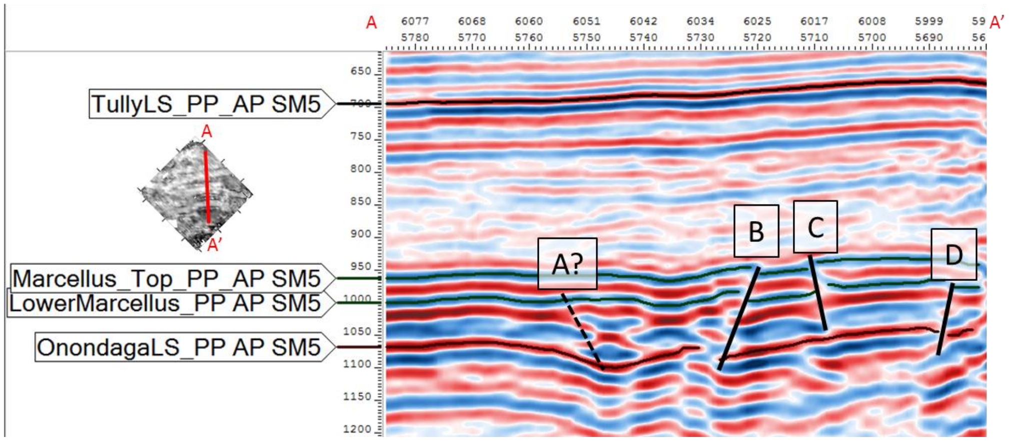

FIG. 3. North to south PP seismic line displaying complex structure in the Marcellus and Onondaga formations

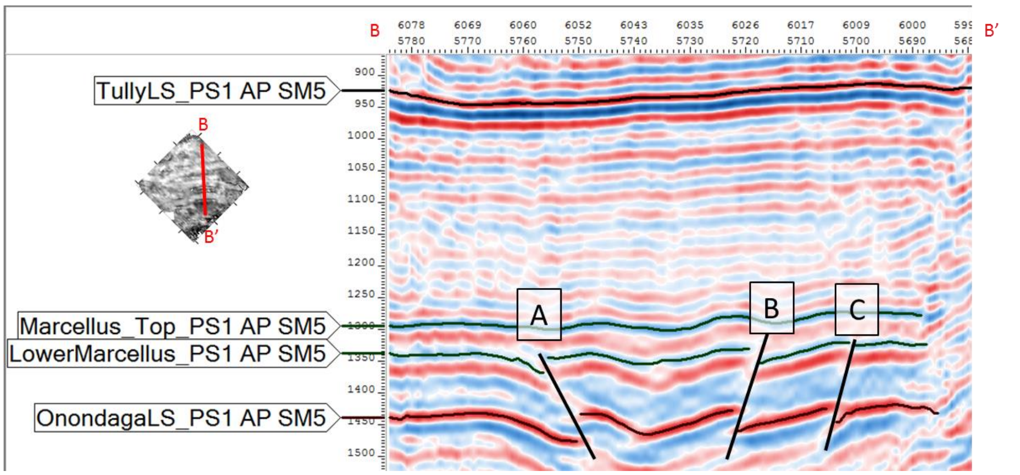

FIG. 4. North to south PS1 converted wave seismic line displaying complex structure in the Marcellus and Onondaga formations

Conclusions

A 3D multicomponent seismic dataset was acquired in Northeast Pennsylvania near the New York border. The 3D seismic data volume targeted the Marcellus Shale in the Appalachian basin. The seismic data was of high quality and pervasive reflections exist on major geologic interfaces throughout the PP, PS1 and PS2 seismic datasets. Interval rock properties and their implications on economic hydrocarbon production were explored using the multicomponent seismic volume. A general seismic interpretation was performed. The Marcellus Shale and surrounding formations have a mildly dipping structural style with East-West trending faults. The fault geometry is somewhat complex and the fault dips may have been misinterpreted based only on the PP seismic data. The converted wave datasets best constrain the structural geometry of the geologic features in and around the Marcellus Formation. Interval Vp/Vs ratios were found for the Marcellus-Lower Marcellus, Marcellus-Onondaga, Lower Marcellus-Onondaga and Tully- Marcellus intervals. The interval Vp/Vs ratios were compared with the isochron difference between the two shear modes. A correlation was found at fault edges between anisotropy and high Vp/Vs ratio. Making complete interpretations with implications on hydrocarbon production is unrealistic without the aid of well data, but qualitative general trends and potential sweet spots were speculated.

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References

Blakey, R., 2011, North American Paleogeography: https://www2.nau.edu/rcb7/nam.html, accessed April 6, 2015

Boughton, C.J., and McCoy, K.J., 2006, Hydrogeology, aquifer geochemistry and ground-water quality in Morgan County, West Virginia: U.S. Geological Survey, Scientific Investigations Report, 2006-5198

Bourbie, T., Coussy, O., and Zinzner, B., 1987, Acoustics of porous media: French Institute of Petroleum Publications, Editions Technip

Chaveste, A., Zhao, Z., Altan, S., and Gaiser, J., 2013, Robust rock properties through PP-PS processing and interpretation – Marcellus Shale: The Leading Edge, 32, No. 1, 86-92

Harper, J.A., Laughrey, C.D., Kostelnik, J., Gold, D.P., and Doden, A.G., 2004, Trenton and Black River Carbonates in the Union Furnace Area of Blair and Huntingdon Counties, Pennsylvania: Introduction: Field trip guidebook for the Eastern Section AAPG Annual Meeting

Marcellus Center for Outreach and Research (MCOR), Extent and thickness of Marcellus Shale: http://www.marcellus.psu.edu/images/Marcellus_thickness.gif, accessed April 6, 2015

Martin, J.P., 2008, The Middle Devonian Hamilton Group Shales in the Northern Appalachian Basin: Production and Potential: New York State Energy Research and Development Authority

Plazak, 2013, Natural gas production from the Marcellus Shale, 2000-2013, Graphed from data on the US EIA website: Natural Gas Weekly, Sept. 11, 2013, http://www.eia.gov/naturalgas/weekly/

Sharma, R.K., and Chopra, S., 2013, Unconventional reservoir characterization using conventional tools: SEG Annual Meeting, SEG 2013

Stewart, R.R., Gaiser, J.E., Brown, J.R., and Lawton, D.C., 2002, Converted-wave seismic exploration: Methods: Geophysics, 67, No. 5, 1348-1363

Sun, S.Z., Sun, Y., Sun, C., Liu, Z., Dong, N., 2013, Methods of calculating total organic carbon from well logs and its application on rock's properties analysis: GeoConvention 2013wick Integration

Walton, T., and McLennan, J., 2013, The role of natural fractures in shale gas production: Effective and sustainable hydraulic fracturing, InTech, Chapter 16

Wickstrom, L.H., et al., 2005, Characterization of geologic sequestration opportunities in the MRCSP region: Phase I task report: Midwest Regional Carbon Sequestration Partnership, 8