Petroleum Technology Transfer Council

APPALACHIAN BASIN

SECONDARY NATURAL GAS RECOVERY IN THE APPALACHIAN BASIN:

Application of Advanced Technologies in a Field Demonstration Site, Henderson Dome, Western Pennsylvania

(Contract No. DE-FC21-97FT34182)

FINAL REPORT

Submitted to

US Department of Energy
National Energy Technology Laboratory
Morgantown, WV 26507

Submitted by

West Virginia University Research Corporation
Appalachian Oil and Natural Gas Research Consortium
Morgantown, WV 26506

and Industry Partner

Vista Resources, Inc
61 McMurray Road, Suite 300
Pittsburgh, PA 15241

December 2000

EXECUTIVE SUMMARY

This project was conceived and designed to test and evaluate technologies that would result in improved characterization of Lower Silurian Medina-Whirlpool fractured natural gas reservoirs in areas where field development had encountered technical barriers to production. The Appalachian Oil and Natural Gas Research Consortium worked jointly with the Texas Bureau of Economic Geology and industry partners Atlas Resources, Inc (now Atlas America, Inc) and Vista Resources, Inc to design, execute and evaluate several field tests toward this end.

The original plan called for a two-phase research effort with a decision point after Phase 1. During Phase 1, tests conducted on acreage held by Atlas Resources south of the Henderson Dome in western Pennsylvania were of two types: (1) tests whereby small-scale microfractures observed in matrix grains of sidewall cores could be scaled up to determine reservoir properties of fractures that control production; and (2) tests that verify methods whereby robust shear (S) waves can be generated to detect and map fractured reservoir facies.

The grain-scale microfracture approach to characterizing reservoir rock was developed by the Bureau of Economic Geology and field tested in the Appalachian basin during this study. As a result of the Appalachian study, a low-cost commercial method now exists that will allow Appalachian producers to use scanning electron microscope (SEM) images of thin sections cut from sidewall cores to infer the orientation, timing and density of reservoir-scale fractures. In the area south of the Henderson Dome, large quartz-lined fractures with N20E strikes, and a subsidiary set of fractures with a N70W strike, are prevalent. The SEM study also resulted in development of a degradation index for partially filled microfractures that can predict commercial versus non-commercial wells.

Two seismic S-wave technologies were developed during Phase 1. The first was a special shaped explosive package that produces more robust S-waves than do standard explosives. This would allow operators to set straight lines through heavy timber country that cannot be done with horizontal vibrators as a source of S-waves. The second S-wave seismic technology that was investigated and confirmed was the natural mode conversion of standard P-waves to robust down going S-waves at the level of the Onondaga Limestone. This was verified by recording and analyzing a 3-component vertical seismic profile (VSP) in Atlas= Montgomery no. 4 well in Mercer County, Pennsylvania. Appalachian operators can thus use converted-mode seismic technology to create S-wave images of fractured and unfractured rocks throughout the basin where the Onondaga is present.

Following the completion of Phase 1 our industry partner, Atlas Resources, was forced to withdraw from the project. Fortunately, we were able to recruit a second industry partner, Vista Resources, Inc, that held an acreage interest in the Henderson Dome area, north of the dome. Vista Resources also had flown an aeromagnetic survey of an area that partially overlapped an area flown by DOE in a prior research effort. Therefore, a decision was made to expand the subsurface study north of the dome, merge the two aeromagnetic data sets into one, generate additional maps to interpret, conduct a lineament study of a 25-quadrangle area, and write a proposal for a Phase-2 effort in the new study area.

The aeromagnetic studies were merged and interpreted, and revealed several interesting relationships between basement structure and/or lithology and shallower reservoirs and potential reservoirs in the deeper Ordovician carbonate section. The results of the lineament study proved to be less applicable in a practical sense in this area, relative to the subsurface, seismic and aeromagnetic control used.

A Phase 2 proposal was written and submitted to NETL in August 2000. The work plan initially would have focused on the confirmation of the natural mode conversion of P-waves to Swaves at the level of the Onondaga Limestone. If confirmed in this second study area, then conventional sources that generate P-waves could be used, and converted S-waves could be received and analyzed to detect fractured reservoir rock.

A second suggestion was to record, process and interpret multi-component seismic data to demonstrate how P-wave and S-wave seismic data can be integrated to improve detection of fractured facies in the Medina-Whirlpool section. This plan was developed as an alternative to a more expensive 3-D seismic program. Assuming positive results were obtained from the interpretation of the 3-C, 2-D seismic data, one or two test wells would have been drilled on separate geological features to obtain a variety of data, including Formation Imaging Logs (FMI), a Vertical Seismic Profile (VSP) and sidewall cores, to provide direct evidence of fracturing a calibration of fractured rocks to the seismic response.

If test results indicated the presence of fractures in the well bores, and efforts to calibrate from well bores to VSPs were successful, then a new seismic survey over each well would have been designed. This could result in a practical application of the naturally mode-converted, multi-component seismic method over a well bore where microfractures and production-scale fractures had been demonstrated to exist, and where the well-bore stratigraphy had been correlated from well logs to the seismic response.

PTTC gratefully acknowledges that its primary funding comes through the US Department of Energy's (DOE) Office of Fossil Energy through the Strategic Center for Natural Gas and Oil (SCNGO) within the National Energy Technology Lab (NETL).