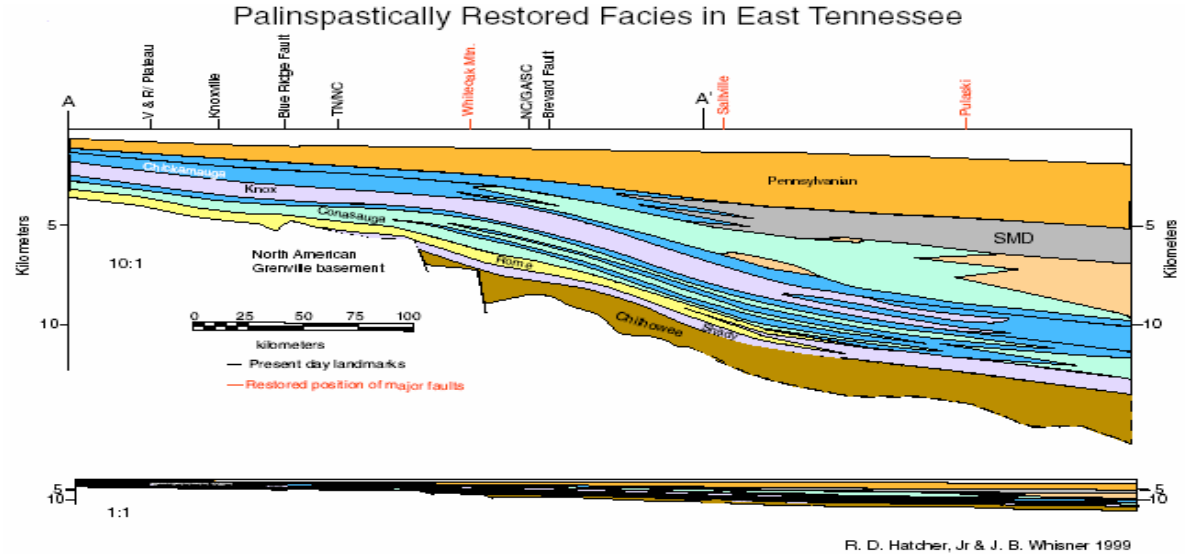
FEAC 310 Oak Ridge National Laboratory
Southern-Central Appalachians Framework & Controls of Hydrocarbon Generation

Success Story Summary



This project began with the simple concept that there could still be commercial quantities of hydrocarbons in the deeper, Lower Paleozoic sediments below the Appalachian or Eastern Overthrust sheets. Clues had come from trace signs of hydrocarbons detected in water samples from deep wells in the overthrust area.

The program focused on the lithologies and structural/tectonic/thermal/pressure history of the study area. The Oak Ridge-University of Tennessee team gathered detailed information on regional stratigraphy. This allowed the thrust sheets to be palinspastically restored to their original position. Rock and included fluid samples were taken for laboratory analysis. The results showed that there was an area surrounding eastern Tennessee with possible source beds where the rocks and their included fluids have remained within the oil and gas window of thermal maturity. Migration pathways were then identified and studied to locate where the oil and gas can now be found. It was found that most of the hudrocarbons were presently trapped in fracture porosity.

As the studies and laboratory analyses were taking place, the team members, including USGS personnel who were now contributing to the project, were making presentations to local operating groups, geologic societies and other oil and gas associations in Tennessee and surrounding states to make them aware of the project and to request assistance in the data collection process. At the same time, the staff was speaking at a minimum of three regional, national or international geologic or industry society meetings each of the four years of the research phase, getting feedback from leaders in the field.

This tech transfer mechanism worked so well that one of the local independent operators, Tengasco, agreed to drill a well before the program was even complete. A promising location was selected and a successful exploratory well was drilled, followed by development drilling. The oil was tested by the USGS and was found to be of Ordovician age, from source beds in the sub-thrust sheet, confirming the basic hypothesis of the research team. Production to date has been 337,000 Bbl, which has been sufficient to repay the research investment by a factor of three, with production continuing. This system holds great potential for application in other overthrust areas in the US and beyond.

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Problem: The southern and central Appalachian overthrust area has been largely ignored in the search for domestic oil and natural gas resources.

Early geologic interpretations of the region failed to identify any hydrocarbon potential or reason to spend money on exploration in the sub-province. By the late 1960s and 1970s, plate tectonics and the overthrust concept suggested the possibility of deep hydrocarbons beneath the well-studied detached sheets but questions remained about the nature of any potential source beds in the deep strata and their age and thermal maturity.

Several large regional seismic surveys were run across the overthrust areas throughout the Appalachians during the 1970s and 1980s by the majors, including Amoco and Exxon. The oil price collapse of the 1980s cut off some potential drilling activity based on the existing data from the southern and central Appalachians. Major questions remained about the nature, age and thermal history of the sub-thrust units.

Project Objective: Oak Ridge and the University of Tennessee at Knoxville combined resources to undertake a detailed analysis of the stratigraphy, structure and deformational/thermal history of a promising study area in the southern-central Appalachians of eastern Tennessee and surrounding states. The majority of the work was actually conducted at the university with extensive collaboration by the USGS.

The primary objective of this study was to use the best computer facilities available to palinspastically unfold and unthrust the detached sheets and to restore a cross-section of the Appalachian continental margin to its original profile at the end of the Paleozoic, with special attention to pressure-temperature histories for the region, the potential and most-likely migration paths for hydrocarbons and the development of fracture porosity in possible reservoir rocks in the region. The work is being done using a petroleum systems approach.

Project Costs: The funding for this project was $375,000, 100% from the DOE, with no cost-share by Oak Ridge or the University of Tennessee.

Technology change: At the outset of the project, the research team began to gather data to allow them to characterize the temperature-pressure (T-P) history of the study rocks and information related to petroleum migration and the boundary of the oil-gas window. They also began work on identifying the local reservoir architecture (both structural and lithologic). This involved collecting information about the attributes of potential and existing reservoirs in relation to fluid generation and migration. They then built an inventory of available thermal maturation data in the study area and began the compilation of maps showing burial depth relative to thermal maturation.

In the tech transfer realm, they began to research “critical industry needs” and to search for potential industry partners. This search was accomplished by attending local industry association meetings and through local publicity and word of mouth.

The Tennessee Division of Geology helped by collecting oil samples from water wells in Middle Ordovician rocks in the Valley and Ridge of eastern Tennessee. These samples were sent to the USGS for analysis of trace elements and isotopic components to help characterize hydrocarbons from this interval. Well cores with hydrocarbons in them were also analyzed by the USGS.

These studies allowed them to identify potential reservoirs and to better characterize them, especially focusing on whether they were fracture-dominated or primary porosity-dominated. The team also studied and evaluated potential fluid migration pathways for hydrocarbons. A reconstruction was completed showing the basement surface configuration for the Virginia portion of the eastern Appalachian basin. Quantitative reconstructions were prepared of major facies and structural boundaries in the deformed parts of the southern Appalachian basin for the northern half of Tennessee and the southwestern part of Virginia.

Tech transfer activities continued through reports at professional meetings and articles in refereed journals. Much of the focus was to get the word out that there really was a possibility of commercial oil and gas deposits in the overthrust belt.

A major effort was made to determine the direction of displacement vectors within the thrust sheets. A new triangle zone was recognized in the southern Appalachians. The general results of these studies were suggesting that the cores of such zones could contain areas that were highly favorable to the preservation of hydrocarbons. Techniques were developed that allowed 2-D seismic data to be used along with focused 3-D studies of select prospect areas to select possible targets for exploration.

Tengasco then drilled a successful discovery well in what is now the Swan Creek Field. Samples were tested by the USGS, demonstrating that the oil was of Ordovician age, validating some of the earlier expectations of the project.

The most recent work has focused on the construction of 3-D models of the study area and the determination of how basement structures have influenced or controlled areas of hydrocarbon generation, migration and/or accumulation and preservation.

The primary aspects of the technology change have been the demonstration that the deep, sub-thrust rocks in an old, highly thermally-mature basin can still retain commercial quantities of oil and natural gas, a concept that was viewed as highly unlikely until this work.

Through excellent tech transfer efforts, the project team inspired sufficient interest in this work that an independent operator drilled an exploratory well, proving the concept that the oil and gas were where the study team predicted.

This same technology suggests that large areas of the deep, sub-thrust rocks to the north and east will not have commercial oil or gas deposits, but this technique has great potential use in other regions with overthrust zones. If there is oil in the sub-thrust of the Appalachians, there may be much larger deposits in younger, less thermally-mature sub-thrust rocks in other basins.

Technology Transfer Methods: The primary means of technology transfer for this project have been presentations made at regional and national professional society meetings and local industry associations, along with word of mouth reports associated with making oil discoveries in a previously virgin area.

Early discussions and informal talks at the Tennessee Oil and Gas Association (5/98), the Kentucky Oil and Gas Association (6/98) and to the Appalachian Basin Geological Society (9/98), good coverage by the local newspaper, along with good support by the Petroleum Technology Transfer Council (PTTC), helped to interest several of the local independent operators in the area in becoming involved in the program, both to collect samples and data and to drill exploratory wells at some of the newly identified prime exploration areas. Tengasco has drilled and made an oil and natural gas discovery at the Swan Creek field. The Tennessee Division of Geology has also provided good support for the program and helped to disseminate information on the program.

A minimum of three talks was made each year at major society conventions or similar sessions for the years 1998 through 2001. Many of these were to the American Association of Petroleum Geologists (AAPG) or to its regional groups or to the Geologic Society of America (GSA). The others were at workshops or international meetings related to thrusting and tectonics.

A field trip to the study area was run for CONOCO in the year 2000.

Poster sessions at AAPG conventions have stirred interest by majors and independents about using the technique in other basins with overthrust and sub-thrust zones.

Two papers are currently in press or peer review for publication by the AAPG. There also was an article on the program that appeared in the Oil and Gas Journal, a leading trade journal in the drilling industry, with a wide circulation.

The greatest spreading of the word has come about due to the discovery well drilled by Tengasco at the Swan Creek Field. Nothing helps to get the word out as rabidly or as far and wide as a new successful discovery well where no one expected oil or natural gas.

Technology Implementation: The first place that the data collected by the study team was used was the overthrust area of the Appalachian Basin. The team and USGS partners evaluated the existing maturity data and coal rank values. This quickly indicated that much of the eastern and northern Appalachian region had been "over-cooked." Coal ranks were high, with many coals quickly moving toward the anthracite

range in the far ends of their exposures, indicating an environment far too hot for the survival of commercial hydrocarbons. Other maturity data suggest that the deeper beds throughout much of Pennsylvania, West Virginia and Maryland are well beyond the desirable maturity window. There may still be some potential to the south through southern West Virginia and northeastern Kentucky.

As one gets closer to eastern Tennessee, the data become more and more favorable.

Through its tech transfer efforts, the Oak Ridge-University of Tennessee team reached out early in the project to local independent operators, interesting them in the program. They helped in the gathering of data that helped to pinpoint a "sweet spot" in eastern Tennessee. Eventually, Tengasco, one of the independents that had taken an interest in the research decided to take the leap and drilled a successful exploratory well.

While Tengasco was not an official initial member of the Oak Ridge-University of Tennessee team, their drilling was clearly a direct result of this DOE research and an example of how quickly a successful tech transfer program can bring about results.

End Users: The successful end user, so far, has been Tengasco, with its discovery well.

Other local operators have assisted in collecting data for the program, but none have drilled any wells in the county, so far, presumably due to low oil prices and few signs that the long-term price trend would justify coming up to speed on intelligent exploration.

If oil prices increase sufficiently, other local operators can be expected to begin drilling and some of the majors might even be expected to move in. Amoco (now BP-Amoco) had a broad interest in the Appalachian basin dating back to the 1970s and had spent considerable money on seismic and other exploration costs in the basin until oil prices collapsed in the 1980s. Exxon also had a major program in the Appalachians. Veterans or sharp youngsters from either of those companies might revive their dormant programs if prices rose sufficiently and looked like they would remain there.

Impacts:

Overall Value of Technology: This modeling and petroleum systems approach to determining the thermal-pressure history of a region, along with fracture studies, migration studies and palinspastic retrodeformation of an overthrust region can be used in many other parts of the United States (like the western overthrust belt and several other, smaller thrust zones) and in many other parts of the world.

While the temperature-pressure data collected in the Appalachian region have condemned large areas to the north, through much of West Virginia, Maryland and Pennsylvania, presumably due to super-maturity and having moved well beyond the oil window, other basins may have large areas with significant sub-thrust hydrocarbon potential.

There is no way to assign a number of barrels of oil to undefined regions, but the proven example of sub-thrust oil and natural gas in an old and highly mature basin like the Appalachians suggests a high likelihood that large quantities of hydrocarbons may still exist in younger sub-thrust rocks around the world.

Increased Oil Production: The latest production data from the State of Tennessee show that the cumulative oil production figure for the county that contains the Swan Creek Field has been 337,000 Bbl. Since there are no other wells in the county, this number equals Tengasco's Swan Creek production.

Increased Gas Production: There is definitely natural gas associated with these discoveries, as is typically the case in the Appalachians, but, thus far, it has been shut in and there has been no measured production or estimate of total reserves. Things will presumably remain this way until a pipeline is completed to the field and a gathering system is installed.

New Products/Technologies: As stated above, this modeling and analysis system may have extensive application in other parts of the country and world.

Income from Taxes and Royalties: The cumulative production from the discoveries so far has totaled 337,000 Bbl of oil, according to data from the State of Tennessee. The natural gas is currently shut in. There has not been any commercial gas production.

Assuming a tax rate of 6.6%, a 15% royalty and a $15/Bbl oil price, this comes to taxes generated, so far, of $334,000 and royalty payments totaling $752,000, roughly three times the amount invested in the research.

Additional Research Investment: The program began at Oak Ridge as a two-year research project approved for a budget of $65,000. In part related to administrative changes in dealing with research at the National Labs, this project was redesignated with a new number. At that time, the work was extended for four additional years, for a total of six years, and the budget was increased to $375,000.

New Markets/Jobs: The discovery of the Swan Creek Field by Tengasco may have helped to keep some people employed in the Tennessee-region oil and gas business at a time of low or unstable prices.

The drilling so far has been limited, due to the economics of operating far from traditional oil or gas pipelines and support centers. Without any pipeline systems at the time of discovery and low prices, production has also been limited.

To date, Tengasco has not added any new personnel with respect to the new field, but the activity associated with the limited development drilling and pipeline activity may have prevented some layoffs that might otherwise have occurred as oil prices fell. Although other companies are presumably watching Tengasco carefully, none are known to have

added any people to their exploration departments or other staff due to this new field or the ODE project.

There is a potential for increased activity in this geographic region if world oil prices increase substantially and appear to be firm for the long run. This could lead to new employment opportunities in the region.

If this technology is extended to the Western Overthrust or to other similar overthrust belts around the world with successful results, there could be major employment increases if there are large discoveries in those regions.

Appendix A

Presentations made by the Oak Ridge – University of Tennessee – USGS team

Hatcher, R. D., Jr., Milici, R. C., and Whisner, J. B., 1998, The southern-central Appalachian triangle zone: An unexplored potential hydrocarbon play from Alabama to Pennsylvania: American Association of Petroleum Geologists (Eastern Section).

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Hatcher, R. D., Jr., Lemiszki, P. J., and Montes, C., 1998, Boundary conditions of foreland fold-thrust belt deformation from 3-D reconstruction of a curved segment of the southern Appalachian basement surface and base of the Blue Ridge-Piedmont thrust sheet: Progress report and initial results: American Association of Petroleum Geologists, v. 1, p. A281-A284.

Hatcher, R. D., Jr., 1999, Development of Triangle Zones in the Evolution of Foreland Fold-Thrust Belts: American Association of Petroleum Geologists Annual Meeting, San Antonio.

Hatcher, R. D., Jr., 1999, Upper bounds for the size of thrust sheets: Thrust Tectonics 99, Egham, England, p.31.

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Hatcher, R. D., Jr., 2000, Properties of orogens illustrated by the Canadian Cordillera and Southern-Central Appalachians: GeoCanada 2000, Calgary, Alberta.

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Hatcher, R. D., Jr., Whisner, J. B., and Lemiszki, P. J., 2000, Quantitative Facies and Bank-Edge Restoration and Evolution of Carbonate Reservoirs in the Appalachian Foreland Fold-Thrust Belt—An Interactive Petroleum System: American Association of Petroleum Geologists Annual Meeting, New Orleans.

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Hatcher, R. D., Jr., 2001, Additional factors brought into play in hydrocarbon exploration in the southern Appalachian foreland fold-thrust belt: American Association of Petroleum Geologists Eastern Section Meeting (Kalamazoo, Michigan) Abstracts, p. 19.

Whisner, J. B., and Hatcher, R. D., Jr., 2001, Geologic GIS database to facilitate kinematic analysis of the Valley and Ridge Province, East Tennessee: Geological Society of America Abstracts with Programs (Annual Meeting), v. 33, p. A-176.

Tavernier, S. A., Williams, R. T., and Hatcher, R. D., Jr., 2001, Shallow fractures and basement faulting in the Swan Creek field, Tennessee: American Association of Petroleum Geologists Annual Convention, v. 10, p. A-199.

Published Journal Articles

Hatcher, R. D., Jr., McCown, M. W., and Williams, R. T., 2001, Tengasco's Swan Creek Field: Isolated Success or Tip of the Iceberg in the Southern Appalachian Thrust Belt?: Oil and Gas Journal, v. 99.40, p. 38–44.

In Press

Hatcher, R. D., in press, Properties of thrusts and the upper bounds for the size of thrust sheets, in McClay, K. R., American Association of Petroleum Geologists Memoir.

Hatcher, R. D., Jr., Lemiszki, P. J., and Montes, C., in review, Controls of reservoir-scale deformation from the boundary conditions and internal deformation of the southern Appalachian foreland fold-thrust belt: American Association of Petroleum Geologists Bulletin.