



2014 ANNUAL REPORT



West Virginia
WEST VIRGINIA

MESSAGE FROM THE DIRECTOR

For several years the big news in West Virginia has been Marcellus Shale gas. We have all learned some new words and phrases: horizontal drilling, hydraulic fracturing or “fracking,” well pads, “crackers,” natural gas liquids, dry gas, Marcellus shale, and Utica Shale. Our state has a long history in producing oil and gas, but an upsurge in activity means increasing numbers of wells, rates of production, and production per year and over the lifetime of a well.

The most recent data available show that horizontal wells with production from the Marcellus Shale increased in number from 631 wells in 2012 to at least 947 in 2013. Total natural gas production increased to 541 billion cubic feet (Bcf) from about 300 Bcf the previous year, and we think our figures are low because not every well was represented in our dataset. Combined oil and natural gas liquids totaled 4.7 million barrels in 2013, again probably an underestimate. Harrison, Wetzel, Doddridge and Marshall were the top gas-producing counties; Ohio, Wetzel, Marshall and Brooke counties ranked highest in production of oil and natural gas liquids.

The future might bring similar activity in the Utica Shale, an organic-rich rock formation that underlies much of northern and western West Virginia. Most of this drilling is taking place in the northern panhandle as well as Wetzel and Tyler counties. We might also expect to see increased interest by companies in applying horizontal well and hydraulic fracturing technology to established oil and gas fields. In the past, many oil wells only produced about a fifth of the oil present in the reservoir. Much of the oil remains and could perhaps be produced with more advanced engineering practices. One of our research projects funded partially by the U.S. Department of Energy examines the possibility of using captured carbon dioxide in enhanced oil recovery in older, established fields.

We post maps and spreadsheets of Marcellus well permit applications and completions on our website (www.wvgs.wvnet.edu/) on a roughly semiannual basis. In addition, we post reports on shale gas activity, sources of information, and links to publications by our geologists and others.

1 Neuendorf, K.K.E.; J. P. Mehl Jr.; and Julia A. Jackson, 2011, Glossary of Geology, Fifth Edition, Revised. American Geosciences Institute, Alexandria, VA, 783p.

KARST

While we do not regulate any aspect of the oil and gas industry, we do provide geologic information that informs regulators and the public as part of our mission. An important part of our geologic mapping each year is delineating areas of karst, defined as “a type of topography that is formed on limestone, gypsum, and other soluble rocks . . . characterized by sinkholes, caves, and underground drainage.”¹ In fact, presence of karst is one of our main criteria for setting priorities for geologic mapping because of the environmental sensitivity of this landscape type.

Two pieces of legislation in recent years underscore public concern over oil and gas development in areas of karst. Specifically, what happens if a company drills a horizontal well in an area with caves? Are landfills in areas with karst appropriate for receiving drill cuttings and associated drilling waste?

Karst is a real concern where drilling and waste disposal take place for at least two reasons. First, special precautions must be taken to mitigate or prevent drilling into a void, which can result in a loss of drilling tools and release of drilling fluids. Second, the interconnectedness of the subsurface voids means that liquids released by accident may travel miles underground and possibly contaminate drinking-water supplies.

Fortunately, the most intensive oil and gas exploration and development occurs in regions of the state without extensive karst topography. Thin limestone beds underlie many counties in the state, but counties with the most karst are in the eastern panhandle and along the border we share with Virginia.

West Virginia is rich in natural resources, from the beauty of the forested hills to the energy-giving coal, oil, and gas underground. Our mission is to provide objective, up-to-the-minute information on our geologic resources for the betterment of the people of our state.



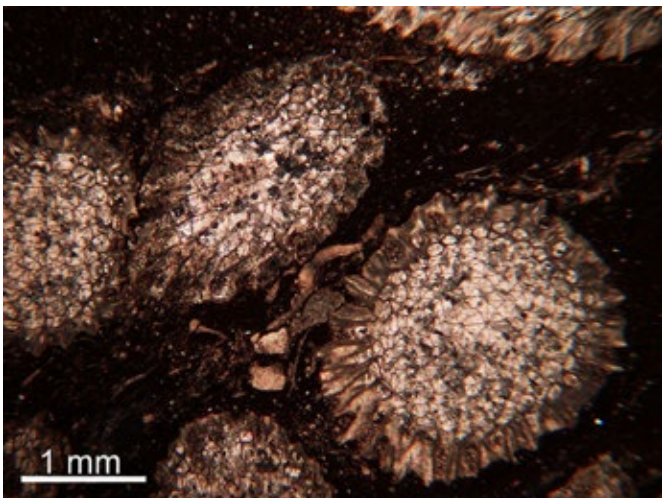
Michael Ed. Hohn

GEOSCIENCE PROGRAM

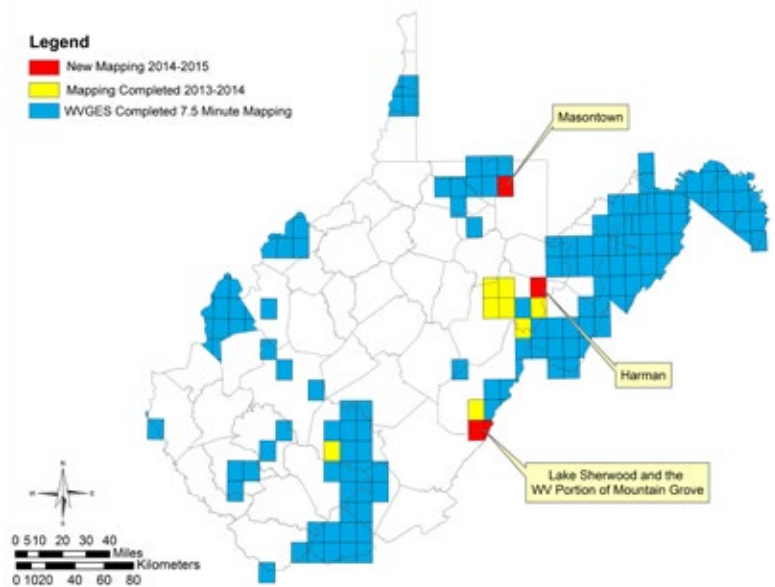
Geologic Mapping

Geologic mapping at WVGES consists of two major components: the direct acquisition of new geological information through field reconnaissance and the conversion of new and existing geological information from hard copy (paper, mylar, etc.) to digital format.

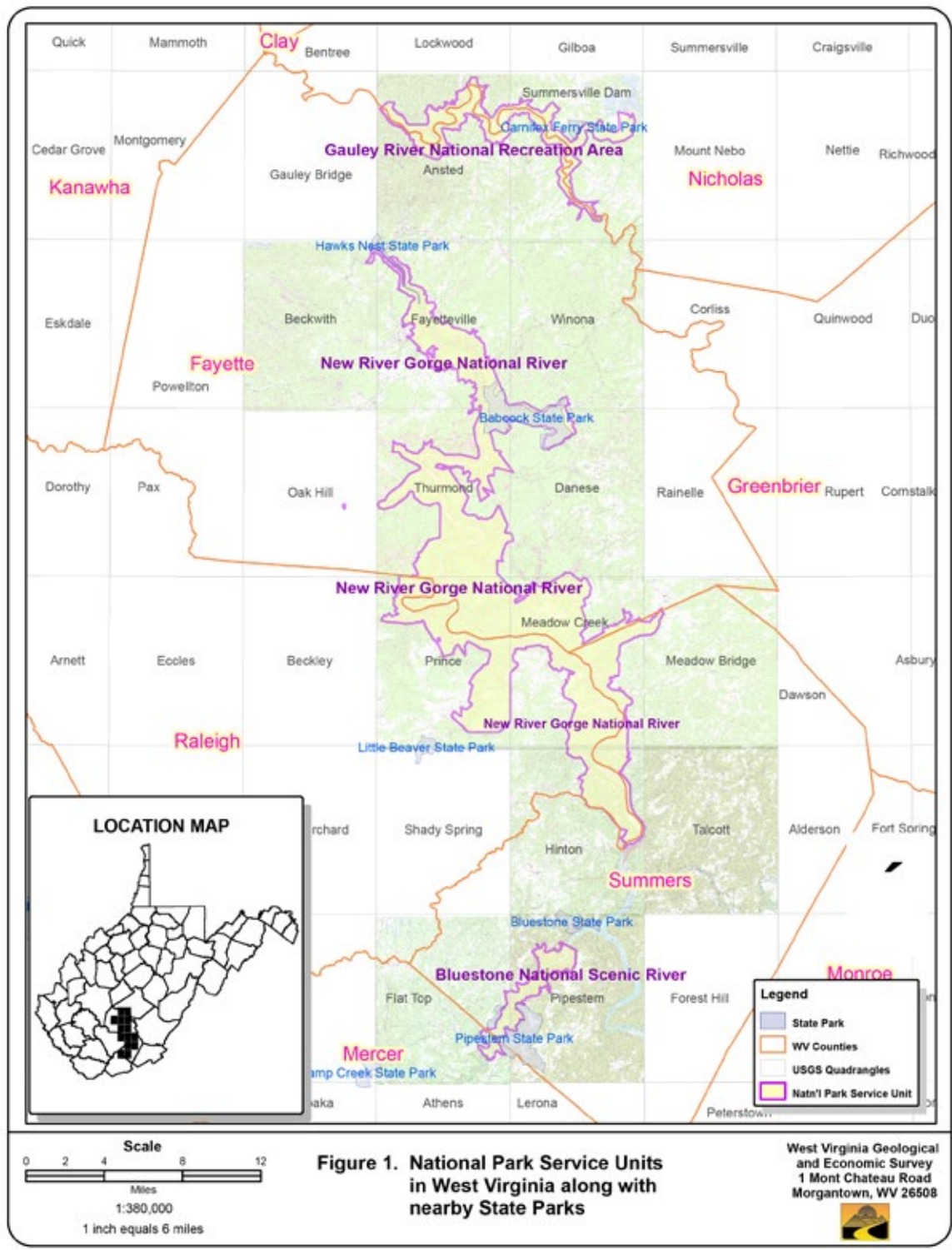
- Acquisition of new geological data is carried out under the auspices of the STATEMAP program funded jointly by the United States Geological Survey (USGS) and WVGES. During the summer and fall of 2013 and spring of 2014, field work was conducted on three 7.5 minute topographic quadrangles in central and eastern West Virginia (Oak Hill, Marlinton, and Whitmer). Published as WVGES Open File Reports, the data are currently available as paper maps, PDF files, and geographic information system (GIS) geodatabases. In August 2013, the STATEMAP Advisory Committee, composed of individuals from industry, government, and academia, met to evaluate new potential map areas within West Virginia for the upcoming 2014 field season. In October 2013, a multi-project proposal was submitted to the USGS and mapping of the Lake Sherwood, Masontown, and Harman quadrangles was partially funded. Fieldwork on new STATEMAP projects began in June 2014.



Thin section through several branching marine bryozoans in the Ordovician Utica Shale from Wood 351 core, 9571 feet below the surface.



- In August 2009, WVGES submitted a successful proposal to the National Park Service to map the geology of three Park units within the state of West Virginia. Over a four-year period, a consortium of geologists from WVGES, West Virginia University, and Concord University mapped the bedrock geology of the Fayetteville, Thurmond, Beckwith, Winona, Danese, Prince, Meadow Creek, Hinton, Meadow Bridge, Talcott, Ansted, Summersville Dam, Flat Top, and Pipestem quadrangles. These map areas cover Park lands within the Gauley River National Recreation Area, the New River Gorge National River, and Bluestone National Scenic River. Surficial geology within the Park units has also been mapped, and those data are being entered into GIS databases. All bedrock geology maps and geodatabases for this project were completed and the finished products were delivered to the Park Service in August 2013. A summary of the Project can be seen on the Survey's website: www.wvgs.wvnet.edu/www/NationalPark/WVGES-NPSMapping.htm.
- A WVGES-funded update of the 1981 Beckley 7.5-minute geologic quadrangle map began during FY 2014 to make it compatible with more recent mapping in the area.



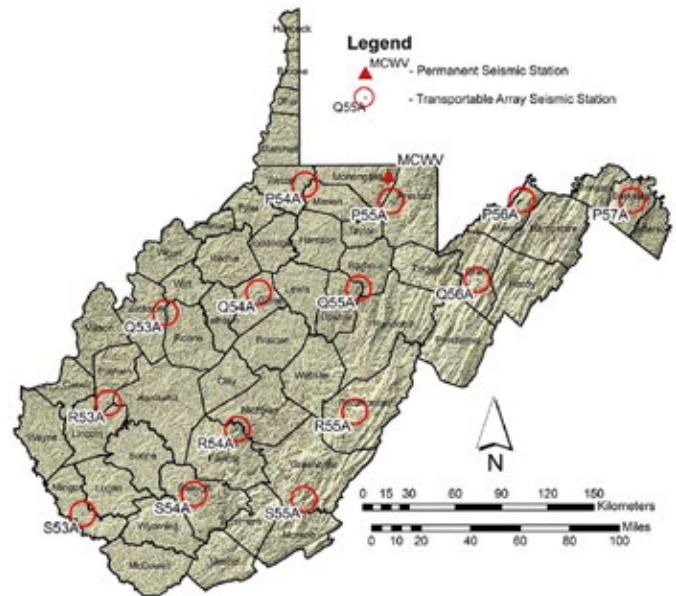
Geothermal Resources

WVGES participated in a three-year project sponsored by the United States Department of Energy and the Association of American State Geologists to increase the publically available data on geothermal resources in all 50 states. At Project end in October 2013, WVGES had provided Web-accessible versions of temperature logs, Bottom Hole Temperature (BHT) data for nearly 4,000 wells, and data for the state's thermal springs and their water chemistry. In addition, WVGES, working in conjunction with researchers from West Virginia University's Department of Chemical Engineering, provided 375 measurements of thermal conductivity taken using well cuttings from deep oil and gas wells in Marion and Randolph counties. Information about the project and data for West Virginia can be found at: www.stategeothermaldata.org/.

Environmental Geoscience and Geochemistry

Environmental and geochemical work at WVGES deals primarily with the evaluation of geologic site characteristics for Underground Injection Control (UIC) permits for injection of fluids into subsurface rock formations, the assembly of a database of selected metals content of the state's rock formations, and answering inquiries regarding geology, surface water, groundwater, geologic hazards, and bedrock chemistry.

- Under West Virginia State Code §22-11-11, the Director of WVGES furnishes consultation to the West Virginia Department of Environmental Protection (WVDEP) concerning UIC draft permits. During FY 2014, WVGES provided input regarding geologic conditions at injection sites for 10 Class V UIC draft permits.
- Geochemical analyses for 44 rock samples collected during STATEMAP mapping reconnaissance were added to the existing stratigraphic geochemical database, bringing the number of samples up to 1034 and covering West Virginia rock units ranging in age from Precambrian through the Pennsylvanian. The database is available as a GIS layer that can be combined with or superimposed on other maps of West Virginia for use in environmental and economic assessments of the near-surface bedrock of a particular geographic location.
- During FY 2014, WVGES provided assistance to the West Virginia Division of Natural Resources (WVDNR) Parks and Recreation in siting a successful public water supply well at Canaan Valley Resort State Park.



Seismic Monitoring

Six earthquakes occurred in West Virginia during the Fiscal Year – one in Braxton, three in Gilmer, one in Greenbrier, and one in Jackson County. All of these events except the one in Braxton County occurred at depths greater than 15,000 feet. The Braxton County earthquake was located at a depth of approximately 9,000 feet and its geographic proximity to previous earthquakes in that area raised renewed concerns about drilling activity, the county's single wastewater disposal well, and induced seismic activity. Geoscience personnel were called upon to respond to public and governmental inquiries regarding this issue.

Since August 2013, 14 new seismic stations associated with the EarthScope Program sponsored by National Science Foundation (NSF) and the Incorporated Research Institutions for Seismology (IRIS) consortium have been operating and providing data regarding earthquakes both within and outside of West Virginia. One of the improvements seen with the utilization of these new stations is reduced error in the vertical location of earthquake hypocenters (the actual point below the earth's surface where the earthquake takes place) from $\pm 10\%$ or greater to $\pm 3\%$, a significant improvement. Twenty-four hours of seismic records can be viewed by interactively selecting individual stations from the Survey's website: www.wvgs.wvnet.edu/www/earthquakes/transportable_array.html.

Outreach Activities

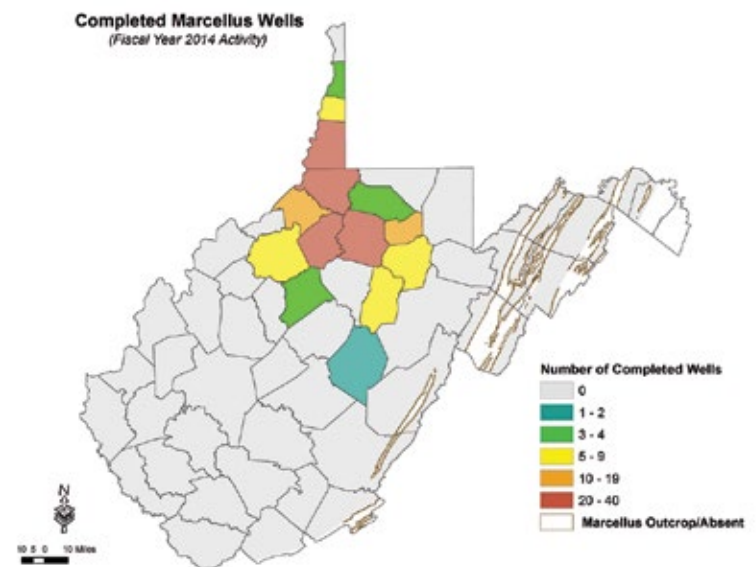
- In July 2013, Geoscience personnel, recruited as members of the Boy Scouts of America Geology Merit Badge Committee, participated in Geology Tent activities at the National Jamboree held at Raleigh County's new Summit - Bechtel Family National Scout Reserve. Activities included local geology orientation for tent staff and developing and conducting twice-daily geology hikes for scouts.
- In March 2014, Geoscience personnel presented two posters at the Northeastern Section – Geological Society of America Meeting in Lancaster, Pennsylvania. Titles were: Surprises from the Devonian Foreknobs Formation of eastern West Virginia (McDowell, Avary, Hitzig, Sydney, and Case, 2014) and West Virginia earthquakes: Crustal adjustments along the Rome Trough or something else? (McDowell, Lewis, and Dinterman, 2014).
- Geoscience personnel attended local, regional, and national meetings featuring topics including geological hazards, induced seismicity, and environmental issues related to oil and gas exploration and development, protection of groundwater resources in karst regions, hazard mitigation, and disaster preparedness.
- In August 2013, Geoscience personnel gave an oral presentation titled Geologic Geospatial Tools and Techniques for Geologic Mapping in West Virginia's Plateaus (McColloch and McColloch, 2013) at the Geohazards Impacting Transportation Technical Forum in Harrisonburg, Virginia.
- In February 2014, Geoscience personnel conducted a half-day fossil identification workshop at the Grave Creek Mound Museum Complex in Moundsville, WV.
- Geoscience personnel taught evening classes in Geological Hazards and Historical Geology at Fairmont State University.

Geoscience Education Outreach

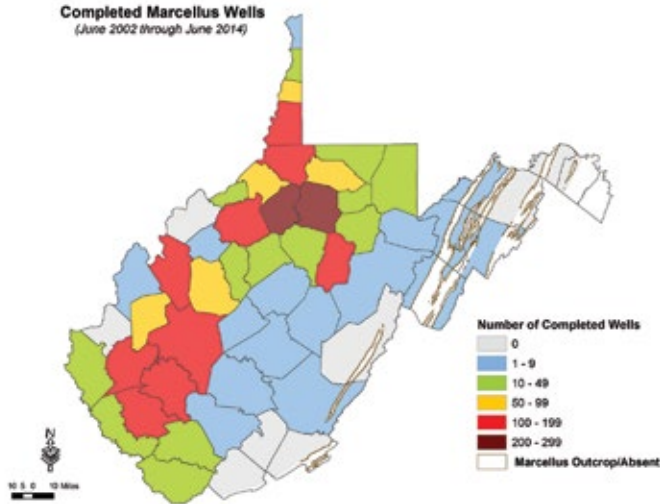
Geoscience Education Outreach operates a completely digital program providing K-12 teachers with products and activities designed for their classroom use. The link to this information on the Survey's website is www.wvgs.wvnet.edu/www/geoeduc/geoeduc.htm.

OIL AND GAS PROGRAM

Geologists in the Oil and Gas Program continue to investigate every stage of a reservoir's life cycle, from the potential of some of the oldest rocks in the Appalachian basin to yield hydrocarbons to discoveries and exploration in the Utica Shale and the optimization and maximization of production in the prolific Marcellus Shale. Older fields are also being examined—depleted oil fields are being revisited with new techniques and technologies for extracting residual oil, while several abandoned gas fields are undergoing suitability tests for disposal of produced waters and brines. Decades-old cores and cuttings have been re-sampled as new plays emerge, and drilling records from more than a century ago are often relied upon for important information. Each of these projects underscores the importance of record-keeping and stewardship of geologic data—something the Oil and Gas Program takes seriously and constantly strives to achieve.



Completed Marcellus Wells
(June 2002 through June 2014)



Marcellus Shale

The Marcellus Shale remains the primary natural gas and natural gas liquids producer in the state, and the volume of production continues to climb. Well counts for FY 2014 stand at 2,493 completed wells and 1,088 active permits. In addition, new reporting requirements have been adopted by the West Virginia Department of Environmental Protection's Office of Oil and Gas to help quantify the amount of natural gas liquids (or NGLs) being produced, the vast majority of which are derived from the Marcellus. Prior to this year, the NGLs were reported in the same category as oil, which did not accurately reflect the type of hydrocarbon being produced. Although it will likely take time to fully adopt the NGL reporting standards, its recognition as a separate product will definitely aid in our understanding of the geologic trends of NGL generation.

In addition to trying to understand the geologic trends that drive Marcellus production, a volumetric resource assessment is being conducted from a wide range of geologic factors and reservoir parameters. A preliminary estimate indicates that the Marcellus may contain approximately 122 Tcf (trillion cubic feet) of gas in-place. Future work on the resource assessment will take into account current technologies and economic conditions to determine one or more recovery factors, which will then be applied to estimate the approximate volume of gas that can be extracted from the Marcellus.

Utica Shale

Well counts for the Ordovician Utica Shale in FY 2014 stand at two completed wells and eight permits, with an additional two permits pending approval. The first well to report production (the BRK 3H well drilled by Chesapeake Appalachia in Brooke County) produced 832 Mmcf (million cubic feet) of gas in its first seven months online, suggesting promising results for the Utica in West Virginia.

The Oil and Gas Program also received a donation of several shallow cores taken from eastern West Virginia, where strata equivalent to the Utica shale are present at or near the surface. The acquisition of these core samples enabled a west-to-east comparison study of the Utica between a core taken from Wood County, in close proximity to the productive fairway, to the cores from the eastern portion of the Utica, which is generally not as well-understood due to a lack of subsurface data. The study, undertaken as a capstone project by a West Virginia University geology student, revealed significant differences in the marine fauna and depositional environments as well as major structural deformation in the eastern cores.

Rogersville Shale

An additional shale play that has experienced increased attention is the Cambrian Rogersville Shale. This shale, located within the Conasauga Group, represents some of the oldest (and deepest) strata in the Appalachian basin. The Rogersville is present in several cores taken as part of a study of the Rome Trough in southwestern West Virginia and eastern Kentucky. Several requests have been received to sample these cored sections, and a test well targeting the Rogersville has been permitted in Putnam County.

CO₂ Research and MRCSP Participation

Work continues on the Midwest Regional Carbon Sequestration Partnership, or MRCSP, to characterize reservoirs that may be suitable for enhanced oil recovery (EOR) or enhanced gas recovery (EGR) via CO₂ floods. In support of these reservoir studies, WVGES geologists are working to develop a ranking system for depleted oil fields across the partnership region. This ranking system will enable other geologists in the project to evaluate fields in their respective states. The fields identified as being most favorable for EOR via CO₂ floods will then be evaluated in more detail. West Virginia contains several fields that appear to be good candidates for the technique.

Brine Disposal and RPSEA Participation

The Research Partnership to Secure Energy for America (RPSEA) is a multi-state research consortium to evaluate depleted reservoirs for their potential to store the brine or water that is produced as a by-product of oil and gas drilling. The project has a two-year duration, and in FY 2014 WVGES contributed several core samples for mechanical testing of reservoir properties. Potential units are also being mapped in the subsurface to determine thickness and extent of viable reservoirs. Results will then be incorporated into a geocellular model that will perform simulations of brine injections to determine which reservoirs demonstrate the most ideal conditions for brine disposal and storage.

Service and Outreach

An important part of the Oil and Gas Program continues to be service and outreach. Requests for information are received on a daily basis and originate from both the public and private sector. WVGES staff are committed to providing the highest level of service and always strive to complete requests for information in a timely and professional manner. In addition to the requests for information and data, staff are also frequently asked to give presentations to groups. This year, three presentations were given to participants in the Tree Farm Program, a federally funded program for landowners of forested property. Landowners who participate in the Tree Farm Program typically own large tracts of land, many of which are in locations that are also seeing development of the Marcellus Shale. These landowners had many questions related to shale gas drilling and development and expressed appreciation for the geologic background information presented by WVGES.



GEOGRAPHIC INFORMATION SYSTEM

This program is responsible for planning, organizing, coordinating and delivering high-level Geographic Information System (GIS) services to agencies in state government; it is headed by the statewide GIS Coordinator, based in Charleston.

The program continues to make headway in a number of critical areas: promoting data sharing among agencies; providing technical assistance to state, county, and local government and the public; and fostering efficient and effective use of the state's geospatial capabilities.

The GIS Coordinator continues to provide general administrative oversight of the Mineral Lands Mapping Program in collaboration with the Survey's Coal Bed Mapping Project and the State Tax Department, Property Tax Division. During the year, procedures were refined and implemented, producing significant results in the number of mineral parcel outlines and attributes in the Property Tax Division's GIS.

The coordinator provided support to the Division of Homeland Security, Department of Environmental Protection, the Water Development Authority (WDA), Infrastructure and Jobs Development Council (IJDC), the National Guard, the West Virginia Intelligence Fusion Center, Hazard Mitigation section, and other state and local agencies in their search for GIS contract services, funding, and GIS application development.

The State GIS coordinator was appointed to the Geographical Information Systems Certification Institute (GISCI) Board of Directors.

Data exchange protocols to enhance data sharing and exchange between state and local agencies established in the previous years have proven to be successful. The protocol began the inclusion of state and locally produced datasets in the GIS Clearinghouse.

GIS workshops created in collaboration with the West Virginia Association of Geospatial Professionals, West Virginia GIS Technical Center, Rahall Transportation Institute, Property Tax Division, County Assessors, and 911 directors continued to be popular among GIS professionals. These workshops were designed to inform, train and advise county and local government officials that have GIS programs in the latest technology and at the same time to educate those officials who have not embraced GIS technology in their

own organizations. The workshops emphasize inter-agency collaboration and are given at different locations throughout the state.

The GIS coordinator attended sessions and made presentations at the mid-year National States Geographic Information Council (NSGIC) in Annapolis, Maryland and the West Virginia Association of Geospatial Professionals 2014 Conference held in Charleston, West Virginia. The coordinator participated in sessions of the GISCI Board of Directors, NSGIC Leadership group, West Virginia Information Technology Council, West Virginia Broadband Deployment Council, E911 Council, West Virginia Association of Professional Surveyors, and NSGIC's NextGen 911 and Broadband workgroups.

Broadband Mapping and Planning Program

Statewide broadband mapping, planning, and technical assistance continue with the support of a \$4.7 million grant from the U.S. Department of Commerce National Telecommunications and Information Administration (NTIA), funded through the American Recovery and Reinvestment Act. The goal of this project is to increase broadband access and adoption through better data collection, broadband planning and technical assistance. Besides being displayed in NTIA's national broadband map, data gathered under this program is displayed on a state interactive mapping application. This tool informs policymakers' planning and build-up efforts and provides WV citizens with improved information on the broadband Internet services available to them.

Technical Assistance: After conducting community-level research to assess and investigate areas with low broadband adoption rate, the West Virginia Geological and Economic Survey developed a statewide Broadband Technical Assistance Grant Program to improve broadband adoption. The program provides direct technical assistance and funding to organizations authorized under the program, as well as to individual municipalities that want to promote broadband demand and adoption. 39 grants were awarded during the second round of funding, for a total of 72 grants for the entire Program period.

Regional Broadband Technologies Planning Teams: This project supports local planning groups in each of the 11 West Virginia Planning and Development regions. Each planning and development region hosted a regional council that worked with stakeholders to develop regional broadband

awareness and adoption plans for their individual regions. As part of this work, each regional council administered and analyzed a survey designed to assess the opportunities for broadband-based economic development. The resulting regional plans serve as foundation for the Statewide Broadband Strategic Plan.

Mapping: Twice during the year, data from the state's broadband providers was collected and submitted to NTIA for inclusion in the National Map. This data was verified and then used to update the interactive online map.



COAL RESOURCES

Coal-bed Mapping Project (CBMP)

Survey coal geologists continue to characterize West Virginia's large coal resources using the statewide GIS (Geographic Information System). Seam-based GIS layers include structural contours, outcrops, mined areas, isopachs and percent partings. Mapping of coal quality parameters is slowly being developed. All products are regularly updated and can be viewed on the Survey's web site. Shapefiles of all products are made available to all interested parties that request them. In addition, products are used by the West Virginia Department of Tax and Revenue to generate tax revenues to fund many important parts of the State's infrastructure, notably, county education systems. The past fiscal years have been challenging as training replacements continues to impact

productivity. Personnel losses continue to adversely impact progress towards completion of the project. However, nearly 95% of the coal measures have been mapped to date and, barring future personnel disruptions, the initial mapping of the entire state is anticipated in the near future. Resources are being focused on updating, refining, and increasing products provided to customers.

New data are being added continually to the Oracle-based stratigraphic database through cooperation with industrial and governmental agencies, targeting areas of low data density. These additions allow continual refinement of map products.

Geologic Mapping Projects

Coal Program geologists continue to participate in the federally funded STATEMAP project, mapping quadrangles that lie between internally mapped Elk Map areas and eastern panhandle areas currently being mapped by other Survey staff geologists. Numerous data have been collected, geologic contacts have been drawn and the new products are constantly being reviewed by Survey geologists. These projects produce 1:24,000-scale geologic maps in digital format for parts of the state that have received little attention since the early 1900s. These geologic maps will enhance on-going efforts in adjacent areas to update the state's quadrangle geology. Witmer quadrangle was finished this spring; Harman quadrangle is currently being mapped.

Coal Quality

The Coal Program maintains a large and growing computerized database of various chemical and physical characteristics of West Virginia coals. This valuable database has been very effective in aiding potential customers to identify specific West Virginia coals that meet their needs for power generation and to serve as chemical feedstock or as a source of coal-to-liquids applications. Discussions between the Coal Program and National Energy Technology Laboratory (NETL) continue to examine the relative concentration of rare earth elements (REE) in West Virginia coal beds and partings. Early data collected by the Survey through past projects suggest that some coal beds contain high enough concentrations of a suite of REEs to be economically viable. Early results are promising and it is hoped that this important project will be continued.

National Coal Resources Data System (NCRDS)

This long-running cooperative research initiative between the U.S. Geological Survey and the WVGES Coal Program has enabled both partners to maintain and grow their respective coal databases. In addition to facilitating important research on various aspects of coal, coal mining, and resource analyses, the cooperative has resulted in the collection of valuable data on the occurrence, distribution and quantities of various trace elements found in West Virginia's coal measures. While many federal programs are under economic stress, the NCRDS program in West Virginia has been continued through June 2015.

Underground Mine Mapping Project

Coal Program geologists, in conjunction with the West Virginia Office of Miners' Health, Safety and Training (MHST), continue to expand the large collection of coal mine maps by obtaining previously unavailable historic underground mine maps from various repositories. The footprints of newly obtained maps are digitized and added to the Survey's coal bed GIS. Ancillary information is entered into WVGES's stratigraphic database for use in the statewide coal bed GIS. This past year, Coal Program geologists, in cooperation with MHST, collected several thousand mine maps from a newly discovered repository. These have been scanned and currently are undergoing review and processing prior to inclusion in the permanent collection. This massive task continues.

Mine Information Database System

Work continues on updating and expanding WVGES's Mine Information Database System (MIDS) as new mine maps and information become available. The MIDS database contains information on mine maps, including bed mined, mine names, company names, location information and permit numbers. MIDS contains records of every mine map available at the WVGES and comprises more than 44,000 documents depicting more than 71,000 mines. Submissions and comments from online users are requested to make the system more complete and user friendly.





WEST VIRGINIA GEOLOGICAL AND ECONOMIC SURVEY

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