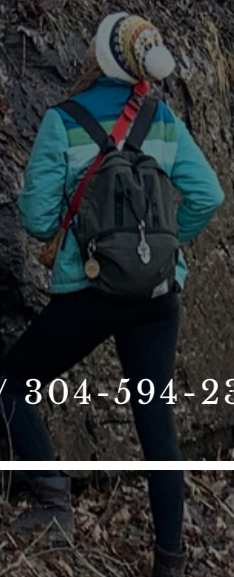
WEST VIRGINIA GEOLOGICAL & ECONOMIC SURVEY

WVGES

West Virginia Geological and Economic Survey

2023 ANNUAL REPORT



www.wvgs.wvnet.edu / 304-594-2331 / info@wvgs.wvnet.edu

Cover Photo

A WVGES geologist observes a road cut while conducting mapping field work in Glenray, West Virginia.

West Virginia Geological and Economic Survey
Mont Chateau Research Center
1 Mont Chateau Road
Morgantown, WV 26508

Phone: (304) 594-2331
Fax: (304) 594-2575

Email: info@wvgs.wvnet.edu
Website: www.wvgs.wvnet.edu

WVGES
West Virginia Geological and Economic Survey

EXECUTIVE SUMMARY

Jessica P. Moore, Director and State Geologist

The following report details activities conducted during Fiscal Year 2023 by the geoscientists and professional staff of the West Virginia Geological and Economic Survey (WVGES). Starting the year in July means that we begin with STATEMAP bedrock geologic mapping in full swing, with field crews making the trek across the Greenbrier Valley to map several quads, including Asbury, Cornstalk, and Lewisburg. In the coal measures to the north and west, a geochemical reconnaissance study funded by the U.S. Geological Survey's Earth MRI Program reports that clay-rich units associated with Allegheny Formation coals are consistently enriched in critical minerals such as rare earth elements. These results are included in an eight-state regional study to be published as WVGES Reports of Investigation 37, with a companion study of metalliferous organic shales funded for FY24. The geochemical data will be synthesized with Earth MRI high-resolution radiometric and magnetic surveys collected over an aerial transect from Morgantown south to Elkins and across the eastern panhandle to Harpers Ferry. When combined, these modern datasets provide an unparalleled opportunity to examine the region's geologic framework and mineral systems.

Potential beneficial reuse of coal waste for critical minerals is also being examined as part of the U.S. Department of Energy's CORE-CM Program. Much of this work focuses on building local stakeholder networks, including a capsule project in Logan and Mingo counties. The rugged topography and dense tree cover of Appalachia makes it difficult to identify and characterize gob piles and impoundments from remotely sensed data, underscoring the importance of gaining insight and knowledge from the people who live and work in our coalfield communities. There is a strong generational component to this knowledge base, and efforts must be made now to collect and preserve data and materials from legacy energy communities before they are lost to time. With the support of U.S. Senators Shelley Moore Capito and Joe Manchin, the WVGES fortunately received a Congressionally Delegated Spending award for construction of a modern storage facility to preserve geologic samples and inform energy communities of the future.

As the nation transitions to more diverse energy sources, research into the potential for deep direct-use geothermal systems and carbon capture and storage (CCS) continues to gain momentum. Recent policies established by the West Virginia Legislature position the state to be a leader in these technologies. WVGES supports CCS and geothermal research through multiple projects funded by the U.S. Department of Energy, including the Midwest Regional Carbon Initiative, Consol's 21st Century Power Plant Project, and West Virginia University's Deep Direct Use Geothermal project, which will collect data from a newly drilled deep test well located just outside of Morgantown.

In support of West Virginia's past, present, and future energy communities, the Geological and Economic Survey remains faithful in our mission to examine, document, and preserve the geological record of our remarkable State.

I hope you enjoy this year's Annual Report and we invite you to learn more on our website or by visiting our free mini-Museum in Morgantown!

COALBED MAPPING PROJECT (CBMP)

The CBMP continues updating the Geographic Information Systems (GIS) database of mined and remaining coal to provide as complete a snapshot of known mining as possible.

A large donation of thousands of underground mine maps, property maps, engineer drawings, geologic cross sections and data were given to the WVGES to archive. (For more information see the Donations, Samples, and Data section on page 5).

The WVGES was able to rescue several hundred out of state mine and property maps that were passed on to Pennsylvania, Kentucky and Virginia representatives to be added to their archives.

CBMP's 86 mineable coal seams and splits are updated to improve the overall data model utilizing an Oracle database of coal elevations and thickness data with nearly 191,650 points. Over 38,000 of these points are detailed drill holes, 437 of which were added in FY23. Furthermore, an additional 3230 thickness or elevation points were collected from scanned mine maps adding to the 134,764 total points.

The State Tax Department uses CBMP to accurately and equitably value properties for tax assessment. Shape files of coal mine location, mining type, coal thickness, elevation, and percent parting grids, mined and remaining areas and overburden information are created from the CBMP database for easy online access.

Data sets are free and easily accessible to everyone on the WVGES website at http://www.wvgs.wvnet.edu/www/coal/cbmp/coalims.html

UNDERGROUND MINE MAPPING PROJECT

New and legacy mine maps were collected from various sources including industry archived datasets and private collections. Several paper maps of higher quality than existing scanned images were collected, scanned and added to the data set. Paper copies are archived when possible.

The project received 71 new mine maps representing 188 individual mines in FY23. Each mine map was examined to see if it is in our system. If new mined areas are identified, they and any associated data, are entered into the data model.

Large-format historical mine maps are scanned to create high-resolution digital images. Many small areas were added to existing mine footprints along with several 'new' mines in depleted areas where mine maps have been difficult to collect.

The CBMP continues to increase the accuracy of the data model. As more data is added, a clearer understanding of the depositional environment associated with the coal seam comes into focus.

All information is made available to the public, industry, and government to inform companies, landowners, and citizens about potential hazards while allowing more accurate equitable property valuation.

The CBMP works in cooperation with the West Virginia Office of Miners Health, Safety and Training, West Virginia Department of Environmental Protection, and the West Virginia Department of Tax and Revenue, Property Tax Division, the Department of Interior Office of Surface Mining Reclaimation and Enforcement.

MINE INFORMATION DATABASE SYSTEM (MIDS)

MIDS houses publicly accessible information collected from mine maps including mine name, company name, mined seam, county and quad and various notes with a link to download most scanned mine maps images.

The database contains 49,953 documents representing 91,741 mines in total.

WVGES encourages mine-map submissions and remarks from the public to improve our database. If you have a mine map that you would like to donate, allow us to scan or if you see an error in our database, please contact us at info@wvgs.wvnet.edu.

MIDS is accessible from the WVGES website at
http://www.wvgs.wvnet.edu/www/mids/main.php

COAL CHEMISTRY DATABASE

The Coal Chemistry database contains coal analyses, accessory minerals, and critical mineral data, including Rare Earth Elements (REEs), and many other types of information for all mined and unmined coal in West Virginia. This includes a large archive of physical samples, many of which have been re-analyzed for recent critical mineral projects.

The database provides non-confidential laboratory analyses of coal samples from industry donations and decades of WVGES sample collection.

The first iteration of a publicly accessible data search engine has been created showing critical minerals and rare earth elemental data and is available at WVGES Coal Sample Records.

This can be accessed here:
https://www.wvgs.wvnet.edu/www/critical_minerals/app/CoalSampleSearch.aspx

BACKPACK CORE DRILLING

WVGES Coal section purchased a backpack core drilling unit partially funded by a Federal grant. This unit allows the collection of shallow cores for formation characterization. The resulting material was used for investigations into REEs and Critical Minerals (CMs).

Two WVGES geologists collect core samples using the backpack core drilling unit.

A WVGES geologist prepares the backpack core drilling unit to collect samples in the field.

WV COAL AND CRITICAL MINERALS (CMs)

Could the nation's (and, closer to home, Appalachia's) historical problem with coal waste help pave the way for our energy future?

That's the question the U.S. Department of Energy's Mineral Sustainability Program aims to answer through its Carbon Ore, Critical Minerals, and Rare Earths (CORE-CM) funding opportunities, which were awarded to 13 multidisciplinary teams located in coal basins throughout the United States. Researchers from WVGES, West Virginia University, Virginia Tech and the University of Kentucky received an award for the Mid-Appalachian Carbon Ore

and Rare Earths (MAPP-CORE) initiative, which will characterize critical mineral concentration and distribution in several legacy waste streams, including acid mine drainage, coal fly ash and gob piles. In addition, the coal and carbon-rich waste materials (aka "carbon ore") will be evaluated for use in advanced materials and manufacturing. Research performed by WVGES includes a basinal analysis of the resource performed by calculating mined and remaining coal for major seams in Kentucky, West Virginia, and western Pennsylvania. When this data is assembled a database of elemental composition and concentrations of critical minerals (several of which have been identified in previous studies), and location and volumetric assessment of waste impoundments and ash ponds is created.

The location and assessment of legacy waste impoundments presents several unique challenges such as, older refuse piles have been re-vegetated and are difficult to locate using aerial photography, but were sorted using older technology, leaving behind significant volumes of higher quality coal along with rare earth element-bearing clays in the discarded floor and partings. Newer impoundments, especially those constructed after federal regulations were instituted in the late 1970s, are highly engineered structures that were not designed to be disassembled but contain large volumes of materials, often have supporting data and information available from regulatory agencies and are easier to locate and access.

Critical Minerals, as defined by Federal Executive Order 13817, include 31 elements, oxides or mineral compounds used in modern technological applications including renewable energy sources, communications devices, household products, and defense tools. A majority of the critical minerals come from non-domestic sources, which has significant economic and security implications for the country.

The Earth MRI project uses a mineral systems approach to define areas of enrichment, and the mineral systems that potentially contain rare earth elements (REEs).

EARTH MAPPING RESOURCES INITIATIVE (MRI) FOR CRITICAL MINERALS

In FY21, WVGES was awarded $125,000 from the U.S. Geological Survey to coordinate a geochemical reconnaissance study across an eight-state region spanning the Appalachian and Illinois basins.

The study evaluated the critical mineral potential of clay-rich strata associated with coal beds, often known as underclays. The clay-rich material is often discarded during the mining process and could potentially be processed for beneficial reuse.

Multiple areas of critical mineral enrichment were identified in underclays across the region, especially rare earth elements, but also other critical mineral resources such as lithium.

Work focused on the Pennsylvanian-aged coal measures, which were deposited in an equatorial climate with humid, ever-wet conditions creating laterite (a soil type rich in iron and aluminium) deposits similar to those being mined in China today.

The study concluded in June of 2023 and will be published in FY 2024 as WVGES Reports of Investigation 37.

DONATIONS, SAMPLES, & DATA

A large contribution from a generous patron provided a moving van full of maps and data from properties scattered throughout the state. Much of the new data was situated in central WV where drill hole data is scarce. This allowed for a reworking of the previous correlations extending roughly from northern Kanawha county through Clay, Nicholas, Webster and into Barbour counties. Coal Section geologists revisited and corrected historic correlation issues that were previously unresolvable due to lack of data.

SOFTWARE LICENSES

The IHS Markit University Grant Program generously donated networked software licenses for both the seismic data interpretation Kingdom® software, as well as the subsurface mapping program Petra™. These modern software applications are essential to assimilate, analyze, and map disparate datasets. They enable WVGES to develop analysis skills and keep current with other state geological surveys. This software allows WVGES to interpret, map, and package data used by a variety of stakeholders. Their acquisition can be financially challenging for government organizations. These donated network licenses are valued at more than $750,000, a generous award at no cost to the taxpayers of West Virginia, and an amount WVGES would be unable to afford otherwise.

MAINTAINING WVGES' SAMPLE REPOSITORY

This collection represents the most comprehensive group of geological samples in West Virginia. WVGES maintains over 28,000 linear feet of core from coal, oil and gas exploration, cuttings samples from thousands of wells and boreholes, and hundreds of samples collected during fieldwork by agency geologists. Housing, cataloging, curating, and updating this large, complex, and irregular collection is difficult and space is always an issue. Our facilities are near-capacity and not all climate-controlled; it is imperative that physical material be preserved for current and future research. As oil, gas, and coal companies downsize their operations in Appalachia, elimination of sample storage space is often one of the first cost-saving measures adopted. Many of these companies have long standing relationships with WVGES and frequently offer to donate sample material rather than see it disposed of and/or destroyed. Cores and cuttings can also be requested by WVGES via legislative authority outlined in WV

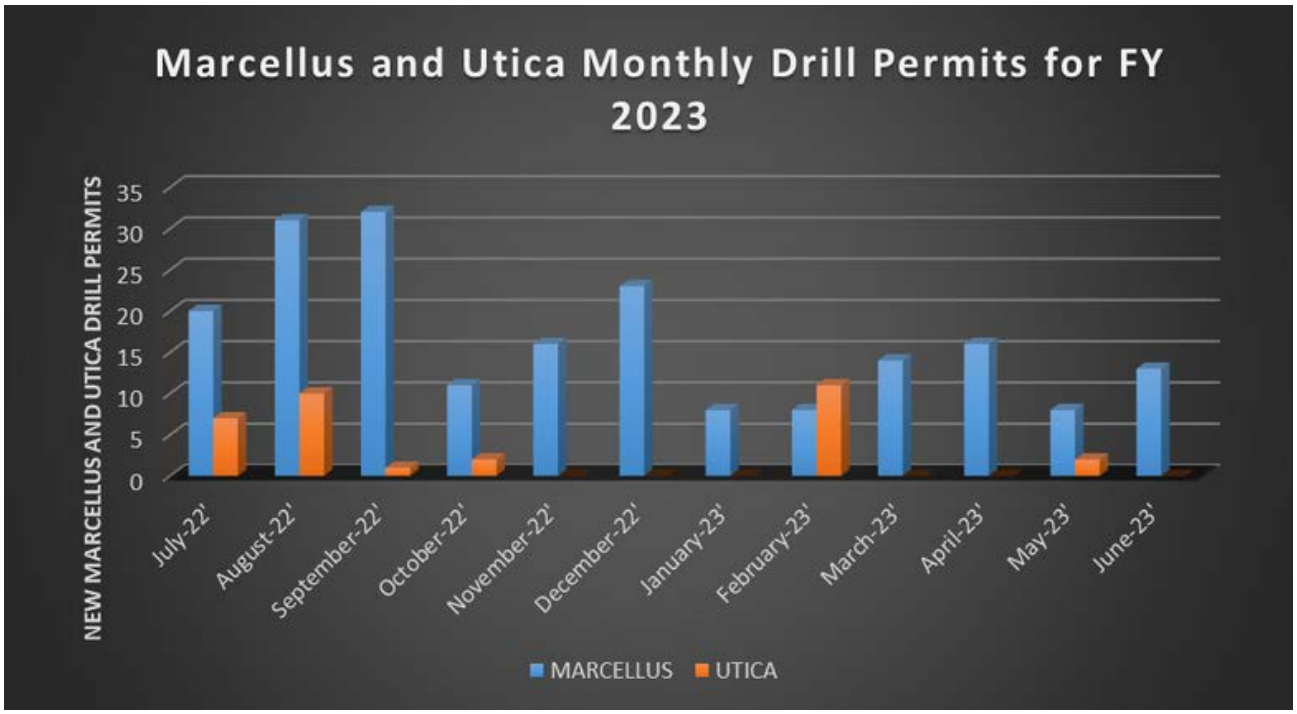
Code 22-6-22. Additionally, results and analyses from outside researchers must be submitted to WVGES resulting in advanced analytical data sets at no cost to the taxpayer.

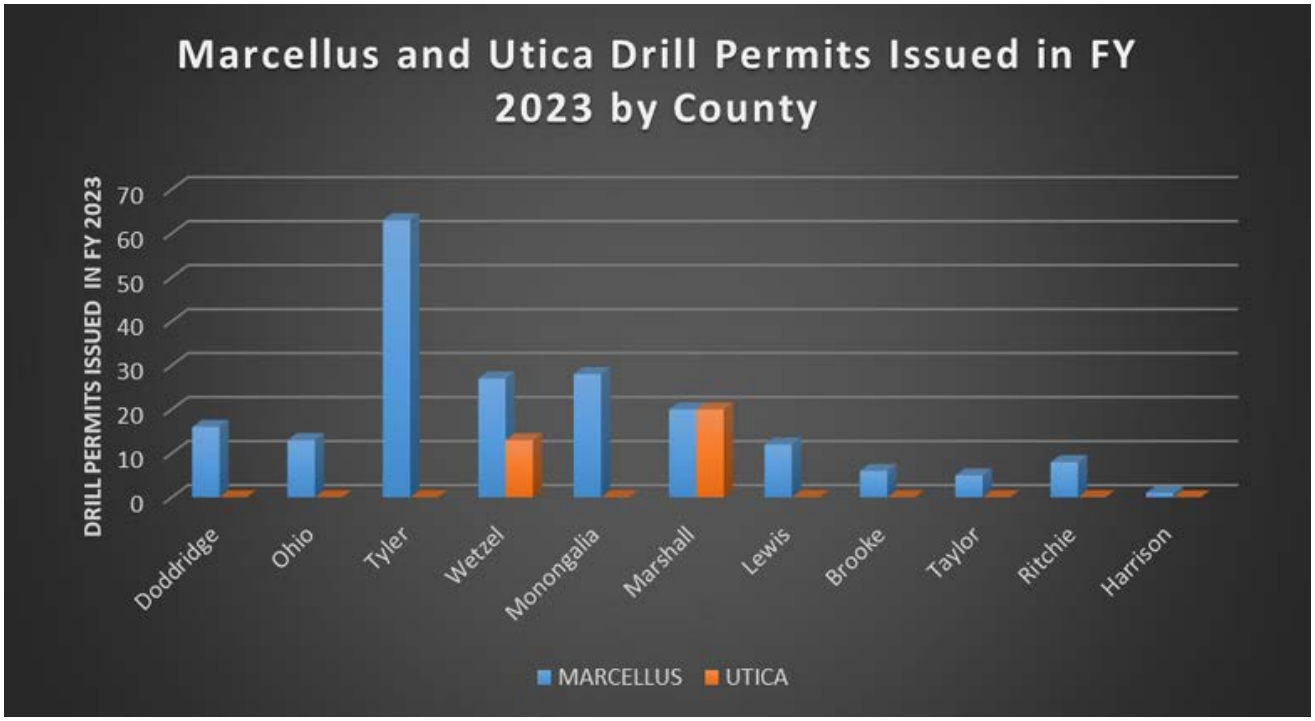
In addition to the requests outlined in WV Code, WVGES accepts donations of geologic material and data from individuals, industry professionals, and academic institutions. WVGES, in turn, makes access to these collections public. Preserving data and samples has heightened importance as exploration companies enter and exit the basin with assets continually changing hands. WVGES seeks to maintain and foster deep relationships with industry partners and stakeholders. Additionally, as a generation of geoscientists and engineers retire, many have contributed personal collections of records, maps, and geophysical logs. Over the past fiscal year WVGES received three significant core collections from Berkshire Hathaway Energies Eastern Gas Transmission and Storage, EQT, and TC Energy. In addition to geological samples that were received, a large collection of maps and data from the family of Philip Martin, who worked in the oil and gas industry, and later as a geologic consultant. WVGES appreciates these donations and has already incorporated these samples into current research.

OIL & GAS

Oil and gas drilling decreased by 14% in FY 2023. The number of permitted wells in FY 2022 was 271 but in FY 2023 that number dropped to 232. Tyler County has the most marcellus well permits totaling at 63 permits with Marshall County having the most Utica permits totaling at 20. The Marcellus is still the primary drilling target and accounts for 86% of the total drilling permits, with 199 wells permitted to be drilled. The second major target point is Utica/Point Pleasant, issuing a total of 33 permits in FY 2023. A total of 225 wells were plugged in WV in FY 2022 and compared to the 227 in FY 2023.

The OIL & GAS PROGRAM is responsible for research into current oil and gas trends, fields, and the evaluation of specific horizons using data such as well logs, cores, and associated samples. Managing physical samples as well as database curation allows requests from researchers, industry professionals, and governments to be easily accommodated. Historical documents and legacy samples are of new interest as scientific advances are made.





Total number of Marcellus and Utica drill permits issued by county. Tyler County had the most permits in FY 2023 with 63 new Marcellus wells being permitted.

GEOTHERMAL

NEW GEOTHERMAL TEST WELL AT WVU

West Virginia University continues to investigate utilization of deep geothermal resources for the energy demands of its Evansdale Campus, which was designed to run on electricity and steam produced from waste coal and generated at the WVU Physical Plant on Beechurst Avenue. The plant, slated to close in 2027, now supplies only steam to both WVU campuses and the university is actively researching ways to offset the energy load of its facilities. Following a feasibility study conducted in 2019 to characterize the geothermal potential of a local low-temperature anomaly, WVU received funding from the U.S. Department of Energy's Geothermal Technologies Office to drill a deep stratigraphic test well to a proposed total depth of 15,000 feet. The well is located at the Morgantown Industrial Park and was drilled by Northeast Natural Energy beginning in May of 2023. Core sampling is planned over several intervals along the wellbore, including from the shallower Devonian and Silurian sections, toinvestigate the potential for other applications, such as subsurface storage of CO2 or geothermal brines. WVGES will participate in the analytical work following sample retrieval.

GRANT WORK

NATIONAL GEOLOGICAL AND GEOPHYSICAL DATA PRESERVATION PROGRAM GRANT (NGGDPP)

The U.S. Geological Survey NGGDP program requires and evaluates submitted proposals each year and, if approved, provides funding to rescue and preserve at-risk scientific data while also making that data publicly available in accessible formats. WVGES has successfully been awarded funding multiple times, has an ongoing project that ends in July 2023, and was most recently awarded another two year project that began in May 2023 and will run until May 2025.

The activities undertaken by WVGES within this NGGDPP project will allow for better organization of collections, a higher quality of curation, and easier retrieval for current and future research. Increasing access to available samples and data will allow further research by the U.S. Geological Survey, WVGES and other entities of the state. Surrounding states in need of physical geological samples allows for partnership within, both, academia and private industries who are working to better characterize the resources of the country.

FY23 ONGOING DATA PRESERVATION PROJECTS

Project 1 (ending in July 2023)

WVGES capitalized on changes in the usage of funds permitted in the NGGDPP program announcement in FY22. Support for infrastructure improvements have been supported with an approval of funds for the WVGES to build a storage facility for the state's core, cuttings, and geological samples collection. In addition to the storage facility, funds were requested to curate crushed coal samples that were in deteriorating conditions. Furthermore, the survey has proposed to continue photographing cores through the coal measures that have been utilized for critical minerals research. The WVGES proposal was funded in full, and work began in May 2022.

Storage space for physical material at both WVGES headquarters and existing offsite locations was inadequate and the amount of core material donated or requested has continued to increase. As oil, gas, and coal companies downsize their operations in Appalachia, elimination of sample storage space is often one of the first cost-saving measures adopted. Many of these companies have long standing relationships with the state geological surveys in the Appalachian basin and frequently offer to donate sample material rather than see it disposed of and/or destroyed. Acquisition of high-quality core material via either mechanism is extremely advantageous for WVGES, but identification and maintenance of storage space is untenable.

A new 30' x 40' building was constructed on deeded parcel space at the WVGES office in Morgantown. The building, cement slab, and site preparation were completed in the period of performance and WVGES has been moving material into the building after construction was completed. One challenge that made the completion of this project difficult was the change in construction costs from when the quote was solicited to when the project was awarded and construction finished. Overall, the total costs incurred were well above the quoted materials and activity. While all goals of the project were completed the increased costs required WVGES to increase its contribution significantly.

With the completion of the building WVGES has significantly expanded the amount of available space for physical samples. Material that includes both oil & gas cores as well as coal exploration cores have been transferred to the new facility. However, much work remains with the building currently lacking electricity and shelving to fully utilize the space. WVGES is currently moving numerous cores and cuttings into the building, which are stacked on pallets and staff geologists are looking to move forward with fully equipping the space and maximizing use of the newly constructed facility.

WVGES has a decades-long history of curating samples collected from coal mining operations and the WVGES coal sample repository holds over 10,500 samples. Additionally, as coal mines close, the subsurface locations where the samples were collected are inaccessible; mines are either flooded post-closure, abandoned and permanently sealed, or are designed to collapse as the longwall mining proceeds through the seam. Therefore, these materials form a

representative sample set that cannot be replicated. WVGES is in the process of preserving these samples in plastic containers that will securely store the geological samples and provide a more easily accessible collection. WVGES has proposed to transfer 10% of this at-risk collection to newly purchased containers. Additionally, WVGES will be photographing two more cores that extend through the coal measures and have been used in critical minerals research.

Project 2 (May 2023-May 2025)

A two-year project began in May 2023 that will address several needs to preserve and make accessible geological data. Overall, six total subprojects will be undertaken by WVGES personnel. Two of these (critical mineral sample preservation and core photography) are continuations to the ongoing projects described above. These continuations will allow for a larger percentage of holdings to be preserved and more accessible.

In addition to the continuing projects, WVGES has commenced work on multiple fronts to both transfer data from legacy formats to modern formats as well as acquire new data from legacy geological samples. First, WVGES has an existing "Mine Information Database System" (MIDS) that contains information about specific mines in West Virginia. This system contains information such as location, company name, mine name, permit number, and targeted coal bed. Additionally, many entries in this system have mine map images with associated coal thickness, elevation data and other important geologic notes. Details on many of these images are illegible because they were originally scanned at low resolution from microfilm. WVGES requested funds to purchase an aperture card/microfilm scanner to produce high resolution images of these aperture cards. There are over 40,000 aperture cards in the WVGES collection. It is proposed that the selected images be scanned to record the data from the aperture cards.

Second, WVGES curates both physical samples and digital data associated with those samples. To make the collections of both more publicly accessible, WVGES will be constructing a database of available samples and data and create an interactive map web service for end users to access both the inventory and the data. Data is available from a wide variety of sources and includes expensive sample analysis conducted by industry partners that are now publicly available.

Third, WVGES previously established the digital framework of a comprehensive inventory and modern database of legacy coal samples and chemistry data. This effort modernized a portion of a substantial coal chemistry database containing greater than 40,000 analyses and over 10,000 physical samples, the majority of which were collected from exploratory drilling, active underground mining operations, or other field work. In this portion, WVGES focused on the major and trace element geochemical data. This database was previously compiled in numerous tabular and document files, in unsupported formats, and was not linked to information on sample availability. A comprehensive modernization of these data was conducted using an Oracle cross-linked table-based interface focusing on major and trace element geochemistry. In this current project,

WVGES will continue the modernization of the database including additional data and analyses not previously included (proximate and ultimate analysis). A web-based interface will also be created where this data can be searched by individual or multiple variables. Completion of this work would mark the first time much of this data and associated files would be available to the public via the WVGES website.

Lastly, WVGES will send 200 distinct samples to the USGS Geochemical Laboratory for new analyses to further the understanding of critical mineral resources in the rocks of West Virginia. These sample results will be completely new analyses that will add to a growing dataset of critical mineral potential in the state. These analyses will be publicly available and added to the national critical minerals datasets.

MIDWEST REGIONAL CARBON INITIATIVE (MRCI)

This project continues the work of the multi-decadal Midwest Regional Carbon Sequestration Partnership by combining forces with the Midwest Geologic Carbon Storage program in cooperation with state geological surveys and other stakeholders from 21 states in the Atlantic and Midwest regions. The goal of the project is leveraging knowledge gained through hydrocarbon exploration to identify reservoirs amenable to carbon capture utilization and storage (CCUS).

Reservoir evaluation is accomplished by defining regional carbon storage systems, constructing detailed geologic models, and packaging technical results in the form of searchable databases, maps, and web pages. Over 600 geologic layers were aggregated into an interactive map application during FY23, with future work focused on refining map data and adding well log data reference locations.

Targets in the Appalachian Basin include shallow depleted oil fields for enhanced hydrocarbon recovery and eventual CO2 storage via CO2 flood, deep saline reservoirs, or a combination of both for “stacked” storage. The project is funded by the U.S. Department of Energy in long-standing partnership with Battelle Memorial Institute.

This project is funded by the Dept. of Energy (DOE) with a focus on carbon capture, utilization, and storage (CCUS) projects and research. MRCI is a collaboration of the two following organizations: Regional Carbon Sequestration Partnerships (RCSPs) – the Midwest Regional Carbon Sequestration Partnership (MRCSP) led by Battelle and the Midwest Geologic Sequestration Consortium (MGSC).

Primary storage targets in the MRCI region include depleted petroleum fields and saline aquifers with recent interest in carbonate reservoirs; targets potentially can be combined for “stacked” storage providing multiple storage options for particular geographic areas. During FY23, an extensive report was written detailing MRCI research based on Carbon Systems or reservoir-caprock pairs. During FY23, work continued on the MRCI Interactive Map which provides

MRCI researchers access to over 600 maps. Focus was on summarizing log and core data for potential storage targets, developing test map tools, and documenting maps

- Basic geologic and injectivity data were assembled for various sites across the MRCI region, including two sites in West Virginia, for detailed geologic modeling, injectivity analysis, and reservoir simulation. Geologic models were built for both WV sites and preliminary carbon storage volumes were estimated. In addition, injectivity was analyzed. Furthermore, a multi-year injection and storage simulation was conducted for one of the WV sites to model CO2 injection and migration through the system, evaluate trapping mechanism(s), and refine storage volumes estimates, analysis, and reservoir simulation.
- A presentation was given at the annual American Association of Petroleum Geologists (AAPG) Carbon Capture, Utilization, and Storage (CCUS) Conference, "Defining CCUS in the Midwest, Northeast, Coastal Plain, and Northeast Offshore USA—A Bottoms Up Approach."

21ST CENTURY POWER PLANT (21CPP) INITIATIVE RESEARCH GRANT

This ongoing project will deploy modular high pressure fluidized bed combustion power generation, utilizing waste coal and biomass as feedstocks, with on-site carbon capture capabilities.

Funding is from the U.S. Department of Energy while research is conducted by Battelle Memorial Institute, Carbon Solutions, LLC, and both the Pennsylvania and West Virginia geological surveys in conjunction with industry partner Consol Energy.

In FY23, the project team evaluated multiple sites in Pennsylvania and West Virginia in proximity to Consol's Bailey Mine complex with formations prospective for storage of CO2. Deep geophysical logs and regional two-dimensional (2D) seismic lines are being evaluated. Site-specific locations and their most prospective geological formations were proposed for further investigation.

GEOSCIENCE AND MAPPING PROGRAM

WVGES completes new geologic mapping in West Virginia annually. The resulting maps and associated data serve as products to understand the geology of the state more fully at the surface. WVGES has been producing geologic maps since the survey's creation in 1897. Through time and with newly collected data the goal is to create more detailed mapping of the geology of the state. WVGES currently produces maps at 1;24,000 scale in conjunction with the U.S. Geological Survey's STATEMAP Program. This program is a part of the National Cooperative Geologic Mapping Program and partial funding is secured through the National Geologic Mapping Act. The program is a partnership between the U.S. Geological Survey, the Association of State Geologists, and State Geological Surveys. Funding is a 1:1 match between WVGES and the U.S. Geological Survey. WVGES continues to expand the program in West Virginia to generate coverage of more areas within the state.

STATEMAP

COMPLETED PROJECTS

Maps and reports for the Asbury, Cornstalk, Lewisburg, and Williamsburg quadrangles as well as a portion of the Ronceverte quadrangle in Greenbrier County were delivered to the U.S. Geological Survey STATEMAP program in September 2022 and published as WVGES Open File Reports. They are available as paper maps, PDF files, and geographic information systems (GIS) geodatabases. Additionally, a new component, the U.S. Geoframework Initiative, works towards seamless 2D and 3D mapping for the nation. Under this component, WVGES delivered a compilation map of the West Virginia portion of the Hagerstown 1:100,000 mapping area and has been working to update databases and correct edge-matching issues across map boundaries.

ACTIVE PROJECTS

WVGES utilized a change to the STATEMAP program announcement allowing for proposed projects over a two-year timeframe rather than the previous one-year period of performance. Also, during this mapping cycle WVGES was finally able to move beyond COVID-related disruptions in the STATEMAP program in FY23. WVGES received notification of partial funding in April 2022 to proceed with mapping in three different areas of the state with a two-year project beginning September 2022. Work began on five full and seven partial 1:24,000 quadrangles (Figure 1) in Greenbrier, Marshall, Mercer, Preston, and Summers counties. Full quadrangles included in this series are Brandonville, Bruceton Mills, Dawson, Majorsville, and Moundsville. Portions of the Alderson, Forest Hill, Fort Spring, Greenville, Peterstown, and Narrows quadrangles in Greenbrier, Mercer, and Summers counties are also included. Maps will be completed and delivered in FY25.

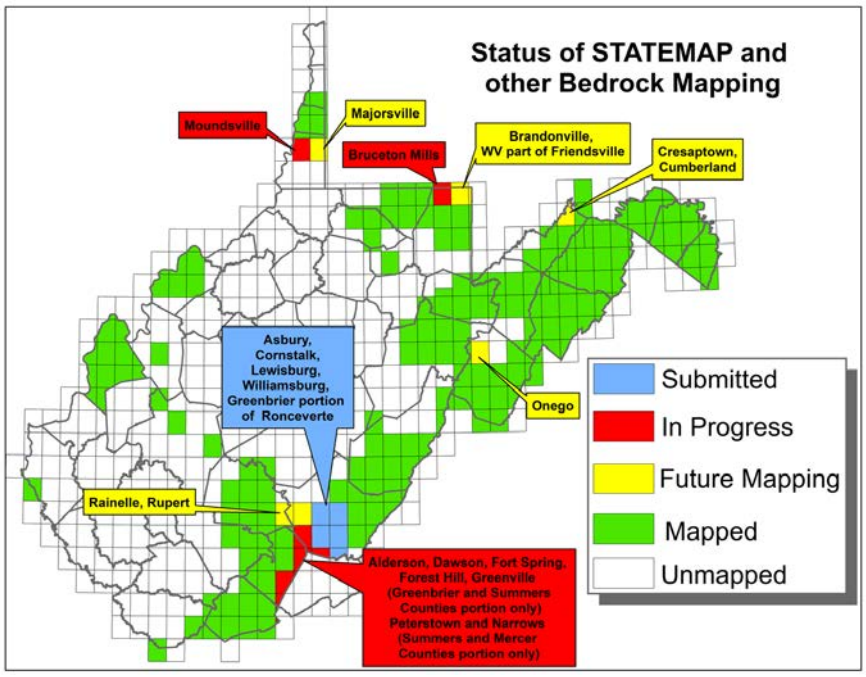


FIGURE 1

Additional funding was requested to improve previously published geologic maps by edge-matching, digital database updates, addressing geologically difficult problem areas via focused field work, and using newly available LiDAR imagery. Under the U.S. Geoframework Initiative, the survey is working to build seamless, edge-matched 1:24,000 geology organized by 1:100,000 sheets. This includes the WV portion of the Cumberland and Front Royal 100k map areas. Conversion to the newly required U.S. Geological Survey's Geologic Map Schema (GeMS) digital map database format is in progress. This database format has many complexities and will be mandatory for all future map submissions to the U.S. Geological Survey. Finally, WVGES is working with surrounding states to develop a draft cooperative interstate surficial mapping framework for creating seamless Appalachian surficial geology map databases across state lines and a draft cooperative report of best practices for Appalachian surficial mapping.

PROPOSED PROJECTS

The program announcement from the STATEMAP program was released in October 2022 and the annual meeting of the STATEMAP Advisory Committee, a group of industry, academia, and government professionals, was held virtually in November 2022. WVGES personnel presented proposed mapping areas in West Virginia. A two-year project was submitted and received notice of funding to complete 1:24,000 mapping of three full quadrangles (Onego, Rainelle, and Rupert) and two partial quadrangles (Cresaptown and Cumberland) in Fayette, Greenbrier, Mineral, and Pendleton counties. This work will begin in September 2023 in addition to the new mapping compilations of the Frederick and Morgantown 100k map areas, along with a compilation of six quadrangles in Mercer County.

WVGES continues to create new bedrock geologic maps. In the past year, WVGES has added the capability to download GIS spatial files to all users. These maps can be found at https://experience.arcgis.com/experience/9cbdcc9d316d462cbc6c8c6714c8570d

FACILITY MAINTENANCE

Several small and medium sized projects were accomplished in FY 2023.

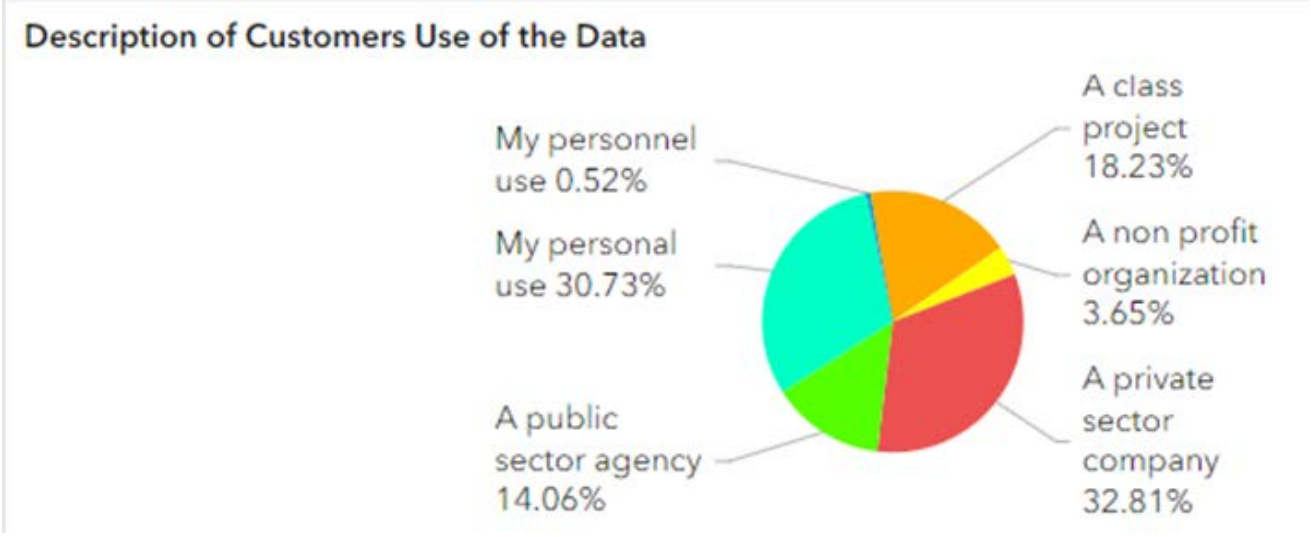
- Over 20 trees were removed from the property that threatened buildings or other infrastructure
- Main vertical steel support beam was replaced underneath the Activities Building deck
- Much of the exterior of the Activities Building was painted
- Interior basement of Activities Building was converted into clean storage area for historic coal samples
- Garage was reroofed by staff following windstorm damage
- Security camera upgrade (added 4 new cameras to property)

INFORMATION SERVICES

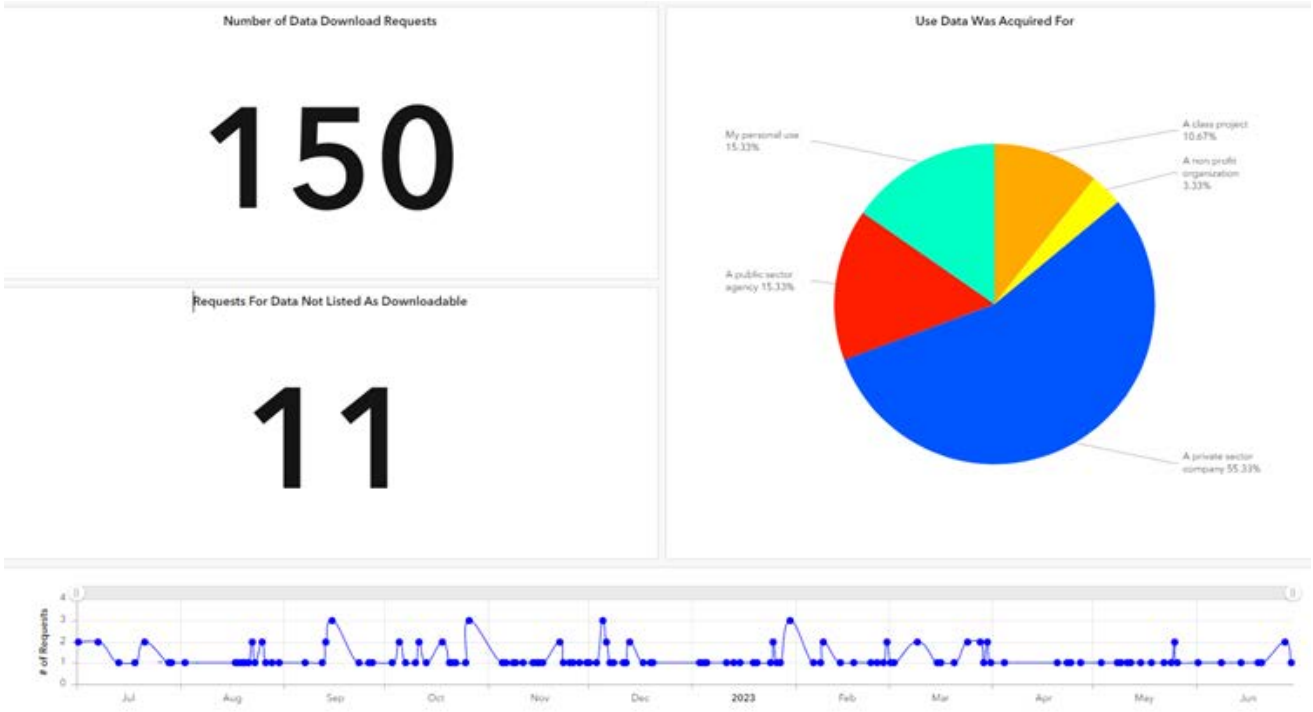
APPLICATIONS

The new interactive Geologic Map of West Virginia is currently available and can be accessed on our website. Based on the 1:250,000 scale State Geologic Map-1, originally published in 1968, this re-worked, re-designed spatial database (modeled in the USGS-Geologic Map Schema (GEMS)) correctly represents the original paper map. For the first time, users can explore and download spatial files featuring: Rock Units in Geologic Ages, Igneous Intrusions, Faults, Anticlines and Synclines, and Contact and Boundary Lines.

The new online self-service WV Geologic Data Explorer and Download Access Request Form streamlines customers' ability to research and obtain spatial data available for the various and numerous geologic publications provided by WVGES. Since the roll out on August 1, 2022, this cloud-based data repository and application has automatically serviced 114+ data access requests while simultaneously logging customer information and usage descriptions of the data.



The automated coal seam and coal mining spatial data request form and cloud-based data delivery access was expanded. For the current reporting period 150 customer service requests were processed.



UPDATES

- All oil & gas wells in West Virginia, including Marcellus Formation and Utica Shale Plays data updated
- Lithostratigraphy of Middle and Upper Devonian Organic-Rich Shales updated
- West Virginia Underground and Surface Mining interactive mapping layers updated
- Expansion of the Coal Bed Mapping Project data holdings incorporated
- And others, see http://ims.wvgs.wvnet.edu

HARDWARE AND SOFTWARE SUPPORT FOR OFFICE AND FIELD ACTIVITIES

- Obtained funding for a Dell PowerEdge R6515 Server which will facilitate the digital storage of, and public access to, records processed through various data preservation projects performed with the USGS
- Expanded the enterprise level geologic database based on the national USGS GeMS data model providing, for the first time, a comprehensive dataset of all previous geologic mapping projects made available from one location.
- Using the latest release of state-wide 1-meter high-resolution LiDAR imagery on desktop workstations as well as mobile mapping devices along with direct observation to identify previously hidden landforms.
- Continuing to advance processing capabilities for extremely large, high-resolution imagery (LiDAR) datasets.
- Providing support for staff who are virtually attending meetings, workshops, and conferences, including the Geologic Mapping Forum, Digital Mapping Techniques, and corresponding workshops with other state and federal geologic mappers and GIS professionals.
- Assisting mappers apply new techniques, hardware, and methods to collect and utilize digital data in the field.
- Standardizing data collection with handheld mapping units and developing data-entry forms using built-in GPS technology and field photography. This allows mappers to acquire and integrate data in a more systematic manner.

OUTREACH AND GEOSCIENCE EDUCATION

MUSEUM

Several fossils were donated from southwest England, including ammonites, urchins, and an ichthyosaur vertebra. These fossils have been added to the collection and help contribute to outreach programs by having new displays for the museum and allowing for data collection and analysis of specimens for the agency's research initiatives. A *Camarasaurus* leg and the *Deinosuchus* skull are two new exhibits that are currently on display. The *Triceratops* skull was switched for the leg to bring something different to the museum. Additionally, a *Smilodon fatalis* skeletal (Saber-toothed cat) replica has been added as well as a shelf that was built to display it.

More groups are visiting the museum, including school groups, scouts, and Master Naturalists, as well as the occasional tourist or local who stops in to visit the survey's facilities. To increase our geoscience educational outreach initiatives a Draw Jeff (a *Megalonyx jeffersonii*, WV's state fossil) contest was held for K-12 students across the state, with the winner getting their drawing on museum merchandise. In addition to this we hosted groups from WV Department of Natural Resources, Rock Cave Elementary School, Glenville State University School of Surveyors, Living Oaks Academy, Mont Chateau Estates, West Virginia Academy, and North Elementary School this past year.

WVGES geologist meets with Draw Jeff Contest winner, Wyatt Shipman, of East Dale Elementary School

New *Smilodon fatalis* replica display

MUSEUM VISITOR STATISTICS

- **454 visitors**
- **61% in-state visitors**
- **39% out-of-state visitors**

STATE PARK VISITING GEOLOGIST PROGRAM

This program is hosted by each state park in conjunction with several WVGES geologists who enjoy assisting in public education and spending time in nature. For each visit scheduled there is a presentation as well as an accompanying nature walk each led by the visiting geologist. These programs sometimes take place in one day or are spread out over a two-day period.

A total of five programs were held at the following state parks: Cacapon Resort State Park, Canaan Valley State Park, Blackwater Falls State Park, Tygart Lake State Park, and Twin Falls State Park.

COMMUNITY & STAKEHOLDER SUPPORT FOR PRESERVATION OF GEOLOGIC SAMPLES

For the first time in many years, Congress accepted applications for Congressionally Delegated Spending (CDS) requests, also known as earmarks. These requests reflect spending needs not necessarily included in Federal funding language but applicable under existing programs. WVGES was fortunate to be included in CDS requests from the offices of Senator Capito and Senator Manchin for the construction of a new core building to be constructed at Mont Chateau.

OUTREACH

Survey staff attended Nasa Kids Day in December of 2022 to help promote geoscience education as well as showcase future potential career opportunities. Middle and high school students were welcome to chat with industry professionals and gain a better insight to a possible career path and learn more about the geoscience field.

Pete Sullivan from the Appalachian Geological Society contacted the survey to assist with the creation and implementation of kiosks south of Charleston, WV in the Kanawha State Forest. The kiosks were officially installed in August 2022.

EQUAL EMPLOYMENT OPPORTUNITY

The agency has undertaken major initiatives to achieve pay equity among similarly classified and experienced professionals regardless of race, religion, gender, sexual orientation, national origin, age, or disability. However, a major issue within our recruiting efforts continues to be that the agency operates within an outdated pay scale that does not attract those, including females and minorities, within the Geoscience field. This includes new graduates, as they have learned they can secure more lucrative positions within the private sector. Although great efforts are being made to increase pay and put an end to pay inequality, budgetary constraints remain. WVGES will continue to devote a serious and sustained effort to educate the community through outreach programs. By increasing knowledge and awareness of the Geosciences through the agency's presence within these programs the goal is to reach a greater diversity of people, thereby creating a greater diversity in the candidates who wish to fill vacant positions. As a state agency internally and externally disseminating the affirmative action policy and plan is important for the success of the survey.

AWARDS, PRESENTATIONS, AND PUBLICATIONS

AWARDS

American Association of State Geologists (AASG) 2022 Charles J. Mankin Award (Fall 2022), presented to: Susan E. Pool, Ray M. Boswell, John T. Saucer, and B.J. Carney for peer-reviewed paper/research:

"Estimates of Natural Gas Resources and Recovery Efficiency Associated with Marcellus Development in West Virginia"

Award given at 2022 Annual Geological Society of America (GSA) Meeting

Photo taken at WVGES with three of the recipients present

PRESENTATIONS

U.S. Energy Information Administration (EIA) Special Meeting (April 2023): "Preliminary CO2 Shale Storage Investigations for West Virginia; Phase 1—Prospective Storage Resources"

American Association of Petroleum Geologists (AAPG) Carbon Capture, Utilization, and Storage (CCUS) Conference (April 2023): "Defining CCUS in the Midwest, Northeast, Coastal Plain, and Northeast Offshore USA—A Bottoms Up Approach"

Poster Presentation at the Joint Southeastern-Northeastern GSA Section Meeting in Reston, VA in March 2023. The poster title is "*Pteridichnites biseriatus* Abundance Zone - 25 Years On"

Abstract link:
https://gsa.confex.com/gsa/2023SE/meetingapp.cgi/Paper/385699
Publications

Technical Report (September 2022): "Midwest Regional Carbon Initiative (MRCI): Defining Sub-Regional Carbon Storage/Carbon Utilization and Storage (CS/CUS) Systems"

MAP UPDATES AND PUBLICATIONS

Updates

Along with all the annual updates there was a significant update/republishing of the two following publications and a geologic map:

OF1503A Bedrock Geologic Map of the Alvon and Rucker Gap 7.5' Quadrangles, Greenbrier County, West Virginia: P.J. Hunt, R. R. McDowell, S. R. Brown, S. J. Hostetler, G. J. McClure, M. S. Burns; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 36p, 60" x 42", full color map shows geology and structure, strike/dip of WV portion only. Map layout includes stratigraphic column, legend, and cross sections. Text in booklet. 2-page Geochemical Report insert. Scan available and files for GIS.

OF1705A Bedrock Geologic Map of the White Sulphur Springs and Jerrys Run 7.5' Quadrangles, Greenbrier County, West Virginia: P.J. Hunt, R.R. McDowell, S. J. Hostetler, S. R. Brown, M.S. Burns; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 2p, 70" x 38", full color map shows geology and structure, strike/dip. Map layout includes text, legend, 2 cross sections and stratigraphic column. 2-page Geochemical Report insert. Scan available and files for GIS.

New Map Publications

OF2101 Bedrock Geologic Map of the Asbury 7.5' Quadrangle, Greenbrier County, West Virginia: D.L. Spurgeon, J.W. Perkins, J.K. Tudek, S.E. El-Ashkar, R.T. Toth; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 8 p, 42" x 42", full color map shows geology and structure, strike/dip. Map layout includes legend, cross sections and stratigraphic column. Text in booklet. Files for GIS available.

OF2102 Bedrock Geologic Map of the Cornstalk 7.5' Quadrangle, Greenbrier County, West Virginia: S.E. El-Ashkar, J.W. Perkins, J.K. Tudek, P.A. Dinterman, P.J. Hunt, D.L. Spurgeon; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 13 p, 42" x 42", full color map shows geology and structure, strike/dip. Map layout includes legend, cross sections and stratigraphic column. Text in booklet. Files for GIS available.

OF2103 Bedrock Geologic Map of the Lewisburg 7.5' Quadrangle, Greenbrier County, West Virginia: J.K. Tudek, E.C. Rhenberg, D.L. Spurgeon, S.E. El-Ashkar, P.A. Dinterman, J.W. Perkins; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 14 p, 42" x 42", full color map shows geology and structure, strike/dip. Map layout includes legend, cross section and stratigraphic column. Text in booklet. Files for GIS available.

OF2104 Bedrock Geologic Map of the Greenbrier County Portion of the Ronceverte 7.5' Quadrangle, Greenbrier County, West Virginia: P.A. Dinterman, P.J. Hunt, J.K. Tudek, D.H. Doctor, S.E. El-Ashkar; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 15 p, 42" x 36", full color map shows geology and structure, strike/dip. Map layout includes legend, cross section and stratigraphic column. Text in booklet. Files for GIS available.

OF2105 Bedrock Geologic Map of the Williamsburg 7.5' Quadrangle, Greenbrier County, West Virginia: J.W. Perkins, J.K. Tudek, S.E. El-Ashkar, D.L. Spurgeon, R.T. Toth, L.A. Woodward, C.F. Lindsay; Digital Cartography by S.E. Gooding, 2022, 1:24,000 scale, 9 p, 42" x 42", full color map shows geology and structure, strike/dip. Map layout includes legend, cross sections and stratigraphic column. Text in booklet. Files for GIS available.

WV GIS TECHNICAL CENTER

The West Virginia GIS Technical Center, located in the Department of Geology and Geography, West Virginia University, provides focus, direction, statewide coordination, and leadership to users of geographic information systems (GIS), digital mapping and remote sensing within the state of West Virginia. The Center was established by Executive Order 4-93 to provide coordination and technical support in the development and operation of geographic information systems (GIS) for the state' spatial data infrastructure. Statewide geospatial activities are coordinated through the WV Office of GIS Coordination, WV Geological and Economic Survey. Below are highlights of GIS Services that support 13 state agencies as well as local governmental offices that include E-911 (addresses), county assessor (tax parcel), and county clerk (elections and boundaries).

GIS SERVICE	DESCRIPTION
Addresses	Host the statewide addressing and mapping system (SAMS) for the WV Emergency Management Division that incorporates 1.0 million site addresses along with road centerlines from the local E-911 Addressing Offices. See www.mapwv.gov/address. Completed a conflation study sponsored by the WV Division of Transportation for conflating road centerline geometry between the SAMS and DOT geodatabases.
Address Locator Services	Create bi-monthly locator services from statewide E-911 road and site addressing files for bulk geocoding that allows local and state agencies to convert their lists of addresses to map locations.
Aerial Imagery	Maintain and update the statewide web map service, an essential base map service for the state, in which new countywide leaf-off imagery is procured via a state contract administered by the Center.
Boundaries - Election Districts	Support the offices of county clerk and secretary of state in updating voting precincts and magisterial districts to include hosting a public voting application (www.mapwv.gov/vote). Perform monthly statewide audits of all 1.1 million voter points to ensure voters are assigned to the correct election districts.
Boundaries - Legal, Public Lands, Tax Districts	Perform state-level boundary change submissions for county and municipal legal boundaries to the U.S. Census. Submit state public land boundary updates for the WV Division of Natural Resources and WV Division of Forestry to the nationwide PAD-US database. Update the statewide rural and corporation tax district reference map file in coordination with the WV State Tax Department.

GIS SERVICE	DESCRIPTION
Building Footprints	Create building footprints from high-resolution aerial imagery using deep-learning software.
Elevation	Host for the public the statewide FEMA-purchased LiDAR, including downloadable elevation products (1-meter elevation grids; 1-ft. contours) and online map services valued at $10 million. Refer to the WV Elevation Download Tool at www.mapwv.gov/elevation.
Hazard Flood	Support the public and floodplain managers of 268 flood-prone communities with regulatory and flood risk products including maintaining an inventory of 98,000 structures located in high-risk floodplains. Refer to www.mapwv.gov/flood.
Hazard Landslide	Completed the inventory of more than 100,000 landslides inventoried from the high-resolution LiDAR elevation data and re-published a new statewide 2-meter landslide susceptibility grid.
Highway Plans Scanning	Provide scanning and GIS support for the WV Department of Transportation to include scanning more than 10,000 archival highway plans and publishing to an online retrieval system (www.mapwv.gov/DOTplans).
Tax Surface Parcels	Coordinate with the county assessors and WV State Tax Department to maintain 1.4 million parcels on the WV Property Viewer (www.mapwv.gov/property), the most popular website hosted by the Center. This viewer includes weekly updates of delinquent properties from the WV State Auditor's Office.
Tax Mineral Parcels	In a collaborative effort with the WV State Tax Division and WV Geological and Economic Survey to support the mineral lands mapping program, this past year the Center reviewed 38,028 mineral records, whereby 4,818 unique mineral records were mapped and 376 well plats geo-referenced.

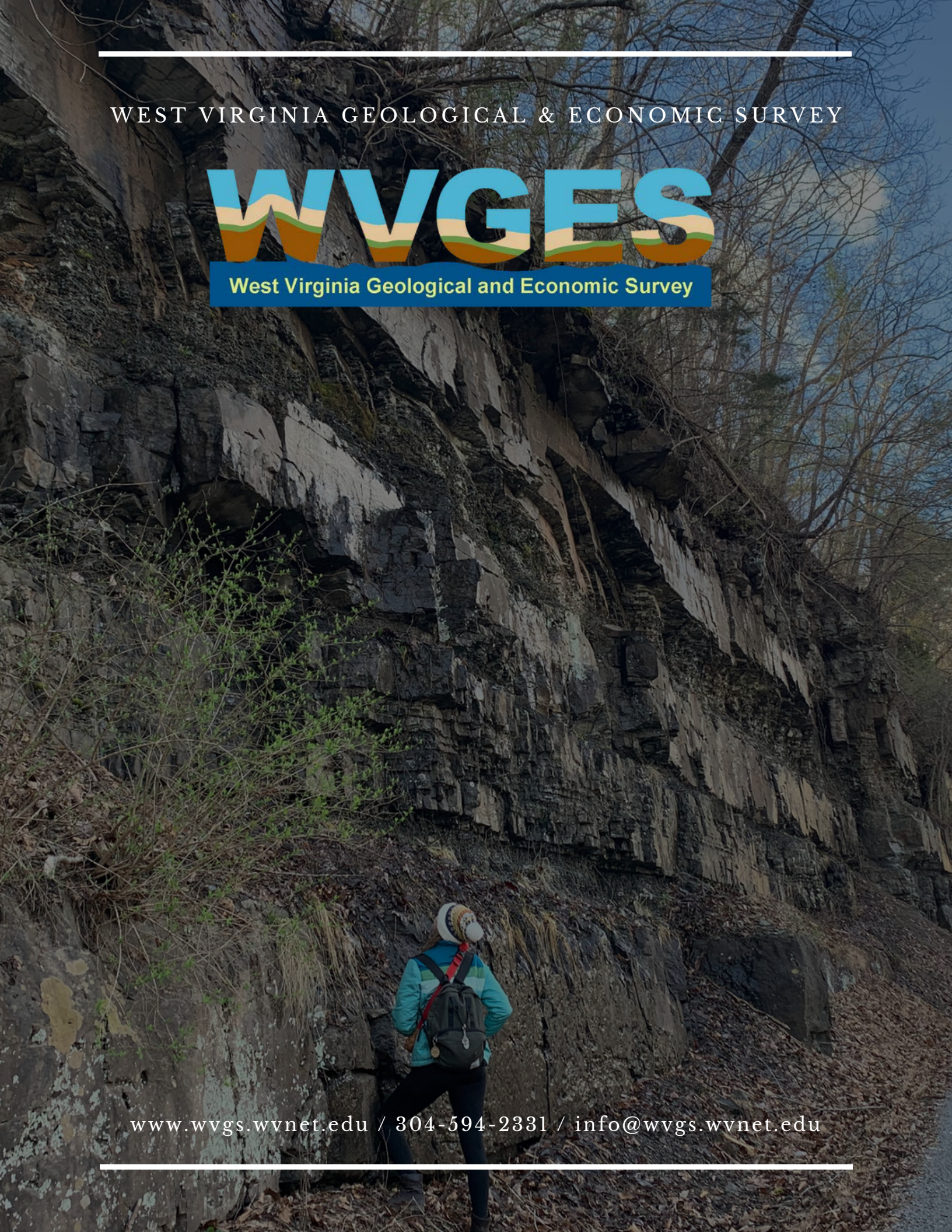
GIS SERVICE	DESCRIPTION
WV GIS Support for Other Agencies	The Center provides hosting and e-government geospatial services for the State Historic Preservation Office (cultural resources), WV Department of Environmental Protection (wetlands), Department of Natural Resources (hunting and fishing; land and streams), WV Department of Transportation (trails; highway plans), WV Natural Resources Conservation Agency (NRCS) (environmental resources screening), State Resiliency office (flood resiliency tool), and state legislature task force (NEPA screening tool).
WV State Base Layer Map Services	MapWV.gov (www.mapwv.gov) provides a publicly accessible gateway to essential base map layers and geoprocessing services (e.g., aerial imagery, elevation, address geocoding) utilized by many organizations in the state for their mapping activities.
WV State GIS Clearinghouse	The WV State GIS Data Clearinghouse (wvgis.wvu.edu) catalogs over 300 unique datasets and 120 web services valued at more than $70 million dollars. To support the state's spatial data infrastructure, a new three-server SAN hardware system was installed at a cost of $150,000 that expands the raw storage to 500 TB.
WV Technical, Training, & Outreach Services	Provides the WV Geospatial Community with advisory, training, and outreach services. These services are coordinated with the WV Office of GIS Coordination and WV Association of Geospatial Professionals. The Technical Center responds to an estimated 12 calls per week from the public and clients regarding GIS data and applications.

PROPERTY TAX DIVISION

The Property Tax Department has the responsibility of assessing West Virginia mineral extraction and reserves. This activity requires the collaboration of different stakeholders and merging different data types from a wide range of sources. The statewide assessment requires a comprehensive collaboration to be accurate, systematic, and fair.

The GIS Section produces a coal thickness contour dataset once a year. It incorporates existing coal thickness and newly created individual thickness contours for each of the coal seams in the State. The recently created coal sample dataset (CSD) is the drilling location that measures the thickness and depth of a particular seam. The GIS section creates a raster surface representation using these points as reference points. These are used for an inverse distance weighted (IDW) interpolation using a commonly adopted geostatistical model. The GIS Section developed a concept model by using the parameters and interpolation used by WVGES to generate a uniform set of geospatial settings. These are used to create the raster layer surface. The raster layer surface for each seam is resampled to a more detailed cell size and reclassified so that thicknesses are in six inches increments. These rasters are then converted into polygons and smoothed. Multiple layers such as state boundary, seam outcrop, all mining, and environmental restrictions are used as coal limitation extraction. These areas are removed from the contour datasets as environmental constraints. These contours are then checked against the CSD points by performing a spatial joint and identifying any upper or lower bound thickness outliers based on the CSD point thicknesses.

The Tax GIS section has been working on the development of a consolidated systematic approach to assist with annual mineral assessment. Our goal is to create a "Google Maps for Minerals", combining various sources such as public or proprietary datasets regardless of the size of the files in one web application. The web application framework design has basic similarities with enough flexibility to target the specific differences among all natural resources. The immediate benefit is the visualization of relationships between federal and state government, business, and public/privileged datasets. By utilizing the web application platform, we have centralized access to the required datasets. Tables are quarriable, locations are visualized, and layers are dynamic. The application provides the ability to answer specific questions related to assessment.



WEST VIRGINIA GEOLOGICAL & ECONOMIC SURVEY

WVGES

West Virginia Geological and Economic Survey

www.wvgs.wvnet.edu / 304-594-2331 / info@wvgs.wvnet.edu