First-Year Summary of Results for the Project "Geologic controls of hydrocarbon occurrence in the southern Appalachian basin in eastern Tennessee, southwestern Virginia, eastern Kentucky, and southern West Virginia"

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ABSTRACT

This report summarizes the first-year accomplishments of a three-year program to investigate the geologic controls of hydrocarbon occurrence in the southern Appalachian basin in eastern Tennessee, southwestern Virginia, eastern Kentucky, and southern West Virginia. The project: (1) employs the petroleum system approach to understand the geologic controls of hydrocarbons; (2) attempts to characterize the T–P parameters driving petroleum evolution; (3) attempts to obtain more quantitative definitions of reservoir architecture and identify new traps; (4) is working with USGS and industry partners to develop new play concepts and geophysical log standards for subsurface correlation; and (5) is geochemically characterizing the hydrocarbons (cooperatively with USGS).

First-year results include: (1) meeting specific milestones (determination of thrust movement vectors, fracture analysis, and communicating results at professional meetings and through publication). All milestones were met. Movement vectors for Valley and Ridge thrusts were confirmed to be west-directed and derived from pushing by the Blue Ridge thrust sheet, and fan about the Tennessee salient. Fracture systems developed during Paleozoic, Mesozoic, and Cenozoic to Holocene compressional and extensional tectonic events, and are more intense near faults. Presentations of first-year results were made at the Tennessee Oil and Gas Association meeting (invited) in June, 2003, at a workshop in August 2003 on geophysical logs in Ordovician rocks, and at the Eastern Section AAPG meeting in September 2003. Papers on thrust tectonics and a major prospect discovered during the first year are in press in an AAPG Memoir and published in the July 28, 2003, issue of the *Oil and Gas Journal*. (2) collaboration with industry and USGS partners. Several Middle Ordovician black shale samples were sent to USGS for organic carbon analysis. Mississippian and Middle Ordovician rock samples were collected by John Repetski (USGS) and RDH for conodont alteration index determination to better define regional P-T conditions. Efforts are being made to calibrate and standardize geophysical log correlation, seismic reflection data, and Ordovician lithologic signatures to better resolve subsurface stratigraphy and structure beneath the poorly explored Plateau in Tennessee and southern Kentucky. We held a successful workshop on Ordovician rocks geophysical log correlation August 7, 2003 that was cosponsored by the Appalachian PTTC, the Kentucky and Tennessee geological surveys, the Tennessee Oil and Gas Association, and small independents. Detailed field structural and stratigraphic mapping of a transect across part of the Ordovician clastic wedge in Tennessee was begun in January 2003 to assist in 3-D reconstruction of part of the southern Appalachian basin and better assess the nature of a major potential source rock assemblage. (3) Laying the groundwork through (1) and (2) to understand reservoir architecture, the petroleum systems, ancient fluid migration, and conduct 3-D analysis of the southern Appalachian basin.

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INTRODUCTION

The purpose here is to provide a summary of results related to the first year of the three-year project “Geologic controls of hydrocarbon occurrence in the southern Appalachian basin in eastern Tennessee, southwestern Virginia, eastern Kentucky, and southern West Virginia,” DOE Contract Number DE-FC26-02NT15341 (Fig. 1). This project is a multifaceted effort to understand the petroleum systems (Fig. 2) in this region and particularly to shed light on the less well-known pre-Devonian Ordovician petroleum systems that are currently a frontier area and the focus of much industry exploration effort. Recognized petroleum systems here consist of the Devonian-Mississippian system, sourced from the Devonian Mississippian Chattanooga Shale, and the less well-known Ordovician system consisting of the carbonate rocks of the Knox Group and the Middle Ordovician Stones River (“Black River”) and Nashville (“Trenton”) Groups.

We feel that, even in the first year of the project in addition to meeting all of our broad milestones, we have made a major contribution toward identification of a large prospect in the Tennessee Valley and Ridge (Whisner and Hatcher, 2003) and contributed a major breakthrough in the subsurface geophysical log subdivision of the Middle and Upper Ordovician stratigraphy beneath the Plateau of east-central Tennessee and southern Kentucky. We also have recognized a new structural province beneath the pre-Chattanooga (Devonian-Mississippian shale) unconformity that involves previously unrecognized post-Silurian, pre-Chattanooga deformation. Better resolution of the structure here will doubtlessly have a major impact on identification of prospects and future development of the hydrocarbon resources in the Ordovician (Knox-Stones River-Nashville Groups) petroleum system.

EXECUTIVE SUMMARY

This report summarizes the first-year accomplishments of a three-year program to investigate the geologic controls of hydrocarbon occurrence in the southern Appalachian basin in eastern Tennessee, southwestern Virginia, eastern Kentucky, and southern West Virginia. The project: (1) employs the petroleum system approach to understand the geologic controls of hydrocarbons; (2) attempts to characterize the T–P parameters driving petroleum evolution; (3) attempts to obtain more quantitative definitions of reservoir architecture and identify new traps; (4) is working with USGS and industry partners to develop new play concepts and geophysical log standards for subsurface correlation; and (5) is geochemically characterizing the hydrocarbons (cooperatively with USGS).

First-year results include: (1) meeting specific milestones (determination of thrust movement vectors, fracture analysis, and communicating results at professional meetings and through publication). All milestones were met. Movement vectors for Valley and Ridge thrusts were confirmed to be west-directed and derived from pushing by the Blue Ridge thrust sheet, and fan about the Tennessee salient. Fracture systems developed during Paleozoic, Mesozoic, and Cenozoic to Holocene compressional and extensional tectonic events, and are more intense near faults. Presentations of first-year results were made at the Tennessee Oil and Gas Association meeting (invited) in June, 2003, at a workshop in August 2003 on geophysical logs in Ordovician rocks, and at the Eastern Section AAPG meeting in September 2003. Papers on thrust tectonics and a major prospect discovered during the first year are in press in an AAPG Memoir and published in the July 28, 2003, issue of the *Oil and Gas Journal*. (2) collaboration with industry and USGS partners. Several Middle Ordovician black shale samples were sent to USGS for organic carbon analysis. Mississippian and Middle Ordovician rock samples were collected by John Repetski (USGS) and

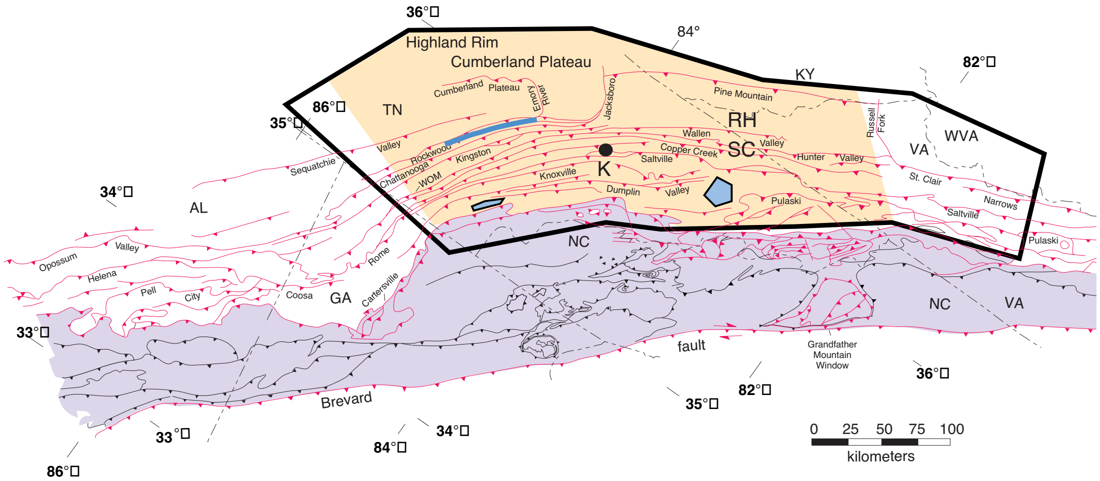

Figure 1. Major faults in the Valley and Ridge, Cumberland Plateau, and the Blue Ridge, southern Appalachians. Red lines are Alleghanian faults, black lines are earlier faults. The area shaded tan is the area of concentrated investigation to date; thatoutlined by the heavy black line is the expanded study area. The outlined light blue shaded areas are the areas of concentrated field investigation. The heavy Blue line in the wetern Valley and Ridge is the location of the Eureka structure described in the *Oil and Gas Journal* article. WOM–Whiteoak Mountain fault. SC–Swan Creek field. RH–Rose Hill field. K–Knoxville. Geologic base from Hatcher et al. (1990).

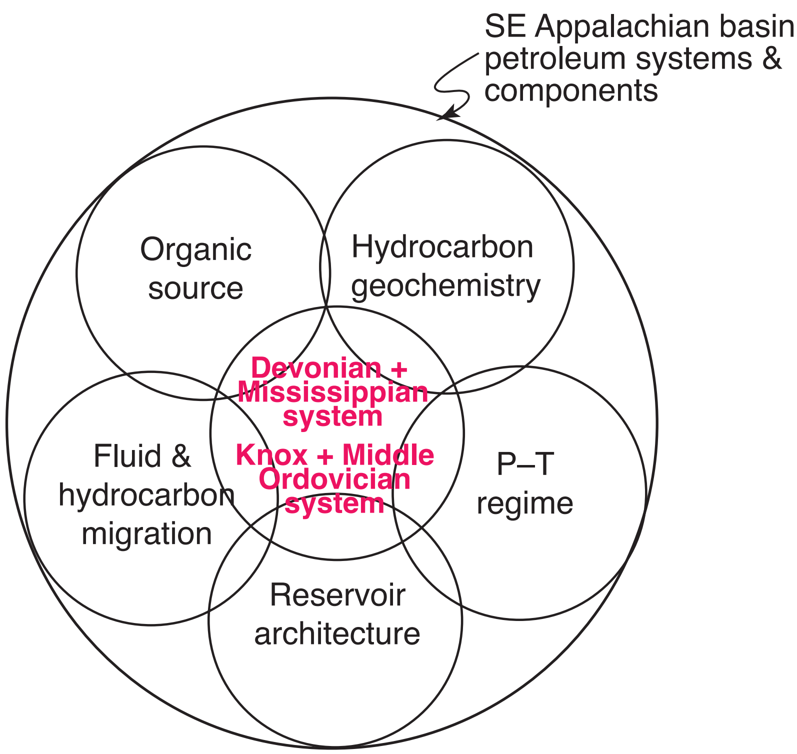

Figure 2. Elements of the southeastern Appalachian basin petroleum systems and their interdependencies.

RDH for conodont alteration index determination to better define regional P-T conditions. Efforts are being made to calibrate and standardize geophysical log correlation, seismic reflection data, and Ordovician lithologic signatures to better resolve subsurface stratigraphy and structure beneath the poorly explored Plateau in Tennessee and southern Kentucky. We held a successful workshop on Ordovician rocks geophysical log correlation August 7, 2003 that was cosponsored by the Appalachian PTTC, the Kentucky and Tennessee geological surveys, the Tennessee Oil and Gas Association, and small independents. Detailed field structural and stratigraphic mapping of a transect across part of the Ordovician clastic wedge in Tennessee was begun in January 2003 to assist in 3-D reconstruction of part of the southern Appalachian basin and better assess the nature of a major potential source rock assemblage. (3) Laying the groundwork through (1) and (2) to understand reservoir architecture, the petroleum systems, ancient fluid migration, and conduct 3-D analysis of the southern Appalachian basin.

EXPERIMENTAL

Activities: Listed in Proposal: Fracture analysis, thrust movement vectors, quant. facies reconstruction, reservoir characteristics
Additional Project-related Activities: Subdivision of the Middle and Upper Ordovician stratigraphy by analysis of several thousand existing geophysical logs from the Plateau of Tennessee and southern Kentucky. Structural analysis of published geologic maps and recognition of pre-Devonian-post-Silurian deformation in the exposed flanks of the Nashville dome that may control the reservoir location in the pre-Devonian rocks. Field investigations in the Middle Ordovician rocks in eastern Tennessee have begun to lay the foundation for revision of existing models of basin evolution and thus any shale-sourced hydrocarbons that may have formed as the basin deepened.

RESULTS AND DISCUSSION

2002-03 Milestones

(1) Thrust movement vectors, (2) fracture analysis, (3) presentation, (4) publication

Completion of Milestone (1): Thrust movement vectors have been determined from a combination of: (a) field measurements of mesoscopic transport indicators (orientations of tectonic stylolites, asymmetric folds, slickenlines), and (b) orientations of normals to map-scale synclines that occur in the footwalls of major thrust sheets (Fig. 3).

Completion of Milestone (2): Fracture analysis has consisted of determination of the orientations of major fracture sets in the Valley and Ridge, noting the aperture and spacing of joints in exposures in the field, and attempting to determine the relative ages of fractures in the region and their relationships to structures that might have a bearing on reservoir integrity.

Completion of Milestone (3): Presentations of first-year results were made at the Tennessee Oil and Gas Association meeting (invited) in June 2003 at a workshop in August 2003 that we convened on analysis of geophysical logs in Ordovician rocks, and at the Eastern Section AAPG meeting in September 2003.

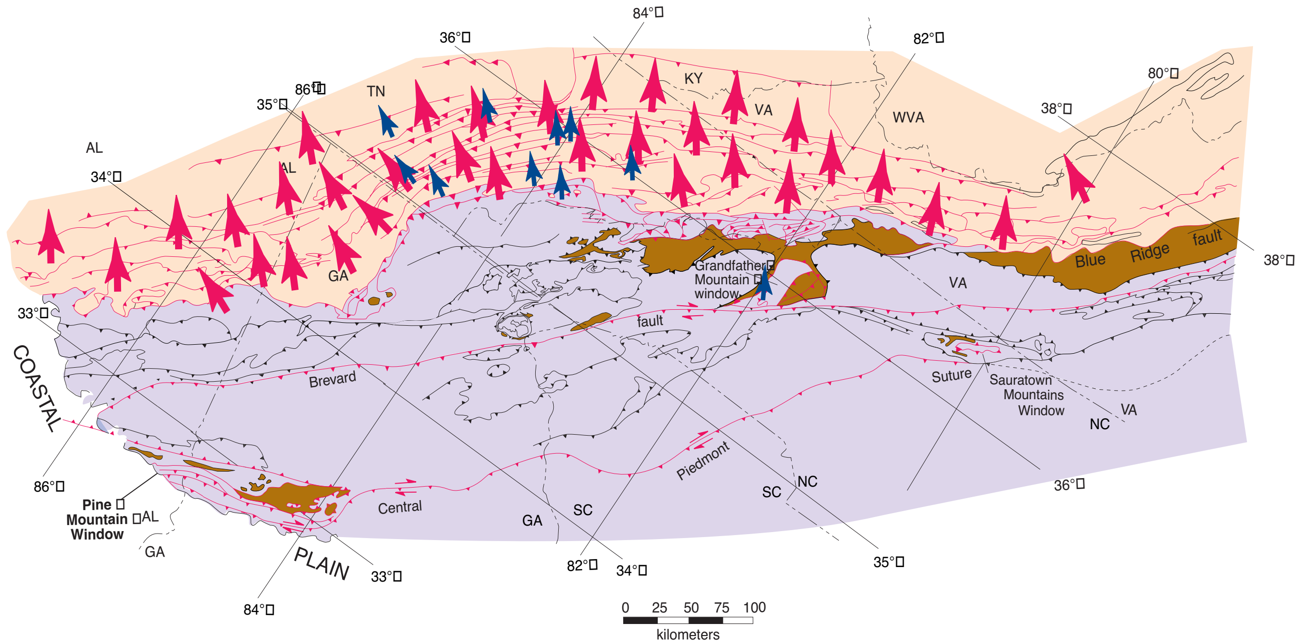

Figure 3. Southern Appalachian tectonic map showing transport vectors from measured mesoscopic structures (blue arrows) and estimated from orientations of hinges of mostly synclines on regional maps. Base modified from Hatcher et al. (1990).

We held a very successful workshop in Knoxville, Tennessee, August 7, 2003, on "Subsurface Geophysical Log Correlation of Middle Ordovician Rocks Beneath the Plateau of Tennessee and Southern Kentucky." The workshop drew 38 participants from industry, the state geological surveys of Kentucky and Tennessee, and from the University of Tennessee. Cosponsors include the Appalachian PTTC, the Kentucky and Tennessee geological surveys, the Tennessee Oil and Gas Association, and small independents in Kentucky and Tennessee.

Completion of Milestone (4): A paper on thrust tectonics is in press in an AAPG Memoir and another describing a major prospect discovered during the first project year was published in the July 28, 2003, issue of the *Oil and Gas Journal*. The thrust tectonics paper addresses the mechanical limits of the size of thrust sheets worldwide. The *Oil and Gas Journal* article defines a major prospect in the western Valley and Ridge, the Eureka structure, which consists of a subsurface faulted anticline over 50 mi long that was identified using regional seismic reflection data; it has no surface expression (Fig. 1). The Wright #1 well (t.d. 7,200 ft) had been drilled and abandoned by Arco during the 1980s; it contains both oil and gas. The hole has been reentered recently and completed by a small company from Michigan. As a result of our publication, at least one company has announced plans to drill the northern end of the structure; several others are busy leasing other parts of the structure for additional exploration.

Specific Activities

Defined Milestone-Related Activities. In addition to the brief summaries above, the field data for Milestone (1) were collected by Ph.D. student Jennifer Whisner and RDH either separately or in the field together. Much of the data from the western Valley and Ridge were collected by Ms. Whisner and consist of asymmetric folds and slickenlines on faults and other movement surfaces. The data from the central Valley and Ridge near Knoxville, consisting of tectonic stylolites and asymmetric folds, were collected by RDH, while the data in the eastern Valley and Ridge and in the Tuckaleechee Cove window were collected by both while conducting joint field investigations. All of the mesoscale data are consistent with the map-scale determinations of transport (Fig. 1). Transport vectors have a consistent NW orientation in central-east Tennessee (latitude of Knoxville), but change orientation to more westerly transport to the south into Georgia and to more northerly transport to the northeast into SW Virginia. These changes reflect the curvature of the Appalachians in the Tennessee salient. This relationship could have been predicted from the curvature alone, but is now confirmed using a combination of mesoscopic and map-scale data.

For milestone (2), fracture orientation data were both compiled from existing sources in the western Valley and Ridge and Plateau in Tennessee and Blue Ridge Foothills (Figs 5 and 6) and new data are being collected in the field areas being mapped in detail, so additional compilations will be made toward the end of the project. The orientation data are mostly consistent across the Valley and Ridge. Some fractures are doubtlessly related to folding, as their orientations are normal and parallel to fold hinges, while others either are deformed by folding (pre-folding) or overprint the folds, indicating they are post-Alleghanian and probably formed during the Mesozoic or Cenozoic, consistent with the findings of Engelder (1982, 1985) in the Appalachian basin in Pennsylvania and New York. In addition, Harris and Milici (1977) noted that fracture intensity increases near faults. Fracture spacing is also directly related to bed thickness (Engelder, 1993), and the late fracture sets

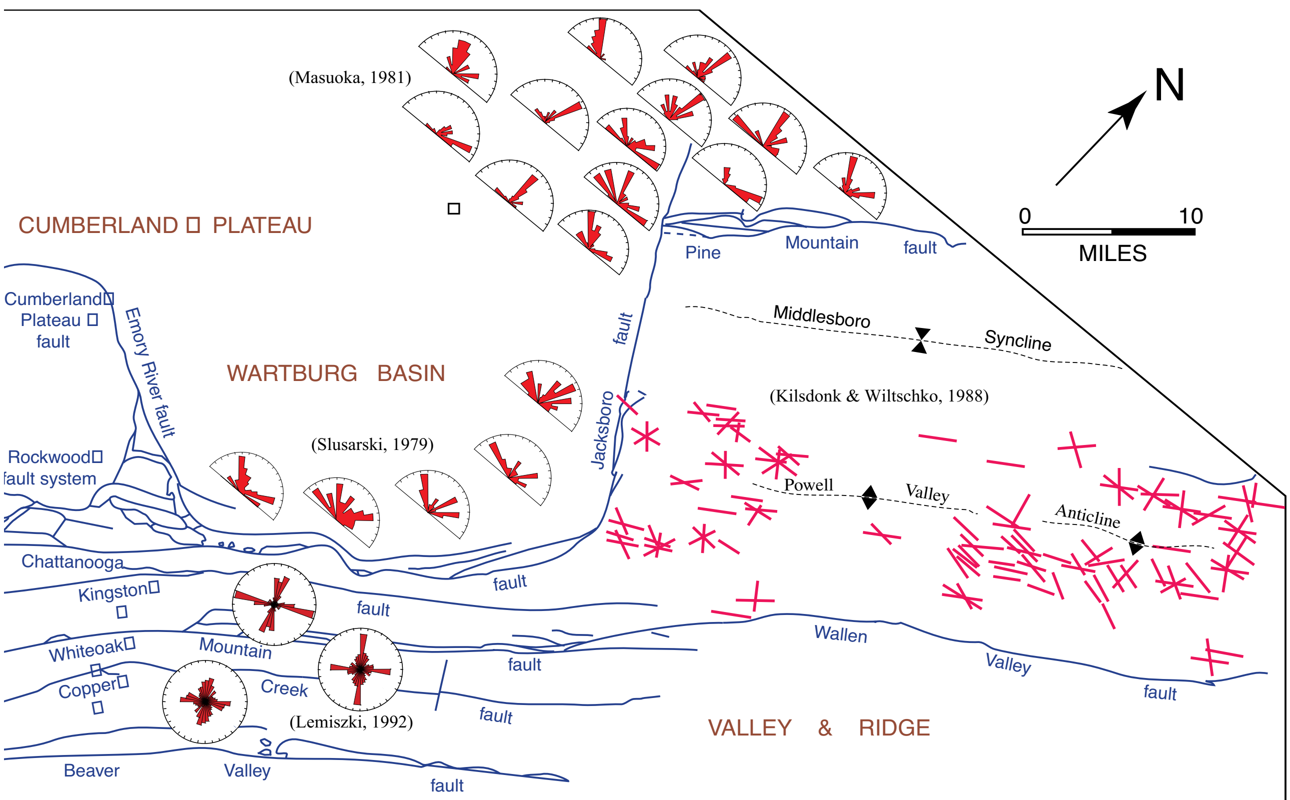

Figure 4. . Major fracture sets in the northwestern part of the Valley and Ridge and adjacent Cumberland Plateau. Four fracture sets in the region are defined by strike direction, which are generally northeast, northwest, north-south, and east-west.

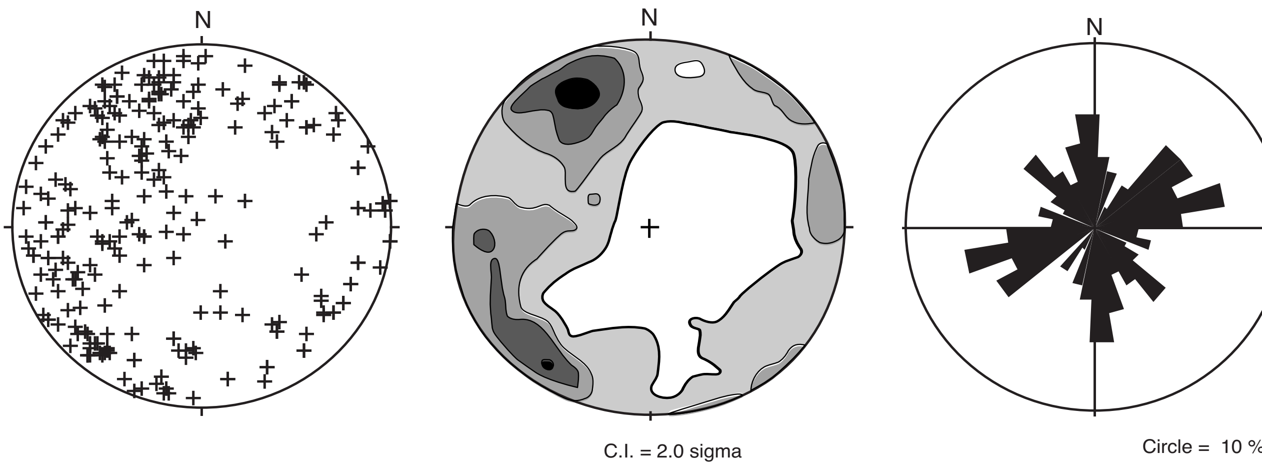

Figure 5. Compilation of 256 joint measurements from the Blue Ridge Foothills. Point diagram to left with plot of poles to joints. Center–contoured data. Right–rose diagram of data. Compare the orientations depicted with these data with those in teh western Valley and Ridge and Plateau in Figure 5.

are clearly related to the measured late Mesozoic to Holocene intraplate stress field in eastern North America (World Stress Map, 2003, www-wsm.physik.uni-karlsruhe.de/). Near-surface fractures tend to be open and very prominent, but most fractures close in the first 200 m below the surface with relatively few throughgoing fractures in massive rocks (Schaeffer et al., 1973), but in bedded rocks a few more opportunities for open fractures exist.

Geophysical Log Analysis and Correlation. Geologists with the small independent companies that do most of the drilling and producing of hydrocarbons in Tennessee, southern Kentucky, and southwestern Virginia have traditionally recognized only the broad stratigraphic subdivisions used farther north in the Appalachian basin for the Ordovician and even employed that terminology: Black River and Trenton Groups. The equivalent units, the Stones River and Nashville Groups, have long been subdivided in Central Tennessee from surface exposures (Fig. 7) (Wilson, 1949, 1962). Farmer and Holyday (1999) demonstrated that the lower Stones River Group in Central Tennessee is readily divisible using geophysical logs from water wells. We have now demonstrated that both the Stones River and Nashville Groups are divisible by making detailed comparisons of the characteristics and thicknesses of surface exposed units and their characteristics in geophysical logs (Fig.8). The key is to locate the two distinctive K-bentonite layers (lower "pencil cave" or Deike bentonite and upper "mud cave" or Millbrig bentonite) at the top of the Stones River Group, then work upward through the shaly limestone of the Hermitage Formation and massive Bigby-Cannon Limestone into the shaly Catheys-Leipers limestone interval; each unit has easily recognized geophysical log signatures. The section downward from the bentonites is also equally divisible into the massive Carters Limestone (containing the bentonites at the top), the thin-bedded shaly Lebanon Limestone, the massive Ridley Limestone, the thin shaly Pierce Limestone, and the more massive Murfreesboro Limestone. The discontinuous Wells Creek (or Pond Spring, Blackford, or Douglas Dam Member) Dolomite, deposited on the Knox (Lower Ordovician) unconformity, also has a distinctive geophysical log signature. Some structural mapping of recognizable horizons has been carried out, but the concentration of wells in particular areas rather than more regional coverage has

Age	Group	East–Cen Tennessee	Southern Kentucky
Miss.-Dev.		Chattanooga Shale	Chattanooga Shale
Lower Silurian	Wayne	Lego Ls. Waldron Sh. Laurel Ls. Brassfield Ls. / Rockwood Fm.	Lego Ls. Waldron Sh. Laurel Ls. Brassfield Ls. / Clinch Ss.
Upper Ord.	Richmond	Sequatchie Fm. Reedsville Sh. Leipers Fm. Inman Fm.	Juniata Fm. Martinsburg Fm.
	Nashville Lexington	Catheys Fm. Bigby-Cannon Ls. Hermitage Fm.	Lexington Ls.
Middle Ord.	Stones River High Bridge	Mud Cave (Millbrig) Bentonite T4 Pencil Cave (Deicke) Bentonite T3 Carters Ls.	Mud Cave (Millbrig) Bentonite Pencil Cave (Deicke) Bentonite Tyrone Ls.
		Lebanon Ls.	Oregon Ls.
		Ridley Ls. Pierce Ls. Murfreesboro Ls.	Camp Nelson Ls.
		Wells Creek Fm.	Wells Creek Fm.
Lower Ord.	Knox	Mascot Ds.	Mascot Ds.

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Figure 6. Comparison of the Middle Ordovician-Silurian stratigraphic sections in East-Central Tennessee (Nashville dome to western Valley and Ridge) with that in Central Kentucky.

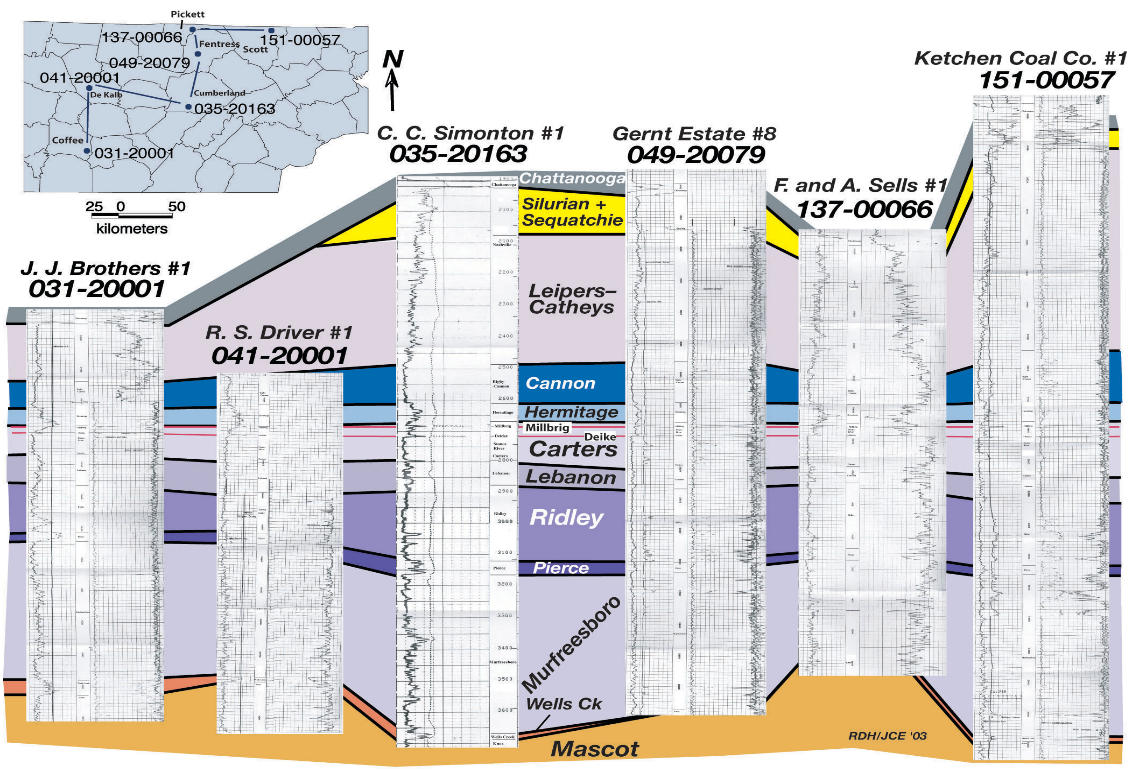

Figure 7. Representative geophysical logs from the Cumberland Plateau in Tennessee illustrating the characteristic geophysical signatures of the Middle and Upper Ordovician section. Gamma ray log is consistently on the left and is most useful for subdivision of the Stones River and Nashville Groups.

prevented us from making major breakthroughs to date into resolution of detailed structure beneath the Cumberland Plateau. *This remains a major goal of this project.*

Field Studies of the Middle Ordovician Tellico-Sevier Basin. Several investigations of the Middle Ordovician rocks of East Tennessee have been made over the past several decades by Rodgers (1953), Benedict and Walker (1978), Shanmugam and Walker (1982), and Walker et al. (1983) (Fig. 9). These studies have provided a clear depositional framework for these rocks that permits understanding of the relationships between the thinner (~700 m) carbonate platform and deep basin (some 3,000 m) of predominantly clastic sedimentary rocks. Questions remain about the actual water depths in the deeper pats of the basin, the thicknesses and character of sediments accumulated in the basin, the 3–D nature and origin of the basin, and the bearing of these factors on the maturation and evolution of organic matter to hydrocarbons that would have accumulated in the basin. In order to better address these questions and the 3–D nature of the basin, we began a

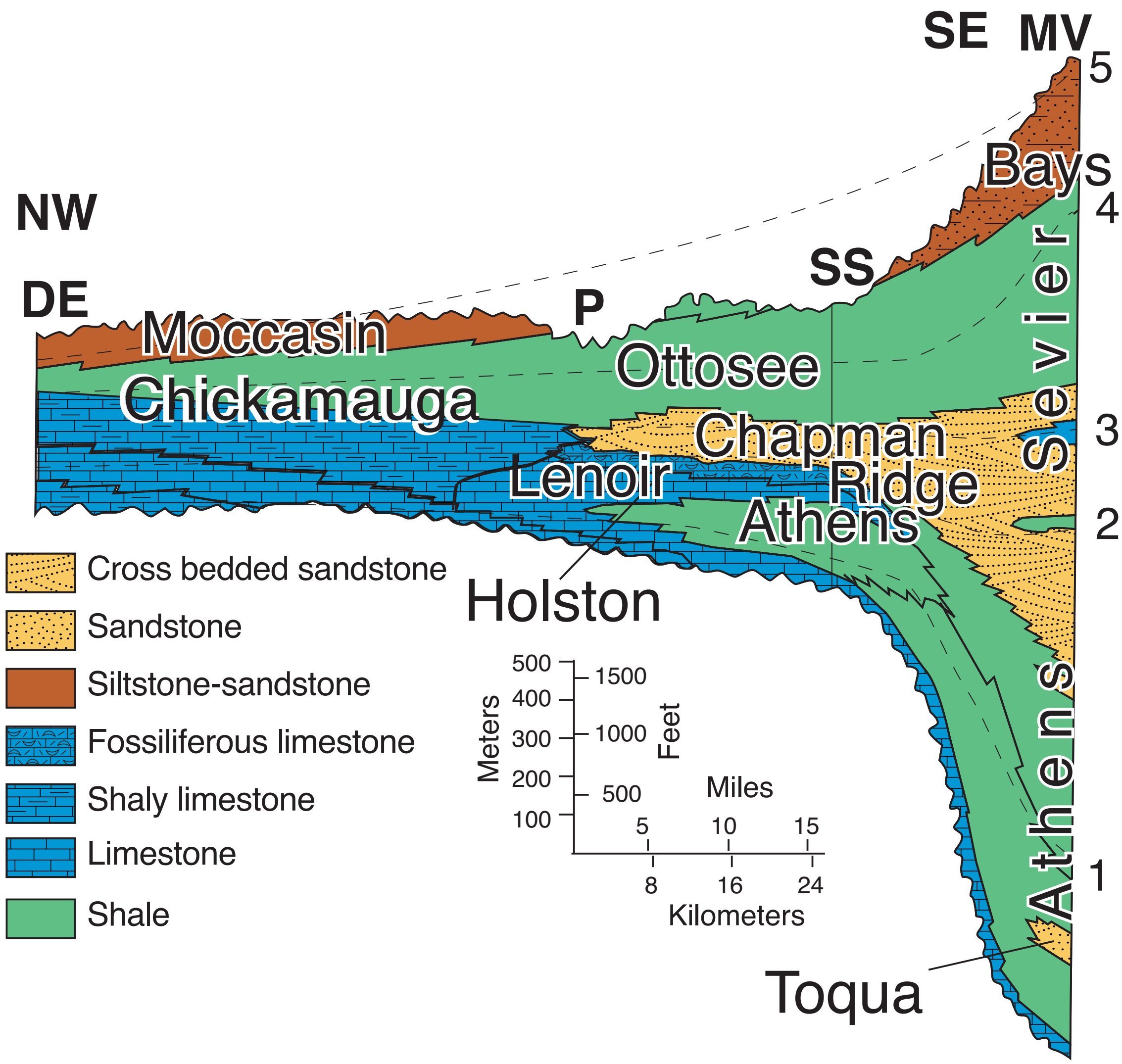

Figure 8. Middle Ordovician facies relationships in the East Tennessee Valley and Ridge, with clastics becoming dominant and very thick to the east. From Walker et al. (1983).

program of detailed geologic mapping (including collection of fracture data) of parts of the basin to gain a better hold on the framework of the basin. Mapping of the southwest end is largely complete (Heath, 2003), but a detailed traverse across the basin in northeastern Tennessee will be completed during the next year, with the cooperative addition of unpublished data by the Tennessee Division of Geology.

The Tellico-Sevier basin has traditionally been considered a foredeep basin (Shanmugam and Walker, 1982), but clasts in easterly derived conglomerates that occur at the same stratigraphic interval in the Middle Ordovician section at localities from northern Georgia to north of Roanoke, Virginia, are overwhelmingly dominated by platform carbonate rocks with lesser amounts of rifted margin sedimentary rocks (Kellberg and Grant, 1956). This and palinspastic considerations suggest the basin may have originated farther into the continent as a secondary "forebulge" basin west of the Ordovician peripheral bulge.

Groundwork Toward Future Milestones

Thermal Models, Thermal Maturation Data. During July, 2003, RDH assisted Dr. John Repetski, USGS–Reston with collection of samples from the Mississippian section in the Plateau and Valley and Ridge in Tennessee for conodont alteration index (CAI) studies. All existing CAI data are derived from Ordovician rocks (Epstein et al., 1977), and the values have been updated where questions existed before (Orndorf et al., 1988). Additional illite crystallinity index data determined on Cambrian and Ordovician rock samples (Weaver and Broekstra, 1984) basically corroborate the Ordovician CAI data. We will have access to the new CAI data and will be able to see if there is an effect of burial depth on CAI values in the southern Appalachians.

We also have submitted several black shale samples form the Sevier Shale to the USGS for organic carbon analysis during the past year and should have the results back soon.

Both of these activities constitute the USGS cooperative component of the project at the present. There are frequent communications with USGS geologists in the Eastern Mineral Resources group, principally Dr. Robert Milici, and also the Eastern Regional Geology group regarding these activities and related topics.

Reservoir Characterization. All of the work being conducted is aimed at better reservoir characterization in this region. The geophysical log and structural work from beneath the Plateau will help enormously in the characterization of reservoirs in the Ordovician rocks, where the least knowledge exists. The structural reconstructions based on interpretation of industry seismic reflection data and fracture studies already have yielded information useful to the petroleum industry (e.g., Whisner and Hatcher, 2003).

3–D Basin Reconstruction. The main field component of this project will provide useful information for 3–D reconstruction of the Middle Ordovician basin and the influence the carbonate-clastic basin had on the expulsion of hydrocarbons and other fluids as the basin evolved and was deformed. We currently have not recognized the pre-Devonian-post-Silurian deformation in the Valley and Ridge, although data from the interior of the orogen indicate a major deformational, plutonic, and metamorphic event occurred at about 350-360 Ma (e.g., Carrigan et al., 2001).

Exploration Models, Probability Maps. Exploration models for reservoirs in the Devonian and Mississippian petroleum systems have been tested and proved by abundant drilling and development of fields in the southern part of the Appalachian basin in West Virginia, Kentucky, and Tennessee (see descriptions of Devonian and younger plays in Roen and Waker, 1996). We therefore expect to concentrate our efforts in development of exploration models, plays, and probability maps and assessments on the poorly known Ordovician petroleum system beneath the Cumberland Plateau of Tennessee and southern Kentucky where opportunities may exist to develop a number of large fields. Currently the largest gas and oil producing wells in Tennessee are in the Ordovician, although do definitive strategy for exploring the Ordovician currently exists.

CONCLUSIONS

1. All first-year milestones for this project were met. Movement vectors for Valley and Ridge thrusts were confirmed to be west-directed and derived from pushing by the Blue Ridge thrust sheet, and fan about the Tennessee salient. Fracture systems developed during Paleozoic, Mesozoic, and Cenozoic to Holocene compressional and extensional tectonic events, and are more intense near faults. Presentations of first-year results were made at the Tennessee Oil and Gas Association meeting (invited) in June, 2003, at a workshop in August 2003 on geophysical logs in Ordovician rocks, and at the Eastern Section AAPG meeting in September 2003. Papers on thrust tectonics and a major prospect discovered during the first year are in press in an AAPG Memoir and published in the July 28, 2003, issue of the *Oil and Gas Journal*.

2. Efforts are being made to calibrate and standardize geophysical log correlation, seismic reflection data, and Ordovician lithologic signatures to better resolve subsurface stratigraphy and structure beneath the poorly explored Plateau in Tennessee and southern Kentucky.

3. Fracture orientation data were both compiled from existing sources in the western Valley and Ridge and Plateau in Tennessee and Blue Ridge Foothills and new data collected in the field areas being mapped in detail. fracture orientations are consistent with those in other parts of the Valley and Ridge, with the exceptions of curvature of some sets around the Tennessee salient. Fracture aperture varies with depth and intensity varies with proximity to faults.

4. We began a detailed field structural and stratigraphic mapping transect across part of the Ordovician clastic wedge in Tennessee to assist in 3-D reconstruction of part of the southern Appalachian basin and better assess the nature of the Ordovician petroleum system source rock assemblage.

5. Cooperative work toward assessment of the geologic controls of hydrocarbon occurrence in this region is being conducted in collaboration with the USGS, state geological surveys of Tennessee and Kentucky, and small independent producers.

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World Stress Map, 2003, www-wsm.physik.uni-karlsruhe.de/.

APPENDICES

Résumé

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Employed by Humble Oil and Refining Company (now ExxonMobil). Served on the faculties of Clemson University, Florida State University, the University of South Carolina, and the University of Tennessee (joint appointment at the Oak Ridge National Laboratory, 1986–2000). More than 35 years of experience in research on the processes related to the formation of continental crust and mountain chains, concentrating on the southern Appalachians, but with considerable familiarity with the Alps, British and Scandinavian Caledonides, Canadian, and U.S. Cordillera, Argentine and Colombian Andes, and Moroccan Atlas and Meseta. Applied interests and research spinoff in petroleum exploration (South Louisiana, Appalachians), eastern U.S. intraplate seismology, hazardous and radioactive waste management, and engineering geology.. Research requires collection of basic geologic data and ability to integrate, manipulate, and interpret geophysical and geochemical data. To date, 160 refereed papers, 8 books, and a tectonic map of the U.S. Appalachians have been published, and some 220 papers have been presented by RDH and coauthors at professional meetings. Serves and has served on numerous advisory committees: National Academy of Sciences (National Research Council) boards and committees; Geological Society of America committees and GSA Foundation Board of Trustees; and as a reviewer of federal, state, and university programs, papers for journals, and proposals for funding by several government agencies. Highest honors received to date include the Geological Society of America Distinguished Service Award (1988), serving as President of the Geological Society of America (1993), President of the American Geological Institute (1996), the I. C. White Foundation Award (1997), being made an honorary citizen by the governor of West Virginia (1998), and the John T. Galey Award (2001).

EDUCATION

Vanderbilt University, Nashville, Tennessee B.A.–1961, M.S.–1962
University of Tennessee, Knoxville, Tennessee Ph.D.–1965

PROFESSIONAL EMPLOYMENT

Distinguished Scientist and Professor of Geology University of TennesseeKnoxville, Tennessee 2000–Present
Distinguished Scientist and Professor of Geology (Tenure Awarded, 1986) University of Tennessee/Oak Ridge National LaboratoryKnoxville/Oak Ridge, Tennessee 1986–2000
Professor of Geology (Tenure Awarded, 1980)University of South Carolina, Columbia, South Carolina 1980–1986
Professor of Geology (Tenure Awarded, 1979) Florida State University, Tallahassee, Florida 1978–1980
North Carolina Geological Survey (Geologic mapping, Part Time) 1974–1980
Georgia Geological Survey (Geologic mapping, Part Time) 1970 (Summer)
South Carolina Division of Geology (Geologic mapping, Part Time) 1966–1982
Professor of GeologyAssociate Professor of Geology (Tenure Awarded, 1970)Assistant Professor of GeologyClemson University, Clemson, South Carolina 1976–19781970–19761966–1970
Humble Oil and Refining Company, New Orleans, Louisiana(Geologist, Southeastern Division Stratigraphic–Paleontological Group) 1965–1966
Teaching AssistantUniversity of Tennessee, Knoxville 1962–1965
Tennessee Division of Geology (Geologic mapping, Part Time) 1961–1964 (Summers)
Teaching AssistantVanderbilt University, Nashville, Tennessee 1960–1962

HONORS AND APPOINTMENTS

President, Geoclub, University of Tennessee	1962–1963
Sigma Gamma Epsilon, University of Tennessee	Elected 1966
President, Carolina Geological Society	1975
Convenor of Geological Society of America, Penrose Research Conferences	1974, 1976. 1980
President, Clemson University Chapter, Society of Sigma Xi	1975–1976
Associate Editor, Geological Society of America Bulletin	1976–1981
Editor, George Swingle Memorial Issue of Southeastern Geology	1979
Chairman, Southeastern Section Geological Society of America	1978–1979
Geological Society of America Council	1980–1982
International Geological Correlation Program—Caledonide Orogen Project (#27). Secretary, U.S. Working Group and Member of International Working Group	1976–1985
Editor, Geological Society of America Bulletin (with W. A. Thomas)	1981–1988
Geological Society of America Committees	
Chairman, Technical Program Committee and Technical Program co-Chairman (with C. E. Weaver) for the Atlanta National Meeting	1980
Program Review Committee	1979–1981
Joint Technical Program Committee	1979–1982
Audit Committee	1981–1982
Chairman, Committee on Publications	1981–1983
Committee on Publications	1981–1988
Chairman, Committee on the Arthur L. Day Medal	1982
Committee on the Penrose Medal	1987–1988
Chairman, Committee on Nominations	1988
Chairman, Committee on Committees	1991
Executive Committee and Council:	
Vice President	1991–1992
President	1992–1993
Past President	1993–1994
Executive Director Search Committee	1993–1994
Foundation Board of Trustees	1999–2003
Honorary Fellows (Chairman, 2003-2004)	2002-2004
Project Director and Chief Scientist, Appalachian Deep Core Hole (ADCOH) Project. Involved management of $2M NSF budget for site study and coordination of research efforts of 10 scientists from University of SC, Virginia Tech, Princeton, Stanford, and Columbia Universities.	1983–1990
Geological Society of America Distinguished Service Award	1988
Elected Fellow, American Association for the Advancement of Science	1989
Chairman, American Geological Institute Committee to Investigate the Need for Accreditation of Geosciences Professional Degrees	1993–1999
National Academy of Sciences Board of Radioactive Waste Management	1990–1997
National Academy of Sciences Committee to Review the Ward Valley, California, LLRW Wilshire Group Objections to the Site	1994–1995

National Academy of Sciences Committee to Review the New York State Low-Level Radioactive Waste Siting Process	1994–1996
Nuclear Regulatory Commission Nuclear Reactor Safety Research Review Committee	1993–1996
National Academy of Sciences National Committee on Geology	1993–1996
American Geological Institute	
President Elect	1994–1995
President	1995–1996
Past President	1996–1997
National Cooperative Geologic Mapping Program Federal Advisory Committee	1996–2002
I.C. White Memorial Award for career contributions	1997
West Virginia honorary citizenship for career contributions	1998
Member, Geological Society of America Foundation Board of Trustees	1999–2003
John T. Galey Award by the Eastern Section of the American Association of Petroleum Geologists	2001

Pertinent Publications

Eberly, L. D., Crowley, D. J., Hatcher, R. D., Jr., and Walker, L. B., 1966, A study of abnormal pressure in South Louisiana: Humble Oil and Refining Company Confidential Report, Southeastern Division Stratigraphic–Paleontologic Group, New Orleans.

Stearns, R. G., and Hatcher, R. D., Jr., 1963, Petrology of the laminated Argillaceous and

Dalmanella coquina in the Hermitage Formation (Ordovician) of central Tennessee: Journal of the Tennessee Academy of Sciences, v. 38, p. 15–22.

Hatcher, R. D., Jr., 1969, Structure of the Dumplin Valley fault zone in East Tennessee: Southeastern Geology, v. 11, p. 85–86.

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Bridge, Josiah, and Hatcher, R. D., Jr., 1974, Geologic map of the New Market Quadrangle, Tennessee: Tennessee Division of Geology, GM 155–SE, scale 1/24,000.

Hatcher, R. D., Jr., and Bridge, Josiah, 1974, Geologic map of the Jefferson City Quadrangle, Tennessee: Tennessee Division of Geology, GM 163–SW, scale 1/24,000.

Hatcher, R. D., Jr. and Odom, A. L., 1980, Timing of thrusting in the southern Appalachians, USA: Model for orogeny?: Quarterly Journal of the Geological Society of London, v. 137, p. 321–327.

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Hatcher, R. D., Jr., 1982, Hydrocarbon resources of the eastern overthrust belt: The Valley and Ridge and Blue Ridge of the Appalachians—A realistic evaluation: Science, v. 216, p. 980–982.

Price, R. A., and Hatcher, R. D., Jr., 1983, Tectonic significance of similarities in the evolution of the Alabama–Pennsylvania Appalachians and the Alberta–British Columbia Canadian Cordillera, in Hatcher, R. D., Jr., Williams, Harold, and Zietz, Isidore, eds., Contributions to the tectonics and geophysics of mountain chains: Geological Society of America Memoir 158, p. 149–160.

Hatcher, R. D., Jr., Odom, A. L., Engelder, T., Dunn, D. E., Wise, D. U., Geiser, P. A., Schamel, S., and Kish, S. A., 1988, Characterization of Appalachian faults: Geology, v. 16, p. 178–181.

Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., 1989, The Appalachian–Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, The Geology of North America, v. F–2, 767 p.

Hatcher, R. D., Jr., Thomas, W. A., Geiser, P. A., Snoke, A. W., Mosher, S., and Wiltschko, D. V., 1989, Alleghanian orogen, Chapter 5, *in* Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., eds., The Appalachian–Ouachita orogen in the United States: Boulder, Colorado, Geological Society of America, The Geology of North America, v. F–2, p. 233–318.

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Keller, G. R., and Hatcher, R. D. , Jr.,, 1999, Some comparisons of the structure and evolution of the southern Appalachian–Ouachita orogen and portions of the Trans-European suture zone: Tectonophysics, v. 314, p. 43–68.

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Montes, C., Restrepo-Pace, P. A., and Hatcher, R. D., Jr., in press, Three-dimensional structure and kinematics of the Piedras-Girardot foldbelt: A window into the structure of the northern Andes and the IbaguÈ transfer zone: AAPG Memoir.

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Potential Ordovician Hydrocarbon Plays in the Cumberland Plateau of Tennessee and Southern Kentucky: Finding a Needle in a Haystack?

The hydrocarbon potential of the Cumberland Plateau has been explored for over a century with most discoveries to date being small oil or gas fields in Mississippian limestone reservoirs sourced by the Devonian-Mississippian Chattanooga Shale. The underlying Knox and Middle-Upper Ordovician (Stones River or Black River Group, and Nashville or Trenton Group) carbonate rocks, however, have only been cursorily explored, with only minimal success in Tennessee. The historic success of the Rose Hill field in southwest Virginia, other fields in Middle Ordovician rocks farther northeast, and the recent development of the Swan Creek field in the Knox and Middle Ordovician rocks in northeastern Tennessee indicate there is greater potential in the Middle and Upper Ordovician rocks beneath the Cumberland Plateau. The source of these hydrocarbons is the Ordovician rocks (gas chromatography by R. Burruss, USGS). Deformed zones related to previously unmapped blind faults and décollements may locally enhance an otherwise primarily porosity-dominated province. Research currently underway intends to identify markers (other than the known K-bentonites) in geophysical logs that will permit detailed resolution of units in the Stones River and Nashville Groups. These units have been mapped in surface exposures on the Nashville dome and in the western Valley and Ridge, as well as in the Sequatchie anticline that dissects the central and southern Plateau in Tennessee. Such resolution will provide new opportunities to better understand the structure and reservoir characteristics in the subsurface beneath the Plateau and Eastern Highland Rim of East Tennessee and southern Kentucky.

Neil E. Whitmer, Robert D. Hatcher, Jr., S. Christopher Whisner, Jennifer B. Whisner, J. Ryan Thigpen, and John G. Bultman, Department of Geological Sciences, University of Tennessee

Middle Ordovician Clastic Wedges in East Tennessee: A New Look at an Old Basin

Two Middle-Upper Ordovician (Taconian) clastic wedges formed in the southern and central Appalachians: the Blountian (Sevier, Middle Ordovician) and the Martinsburg-Tuscarora (Upper Ordovician to Early Silurian). Several depositional models have been proposed for each. We are constructing a 3-D model for the Blountian basin in Tennessee and adjacent states and reevaluating existing models. Development of a 3-D model of the Middle Ordovician clastic wedge in East Tennessee permits reexamination of current models of syn/postTaconic orogenic basin dynamics. Within this basin major facies changes, both along and across strike, have been previously recognized but not examined in mapping context. Detailed geologic mapping, and stratigraphic and structural analysis are being conducted in selected areas where Blountian basin deposits are preserved in several Alleghanian synclines. 1:24,000- and 1:12,000-scale mapping facilitate more precise delineation of facies distributions and refined correlations of units in the Middle Ordovician Chickamauga Group. Two-dimensional industry seismic reflection data and detailed mapping permit a reevaluation of stratigraphic thickness estimates, previously considered as much as 10,000 ft. More quantitative estimates of Alleghanian structural geometries and stratigraphic thicknesses will yield viable palinspastic restorations of basin and facies geometries. Paleocurrent indicators in carbonate bank and basin facies are being employed for the first time to determine sediment dispersal and sources. Facies distributions and source areas are particularly important if tectonic and thermal loading of Middle Ordovician black shales are a source of hydrocarbons in carbonate reservoirs farther west.