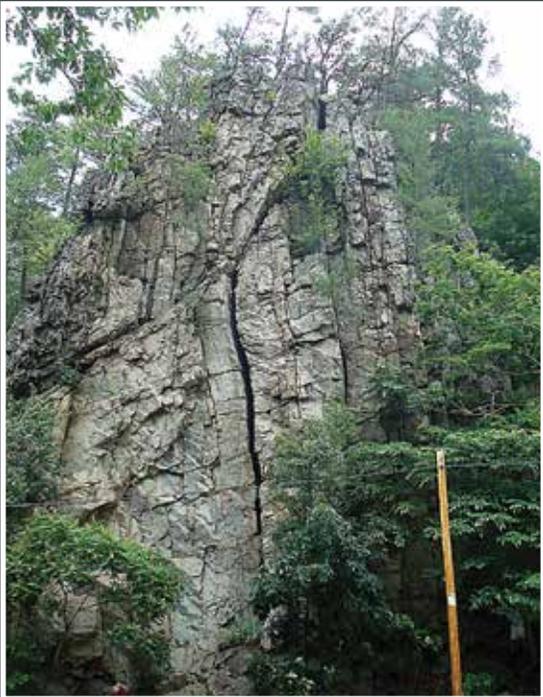




2013 ANNUAL REPORT



West Virginia
WEST VIRGINIA

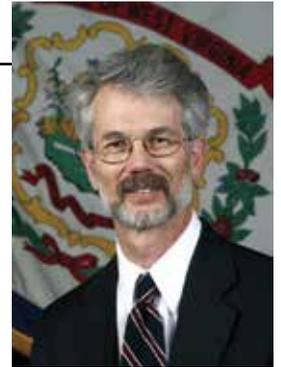
MESSAGE FROM THE DIRECTOR

GEOLOGISTS HAVE MANY TOOLS for studying rock strata underground.

Geophysical tools allow scientists to infer such factors as rock type; porosity, the proportion and connectivity of void space in the rock; number and orientation of natural fractures; and percentage of organic material in a well. After a hole such as an oil or gas well has been drilled, geophysicists lower a string of tools down to the base of the well and record a number of electrical signals while slowly raising these measuring devices back up to the surface. For example, one geophysical tool measures the natural, low-level radioactivity of organic-rich shale units, providing a picture of the thickness and depth of important hydrocarbon reservoirs, including the Marcellus Shale.

Seismic surveys are a way of imaging the subsurface of a geographic area, showing folds and faults as well as the depth and thickness of stratigraphic units. The geophysicist generates sound waves at or near the surface with small amounts of explosives or vibrating plates. Sound waves travel through the rock and are reflected back to the surface by changes in rock density. Tools arrayed on the ground record these returning waves and these data are used to create a seismogram that must be interpreted by a geologist. Despite the power of these tools to help us picture what we cannot see directly, nothing replaces observations made from actual rock. Even a 3-dimensional seismic survey costing upward of \$1 million per square mile needs at least one core to verify the seismic signature from a sequence of rocks. One way to obtain the needed subsurface rock samples is by coring or collecting samples while exploring or developing coal, oil and gas resources. Cores may be recovered at great cost while drilling an oil or gas well or in the form of side-wall cores after the well is drilled and before final completion. Composite samples called "cuttings" are typically taken every 10 feet in an oil or gas well. Coring in the coal industry takes part in both planning a mine and subsequent development. These invaluable samples allow the geologist to directly study rock type, porosity, chemical composition and fracturing.

Our agency stores and makes available for study cores from 153 oil and gas wells, representing 29,704 feet of rock. At an estimated average cost of \$350 per foot, this adds up to \$10.4 million in value. We also store rock samples or "cuttings" from 4,460 wells, representing 9,783,896 feet of rock.



Although expensive to collect, cores and cuttings last for generations if curated properly. Many cores of current interest were collected decades ago. The Sand Hill well was the first in West Virginia to penetrate the deeply buried Precambrian basement rocks. Cored in 1955, until recently it was one of few in our region with samples from strata equivalent to the Utica shale, a unit now being actively researched for oil and gas potential in West Virginia and adjacent states. Similarly, as part of the U.S. Department of Energy Eastern Gas Shales Project in the 1970s and 1980s, several cores were collected in West Virginia from shale units such as the Marcellus and are currently housed at our repository. We receive inquiries nearly every week from researchers looking to examine and analyze these rare samples.

In recent years, researchers from companies, universities, and government agencies have used cores and samples in our repository to study such topics as oil, gas and coal resources; potential for geothermal energy; carbon sequestration; and the thickness and ages of rock strata that underlie West Virginia. Results from all analyses conducted on samples taken from the WVGES are required to be submitted to this agency within a reasonable time period, so we are also building a repository of geological knowledge.

As one of our geologists wrote: "Cores and samples remain the gold standard for geological research."

A handwritten signature in blue ink, which appears to read "Michael Ed. Hohn".

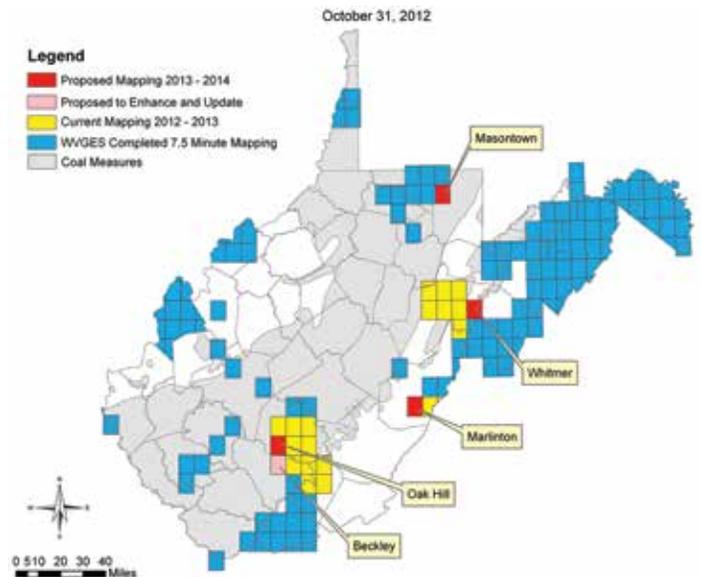
Michael Ed. Hohn

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 digital conversion of new and existing geological information from hard copy (paper, Mylar, etc.).

- 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 2012 and spring of 2013, field work was conducted on three 7.5 minute topographic quadrangles in central and eastern West Virginia (Glady, Minnehaha Springs and Sunrise). Published as WVGES Open File Reports, the data are currently available as paper maps and PDF files; digital conversion of the maps is complete and in the process of review. In October 2012, the STATEMAP Advisory Committee, composed of individuals from industry, government and academia, met to evaluate four new potential map areas within West Virginia for the upcoming 2013 field season. Mapping of the Marlinton, Whitmer, and Oak Hill quadrangles was proposed to the USGS in November 2012 and all three projects were partially funded. Fieldwork on new STATEMAP projects began in June 2013.
- 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 three-year period, a consortium of geologists from WVGES, West Virginia University, and Concord University mapped the bedrock and surficial 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 Area, and the Bluestone National Scenic River Area. Field work and digital conversion of maps for this project continued to the end of the Fiscal Year under a project extension granted by the Park Service.
- Digital conversion of existing and future map information is a high priority at WVGES. During FY 2013, digital maps of the bedrock geology for the Glady, Minnehaha Springs, Sunrise, Morgantown North, Mozer, Maysville, Medley, Beckley, and all NPS project quads were completed. In addition, digital maps of the surficial deposits of the Sector, Romney, Old Fields, Petersburg East, and Petersburg West quads also were finished.



Mine Pool Atlas Project

The Mine Pool Atlas project was a two-year study funded by the West Virginia Department of Environmental Protection (WVDEP) to evaluate abandoned coal mines as potential groundwater sources. This study, which addressed the potential for large volumes of groundwater storage based on mine void volume, was designed to facilitate prospecting for large volumes of water by using available Coal Bed Mapping Program (CBMP) products to identify underground coal mines that have the potential to store large quantities of groundwater, especially those mines located below or near drainage. The completed Mine Pool Atlas was submitted to and accepted by the West Virginia Division of Environmental Protection in October 2012.

Geothermal Resources

WVGES is participating 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. During the third year of the project, WVGES provided Web-accessible versions of temperature logs, Bottom Hole Temperature (BHT) data, 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, submitted 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: <http://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 state's Department of Environmental Protection (WVDEP) concerning UIC draft permits. During FY 2013, WVGES provided input regarding geologic conditions at injection sites for 20 Class V UIC draft permits.
- Geochemical analyses for 38 rock samples collected during STATEMAP mapping reconnaissance were added to the existing stratigraphic geochemical database bringing the number of samples up to 990 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.

Seismic Monitoring

A single earthquake occurred in West Virginia during the Fiscal Year — a 3.4 magnitude quake in Braxton County. Although located more than 25,000 feet below the surface, its magnitude and geographic proximity to previous earthquakes in that area raised renewed concerns about drilling activity, the county's wastewater disposal well, and induced seismic activity. Geoscience personnel were called upon to respond to public and governmental inquiries regarding this issue. During the 2013 Fiscal Year, 14 new seismic stations associated with the EarthScope Program sponsored by NSF and the IRIS consortium went online supplementing the single station located at WVGES. These new stations will be operational for two years and, pending additional NSF funding, two to four of these stations will be left in place. Early in 2013, WVGES became a participant in a new seismic research initiative, MAGIC (Mid-Atlantic Geophysical Integrative Collaboration). MAGIC is an NSF-funded project administered jointly by The College of New Jersey and Yale University. It involves the installation of 28 seismometers from Virginia to Indiana across the Appalachian Mountains. The data gained from these seismometers will be used to help characterize the Earth's mantle and ultimately help in identifying the reasons behind the ongoing uplift of the Appalachian Mountains.

Outreach Activities

- Geoscience personnel were invited to contribute geological materials, information, and expertise for use by the Boy Scouts of America at the National Jamboree to be held at the new Summit - Bechtel Family National Scout Reserve in Raleigh and Fayette counties in July 2013.

- Geoscience personnel authored material on the Marcellus Shale in West Virginia for a new publication by the United States Geological Survey: Enomoto, C., Coleman, J., Jr., Haynes, J., Whitmeyer, S., McDowell, R., Lewis, J., Spear, T., and Swezey, C., 2012, "Geology of the Devonian Marcellus Shale—Valley and Ridge province, Virginia and West Virginia—A field trip guidebook for the American Association of Petroleum Geologists Eastern Section Meeting, Sept. 28–29, 2011": U.S. Geological Survey Open-File Report 2012–1194, 55 p.
- In November 2012, Geoscience personnel presented a poster titled "Some Geospatial Tools and Techniques for Geologic Mapping in West Virginia's Plateaus" (McColloch and McColloch, 2012) at the Southeastern Geological Society of America Meeting in Charlotte, N.C.
- Geoscience personnel attended local, regional, and national meetings featuring major topics including geological hazards, induced seismicity, and environmental issues related to oil and gas exploration and development.
- Geoscience personnel taught evening classes in Geological Hazards and Historical Geology at Fairmont State University.

Geoscience Education Outreach

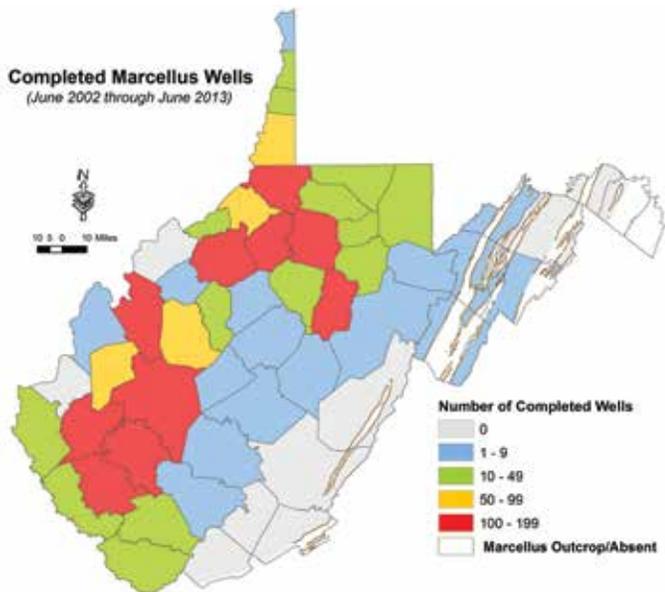
Geoscience Education Outreach operates a completely digital program providing K-12 teachers with products designed for their classroom use. In FY 2012-2013, 153,412 visitors to the website accessed new and updated information and activities.

OIL AND GAS PROGRAM

This year proved to be another exciting and successful year for oil and gas development in West Virginia. Geologists in the Oil and Gas Program continue to explore the wealth of data generated from Marcellus Shale drilling while also delving into historic records to aid in the understanding of ways to maximize the potential of conventional reservoirs. These historic records play a vital role in the understanding of the past 150 years of oil and gas development in the state and also serve as an important component for future drilling programs.

The Marcellus and Utica Shales

The Marcellus Shale remains the largest producer in West Virginia of methane, or "dry gas," as well as ethane and other natural gas liquids known as "wet gas." Well counts for the year stand at 2,155 completed wells and 829 active permits. The number of completed wells increased from FY 2012 while the active permit count decreased slightly, reflecting a continued shift from the exploration to development stage of the play. A majority of wells are now drilled horizontally, with up to six or eight wells located on a single pad. Permitting activity is greatest in the northern panhandle and the northwestern portion of the state. Wells drilled in these areas often yield higher quantities of natural gas liquids and the potential of an area to yield these liquids (which price on-trend with oil) continue to be some of the main driving factors in the play's development.



One of the biggest questions surrounding the Marcellus Shale is “how much gas is there?” To help answer this question, one of our geologists is working toward a comprehensive Resource Assessment of the Marcellus Shale. This Assessment takes into account reservoir parameters such as thickness and area and combines them with gas present in-place to determine total original in-place gas volumes. Large amounts of data, taken from well logs, core samples and production reports, are necessary to conduct the evaluation. Preliminary results were presented at the American Association of Petroleum Geologists (AAPG) annual meeting and were well-received by the geologic community.

The Utica Shale and underlying Point Pleasant Formation also are being targeted in West Virginia. To date, one well has been completed in Brooke County and another permitted in Marshall County. WVGES maintains a collection of core and cuttings samples from deep wells drilled throughout the state, many of which have been sampled recently as operators continue to test the potential of the Utica/Point Pleasant interval. This interval lies at least 1,500 feet below the Marcellus, however, which increases the technical challenges inherent in any horizontal drilling and completion program.

CO₂ Research and MRCSP Participation

Work continues on the Midwest Regional Carbon Sequestration Partnership (MRCSP) study of the viability of enhanced oil recovery via CO₂ flooding. Most of the progress made by WVGES staff on this project involved compilation of data from West Virginia’s historic oil fields for a poster presentation given at the annual AAPG meeting. The presentation, titled “Assessing Suitability of Depleted Fields for Enhanced Oil Recovery in West Virginia,” looked at production from oil fields dating back to the late 1800s and assessed the potential for remaining reserves. Several of the fields appear to have been only minimally depleted and present a good opportunity for future drilling using modern technology. A major hurdle for CO₂ enhanced oil recovery in West Virginia is the sourcing of CO₂. Although coal-fired plants are located close to the fields, the cost to retrofit a plant to capture and utilize the CO₂ requires a large capital expenditure. Nevertheless, the remaining oil reserves do hold significant promise for future production.

Brine Disposal and RPSEA Participation

Work began this year in support of the Research Partnership to Secure Energy for America (RPSEA) basin-wide brine disposal project. Preliminary analyses involve the compilation of injection well data and testing of rock properties from core samples. West Virginia donated several core samples to the project which will yield valuable data to aid in the understanding of brine disposal pathways and best practices for the management of produced water.

Oil and Gas Data Development

A major goal of the Oil and Gas Program continues to be capturing and preserving data from historic records. In many cases, WVGES holds the only copy of location plats and completion reports for wells drilled as far back as the late 1800s. Records for old wells are requested frequently by our user groups, including land men researching ownership records, geologists interested in historic reservoirs, and companies planning the development of coal resources. Many of the records are printed on fragile paper which does not withstand frequent handling. For these reasons, our staff has been working to scan these old well records and make them digitally available. Emphasis has been placed on the oldest records and progress has moved from counties in the northern panhandle to north-central and western counties.

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.

We continue to make headway in a number of critical areas: promoting data sharing between 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 Department of Revenue, 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 received a Special Achievement in GIS award from the Environmental Systems Research Institute (ESRI) for his contributions to the development of the WDA/IJDC Interactive GIS application.

Data exchange protocols to enhance data sharing and exchange between state and local agencies established in the previous year 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 who have GIS programs about the latest technology and, at the same time, 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 Md. and the West Virginia Association of Geospatial Professionals annual meeting held at Stonewall Resort State Park. The coordinator participated in sessions of the WV GIS Policy Council, the West Virginia Information Technology Council, West Virginia Broadband Deployment Council, the GIS Steering Committee, E911 Council, West Virginia Association of Professional Surveyors, and the Statewide Addressing and Mapping Board.

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, 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 buildup efforts and provides West Virginia 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. Thirty-three (33) grants were awarded during the first round of grants and a second round of grants is being developed for the next fiscal year.

Regional Broadband Technologies Planning Teams:

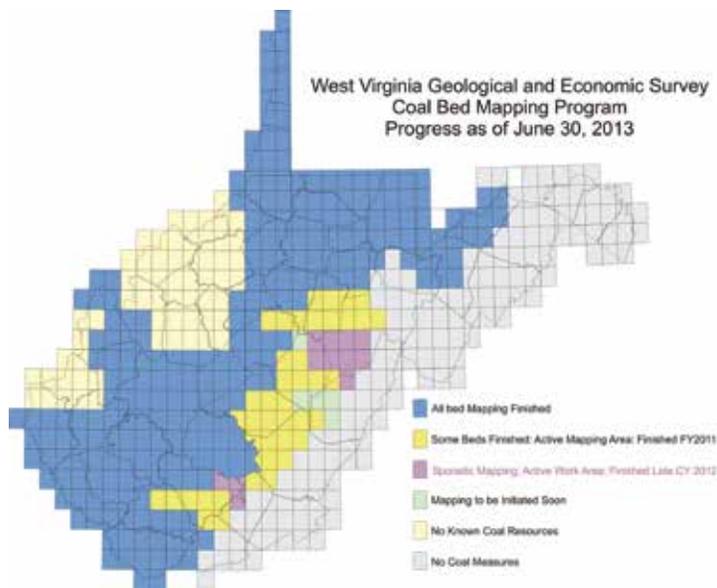
This project supports local planning groups in each of the 11 West Virginia Planning and Development regions. Each planning and development region currently hosts a regional council that works with stakeholders to develop regional broadband awareness and adoption plans for their individual regions. As part of this work, each regional council administers and analyzes a survey designed to assess the opportunities for broadband-based economic development. The resulting regional plans will serve as foundation for the Statewide Broadband Strategic Plan.

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

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 website. Shapefiles of all products are made available to all interested parties that request them. Also available are the various products used by the West Virginia Department of Revenue and the State Tax Department to generate tax revenues to fund many important parts of the state's infrastructure, notably, county education systems. The past fiscal year was challenging as training replacements for two geologists lost to the private sector impacted productivity



and the program slightly missed its annual production goals. Additional personnel losses will adversely impact progress toward completion of the project. However, more than 91 percent of the coal measures have been mapped to date and barring future personnel disruptions, we anticipate completing the initial mapping initiative in the next several years.

We continually add new data to our Oracle-based stratigraphic database through cooperation with various industrial and governmental agencies, targeting areas of low data density. These additions allow continual refinement of the various map products.

Geologic Mapping Projects

Coal Program geologists have finished geologic mapping (Elk Map) on five 7.5-minute quadrangles near Elkins in Randolph County: Junior, Elkins, Beverly West, Beverly East and the Sinks of Gandy. Maps are in various stages of final preparation. In addition, program geologists continue to participate in the federally funded STATEMAP project, mapping quadrangles that lie between Elk Map areas and eastern panhandle areas currently being mapped by other 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 ongoing efforts in adjacent areas to update the state's geology. Gladly quadrangle was finished this spring and Witmer is the current mapping target.

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-liquid applications. Discussions continue between the Coal Program and National Energy Technology Laboratory to examine the rare earth element (REE) content of 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. These early discussions will continue with an eye to analyzing additional coal samples to expand this knowledge base. The cooperative agreement with the Kentucky Geological Survey to analyze coal samples at a reasonable cost was continued in FY 2013. This agreement fills a void created when the Survey lost its laboratory due to infrastructural changes at West Virginia University. The Survey continues to collect coal samples from previously poorly characterized areas to enhance the Survey's Coal Quality databases. Several deep coal bed methane cores, donated to the state by an industry partner, were analyzed through this cooperative agreement.

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 2014.

Underground Mine Mapping Project

Coal Program geologists, in conjunction with West Virginia's 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' stratigraphic database for use in the statewide coal bed GIS. This past year Coal Program geologists, in cooperation with WVMHST, 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.

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 is composed of 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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