

# ASSOCIATION OF AMERICAN STATE GEOLOGISTS

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**AASG**  
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**Front cover:** *Incised channel showing the relationship between the sinuosity of the channel and the texture of the bedding plane surface. (Photograph by Samuel V. Panno.)*

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# PRESIDENT'S PAGE

The 2019 to 2020 year for the AASG was full of changes, both for the betterment of our science and as challenges for all of us. Continuing on the success of previous years and the AASG leadership, our relationships with the U.S. Geological Survey (USGS) and our federal partners grew stronger. Our professionalism, cooperation, collaboration, and strength as a scientific association as well as each independent state geological survey expanded with the true endeavor of pursuing truth and knowledge. However, at the beginning of the 2020 calendar year, the world was challenged with the COVID-19 pandemic. For many of us, this created a dramatic shift in operations, including mandatory telework, fieldwork delays, logistical chain shortages, and even full closures to stop the spread of the virus. While many activities continued virtually, the virus shifted AASG's Annual Meeting into the virtual computer world and challenged us in many ways that we had never experienced.



Despite the challenges of the pandemic, the AASG still had many accomplishments. The newest cooperative program with the USGS, Earth MRI, continued to gain momentum with an increase in funding and additional funded projects. Expanding the 14 geologic mapping projects from 2019, the USGS funded 12 additional geologic mapping projects. Six additional airborne geological surveys were funded on top of the five surveys from 2019, and four geochemistry projects were added, creating a diverse mineral identification program. The cooperation between the USGS Mineral Resources Program and the AASG continues to develop this program to support the national need as well as the states' needs for mineral information. I thank the USGS program staff for all their work on this project and for embracing the states as partners in addressing this national concern. Special thanks go to USGS staff Warren Day, Sarah Ryker, and Suzanne Nicholson, along with State Geologists Karen Berry, Steve Masterman, and Dick Berg.

Our traditional National Cooperative Geologic Mapping Program (NCGMP) also expanded this year. Through the efforts of many, and specifically Harvey Thorleifson and his congressional delegation, the NCGMP gained an additional \$10 million. These monies were provided to the states through a supplemental grant program focusing on regional and 3-D mapping. This funding also stimulated the Phase III work of the National

Geologic Mapping Act, helping start an electronic national coverage of geology. This program increase also created much further discussion between the AASG and USGS, resulting in greater cooperation, refinement of projects, and coordination of activities. Thank you to the USGS NCGMP team of John Brock, Darcy McPhee, Dave Soller, and Michael Marketti and State Geologists Harvey Thorleifson, Dick Berg, Jon Arthur, Steve Masterman, and Karen Berry.

With changing times in our professional societies, this year was also one of change for the AASG. A thorough review of all of our contracts was performed and a review of our constitution and by-laws was begun. I especially want to thank Nick Tew for taking on this task. A committee was established to discuss membership, liability, equal opportunity, and diversity. Because important work takes time and we are changing legal documents, this work continued into the next presidency, and I look forward to the results.

I want to thank Jim Faulds and the Nevada Geological Survey and Erin Campbell for all their hard work planning for a successful AASG Annual Meeting. Unfortunately, the pandemic postponed that meeting, but we all know that much of the work was accomplished beforehand, and Nevada was already working hard. Thank you to the Nevada Geological Survey. With the help of Nelia Dunbar and Mike Timmons of the New Mexico Geological Survey, the AASG was able to transition to a virtual Annual Meeting and accomplish all the mandatory annual work, along with a few educational sessions. Thank you to all who worked on pivoting this Annual Meeting into a successful virtual meeting.

Lastly, these advances and activities do not come without lots of work, phone calls, meetings, and long nights. I thank all members of the AASG Executive Committee for their patience, hard work, dedication, and insights. Karen Berry, Past President; John Yellich, President Elect; Erin Campbell, Vice President; Nelia Dunbar, Secretary; and Harvey Thorleifson, Treasurer, thank you for the passion and sense of duty that you have shared with the AASG and this executive team.

Please enjoy this *State Geologists Journal*. It always amazes me how different each of us is, but how similar we are also. There is much to learn from all of us, our differences and our similarities. I challenge all of us to open our minds to this opportunity that exists already and welcome diversity into our programs and to stretch what has been into what can be.

Best Regards,

Richard Ortt, Jr.  
AASG President



# ALABAMA

## Geological Survey of Alabama/State Oil and Gas Board

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### INTRODUCTION

The Geological Survey of Alabama (GSA) is an independent state agency that reports to the Alabama Legislature and to the Governor. The GSA's mandate is to survey and investigate the mineral, energy, water, coastal, and biological resources of the state; to maintain adequate geologic, topographic, hydrologic, and biologic databases; and to prepare maps and reports on the state's natural resources to encourage the safe and prudent development of Alabama's natural resources, while providing for the safety, health, and well-being of all Alabamians. The State Geologist is Director of the GSA and, by virtue of the position, is also the Oil and Gas Supervisor (i.e., director) of the State Oil and Gas Board of Alabama (OGB). The OGB is the state's regulatory agency for all oil and gas exploration, production, and development.

The State Geologist serves as the Governor's representative to the Interstate Oil and Gas Compact Commission (IOGCC) and holds an appointment from the U.S. Secretary of Energy to the National Petroleum Council. He is Vice-President of the Groundwater Protection Council (GWPC) and chairs the GWPC Task Force on Carbon Capture, Utilization, and Storage. He is a Past-President of the American Geosciences Institute (AGI) and currently serves as a Trustee of the AGI Foundation. Until recently, he served on the Executive Board of the Council of Scientific Society Presidents, was a member of the Steering Committee of the IOGCC, and participated as a member of the National Academies of Science, Engineering, and Medicine's Roundtable on Unconventional Hydrocarbon Development. Within the State of Alabama, the State Geologist serves as an Alabama Natural Resources Trustee and an ex officio member of the Joint Legislative Alabama Permanent Oil and Gas Study Committee and serves as a member of several committees, including the Joint Legislative Permanent Committee on Energy Policy, the Joint Legislative Committee on Water Policy and Management, the Water Resources Council, the Coastal Resources Advisory Committee, the Coastal Area Erosion Task Force, the Alabama League of Municipalities Energy, Environment and Natural Resources Committee, the University of Alabama Museums Board of Regents, and the University of Alabama Department of Geological Sciences Advisory Board.

GSA programs include investigations of the mineral, energy, water, coastal, and biological resources of the state to determine their quality, character, capacity for development, and environmental significance. The GSA collects, analyzes, and transfers resource data, databases, and scientific reports to state and federal agencies to facilitate sound regulatory and other decisions; to industries interested in mineral and energy resource development; and to Alabama's elected leaders and its citizenry. The GSA maintains and makes available comprehensive databases for the mineral, energy, water, coastal, paleontological, and biological resources of the state. The GSA sponsors an annual workshop for earth science teachers that focuses on fossils, provides publications and other resources to teachers and for other educational events, and participates in Earth Science Week celebrations.

The GSA continues to enhance its website. The website serves both the GSA and its sister agency, the State Oil and Gas Board.

Major program initiatives include several new projects with the cooperation of federal and state agencies.

### ENERGY INVESTIGATIONS PROGRAM

The Energy Investigations Program (EIP) is made up of two sections, Resource Assessments and Modeling and Data Management. The Resource Assessments Section performs basic and applied research on Alabama's diverse energy resources, which include conventional oil and gas, coalbed methane, oil sand, shale gas, and coal, as well as work on geologic carbon sequestration. The Modeling and Data Management Section is in charge of maintaining and improving access to our geologic core collection and its related samples and data, and it conducts computer modeling, particularly on discrete fracture networks.

#### Resource Assessments

Coal research includes characterization of coal resources under the auspices of the U.S. Geological Survey's (USGS's) National Coal Resources Data System (NCRDS). Work under the NCRDS includes compiling basic coal resource data from more than 7,000 coalbed methane wells and exploratory cores

that have been drilled in the eastern part of the Black Warrior Basin. In addition, program scientists are developing an integrated database and GIS of underground coal mines in the Black Warrior Basin with the support of the U.S. Department of the Interior's Office of Surface Mining.

Research related to geologic carbon sequestration continues in the EIP through various research projects. The Southeast Regional Carbon Storage (SECARB) Offshore partnership continues investigation of potential targets offshore in the eastern Gulf of Mexico. The partnership's primary objectives are to combine the capabilities and experience of industry, academia, and government to develop and validate key technologies and leading practices to ensure safe, long-term, economically viable CO<sub>2</sub> storage in offshore environments; facilitate the subsequent development of technology-focused permitting processes needed by industry and regulators; collaborate with federal and state agency programs to improve confidence in the containment of CO<sub>2</sub> in the subsea offshore environment in storage reservoirs over both short and long time frames; and provide a comprehensive assessment of the potential to implement offshore CO<sub>2</sub> storage in the defined Gulf of Mexico study area. The SECARB-USA partnership, a coalition of academic, government, and industry groups, covers 10 states and portions of another five, and builds on earlier work by the Midwest Regional Carbon Sequestration Partnership. The primary research areas are to address key technical challenges; facilitate data collection, sharing, and analysis; assess the transportation and distribution infrastructure; and promote regional technology transfer and the dissemination of knowledge. Work from both projects has been presented at national conferences, including the Geological Society of America Annual Meeting and the American Association of Petroleum Geologists Annual Meeting.

The EIP is beginning work on Phase III of Project ECO<sub>2</sub>S in Kemper County, Mississippi. The GSA's role is to further refine geologic models that will inform specific site selection and assist with monitoring and verification efforts. This will primarily be accomplished through interpretation of seismic reflection data that will be collected specifically for this project.

The EIP continues work on multiple other projects. In the past year, for example, the EIP completed a prefeasibility geological evaluation for compressed air energy storage (CAES) in Alabama and Mississippi in collaboration with Southern Company Services, looking at CAES potential in porous rock formations as well as salt caverns in southern Alabama and Mississippi. Other projects include continuation of the Alabama Oil Sands Program (established in 2014) and continued research on coproduced waters related to hydrocarbon extraction.

## Modeling and Data Management

Modeling efforts have focused on further development of software and tools related to discrete fracture networks (DFN). In the past, this work has been geared toward supporting underground injection and fluid migration, but moving forward, it has expanded to address groundwater flow. The DFN modeling

work has been presented at international conferences, such as the American Geophysical Union Annual Meeting.

Efforts continue on improving access to information about our geologic core collection. Most of the samples now have standardized metadata. Registration of all items in the collection with a unique identifier (e.g., an International Geosample Number) to further enable access and discovery is continuing. Our collection is routinely used by universities and industry for teaching and research. Members of the EIP are also engaged in data rescue efforts to modernize records, publications, data sets, and other materials to make them more accessible both in-house and to the public.

Other projects undertaken by the EIP include education and outreach efforts in local schools and for teacher professional development, contributions to the *Encyclopedia of Alabama*, and engagement with policy makers to highlight the value of geoscience in decision making.

## GEOLOGIC INVESTIGATIONS PROGRAM

The Geologic Investigations Program (GIP) conducts research, mapping, and data collection of geology, geologic hazards, mineral resources, paleontological resources, and geography.

### Geologic Mapping

The Geologic Mapping group participates in the STATEMAP component of the National Cooperative Geologic Mapping Program (NCGMP), which is administered by the USGS. Supported through the NCGMP's STATEMAP program, geologic mapping of the Gadsden East, Keener, and Gaylesville 7.5-minute quadrangles was completed in September 2019, and mapping of the Crossville, Leesburg, and Portersville Quadrangles was initiated later that same month. The GIP also began a mapping project in the Piedmont in September 2019 through support from the NCGMP's Earth Mapping Resources Initiative (Earth MRI) program. This 2-year project includes mapping four 7.5-minute quadrangles (Roanoke West, Roanoke East, Milltown, and Wadley South) and collecting samples of regolith for chemical analyses.

The State Geologic Mapping Advisory Committee, chaired by the GIP Geologic Mapping and Hazards Section manager, met twice this past year to review geologic mapping plans in the state, discuss how increasing urban development and growing water-resource requirements contribute to mapping needs, and identify mapping priority areas in Alabama.

### Geologic Hazards

The GIP researches and maps geologic hazards (earthquakes, sinkholes, landslides, and radon). Sinkholes continue to be the largest geological hazard in Alabama, and this past year, GIP staff included karst lidar analyses in its STATEMAP projects. In August 2019, the GIP also assembled and led the Alabama Karst Science and Research Symposium, a new biennial symposium assembling karst scientists from multiple agencies, universities, and other groups in the Alabama area. The GIP also participates in meetings of the State Emergency Response

Commission and State Hazard Mitigation Plan team, led by the Alabama Emergency Management Agency (AEMA). This past year, working with the AEMA, GIP staff contributed to earthquake mitigation planning in a project funded by the Federal Emergency Management Agency's National Earthquake Hazard Reduction Program. The project used Hazus software to estimate damage related to potential earthquakes. Collaborating with AEMA and the Central U.S. Earthquake Consortium, the GIP also helped produce an earthquake video for use in educational outreach.

## Nonfuel Geologic Resources

Nonfuel resource activities in the GIP focus on data gathering, research, and mapping related to nonfuel minerals and fossils. The GIP staff also maintain historic mineral and fossil reference collections for comparative purposes. As part of nonfuel resource activities, GIP staff participated in projects funded by the National Geological and Geophysical Data Preservation Program (NGGDPP). Related to the critical minerals portion of the NGGDPP this past year, staff completed scanning of critical minerals-related maps and compiling a nonfuel minerals information database that was later uploaded to the USGS National Digital Catalog (NDC).

Also with funding from the USGS NGGDPP, the curator of the GSA paleontology collection compiled fossil specimen metadata and uploaded these to the NDC. The GSA paleontology collection was begun in the 1800s by the first State Geologist to support geologic mapping, and since then it has grown to more than 200,000 specimens of Paleozoic to Cenozoic macrofossils. The fossil collection and its database are used by geologists and paleontologists at the GSA, universities, and museums in research and mapping and are also used by oil and gas companies proposing to build or expand pipelines with the need to include a paleontological resources assessment as part of the Environmental Impact Statement section of the application to the Federal Energy Regulatory Commission.

## Geographic Activities

Geography is an important aspect of the GIP's work and GIS is incorporated into many of the division's mapping and research projects. The GIP Director and the State Geologist continue to be involved with state GIS planning and coordination by participating in the Alabama Executive GIS Council and advisory committee. The GIP staff also contribute GIS support to emergency management and other agencies for disaster response and hazards planning. For this reporting period, GIS support for these purposes included geologic hazards, weather events, and COVID-19. The GIP also directs the Alabama Geographic Names Committee, collaborating with the USGS Board on Geographic Names to review proposals for new names and name changes to physical geographic place names in the state.

## COASTAL RESOURCES PROGRAM

The Coastal Resources Program (CRP) conducts land- and marine-based research mainly within Alabama's coastal counties and federal waters to increase our understanding of

beach and nearshore habitat change, environmental quality, terrain- and marine-based use, shoreline best management practices, and research monitoring and to facilitate the identification and archiving of supporting geospatial thematic layers for various stakeholders.

## Beach Monitoring

Alabama's beaches serve as an important tourism resource for the state's economy, and the protection of beach habitat and the coastal built environment serves to enhance and promote this tourist attraction. The Gulf-fronting Shoreline Monitoring Program is a cooperative effort among the GSA, the Engineer-of-Record for the Alabama Department of Conservation and Natural Resources (ADCNR), and the municipalities of Orange Beach and Gulf Shores. This program includes the acquisition of beach topology profiles, nearshore bathymetry, and orthophotography with topographic and beach change detection modeling using historical shoreline and lidar data.

## Data Management and Modeling

In collaboration with the ADCNR, the CRP maintains an inventory of geospatial themes to support planning activities within Alabama's coastal counties and within state and federal waters. Compatible with desktop computers as well as smartphones, this inventory is made interactively available online at <https://www.gsa.state.al.us/apps/CMP/current/>. This partnership also includes planning and advancement of the Coastal Geospatial Data Users Group designed to promote cross-discipline collaboration with GIS users, maintain the awareness of updated data and gaps, and publicize innovative tools and applications of GIS technology.

With increasing interest in the replacement of hard shorelines (e.g., bulkheads, riprap) with living shorelines, the GSA is working with Troy University and the Virginia Institute of Marine Science to finalize GIS and spatial modeling work to support alternatives to hardened shorelines. The modeling effort has generated upland and shoreline best management practices for living shorelines and upland modifications.

In partnership with the University of South Florida, as funded through the Gulf of Mexico Alliance, the GSA is working to acquire and create metadata documentation of terrain- and marine-based monitoring programs to reflect GSA efforts as well as monitoring by federal, state, and local government, nonprofit, private, and academic entities. This effort supports the discovery and links to monitoring efforts through an interactive interface titled GOMA-CAT (Gulf of Mexico Alliance Monitoring & Metadata Catalog). The alpha version is located at <https://goma-cat.usf.edu/>.

## Surface Storm Water Assessment

In addition to its coastal area focus, the CRP works cooperatively with other GSA programs as needed by conducting hydrological research in other areas of the state. At present, and in collaboration with the City of Tuscaloosa, the CRP is assessing surface water and storm water in 25 subwatersheds that, in part, reflect a large percentage of the City of Tuscaloosa

in west-central Alabama. Discharge, sedimentation, and water chemistry data are being collected and evaluated by comparison with previous studies.

## **GROUNDWATER ASSESSMENT PROGRAM**

The Groundwater Assessment Program (GAP) is involved in a wide variety of hydrogeologic and hydrochemical assessments throughout Alabama to support the development and understanding of public, agricultural, domestic, and industrial water supplies; to protect current groundwater sources; and to develop a basic scientific understanding of Alabama's groundwater resources for water management and policy development. The GAP operates under two state mandates: to monitor and to assess the state's groundwater resources. In addition, it supports other programs at the GSA by providing hydrologic expertise and personnel when required. The GAP is organized into two sections to accomplish the program mandates.

### **Groundwater Monitoring Section**

The Groundwater Monitoring Section maintains two groundwater monitoring networks: a periodic network and a real-time network. The periodic network currently includes more than 400 wells and springs throughout the state that are visited on a semiannual basis. Water levels at wells and flow rates at springs are measured and recorded during each visit. The data are transferred to a database and are available for viewing by the public and stakeholders on the GSA GAP website. This information serves as baseline data for GAP assessment projects and allows for yearly evaluations of the long-term behavior of the state's aquifer systems. The real-time network is composed of 30 wells. A pressure transducer installed at each location measures water level, temperature, and specific conductance (in two wells) every 2 hours. Data are transmitted daily to the GSA GAP via a cellular network and are uploaded for viewing on the GSA GAP website. Shallow wells in the real-time network provide data used by the Alabama Drought Monitoring and Impact Group to assess drought conditions in the state. The GAP is currently evaluating all wells and springs in the two networks to determine the impact of different types of stressors, such as climate, land-use changes, and water use, to the hydrologic system recorded by each network. The GAP is in the process of expanding each network to include more wells and springs to further enhance its ability to provide up-to-date information to water managers and policy makers on the status of the state's groundwaters that will assist them in making decisions on water availability issues such as water use and the effects of drought. The GAP has migrated the data from its real-time network to the National Ground-Water Monitoring Network (NGWMN) under a grant from the USGS. More than 25 wells and springs were added to the NGWMN during 2019. The Groundwater Monitoring Section maintains and catalogs more than 100,000 drillers' reports on historical and new wells, in addition to an extensive collection of water-well data in the state. More than 40,000 well records from this catalog have been migrated to digital format and have been entered into a relational database that is accessible online through the GSA GAP website. This conversion to a geographic-based digital format will enhance the GSA GAP's ability to disseminate

groundwater data to the public and its stakeholders in a timely manner.

### **Groundwater Assessment Section**

The Groundwater Assessment Section is tasked with developing a broad array of products for the public and stakeholders, including information on aquifer characteristics and groundwater availability in the form of water table and potentiometric maps, hydrogeologic cross sections, and groundwater productivity maps. The scope of these projects ranges from local and regional to statewide. Local and regional groundwater research is performed in cooperation with local governments and public water supply systems to address stratigraphic and geochemical considerations related to the occurrence and development of potential groundwater sources. Current assessment projects include developing three-dimensional groundwater models, with the attendant water budgets, for karst aquifers in north Alabama and coastal plain aquifers in the west-central part of the state, water-quality studies of Cretaceous aquifers in the central part of the state, water-quality studies of shallow groundwater in coastal Alabama, and the development of an aquifer recharge potential map for the state. The latter project provides baseline data for a joint project with the USDA-Natural Resource Conservation Service (NRCS) to develop a statewide aquifer contaminant vulnerability map by using statistically modified U.S. Environmental Protection Agency DRASTIC methodology. The Groundwater Assessment Section also works with the Ecosystems Investigations Program (EIP) at the GSA to provide hydrologic assessments of cave systems in north Alabama that serve as habitats for several federal and state protected species, which are conducted under grants with the U.S. Fish and Wildlife Service (USFWS) and U.S. Army Corps of Engineers (USACOE). Surface water assessments to evaluate water quality and sedimentation impacts and to assess groundwater-surface water interaction related to runoff and recharge are also conducted by the GAP with the goal of assisting groundwater development activities and management of conjunctive surface water-groundwater resources in the state.

## **ECOSYSTEMS INVESTIGATIONS PROGRAM**

Aquatic biodiversity studies are important not only from the standpoint of faunal inventories, but also because organisms and communities of organisms are very useful tools for monitoring stream water quality. The EIP has conducted scores of studies in this area, including basin surveys of fishes, mussels, crayfishes, cave shrimp, and other aquatic invertebrates, status surveys of federally listed threatened and endangered species and state conservation priority species, and investigations of fish movements in large rivers. EIP biologists recently completed several projects, are continuing others, and are negotiating several new studies, broadening our scope to include new projects that will assist with improvements to degraded streams and assist in reaching and training a broader audience of future researchers, including students in predominantly minority universities. Some new initiatives include efforts to remove in-stream barriers to fish passage in conjunction with The American Forest Foundation, USFWS,

PELA, Inc., and the Winston County Commission; assisting in efforts to monitor restoration efforts on failing stream banks in the Black Warrior River system in conjunction with The Nature Conservancy (TNC); and a pilot project to restore streams near abandoned mine lands in conjunction with the Reclaiming Appalachia Coalition (RAC) and Cawaco. We are also assisting TNC, the USFWS, the Alabama Department of Environmental Management (ADEM), and the USACOE in ascertaining the current state of fishes in the lower Cahaba and Alabama Rivers in anticipation of a possible fish bypass project to improve that fishery. The EIP is finishing a 3-year study aimed at detecting heretofore unknown populations of the federally threatened Trispot Darter in the upper Coosa River system in cooperation with Cawaco, ADEM, USFWS, the Alabama Power Company, the Georgia Department of Natural Resources, the ADCNR, and the University of West Alabama. Annual monitoring of the endangered Alabama Cave Shrimp and the state-protected Tuscumbia Darter on Redstone Arsenal (RSA) continues. Additional funding was provided by RSA to define the recharge of a spring complex on post that harbors a significant Tuscumbia Darter population where anticipated development threatens. An article summarizing past efforts to protect the Alabama Cave Shrimp was published in an Alabama-specific trade journal, *The Wave*, in 2020, and an in-depth 25+-year retrospective of that research is planned in conjunction with the USACOE. A 3-year effort to evaluate toxicity of bed sediments in the Mobile/Tensaw Delta in cooperation with ADCNR is in its second year. The EIP is cooperating with the NRCS to identify areas in need of installation of best management practices in streams on Sand Mountain in the Tennessee River drainage, an area with considerable agricultural impacts.

The EIP initiated a cooperative effort in 2008 with the ADCNR and USFWS and other partners to address the conservation needs of aquatic species through the collection, acquisition, and presentation of integrated aquatic resource data in designated Strategic Habitat Units (SHUs). That initial phase of the project ended in 2019 and a summary report was delivered. The EIP has since acquired additional funding to continue through at least 2023. The data acquired during these project phases are used to provide information to local landowners, watershed organizations, local governments, and regulatory

agencies to enhance conservation opportunities for species recovery and restoration. Publications summarizing that research, such as circulars, bulletins, information series, and special maps, have been published at the GSA, and we anticipate other papers will be published in national and international refereed journals. Some recent products related to the SHU project include a special map summarizing a recent fish Index of Biotic Integrity (IBI) and habitat evaluations in the Bear Creek system of the Tennessee River drainage, a bulletin summarizing a watershed assessment of the Bogue Chitto Creek system, and circulars summarizing fish IBIs in the Choctawhatchee and Sipsy River systems. The EIP is assisting staff and students from the University of North Alabama in preparing a bulletin summarizing an assessment of the historic fish fauna and recent fish IBIs in the Cypress Creek system of the Tennessee River drainage, which has proven to be a remarkably rich and unusually intact fauna. The EIP is also helping write a comprehensive book on the crayfish fauna of Alabama with Dr. Guenter A. Schuster, professor emeritus from Eastern Kentucky University, and Dr. Christopher A. Taylor of the Illinois Natural History Survey at the University of Illinois, which has been accepted for publication by the University of Alabama Press with an anticipated publication date in early 2022. A GSA Information Series written by a retired EIP staff member summarizing the history of dam construction on the lower Tombigbee and Black Warrior Rivers was also published in 2020. Individual EIP staff members also serve on the Alabama Geographic Names Committee, assisting the U.S. Board on Geographic Names in investigating petitions for name changes or new names for geographic features, and for the past year have served as Citizen Scientists with the American Geophysical Union.

### **Geochemical Laboratory Section**

The Geochemical Laboratory continued in its support role for GSA research and regulatory analytical needs and in its acquisition of baseline geochemistry of Alabama waters, soils, rocks, and streambed sediments. Laboratory staff also revised a manual that updates and outlines the standard operating procedures for the laboratory.



# ARIZONA

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## INTRODUCTION

The Arizona Geological Survey (AZGS) and its predecessors have been providing critical geologic information to Arizona since 1893. Other than the period from 1988 to 2016, when it was a separate state agency, the AZGS has been in the University of Arizona in Tucson. The AZGS receives a modest base appropriation from the state legislature; we pursue external funding and cooperative partnerships with federal, state, and local agencies. The AZGS is relatively small, with about 20 staff members, but we have a fairly wide range of expertise, with particular emphasis on geologic mapping, geologic hazards, digital geologic data, mineral resources, and public outreach.

## GEOLOGIC MAPPING

The AZGS maintained its integrated bedrock and surficial geologic mapping efforts through the interesting period of June 2019 and June 2020. The first 8 months or so were business as usual. Draft versions of four 1:24,000-scale geologic maps on the northwest margin of the Phoenix metropolitan area and two near the Colorado River in western Arizona were delivered to the STATEMAP coordinator in September 2019. These areas had been prioritized by our State Mapping Advisory Committee (SMAC) because of geologic hazard issues, mineralization, and complex tectonics and because they complemented our previous mapping. In the Phoenix-area maps, we were able to digitize and incorporate extensive geologic mapping done by AZGS mappers in the 1980s.

We met with our excellent, supportive SMAC in October 2019 to receive their feedback and guidance before we prepared the FY 2021 STATEMAP proposal. At that time, we discussed the possibility that additional funding might be available to the states, and we gave more consideration to compilation mapping projects than we had had for many years. We submitted a STATEMAP proposal to the U.S. Geological Survey (USGS) in December 2019 and rapidly developed a supplemental proposal in February 2020.

Our mapping group began the next cycle of field mapping in late fall of 2019 and continued into early March 2020. Field activities were briefly paused, and our staff transitioned to

working remotely in March. Our highly capable GIS and IT staff were able to get people functioning effectively on our mapping projects via remote connections, and we successfully pursued research waivers through the University of Arizona to restart our field mapping projects in late March. Each of our field areas was conducive to camping, mappers were deployed in separate field vehicles whenever possible, social distancing was observed in any interactions between geologists in the field, and care was taken in obtaining provisions for the field. We were able to complete our field mapping in May with no cases of COVID-19, and we did not find it necessary to request a no-cost extension for our STATEMAP projects.

We participated in the National Geological and Geophysical Data Preservation Program to update and re-release 20 of our digital geologic maps produced in the 2000s. Even though these maps were produced in a GIS format, many of their geodatabases were in poor shape and none conformed to the NCGMP09 (National Cooperative Geologic Mapping Program 2009) standard. In all cases, we updated unit nomenclature to conform with our current usage; for some of the maps, we did more substantial revisions and released new versions of the maps.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Geologic Hazards

AZGS staff conducted several research projects and investigations into various aspects of landslide hazards in Arizona. Post-wildfire hazards are of particular importance, given the size and frequency of wildfires in the western United States in the past few decades. Collaborative research with colleagues in the Department of Geosciences at the University of Arizona and the USGS has focused on understanding triggering mechanisms for post-wildfire debris flows (slopes, rainfall intensity thresholds, changes in runoff parameters). In addition, we are cooperating with state and local emergency managers to model how runoff from forested areas may change after future wildfires, with the focus on identifying potential hazard areas before fires occur. A second landslide project supported by

state funds involved mapping or remapping landslides in a corridor straddling Interstate 17. This is the principal transportation corridor between Phoenix and Flagstaff, and it traverses rugged terrain. We were able to refine mapping of known landslides and identify new landslides in the corridor. A resulting special report was shared with the state Department of Transportation and Division of Emergency Management, the professional geologic community, and the general public.

### **Critical Minerals**

We were very pleased to begin a new Earth Mapping Resources Initiative (Earth MRI) project in June 2020 focused on understanding the distribution and genesis of sedimentary lithium deposits in western Arizona. The 2-year Earth MRI project complements our primary STATEMAP detailed mapping project in the current cycle.

### **Carbon Sequestration**

The AZGS has joined the Carbon Utilization and Storage Partnership (CUSP) to characterize, catalog, analyze, and rank carbon capture, utilization, and storage options for Arizona. The CUSP partnership comprises 13 states and three national laboratories and is one of four regional initiatives recently funded by the U.S. Department of Energy.

### **Digital Geology**

The AZGS completed a rework of the National Geothermal Data System with improved security, improved metadata validation, and several quality-of-life improvements to the user interface. The new site can be seen at <https://data.geothermal-data.org/>. The AZGS expects to continue limited support and further improvements to the site through July 2021. The site will remain online after that date, but the AZGS will provide no further technical support.

# CALIFORNIA

## California Geological Survey

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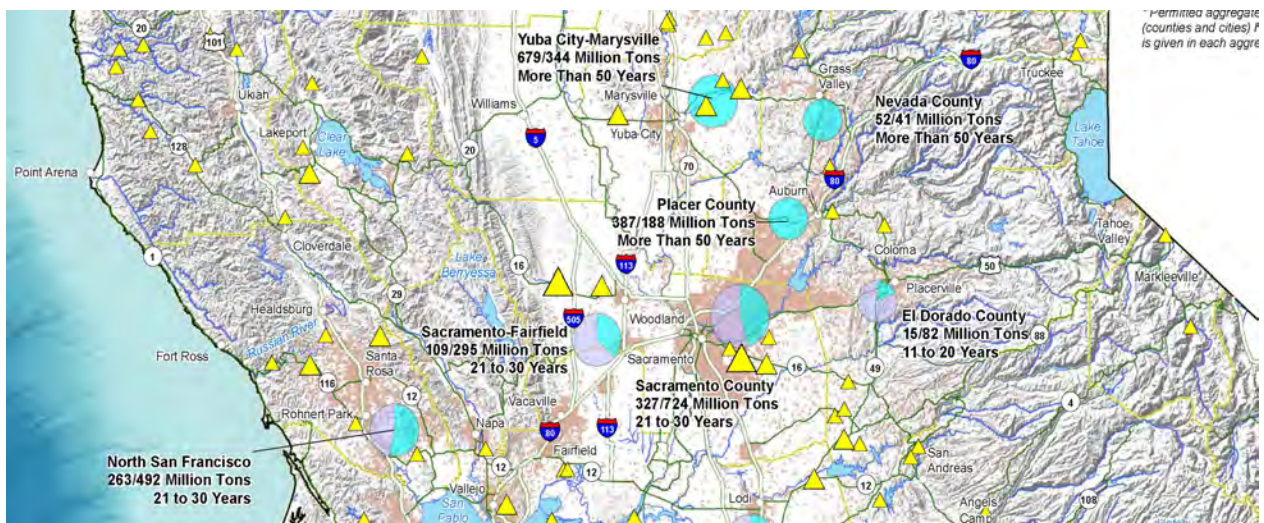
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**Figure 1** Portion of the *Aggregate Sustainability Map of California*.

## INTRODUCTION

The mission of the California Geological Survey (CGS) is to provide scientific products and services on the state's geology, seismology, and mineral resources, including their related hazards that affect the health, safety, and business interests of the people of California. The Office of the State Geologist was created in 1851, and the CGS was established by the State Legislature in 1860. The CGS is a division within the Department of Conservation, which is under the umbrella of the Natural Resources Agency. The CGS has its headquarters in Sacramento and has five field offices throughout the state. The CGS employs 118 geologists, engineers, seismologists, GIS cartographers, field instrument technicians, and clerical staff.

## GEOLOGIC MAPPING

Geologic mapping is completed by the Geologic and Landslide Mapping Program and the Forest and Watershed Geology Program. In addition, the Mineral Resources Program performs

new mapping under a cooperative agreement with the U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI) program. Each year, the CGS completes new geologic mapping, compiles geologic maps into regional maps, and works to publish geologic maps of California. In addition, the CGS prepares inventories of both climate (rainfall) and seismically induced landslides and presents them in a statewide landslide inventory database. In 2020, these programs completed the following projects:

- The Regional Geologic and Landslide Mapping Program completed two 7.5-minute quadrangle geologic mapping projects in Calaveras and Mendocino Counties covering 120 square miles.
- The Mineral Resources staff classified 6.8 million acres of land for the potential to contain economically significant deposits of construction aggregate. The classified lands contain about 22 billion tons of aggregate resources at a total value of about \$240 billion (Figure 1).
- The Mineral Resources staff evaluated deposits likely to contain



**Figure 2** An engineering geologist assessing the water repellency of burned soil on a hillside in Monterey County, California.

32 of the 35 mineral commodities that the federal government has identified as being essential to the economic and national security of the United States.

The Regional Geologic and Landslide Mapping Program is currently expanding to include a 3-D geologic framework pilot mapping program to address multiple benefits in the state. This pilot project is in alignment with the National Cooperative Geologic Mapping Program's Decadal Strategic Plan, and it allows the CGS to build momentum toward achieving wide-reaching geologic mapping goals.

## OTHER ACCOMPLISHMENTS

In 2020, engineering geologists from the Forest and Watershed Geology Program and the Geologic and Landslide Mapping



**Figure 3** Tsunami damage in Crescent City, California, from the 1964 Alaska earthquake.

Program assisted Watershed Emergency Response Teams in assessing 15 wildfires that affected more than 1.7 million acres for post-fire life and safety hazards, such as debris flows, rock-falls, flooding, and sedimentation (Figure 2).

Seismic Hazards Program staff completed updated tsunami hazard maps for emergency planning for Humboldt County and completed new statewide Tsunami Design Zone maps (covering 20 counties) for use on essential and critical structures under the California Building Code (Figure 3).

Seismic Hazards Program staff were able to collaborate via telework to complete four Seismic Hazard Zone Maps (for liquefaction and earthquake landslides) covering 230 square miles in Contra Costa and San Mateo Counties. Seismic Hazards Program staff documented earthquake effects for the Monte Cristo (magnitude 6.5 in Nevada) and Owens Lake (magnitude 5.7) earthquakes, and they evaluated faults in the San Diego, San Francisco, Santa Rosa, and Eureka areas.

The California Strong Motion Instrumentation Program (CSMIP) upgraded 32 stations to real time in 2020 to contribute to the California Earthquake Early Warning (ShakeAlert) System. The CSMIP now operates 192 strong motion stations in real time. The CSMIP generated ShakeMaps for 184 California earthquakes and recorded 6,798 station records from 326 earthquakes of magnitude 3 and above.

# COLORADO

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### INTRODUCTION

The mission of the Colorado Geological Survey (CGS) is “Building vibrant economies and sustainable communities safe from geologic hazards through good science, collaboration, and sound management of mineral, energy, and water resources.” The CGS is part of the Colorado School of Mines. Founded in 1874, Mines is a public research university devoted to engineering and applied science. The Survey employs 22 geologists and other professionals. The Colorado legislature and Mines guide the programs and priorities of the CGS. The CGS focuses on protecting public safety and promoting responsible economic development of the state’s natural resources.

### GEOLOGIC MAPPING

The CGS published geologic maps of six 7.5-minute quadrangles. Mapping included projected high population growth areas, major transportation corridors, and areas with suspected or known geologic hazards. The CGS created the following derivative map products based on the geologic maps:

- Additions to a statewide inventory of mapped landslides
- Additions to mineral resource maps
- Resource maps of sand and gravel
- Geologic hazard inventory maps
- Post-wildfire debris flow maps
- Landslide susceptibility maps
- Aquifer maps

State and local officials regularly use geologic and derivative maps to accomplish the following:

- Locate new municipal wells
- Site waste-disposal facilities
- Identify potential industrial mineral resources and develop mineral resource extraction plans
- Protect citizens and public infrastructure from geologic hazards
- Develop predisaster mitigation and natural hazard recovery plans

### OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

With the still-rising mountains containing thousands of faults, Colorado’s dynamic landscape features more than 90 known potentially active faults and more than 700 recorded earthquakes of magnitude 2.5 or higher since 1867. The state has experienced large natural (magnitude 6.5 or higher) and human-triggered (induced) earthquakes. Colorado will continue to experience large earthquakes periodically in the future.

Knowledge of both hazards and risk is vitally important in the resilience planning for earthquake events. However, Colorado lacks information on faults, and its seismic network is not adequate to assess earthquake hazards and risks. To address these issues, the CGS has added two new stations to the state seismometer network and published two recent studies on potentially active faults.

Wildland fires burned close to 200,000 acres in the state, placing many communities at risk of post-fire debris flows and shallow landslides (Figure 1). In one community where risks are high, the CGS is installing a soil moisture system designed to monitor and forecast processes. Our goal is to understand the instability mechanisms in the area and develop an early warning system that emergency managers can deploy to other post-fire sites.

Groundwater is a critical natural resource issue in Colorado. Colorado developed a statewide water supply plan for surface water and groundwater. The state is also developing a statewide groundwater protection plan that will identify aquifer vulnerability to pollution. The state asked the CGS to augment the programs and develop a comprehensive online portal to the geoscience behind these efforts. An online portal makes information and data available to a broad public audience.



**Figure 1** Photograph of the Calwood Fire, Boulder County, Colorado.

This effort compiles existing material in an easily accessible digital format from many sources. It builds on our award-winning 2003 *Ground Water Atlas of Colorado*. It follows much of the original structure, adding new data and revising information based on expanding scientific knowledge of Colorado's

complex geologic setting. Not only has the technology for conveying information changed dramatically since 2003, but scientific knowledge—both geologic and hydrologic—has also expanded significantly.

# CONNECTICUT

**State Geological and Natural History Survey of Connecticut  
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## INTRODUCTION

The Connecticut Survey is responsible for the coordination and implementation of statewide natural resource data collection inventories in the following areas: surficial and bedrock geology; mines and mineral resources; inventories of fauna and flora, including endangered species; and the development and operation of resource-oriented database management systems. The mission of the Connecticut Geological and Natural History Survey is defined in the Connecticut State Statutes (Ch 462, Sec 24-1 to 24-4). In 2006, the Department of Energy and Environmental Protection (DEEP) separated the State Survey into the Geological Survey within the Office of Information Management (OIM) and the Natural History Survey within the Bureau of Natural Resources (BNR), Wildlife Division. This report pertains to the Connecticut Geological Survey.

## GEOLOGIC MAPPING

### Bedrock Mapping

The Connecticut Survey, in conjunction with the State Geologic Mapping Advisory Committee, adopted a long-range Bedrock Mapping Plan in 2015, with the goal of producing a new statewide bedrock geological map of Connecticut. The vision is an integration of modern mapping and interpretations within a digital geologic framework. New detailed bedrock mapping projects are being pursued as contributions toward the overall effort. Within the National Cooperative Geologic Mapping Program, STATEMAP component and EDMAP educational component, the Connecticut Survey is actively working with federal and academic partners to update the Connecticut Bedrock Map. Traditional field work, petrography, and geochemical analyses support new geologic correlations and tectonic interpretations. Mapping technologies that capture digital field data are integral to the data compilation process. The Connecticut Survey has also embraced the Association of American State Geologists/U.S. Geological Survey (USGS) national Geologic Map Schema (GeMS), providing greater interoperability of geologic map data across Connecticut and across the nation. Completed map products

and geologic reports are available online at [www.ct.gov/deep/geology](http://www.ct.gov/deep/geology) and <https://ngmdb.usgs.gov>.

### Surficial Mapping

Surficial and Quaternary geologic mapping at 1:24,000 scale, developed cooperatively by the Connecticut Survey and the USGS, is available statewide, both onshore and within Long Island Sound. It has been published as USGS Scientific Investigations Map 2784 (Stone et al. 2005). One of the primary resource layers used in environmental analysis by the Connecticut DEEP is the digital geologic data, and this is available for download through the Connecticut DEEP GIS Open Data portal at <https://ct-deep-gis-open-data-website-ctdeep.hub.arcgis.com/>.

## GEOHAZARDS

### Concrete Degradation

Crumbling concrete foundations in eastern and central Connecticut are a crisis affecting hundreds or thousands of homeowners, businesses, and municipal buildings. The deterioration is caused by chemical weathering of sulfides, notably pyrrhotite, in the crushed rock aggregate of the concrete. The Connecticut State Geologist serves as a technical resource on this issue, has been involved in legislative hearings, and has provided technical review of scientific reports. The Connecticut Survey has prepared online [interactive mapping](#) on the statewide distribution of pyrrhotite in Connecticut bedrock. Blasting and rock crushing operations involving sulfide minerals can also have an impact on environmental quality by causing acid drainage, which is detrimental to drinking water quality and can have ecological impacts. To provide more detailed mapping of pyrrhotite and other sulfide minerals, the Connecticut Survey is compiling 1:24,000-scale geologic mapping and analyses for an area of sulfide-rich stratified metamorphic rocks in north-central Connecticut as part of STATEMAP FY 2020. The resulting map will provide context for subsequent geologic investigations on sulfide mineralogy and serve as an important tool for land-use decisions.

## DATABASE DEVELOPMENT

### Resource Inventory and GPS Mapping

Field mapping services are provided for various programs within DEEP's Conservation Branch, including Land Acquisition, Boating, Parks, Forestry, Fisheries, Greenways, and Natural Areas. Mapping services include trail mapping in parks and forests, facility mapping of state parks, public boat launches, biologic and geologic features of significance, and the establishment of survey benchmarks. Hard copy and digital map products are available through the DEEP store and online.

### Bedrock Mines and Quarries

A new bedrock mines and quarries map and database update is underway, with support from the USGS National Geological and Geophysical Data Preservation Program and Earth Mapping Resources Initiative (Earth MRI). Database verification and enhancements are the focus of ongoing Connecticut Geological Survey field work and contribute to the state geologic sites database. This database is used for routine technical assistance to DEEP programs, consultants, state and federal agencies, and citizens. The geologic sites database is also a central resource for Connecticut Geological Survey land acquisition reviews within DEEP.

## COLLECTIONS & DATA PRESERVATION

As a participant in the National Geological and Geophysical Data Preservation Program, the State Survey is making collections information available to academic researchers, educators, and the public. Geoscience data preservation efforts are ongoing for the library collection of books, manuscripts, maps,

scientific specimens, and unpublished survey files. Pipelines and other Connecticut infrastructure projects produce new rock core, providing scientifically important core to Survey collections. The Connecticut Survey Rock Core Collection, Educational Hand Sample Collection, dinosaur track catalog, historic Biennial Reports, and unpublished map files are described on the DEEP website at [www.ct.gov/deep/geology](http://www.ct.gov/deep/geology) and the [USGS National Digital catalog](#). Access to the Connecticut Survey library and the Randolph P. Steinen Collections Facility is by appointment.

## PARTNERSHIPS

The Connecticut Geological Survey continues to develop cooperative partnerships toward the goal of improved geoscience information for DEEP programs and the citizens of Connecticut. Geologic mapping, topical research projects, and database enhancements are pursued through a combination of federal, state, academic, and nonprofit collaborations. The Survey office at the University of Connecticut furthers student engagement in applied geoscience and environmental projects. These collaborations provide valuable work experiences for students, contribute to DEEP environmental protection efforts, and further the Survey mission toward improved geoscience information for resource assessments, hazards mitigation, environmental quality, and outdoor recreation.

## PUBLICATIONS

For publications, please see our [Catalog of State Geological Survey publications](#). Sales are through <http://www.ctdeep-store.com>, (860) 424-3555, or [deep.store@ct.gov](mailto:deep.store@ct.gov).

# DELAWARE

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## INTRODUCTION

The Delaware Geological Survey (DGS) is a science-based, service-driven state agency that is administratively, by statute, under the charge of the University of Delaware. The DGS is responsible for systematic investigation of the geology, water resources, and natural hazards of the state; preparation of reports and maps; and advising state officials on the optimal utilization and equitable administration of the state's geological resources.

The DGS is a unique agency within the Delaware state government because we are both a state agency and a university research and service unit. Financial, personnel, and other administrative matters are managed by the university. The DGS budget is funded by an annual direct appropriation from the State of Delaware with related reporting responsibilities to both the Office of the Governor and the Delaware General Assembly. The DGS contributes to the educational mission of the university through collaboration with faculty and by providing students and interns with hands-on experience working with DGS researchers and exposure to our scientific and field equipment. The DGS became formally affiliated within the university's College of Earth, Ocean, and Environment in July 2008. Most DGS scientists have secondary faculty appointments in the College's Department of Geological Sciences.

## GEOLOGIC MAPPING

The DGS geologic mapping program includes mapping of Delaware's surficial geology, Piedmont bedrock geology, and coastal and offshore geology. Our efforts focus on issues that affect the quality of life of the citizens of Delaware. Many areas of the state have shown significant growth and development over the last several years. DGS geological investigations provide supporting information for the management of natural resources in light of these increasing public needs and environmental pressures with a wide variety of applications, including groundwater, land use, natural hazards, environmental geology, soils and agriculture, geotechnical engineering, coastal protection, and beach nourishment.

The primary goal of the DGS geological mapping program is to map surficial geology of the First State at the detailed scale of 1:24,000. The U.S. Geological Survey's (USGS's) STATEMAP program provides federal dollar-for-dollar matching funds for most of the DGS's geologic mapping efforts. Products from the mapping efforts include PDF map publications as well as digital data (shape and data-point files) that can be downloaded and imported into GIS software. The current surficial geology mapping study area is the Wilmington South and Delaware City Quadrangles. These quadrangles were chosen, in part, with the guidance of the Delaware Geologic Mapping Advisory Committee (DGMAC). The DGMAC is composed of Survey stakeholders from diverse backgrounds, including federal, state, and county government; environmental consulting; academia; and the nonprofit sector. The committee prioritized this area over five other possible project locations because of the high population density, the large number of environmentally compromised sites, and the proposed redevelopment of a state park. Field work for this project will be completed in June 2021.

The DGS maintains the Atlantic Outer Continental Shelf Core and Sample Repository. This repository includes nearly all remaining sample materials related to geologic investigations conducted offshore of the eastern coast of the United States. It has recently been utilized by parties anticipating possible future interest in potential offshore East Coast energy (e.g., wind) resources. The DGS recently concluded a study that reexamined the evidence for buried rift basins under the Delaware Coastal Plain. These basins, which are projected to occur thousands of feet below the land surface, represent ancient rift valleys formed approximately 140 to 250 million years ago as North America and north Africa were torn apart by global tectonic forces. We reexamined the idea of these basins as part of our work for a regional assessment of geological carbon storage potential by the Midwest Regional Carbon Sequestration Partnership.

The DGS also partnered with the Bureau of Ocean Energy Management (BOEM) in the exploration and identification of offshore sand resources for beach replenishment projects.

This endeavor was prompted by the ongoing demand for sand resources and the depletion of resource areas in state waters off Delaware. Targeted areas of exploration funded by BOEM are situated in federal waters. The DGS has taken the lead in identifying which geologic units have the greatest potential for sand suitable for beach replenishment. This research led to a new offshore geologic map, which utilized sediment-core information and geophysical data to map surface geology across the inner continental shelf. Efforts to organize more localized coring activities, designed to fill data gaps and refine sand-volume estimates, are currently underway, with potential collaboration with the U.S. Army Corps of Engineers (Philadelphia District); the Department of Natural Resources and Environmental Control, Division of Watershed Stewardship; and BOEM.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

### Hydrologic Investigations and Services

Surface water and groundwater are among Delaware's most important natural resources. The DGS hydrology program activities include studies of the occurrence, availability, quantity, and quality of groundwater resources, aquifer and water-table mapping, unconfined and confined aquifer hydrology, groundwater modeling, groundwater discharge to surface water bodies, land subsidence, and water-resource issues associated with land-based wastewater disposal.

The DGS is the lead agency for collection and analysis of data on groundwater levels and stream discharges in Delaware. In 2016, the DGS was awarded funds to enhance the state's groundwater monitoring network in southern New Castle and Kent Counties. Well installation is complete, and this project added 34 additional monitoring wells with automated data loggers to our current network, which now totals 90 dedicated monitoring wells. More than 32 million records have been collected to date. Data are reviewed by the DGS for quality control and are then available from DGS online sources.

The DGS also became a node in the National Ground-Water Monitoring Network through a noncompetitive funding agreement with the USGS. The DGS hydrogeologists will select wells from our network and nominate them to be included in the national network based on protocols provided in the Advisory Committee on Water Information, Subcommittee on Ground Water, National Network Framework Document.

We will also continue to track surface water conditions using 16 stream-gage and 9 tide-gage stations that are maintained around the state in cooperation with the USGS. The DGS advises on water-resource management decisions through ongoing monitoring of water conditions, summarized monthly in a Summary of Water Conditions available on the DGS web-site.

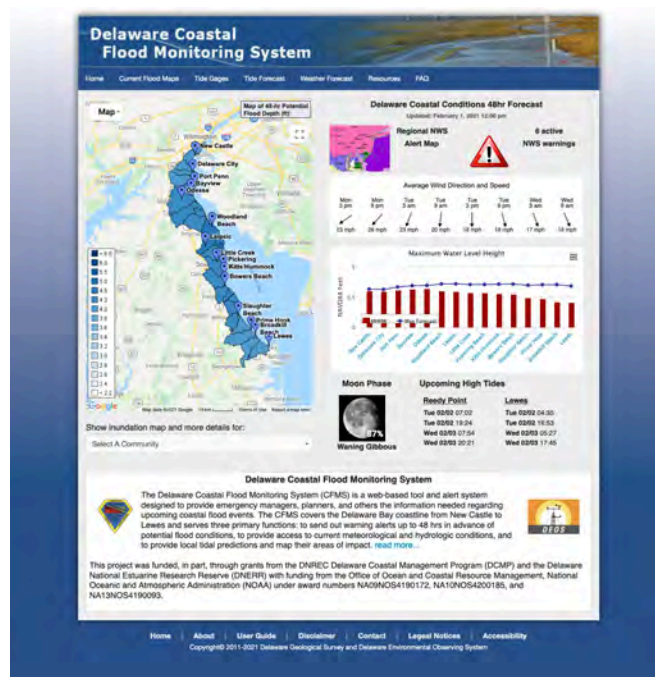
### Geologic Hazard Investigations and Services

The DGS has ongoing responsibilities for understanding natural hazards in Delaware and advising the appropriate

emergency management agencies on these hazards and the related mitigation and response. Flooding hazards, including stream flooding and coastal flooding, and seismic hazards are the main focus of our efforts. The DGS, in cooperation with our university partners, has developed web-based mapping and modeling tools, such as our Coastal Flood Monitoring System, to assist state and local government emergency managers with coastal flooding planning and mitigation (Figure 1).

The DGS maintains a network of five seismological stations in Delaware to monitor earthquake activity. The seismic signals are captured digitally using Earthworm, a seismic processing system developed by the USGS, and are shared with the Lamont-Doherty Cooperative Seismographic Network and the Center for Earthquake Research and Information. We also are part of the Northeast U.S. Seismic Network and the Southeast U.S. Seismic Network. The DGS adopted two multichannel, broadband seismometers, which were installed in 2013 as part of the national EarthScope Transportable Array program.

For data and information from the DGS, visit our public web-site at [www.dgs.udel.edu](http://www.dgs.udel.edu). The DGS Annual Report of Programs & Activities for 2019–2020 can be viewed at [https://www.dgs.udel.edu/sites/default/files/annual\\_report/DGS\\_Annual\\_Report\\_2019-2020.pdf](https://www.dgs.udel.edu/sites/default/files/annual_report/DGS_Annual_Report_2019-2020.pdf).



**Figure 1** Screenshot of the home page of the Delaware Coastal Flood Monitoring System, which is a web-based tool and alert system designed to provide emergency managers, planners, and others the information needed regarding upcoming coastal flood events.

# FLORIDA

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### INTRODUCTION

The Florida Geological Survey (FGS) was established by the Florida Legislature as an autonomous state agency in 1907. Today, the FGS is a division within the Florida Department of Environmental Protection (DEP), which has oversight of environmental regulation, ecosystem restoration, and land management and recreation programs. The FGS serves the needs of DEP and its mandated geoscience mission through the four sections highlighted below. In FY 2019–2020, several research activities were completed to improve the characterization of the state's geology, geomorphology, hydrogeologic systems, and geohazards. These focus areas strike a balance with the roles of other geoscience-related regulatory agencies in Florida.

The FGS also continued its outreach activities, reaching thousands of its customers through field trips, presentations, and its [newsletter](#). Individual staff also served groups, including the [Water Science and Technology Board](#) of the National Academies, the [Florida Board of Professional Geologists](#), and the [Florida Coastal Mapping Program](#). In the spring of 2020, work-at-home orders in response to the COVID-19 pandemic created workflow inefficiencies and hindered field activities.

### GEOLOGIC MAPPING

The Florida Geological Survey Mapping Initiative (FGSMI) serves as a framework to expedite completion of a new statewide surficial geologic map of Florida, as well as to produce a demonstration-scale 3-D geologic model. This initiative is led through the FGS Geologic Investigations Section and the Director's office. The path of the FGSMI is framed by a Project Management and Implementation Plan that includes risks, resources, dependencies, communications, policies, tasks, and timelines. Fifteen geoscientists are contributing to this initiative. In addition, during the 2020 Florida legislative session, a new drill rig and two new geologic mapping positions were approved for the FGS. Paramount to the success of the FGSMI is its integration with FGS's new GEOlogic Data Enterprise System (GEODES), which is a cloud-based system that ties together borehole data, descriptions, geophysical logs, geologic collections, well locations in the field, and sample locations in the core repository. GEODES provides the digital

infrastructure for the FGSMI. The produced statewide coverage will be seamless and Geologic Map Schema ([GeMS](#)) compliant. STATEMAP predates the FGSMI and is a principal component of the initiative.

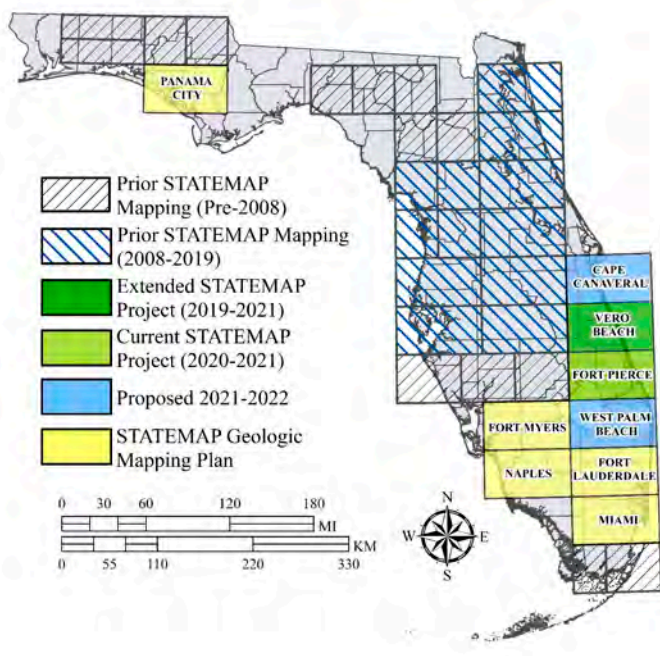
### STATEMAP

To date, the [FGS STATEMAP program](#) has mapped 56.4% of the state, collected more than 1,475 outcrop samples, produced 155 new geologic cross sections, and interpreted formation data on thousands of boreholes. The program has generated new geologic maps for more than 31,700 square miles of Florida at an average cost of \$218.49 per square mile and has produced 40 new publications. As of 2020, the total state plus federal investment in STATEMAP exceeds \$6.6 million.

The STATEMAP team is composed of 3.5 full-time staff (which includes grant-match positions) and is guided by a STATEMAP Advisory Committee, which annually defines a 5-year mapping plan. The FGS STATEMAP program nearly doubled its rate of mapping in 2011. Even with that increase, STATEMAP alone would not be able to complete mapping of the entire state until well beyond 2030. Additionally, those areas mapped prior to 2008 need to be revisited to take full advantage of high-resolution lidar data sets, include more recently acquired subsurface data, and utilize shallow 3-D stratigraphic models to refine surface map-unit contacts. Figure 1 allows comparison of the areas mapped since 2008 and includes the current long-range STATEMAP plan.

### FLAGMAP

The Florida Geologic Mapping Program (FLAGMAP) is designed to parallel STATEMAP toward the completion of the FGSMI through new geologic mapping within non-STATEMAP areas and, in some cases, pre-2008 STATEMAP areas. Data density will vary according to local complexity of the topography and stratigraphy. Data sources will include strategically selected borehole samples, including newly drilled boreholes, to establish a network of wells serving as data control for surficial and subsurface geological modeling. A new pickup truck-mounted hydraulic hammer rig, capable of retrieving push cores from as deep as 10 meters, will improve data coverage beyond existing [FGS Geologic Sample Repository](#) holdings.



**Figure 1** Mapped areas of Florida since 2008, including the current STATEMAP long-range plan.

### 3-D Florida

The 3-D Florida initiative is a precursor to the FGSMI and included three long-term goals: completion of a 3-D geologic model of Florida, acquisition of statewide Quality Level 1 lidar data, and completion of a new digital elevation model-draped statewide geologic map. In part because of the [Florida State-wide Lidar Assessment](#) and funding by the U.S. Geological Survey (USGS) and the Florida Legislature, [statewide Quality Level 1 lidar acquisition](#) is underway and will be completed in 2022. With this goal nearly complete, the surface mapping function has shifted to the FGSMI, which also includes a 3-D geologic demonstration project. These activities feed into long-term completion of the statewide model, 3-D Florida. During the demonstration project, open-source 3-D modeling software will be evaluated in the context of GEODES and GIS workflows, Florida's geologic framework, and their suitability for being upscaled statewide.

### Earth MRI

The FGS was awarded \$100,000 to complete a study of the distribution and geochemistry of heavy mineral placer deposits adjacent to and along Trail Ridge in northeastern Florida. This funding came through the USGS's Earth Mapping Resources Initiative (Earth MRI) based on interest in titanium, a Phase 3 mineral commodity. The study began in December 2020 and is funded for 2 years, with 1:1 matching by the FGS for a total project cost of \$200,000. The deliverables will include a surficial geologic map of the [Florida Focus Area](#), which is composed of approximately 2,000 square kilometers (more than

750 square miles) adjacent to the Georgia border. Multiple cores will be acquired, which will also meet the mutual 3-D data needs of the FGSMI.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

### Applied Geoscience Services

The Applied Geoscience Services Section continues to provide technical assistance with the development and review of hydrologic models in support of environmental restoration and conservation. The reviews are often associated with regulatory issues pertaining to waste disposal, including landfills and underground injection control wells. The FGS also proactively responds to requests for local subsurface characterization in support of historic land use and ground collapse. Our ground-penetrating radar team completed surveys related to potential sinkhole hazards in state parks, illegal dumping, and historic cemetery delineation.

The section continues its production of [statewide potentiometric surface maps](#) of the upper Floridan aquifer system. The mapping is being conducted in cooperation with the state's five water management districts. The districts provide water-level measurements obtained from monitoring wells twice a year in May and September. In addition, during the drawdown of the Rodman Reservoir in central Florida, the team mapped previously unknown springs and collected discharge measurements from springs and along the Ocklawaha River to help identify areas of groundwater recharge and discharge, which helps inform water management activities.

### Geologic Information and Data Management

In FY 2019–2020, the Geologic Information and Data Management Section was awarded a USGS National Geological and Geophysical Data Preservation Program grant to photograph, scan, and transcribe historic FGS field books from the early 1900s and make them publicly available. These resources include notations on Florida-specific geoscience locations (e.g., sinkholes, springs, or mines and mining operations). Over the life of the project, approximately 300 books were digitally preserved either as PDFs or images. This totaled more than 25,000 pages, with 2,700 being transcribed to searchable text. After final quality assurance/quality control processes, all books were uploaded and made publicly available to serve as important historical, scientific, and economic data resources.

The [GEODES data solution](#) was completed at the end of FY 2018–2019 through project management that included weekly requirement validation workshops attended by FGS database managers and geologists, as well as the contractor programming team at Kyra Solutions LLC. Upon completion, GEODES contained information for more than 19,850 borehole records, 5,400 suites of geophysical logs totaling 19,000 individual logs, 9,427 archived surface samples, and more than 600 exposures. During FY 2019–2020, the FGS and its contractor migrated

more than 5,500 legacy descriptions from a much older database, bringing the total borehole descriptions to more than 10,000.

The data solution can be accessed via the internet and a [web map application](#), and logins with different user permission levels can be customized to allow data entry from trusted partners in other state agencies, such as water management districts. Completion of GEODES sustains long-term FGS support for the FGSMI, including 3-D geologic mapping. It will also address client needs for detailed lithologic, borehole, stratigraphic, and geophysical data, with options for expansion capabilities to assimilate other public geologic information sources.

## **Geological Sample Acquisition and Management**

The Geological Sample Acquisition and Management Section maintains the FGS Geological Sample Repository and provides access to it for research by the academic, scientific, regulatory, and private sector communities. The section also maintains the FGS drill rigs and associated equipment required for collecting geological samples and borehole geophysical log data in support of subsurface characterization. Monitoring wells were installed by the team support agency to assess groundwater quality and develop minimum flows and levels. Despite field delays caused by staff turnover and the pandemic, the team completed two new cores totaling 665 feet and acquired geophysical logs from both boreholes. Staff also repaired a DEP groundwater network monitoring well.



# IDAHO

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## INTRODUCTION

The Idaho Geological Survey (IGS) is a nonregulatory state agency that leads in the collection, interpretation, and dissemination of geologic and mineral data for Idaho. Formerly known as the Idaho Bureau of Mines and Geology, the agency has served the state since 1919. The Survey's mission is to provide the state with timely and relevant geologic information. Members of the IGS fulfill this mission through applied geologic research and strong collaborations with federal and state agencies, academia, and the private sector. IGS research focuses on geologic mapping, geologic hazards, hydrogeology, geothermal energy, oil and gas, and metallic and industrial minerals. The Survey's Digital Mapping Laboratory produces new digital geologic maps, data sets, and publications, which are available to the public on the IGS website. The IGS is also engaged in the archiving and dissemination of historic mining records, community service, and earth science education.

## GEOLOGIC MAPPING

In FY 2020, new mapping funded by STATEMAP was conducted in the Elk City, Preston, Salmon, and Weiser-Boise project areas, where Survey geologists mapped five 7.5-minute quadrangles (Sawyer Ridge, Hungry Ridge, Georgetown, Leesburg, and Weiser Cove). One 7.5-minute quadrangle map from the Salmon project area (Ulysses Mountain) was published, as was a map from the Weiser-Boise project area (Crane Creek Reservoir).

Mapping in the Elk City project area is needed to better define the stratigraphy and structure of metasedimentary rocks in the area. Quaternary deposits have been underemphasized in previous regional geologic mapping and need to be subdivided and better characterized because of their importance to transportation, water quality, fisheries, and forest management. The Elk City area continues to be an active area of mineral exploration, and long-term mapping efforts in Cretaceous and Proterozoic rocks near Elk City will enhance our understanding of the structural setting for these gold-bearing deposits.

Geologic mapping in the Preston project area is a high priority because of important natural resources, geologic hazards, and scientific advancement. Mapping of Paleozoic and Mesozoic strata and associated structures in the Idaho-Wyoming thrust belt will contribute to assessing the petroleum potential of southeast Idaho, as well as the potential for underground phosphate mining that is being proposed for the area northwest of Bear Lake. Regional highway, railroad, and natural gas pipelines are present, and water supply is a common problem in this semiarid portion of the state. Geologic hazards include recent seismic shaking from the Bear Lake fault system.

The Salmon project area continues to be one of the most active areas of mineral exploration in the state. Proterozoic rocks in the area host cobalt, copper, rare earth elements (REE), and gold mineralization, the age of and controls for which are poorly understood. Detailed mapping will enhance our understanding of the stratigraphic and structural setting for these deposits and help guide future exploration efforts.

Geologic mapping in the Weiser-Boise project area is needed to better understand how the rapid population growth in the area will affect land development, natural resources, groundwater and surface water, and agriculture. Mapping the Weiser Cove Quadrangle will give an up-dip perspective on the Hamilton and Willow hydrocarbon fields. Development of these fields is in the early stages, and it is critical that the growth in these fields be monitored and studied by the IGS.

The IGS received Earth Mapping Resources Initiative (Earth MRI) funding in FY 2020 to begin a 2-year mapping program in the Idaho cobalt belt near Salmon. Both cobalt and REEs are the focus of this effort.

Industry-funded geologic mapping was also conducted by the IGS. The Horse Heaven Syndicate funded mapping of the Yellow Pine Quadrangle in central Idaho, west of the previously mapped Stibnite Quadrangle funded by Midas Gold. Integra Resources Corporation funded the geologic mapping of two 7.5-minute quadrangles, De Lamar and Swisher Mountain, at and northwest of the De Lamar gold and silver mine in southwest Idaho.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Hydrogeology

Hydrogeologic activities performed by the IGS during FY 2020 included continued work on water budgets for the Big Lost River valley in east-central Idaho and initiation of a one-year hydrogeologic investigation in the Raft River valley in south-central Idaho. Both basins support agricultural resources for the state and are tributary to the Eastern Snake Plain aquifer.

### Geologic Hazards

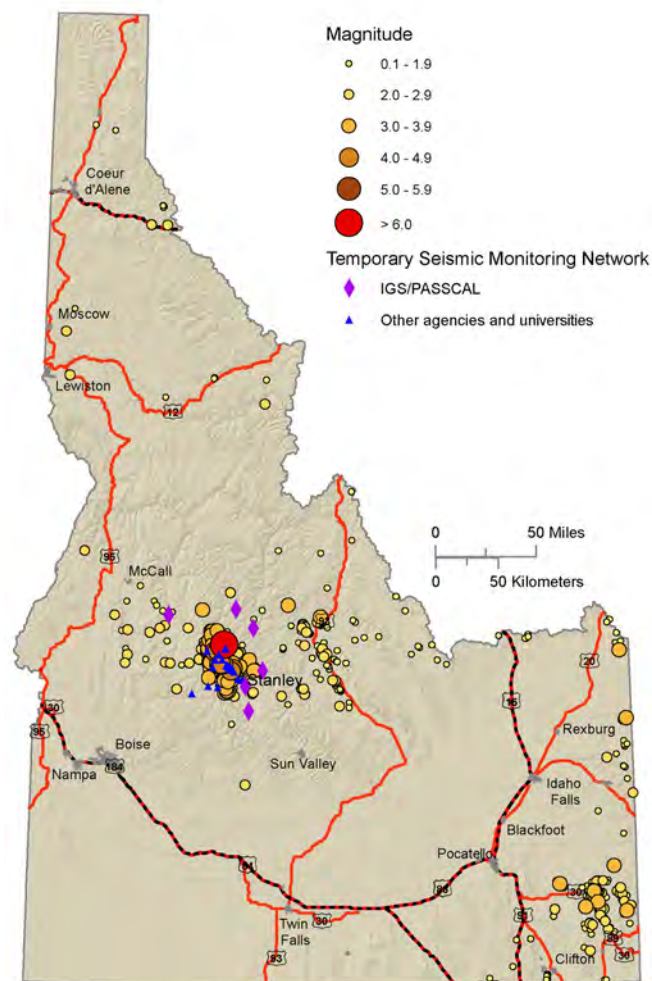
Significant seismic activity occurred in Idaho during FY 2020. On March 31, 2020, a magnitude 6.5 earthquake occurred approximately 30 kilometers north-northwest of Stanley, Idaho (Figure 1). This was the second largest earthquake to occur within Idaho in recorded history. The main shock was followed by an aftershock sequence that continues to produce magnitude 3 and 4 earthquakes.

Shaking from the magnitude 6.5 Stanley earthquake was felt widely across the western United States, but no major damage or injuries were reported. Because of heavy snowpack in the mountains near the epicenter, the shaking triggered numerous snow avalanches. Shaking also caused rockfalls and toppled several rock formations in the Sawtooth Mountains that hosted popular climbing routes. Liquefaction and lateral spreading caused by the main shock or early aftershocks were observed at Stanley Lake, where the inlet delta collapsed and disappeared into the lake.

In response to the Stanley earthquake, the Survey conducted aerial reconnaissance flights, deployed and maintained seismometers, visited Stanley Lake to map liquefaction, provided scientific information to the Idaho Office of Emergency Management, gave interviews to regional media outlets, posted timely information on social media, coauthored a peer-reviewed journal article, built and managed a virtual clearing-house for scientific data, and hosted web pages with summaries of the earthquake event and the liquefaction event.

### Minerals-Related Research

Three minerals-related research projects, all involving 1:24,000-scale mapping, are ongoing. The first, funded by Integra Resources Corporation, is in the De Lamar and Swisher Mountain Quadrangles in southwest Idaho. The area includes the past-producing De Lamar and Florida Mountain Mines, and mineralization consists of epithermal veins hosted in Miocene rhyolite and underlying Cretaceous granitic rocks. A second project, funded by the Horse Heaven Syndicate, is



**Figure 1** Map showing the epicenter of the March 31, 2020, magnitude 6.5 earthquake and aftershocks, and the temporary seismic monitoring network deployed by the Idaho Geological Survey (IGS) in partnership with Boise State University. PASSCAL, Portable Array Seismic Studies of the Continental Lithosphere.

in the Yellow Pine Quadrangle in west-central Idaho. Here, mapping has delineated a silicified shear zone that hosts gold, tungsten, and antimony mineralization. Last, the IGS has obtained both STATEMAP and Earth MRI funding to map several quadrangles in and near the Idaho cobalt belt in east-central Idaho. Significant north-south structures have been identified, along with a magnetite-rich belt of Mesoproterozoic strata in the footwall of bedded cobalt deposits.

# ILLINOIS

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## INTRODUCTION

The Illinois State Geological Survey (ISGS) first formed in 1851 but has been continuously operational since 1905, when it was formally reestablished by an Act of the Illinois General Assembly and organized as a state government agency, along with the Illinois Natural History Survey and Illinois State Water Survey. It was located on the campus of the University of Illinois at Urbana-Champaign. All three scientific surveys were reorganized within the Illinois Department of Registration and Education in 1917, where they remained until 1979, when the Illinois Institute of Natural Resources was formed. This institute was then merged into the Illinois Department of Natural Resources in 1995. The last reorganization occurred in 2008, when the University of Illinois State Scientific Surveys Act was passed, and the ISGS and other Surveys became an institute within the University of Illinois, where they reside today. The Prairie Research Institute (PRI) now houses five surveys—the ISGS, Illinois Natural History Survey, Illinois State Water Survey, Illinois State Archeological Survey, and Illinois Sustainable Technology Center—together employing about 900 scientists and support staff. The ISGS has about 170 scientists and support staff. Although the ISGS and sister surveys are no longer considered state agencies, their mandates remain the same.

During the past year, the ISGS continued to provide innovative research, as well as support service initiatives, that had a significant impact on the state's economic development, energy and water resources, environmental protection, and overall scientific understanding of the geology of Illinois.

## GEOLOGIC MAPPING

### STATEMAP

#### STATEMAP FY 2019 Maps

In FY 2019, the ISGS worked on STATEMAP projects from September 2019 to November 2020 and completed four quadrangle maps and a county map. Bedrock geologic maps were

completed for the Davenport East (Illinois portion) and Milan Quadrangles of the Quad Cities area and Franklin Grove Quadrangle located in north-central Illinois near the Sandwich Fault Zone. Production of both maps contributed to the resolution of stratigraphic issues and information on the economic resources of each area (coal, limestone, groundwater, land use). Surficial geologic maps were completed for the following quadrangles: Crossville, Harvey, and Steger. The Harvey and Steger Quadrangles, located in the Chicago metropolitan area, yielded more information about beach and glacial lake deposits, including radiocarbon ages and identification of diamicton units. The Crossville Quadrangle, located in the Wabash River valley, helped with understanding the timing of glacial episodes through radiocarbon dating, thickness of sediments, and the contour of the bedrock surface. Surficial and bedrock geologic maps were completed for Williamson County, which included analysis of the county's economic resources, bedrock, and glacial or surficial deposits (the limit of significant glacial advance is shown), and environmental hazards.

#### STATEMAP FY 2018 Maps

In FY 2018, the ISGS completed seven quadrangle maps as STATEMAP projects from September 2018 to August 2019. Bedrock geologic maps were completed for the Rochelle, Otterville, New Haven Southwest, and Wabash Island Quadrangles. Research in the Rochelle Quadrangle, located in north-central Illinois near the Sandwich Fault Zone, led to a better understanding of the area's stratigraphic and structural relationships. Mapping in the Otterville Quadrangle, located near the St. Louis metropolitan area, led to a better understanding of stratigraphic relationships. The maps of the New Haven Southwest and Wabash Island Quadrangles confirmed previous understanding of the stratigraphic and structural features and led to a better understanding of igneous rocks and oil and gas resources in the area. Surficial geologic maps were completed for the Palos Park, Beaver Creek, and Lawrenceville Quadrangles. Mapping the Palos Park (located in

the Chicago metropolitan area) and Beaver Creek (located in south-central Illinois in the Kaskaskia River basin) Quadrangles led to a better understanding of the glacial units and geomorphic features in each area. Research in the Lawrenceville Quadrangle, located in the Wabash River valley, led to a better understanding of the various eolian and fluvial landforms, stratigraphy, and seismic hazards in the area.

## **Earth MRI**

The ISGS is completing a seamless Geologic Map Schema-compliant 1:24,000 bedrock map coverage of a 38-quadrangle region in southeastern Illinois, which coincides with the U.S. Geological Survey's (USGS's) Earth Mapping Resources Initiative (Earth MRI) Hicks Dome geophysical survey area. Over the last 40 to 50 years, twenty-six of the thirty-eight 7.5-minute quadrangles have been mapped by different scientists using diverse software, applying varied mapping styles, and choosing different formation contacts. These maps are being updated in addition to new mapping of 12 previously unmapped quadrangles. Because of the complexity of the Hicks Dome area, an ancillary 1:12,000-scale map of the Hicks Dome region is also being constructed at the apex of Hicks Dome. The mapping of this region will provide needed geologic data to assist with interpreting geophysical anomalies identified by the USGS geophysical survey.

## **Coastal Geological Mapping**

The ISGS Coastal Geology Group has been involved in active topographic and bathymetric monitoring of select stretches of the Illinois coast of Lake Michigan. Monitoring efforts involve high-resolution topographic mapping by drones at select priority sites, allowing evaluation of geomorphic change and assessing sand volumetric changes. Annual to biannual bathymetric surveys of the nearshore complement terrestrial data sets for a more complete picture. Other activities include monitoring hydro- and shoreline dynamics during high-energy events from cameras strategically installed at select

survey sites and maintaining a weather station that provides data on local atmospheric conditions. Efforts also involve spatially referencing historic aerial images (beginning in the late 1930s) for shoreline reconstruction purposes. Building on a 3-year data set of active beach monitoring, the group better understands coastal dynamics from detailed models of beach and nearshore geomorphic change, coupled with insights into storm and ice hydrodynamics. Establishing coastal process-landform interactions at this resolution and scale is needed for future planning, given the anticipated climate changes. Orthoimages and derivative digital elevation models developed from beach surveys are available through the ISGS Data Clearinghouse.

## **OTHER MAJOR HIGHLIGHT**

### **Coal Fly Ash Assessment**

Like many states, Illinois is working toward solutions that reduce the negative impacts from surface impoundments of coal combustion residuals. Coal combustion residuals are by-products of coal burning and contain the elements present in coal, including arsenic, boron, cadmium, chromium, cobalt, lead, lithium, manganese, molybdenum, radium, selenium, sulfur, and thallium. These elements can persist and accumulate in the environment and be associated with negative health impacts.

An ISGS-led interdisciplinary Coal Ash Response Team (CART) within our parent PRI assessed coal ash-related information that was available from the Illinois Scientific Surveys (a bibliography of PRI coal ash publications is available online). The CART report includes information about potential impacts of coal ash impoundments, a review of federal and state laws and regulations, and an overview of how coal ash can be diverted for beneficial reuse. Efforts by the CART can be of value to all stakeholders, including governmental and nongovernmental organizations, site operators, research institutions, and the public.

# INDIANA

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## INTRODUCTION

The Indiana Geological and Water Survey (IGWS) is a research institute of Indiana University; its mission is to provide geological information and counsel that contribute to the wise stewardship of the energy, mineral, and water resources of the state and mitigate potential geologic hazards. Indiana's citizenry continues to benefit from a number of IGWS activities—focused research initiatives and cooperative investigations with governmental agencies, businesses and industries, and educational organizations; geologic sample and data collection and archiving; and dissemination of information in many forms, including published maps, the *Indiana Journal of Earth Sciences*, databases, and educational outreach programs.

The IGWS remains in temporary quarters as its 60-year-old main office and laboratory building undergoes renovation to provide enhanced laboratory capabilities. The expected move-back date is early 2021. At present, the Survey is rewriting its mission and strategic plan, which should be completed by the end of 2020.

## GEOLOGIC MAPPING

The IGWS long-range geologic mapping plan is targeted at providing map products that address Indiana's most pressing concerns in a timely manner. The goal is to map the entire state at 1:100,000 scale and its metropolitan areas at 1:24,000 scale by the IGWS bicentennial in 2037. Indiana is currently one of a number of states in the U.S. midcontinent not yet completely mapped at 1:100,000 scale.

## Bedrock Mapping

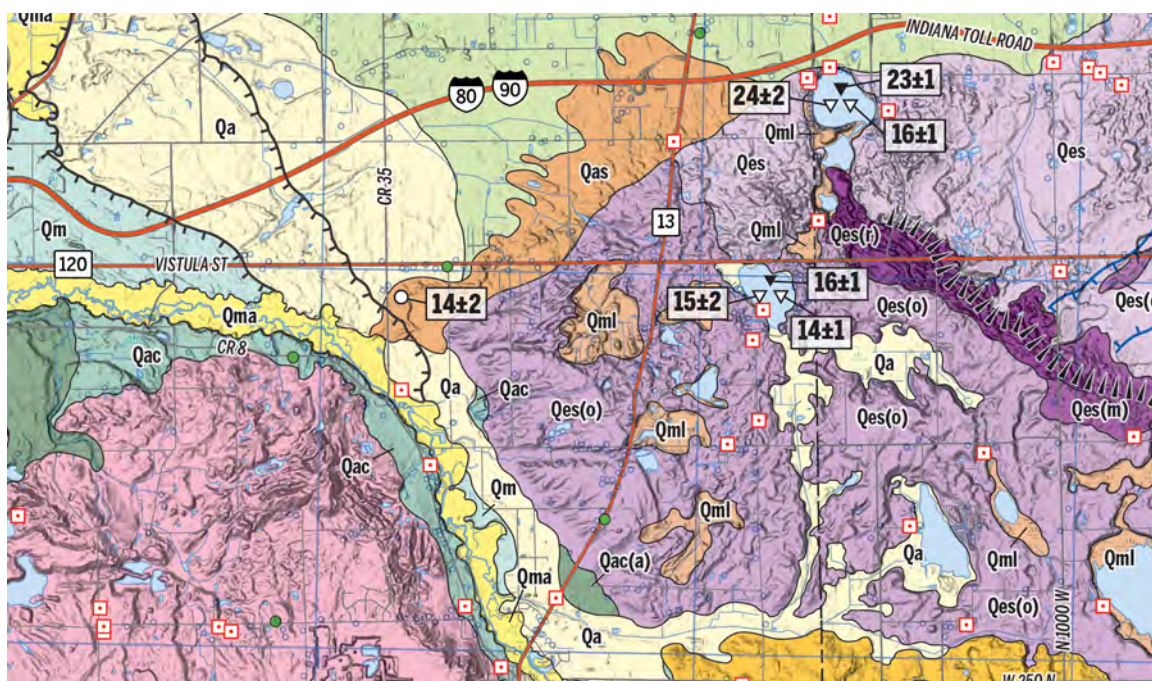
### ***Bedrock Geology of the Logansport Quadrangle (1:100,000 scale)***

This U.S. Geological Survey (USGS) STATEMAP-funded map was the culmination of a 2-year project focused on mapping the Logansport Quadrangle at a scale of 1:100,000 (Figure 1). The Silurian–Devonian bedrock aquifer is the largest bedrock aquifer in the region and a poorly explored resource in Indiana. Silurian reefs, abundant in the study area, have been a major source of oil and gas in southern Michigan and are now a major target for geological sequestration of liquefied CO<sub>2</sub>. Developing the bedrock-mapping framework will provide fundamental new data for the ongoing investigation of water resources in Indiana, for carbon sequestration potential, and on deep-time carbon cycle dynamics.

## Surficial Mapping

### ***Quaternary Geology of the Indiana Portion of the Elkhart 30 × 60-Minute Quadrangle***

This map is part of a project to generate a series of 1:100,000-scale maps across the Northern Moraine and Lake region of Indiana. The goal is to develop 3-D mapping on a distributed software platform that will support future study of the glacially derived unconsolidated aquifer system of northern Indiana while putting all information on a platform with easy access for users. We are developing the subsurface data set needed by researchers to understand older glaciation records



**Figure 1** A clipped portion of the map *Quaternary Geology of the Indiana Portion of the Elkhart 30 x 60-Minute Quadrangle*.

and the connections to the linked climate–landscape evolution in the Midwest since the Pliocene. This effort will directly benefit water-resource management in the region.

For this map, IGWS Cartographer Matthew Johnson won one of only two awards given this year “in recognition of excellence in cartography” by the [Esri International Cartographic Association/International Map Industry Association](#). The award promotes and recognizes excellence in map design and advancement in cartography.

#### Quaternary Geology of Morgan County

- *Preliminary Map Showing Quaternary Geology of the Cope 7.5-Minute Quadrangle, Indiana* (1:24,000 scale)
- *Preliminary Map Showing Quaternary Geology of the Mooresville East 7.5-Minute Quadrangle, Indiana* (1:24,000 scale)

The primary goal of this STATEMAP-funded project is to develop a 3-D chronostratigraphic framework for the unconsolidated deposits (mainly glacial deposits) of Morgan County to help address several societal issues, including increased water demand for irrigation and municipal supplies, as well as naturally occurring arsenic in groundwater. The final map in this multi-year project, compiled at a scale of 1:48,000, and the associated data sets, will provide foundational knowledge to support further infrastructure development as the population of this county expands in the coming years with the northward construction of Interstate 69. The construction of the highway and anticipated growth of infrastructure along

this corridor require more detailed geological information to ensure the protection of sensitive aquifer recharge areas and delineation of an adequate public water supply to support the projected growth.

## HIGHLIGHTS

The unique properties of rare earth elements (REEs) have created a surge in demand that is largely being met by China, and this, combined with their use in a number of U.S. military defense applications, presents a national security concern. As part of a cooperative agreement with the USGS for their [Earth Mapping Resources Initiative](#) (Earth MRI), the IGWS will coordinate a project across 15 states to evaluate REE-enriched phosphatic sedimentary rocks. The study will provide new science on the concentration and spatial distribution of REEs in Devonian- to Mississippian-age phosphatic sedimentary rocks in the eastern United States, with the potential to map some of the largest heavy REE deposits in the world.

An innovative software package known as [SimCCS](#) received an R&D 100 award. Widely known as the “Oscars of Invention,” these awards celebrate research and development pioneers and their contributions to science and technology. A team of researchers from Indiana University and the IGWS is partnering with Montana State University and the lead organization, Los Alamos National Laboratory, to develop the SimCCS software, which provides novel capabilities for decision support and design of integrated carbon capture, utilization, and storage technologies.

Maria Mastalerz, IGWS geologist, was awarded the Reinhardt Thiessen Medal, the highest honor bestowed by the [International Committee for Coal and Organic Petrology](#). The award recognizes persons who have made significant achievements and outstanding contributions in the fields of coal and organic petrology.

The American Association of State Geologists awarded the 2019 Charles J. Mankin award to W.A. Hasenmueller and R.F. Rupp for *The Bedrock Geology of Bartholomew County, Indiana*.

The American Library Association awarded the title of Notable Government Document to two IGWS publications: *Indiana Rocks: A Guide to Geologic Sites in the Hoosier State and Landmarks in Geology: A Timeline*.

## DATA AND COLLECTIONS

The IGWS continues to engage the entire staff in efforts toward streamlined data integration for the Survey's born-digital and digitized data, in addition to data and metadata about physical samples. The Survey is well underway in a substantial effort to make these collections and data more FAIR (Findable, Accessible, Interoperable, and Reusable) and promote the long-term usefulness of our data and collections for purposes beyond which they were originally collected or developed. Digital data are more centrally discoverable in our digital asset management system, and metadata about our physical samples is readily accessible in our collections management system. These efforts aim to promote closer proximity of Survey data and collections to end users and collaborators at the USGS, state and local governments, and industry collaborators in real estate, transportation, planning, natural resources conservation and development, the energy sector, and many more.



# IOWA

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## INTRODUCTION

The Iowa Geological Survey (IGS) was established by the Iowa legislature in 1855. The IGS is a part of IIHR-Hydroscience & Engineering, a research institute within the University of Iowa's College of Engineering. The IGS currently reports through the Board of Regents State of Iowa, having been legislatively transferred to the University of Iowa in 2018 from the Iowa Department of Natural Resources. Currently, 10 full-time professional positions and 1 part-time support position are supported on a mix of state appropriations, grants, and contracts.

The mission of the Survey is to collect, reposit, and interpret geologic and hydrogeologic data, to conduct foundational research, and to provide Iowans with the knowledge needed to effectively manage our natural resources for long-term sustainability and economic development.

## GEOLOGIC MAPPING

Recently completed mapping by the IGS under the U.S. Geological Survey's (USGS's) STATEMAP program included two subprojects in vastly different geologic areas of the state with a focus on impaired watersheds and developing areas. Surficial geologic maps were completed for the Van Horne and Keystone South Quadrangles (1:24,000 scale) in Benton County. This mapping area included the boundary between the Southern Iowa Drift Plain and Iowan Surface landform regions. Local and regional watershed groups are focused on water quality and quantity, land-use planning, and flood mitigation strategies. Surficial mapping helped characterize the Iowan Surface materials, an area of poorly consolidated glacial deposits, and delineated upland sand and silt deposits of eolian origin.

Mapping was also continued in southeast Iowa with the completion of bedrock and surficial geologic maps of the Donnellson and West Point Quadrangles (1:24,000 scale). Current issues related to groundwater quantity and quality, flood mitigation, and aggregate resource protection in an area of rapid development are of interest to many stakeholders. This mapping area is also critical to unraveling the complexities of the Mississippian stratigraphic sequence in Iowa and further

characterizing the Illinoian glacial advance into the state.

Combining the bedrock and surficial map information allows stakeholders to address key questions related to land-use in shallow bedrock areas, aggregate resource potential and protection, and groundwater vulnerability. A bedrock elevation map and a Quaternary thickness map were also completed for each quadrangle in both mapping areas.

## OTHER HIGHLIGHTS

### Geophysics

The IGS incorporates electrical and seismic geophysical methods into a host of geologic and hydrogeologic research projects. Geophysical surveys provide a model of the shallow subsurface, complementing existing data.

Through geophysical surveying and groundwater modeling, possible well locations are identified and electrical resistivity geophysical surveys are completed in each location. These surveys allow water managers to make an informed decision on the best location for a new well. Choosing the proper well location the first time can make financial sense and save undue problems down the road. The IGS also uses passive seismic methods to help determine the depth to bedrock in areas lacking existing information.

### Data Preservation

The IGS recently completed a pilot project converting a subset of the IGS' paper strip logs to digital versions. This project was part of a data preservation effort supported with funding from the USGS. Using a newly created database and web application, students transferred more than 40,000 sample descriptions from more than 750 sites. The project offers numerous benefits. The geological data presented on the strip logs is preserved in a digital format for future generations to use. IGS staff will be able to query and manipulate the digital data, allowing for more efficient searches of economic deposits or geological hazards. The electronic strip logs are available to the public on the IGS' GeoSam website (<https://www.iihr.uiowa.edu/igs/geosam>).

## Water Resources

The Water Resources Management program of the IGS evaluates the availability and sustainability of Iowa's groundwater resources. Numerical methods and modeling are used extensively to try to predict and reduce future impacts and conflicts between water users. The long-term management of groundwater resources is essential to promote economic growth and at the same time preserve water resources for future generations.

The IGS investigated and quantified the long-term availability of water in the Jordan aquifer for the Des Moines metropolitan area. A three-dimensional local-scale groundwater flow model was developed and calibrated, and this model was used to predict future water availability for both industrial and municipal users. Groundwater modeling results indicated that the Jordan

aquifer can remain a long-term source of water for users in the Des Moines area. However, it is important for users to identify and develop alternative water sources to ensure a sustainable future water supply.

The IGS completed a source water evaluation for the Lyon-Sioux Rural Water District (LSRWD) in Doon, Iowa. The evaluation involved well installations, aquifer pump tests, and the development of a groundwater flow model. The model was used to evaluate nitrate sources and identify conservation practices to reduce long-term nitrate concentrations in the LSRWD production wells. Conservation practices were initiated in the fall of 2019 and include tree and shrub buffers, wetland plantings, and cover crops. Funding for the conservation practices was obtained from the U.S. Department of Agriculture 2019 Farm Bill.

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## INTRODUCTION

The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas (KU). The KGS has no regulatory authority and does not take positions on natural resource issues. It has a 12-member advisory council that meets three times a year to provide review and guidance. The main headquarters is in KU's West District in Lawrence, and its Wichita location houses the Kansas Geologic Sample Repository.

KGS research focuses mainly on groundwater, oil and gas, and other natural resources; seismic monitoring and imaging; and basic geology. It is the repository for water-well records; oil and gas records and logs; drill cuttings submitted to the State of Kansas; and donated historical records, logs, and drill cores. With a staff of about 105 employees, the KGS has an annual state-appropriated budget of approximately \$6.2 million. Another \$5.1 million in grants and contracts was awarded in FY 2020.

## GEOLOGIC MAPPING

The KGS has been involved in the U.S. Geological Survey's (USGS's) STATEMAP component of the National Cooperative Geologic Mapping Program since its inception. Current mapping projects are focused in counties encompassing and surrounding the City of Wichita, one of the fastest growing metropolitan areas in Kansas and in a region experiencing high levels of induced seismicity. In 2019, KGS personnel mapped eight USGS 7.5-minute quadrangles in Sedgwick, Harper, Sumner, and Cowley Counties. In addition to mapping quadrangles, stratigraphic scientists are investigating concerns related to shallow groundwater resources and the age and distribution of upland alluvial deposits. As mapping is completed in a county, stratigraphic staff members work closely with the KGS Cartographic Services to merge and publish the mapped quadrangles as new 1:50,000-scale county geologic maps. Completed map products and interim mapped quadrangles

are available as PDFs on the KGS website (<http://www.kgs.ku.edu/General/Geology/index.html>).

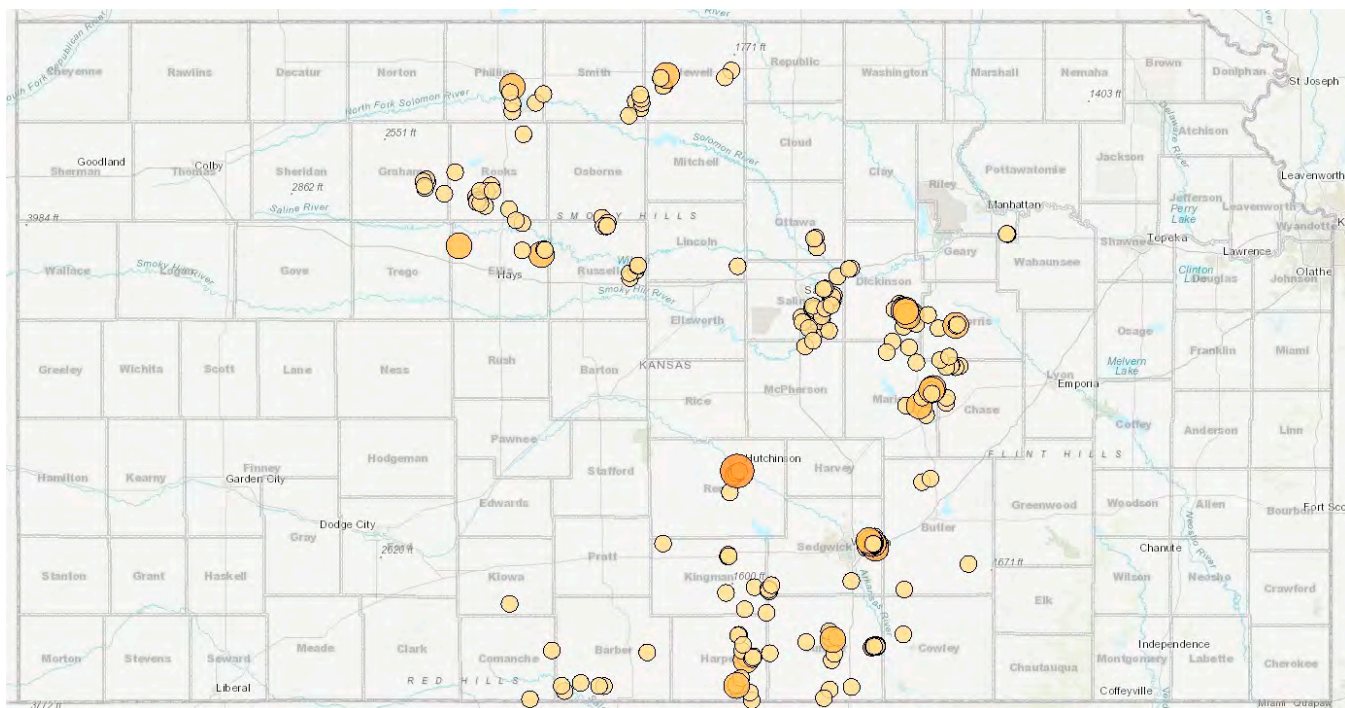
The KGS GIS support unit provides desktop and web-based application development in the form of maps, GIS data, and web applications. Prime examples are the interactive Kansas Water Well Map (<https://maps.kgs.ku.edu/wwc5/index.html>), the Kansas Oil and Gas Field Map (<https://maps.kgs.ku.edu/oilgas/index.html>), and the Map of Kansas Earthquakes ([http://maps.kgs.ku.edu/earthquake\\_mini\\_viewer](http://maps.kgs.ku.edu/earthquake_mini_viewer)).

Cartographic Services is responsible for the production of KGS county geologic maps, the geology GIS data for those maps, an oil and gas map series for the state, and other products. Cartographic staff collaborate with the mapping geologists on mapping done for the STATEMAP program, which results in the county geologic maps. Staff recently completed an [updated version of the Bourbon County geologic map](#) and a new interactive StoryMap, [Surficial Geology of Morris County, Kansas](#).

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Energy Research

Energy Research is finalizing multi-year projects to develop the science behind and investigate the use of anthropogenic CO<sub>2</sub> for both enhanced oil recovery in favorable oil fields and safe storage of CO<sub>2</sub> in closed geologic structures. The section is completing Phase II of the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) program, in collaboration with Battelle and the Energy and Environmental Research Center. This program targets potential geologic CO<sub>2</sub> storage sites in southwest Kansas and Nebraska. In addition, the KGS is a very active member of the Regional Carbon Capture Deployment Initiative and the Carbon Utilization Research Council. In September 2019, the KGS received a subaward from the U.S. Department of Energy's National Energy Technology Laboratory (DE-FE0031837) and joined the Carbon Utilization and Storage Partnership for the western United States.



**Figure 1** The KGS Interactive Mappers reveal the locations of earthquake epicenters across the state. This map shows all the earthquakes recorded in calendar year 2020 that were greater than magnitude 2.

## Geophysics and Exploration Services

Geophysics and Exploration Services staff members maintain and collect data from a multi-station seismic monitoring network. In 2020, four additional stations were installed in four counties. An updated list of Kansas earthquakes, an interactive map showing earthquake locations (Figure 1), and other resources are available on the KGS earthquake webpage.

## Geohydrology

The KGS has recently initiated a new project to study the interactions between the Kansas River and the underlying alluvial aquifer. The initial phase of the project involved the installation of 11 index wells from west of Manhattan to near the confluence with the Missouri River in Kansas City. The well network will expand in the coming years, and the project includes a groundwater quality component.

## Public Outreach and Service

The Data Resources Library serves as the State of Kansas repository for historical aerial photographs and oil, gas, and water-well records. It houses geologic and production records for more than 450,000 oil and gas wells and 273,000 water wells. The Kansas Geologic Sample Repository, previously named the Well Sample Library at KGS–Wichita, is the state repository for geologic samples of more than 149,000 oil, gas, and exploratory wells. The KGS received increased annual funding from the USGS to continue its long-term efforts to preserve its collections. In addition, the USGS award will be used, for the first time, to inventory the state's critical minerals.

The KGS's annual Kansas Field Conference for state legislators and other decision makers was held virtually in 2020 because of the pandemic. The field conference featured sustainability projects in northwest Kansas. [Videos from the field conference are publicly accessible on the KGS YouTube page.](#)

# KENTUCKY

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## INTRODUCTION

The Kentucky Geological Survey (KGS) is a state-supported research center and public resource within the University of Kentucky. The KGS has investigated the mineral, energy, water resources, and geologic hazards of Kentucky for more than 180 years. Our mission is to support sustainable prosperity of the commonwealth, the vitality of its flagship university, and the welfare of its people. With approximately 50 full-time staff, we accomplish our mission by conducting research and providing unbiased information about geologic resources, environmental issues, and natural hazards affecting Kentucky. In addition to on-campus facilities, the KGS has offices, laboratory facilities, a well sample and core library named the Earth Analysis Research Library (located off campus in Lexington), and an office located in Henderson in western Kentucky. The KGS has hired six new employees this year in the areas of geohealth, geochemistry, geoscience communications, data management, geologic mapping, and seismology.

## GEOLOGIC MAPPING

### Bedrock Mapping

In collaboration with the U.S. Geological Survey, Kentucky completed its 1:24,000-scale bedrock geologic mapping program in 1978 and published the last of the resulting 707 geologic quadrangle maps covering the state in 1982. Part of our STATEMAP supplemental work for the next fiscal year is to generate a bedrock-specific layer from our digital statewide geologic data.

### Surficial Mapping

We are mapping the areas near Elizabethtown, following the suggestion of our State Mapping Advisory Committee to address areas of likely economic development along a major transportation corridor. COVID-19 restrictions on travel and

field work created obstacles, but the mapping team was creative and completed the work under a no-cost extension from the National Cooperative Geologic Mapping Program.

### 3-D Mapping

We have been networking with external colleagues in geophysics and hydrology to develop a flexible data structure to meet the 3-D data needs of a variety of internal and external users. One of our COVID-19 responses was a hiring freeze, which precluded employing a full-time staff member to focus on 3-D modeling.

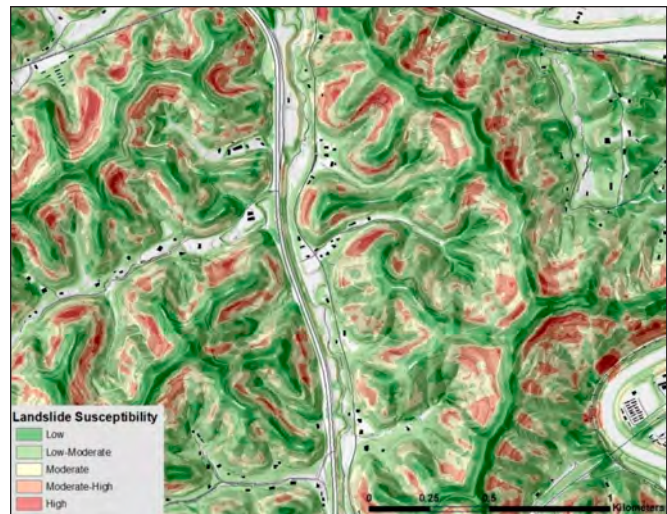
## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

Additional research at the KGS during FY 2020 covered a variety of topics funded by agencies such as the U.S. Departments of Energy, Interior, and Agriculture; the National Academies of Science, Engineering, and Medicine; the National Institute of Environmental Health Sciences; the Federal Emergency Management Agency; the National Science Foundation; the Institute for Museum and Library Services; and other state and local sources.

Following are selected externally funded research topics:

- Geologic aspects of regional carbon capture and storage
- Unconventional resource potential of the Cambrian Conasauga Group
- Creation of a digital core image archive
- Engaging nontraditional geological survey stakeholders
- Critical minerals data compilation for the Hicks Dome area
- Derivative surficial geologic maps for seismic hazard planning
- Data coordination in environmental exposure and health outcome assessments
- Indoor radon measurement, mitigation, and community involvement

- Multi-jurisdictional landslide hazard and risk mitigation planning (Figure 1)
- Improved estimates of site response in the New Madrid Seismic Zone
- Data fusion for characterizing and understanding karst groundwater systems
- 3-D electrical resistivity methods for understanding shallow karst groundwater flow
- Edge-of-field agricultural runoff monitoring
- Nutrient and sediment runoff assessment



**Figure 1** Landslide susceptibility for a part of Floyd County, Kentucky.

# MAINE

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## INTRODUCTION

Although the first geological survey of Maine was conducted in 1836, geological activity was intermittent until the early 1930s, when the modern survey was established. Since that time, the Maine Geological Survey (MGS) has grown from one State Geologist to its current staff of 10. Programs of the MGS reflect a broad application of geology to societal issues:

- The Bedrock and Surficial Geology program provides basic geologic mapping and interpretation of surficial materials and bedrock mapping and interpretation of rock types and structures.
- The Hydrogeology program assesses groundwater quality and quantity, compiles statewide water-use information, and manages data from wells that contribute to the National Ground-Water Monitoring Network.
- The Marine Geology program conducts research on the geological processes of the coast and near-shore submarine environment and the impacts of sea-level rise and storm surge on coastal infrastructure.
- The Hazards program focuses on landslide hazards, mostly driven by sensitive marine clays underlying coastal Maine.

## GEOLOGIC MAPPING

### Bedrock Mapping

A key emphasis of our STATEMAP program is on areas with important societal issues for which only regional or reconnaissance maps are available. The Rumford region in western Maine is one such area, in which forest products and four-season recreation drive the economy.

Basement is exposed at the surface throughout Maine, covered by a thin veneer of glacial deposits. The MGS continued a bedrock mapping project begun in 2017 in the Rumford region. The reconnaissance maps currently available show large, seemingly uniform granitic intrusions surrounded by meta-sedimentary units. Among the many resources of the region are abundant pegmatite deposits that have produced some world-class specimens of tourmaline, beryl, and other gemstones. Pegmatite deposits like these and salt brines are the only two geologic settings globally for significant lithium resources. For many decades, the common interpretation for

the origin of pegmatites has been that they were the final distillates of large magmatic intrusions, enriched in fluids with incompatible elements (Be, B, Li, Cs) that did not fit into the common rock-forming minerals that crystallized first. Recent work shows that the large tracts mapped as granite are mostly migmatite, with which the pegmatites are spatially associated. Additionally, radiometric dating of pegmatites and detailed geochemistry argue against a genetic link with mapped intrusions. Our bedrock mapping in the Rumford area is aimed at further understanding the setting of pegmatite deposits and their association with migmatites, and it has already garnered additional funding through the Earth Mapping Resources Initiative (Earth MRI) program.

The MGS continued a bedrock mapping project in northern Maine begun in 2016, focused on Ordovician volcanic rocks. The southwestern portion of the Munsungun Inlier was mapped in detail in the 1960s, but the geology of the northeastern part was known only from reconnaissance mapping in advance of the 1985 bedrock geologic map of the state. The justifications for this mapping project are mineral and cultural resources. The volcanic rocks host the state's largest volcanogenic massive sulfide deposit at Bald Mountain (34 million tons). Our mapping has reinterpreted the context of the Bald Mountain deposit and potentially expanded the mineral potential of the area. Chert layers in the volcanic rocks were exploited by Native Americans for toolmaking, as evidenced by numerous quarries. Our mapping has led to the discovery of many previously undocumented quarry sites.

### Surficial Mapping

With the only surficial geologic map coverage at 1:250,000 scale, we also mapped surficial geology in the Rumford area, continuing a project begun in 2016 to complete detailed surficial mapping for a block of eight quadrangles. The focus is on providing details of glacially derived surficial units that represent potentially significant aquifers and sources of aggregate. Glacial lake deposits and some till units are also susceptible to landslides. Newly available lidar for the region greatly facilitated mapping. Our work refined the distribution of sand and gravel deposits and hummocky moraine and end moraine

complexes, and identified significant glacial meltwater channels. MGS geologists also identified prehistoric landslides in till and glacial lake sediments.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Landslide Studies

The MGS worked with the Maine Emergency Management Agency (MEMA) to increase the focus on landslide hazards in Maine's State Hazard Mitigation Plan. Southern and mid-coastal areas of the state are particularly vulnerable because of a thick succession of marine mud underlying the area, deposited shortly after deglaciation when sea level was temporarily higher. Our research focused on establishing the ages of many landslides, newly recognized via lidar. Working with the MEMA, the MGS received funding from the Federal Emergency Management Agency to investigate and date these features. Our analysis shows that landslides have occurred sporadically over time, but with a cluster of events in the 500- to 700-year range, leading us to conclude that landslide hazard is ongoing. We continue to generate more age data on landslides and investigate potential triggering mechanisms for the 500- to 700-year cluster, including wildfires and earthquakes.

### Coastal Erosion

Approximately 40% (1,400 miles) of Maine's coastline is composed of soft bluffs underlain with marine mud with steep slopes. Chronic erosion, a serious problem in these high coastal bluffs made of muddy sediment, prompt many property owners to armor their shorelines.

In a project funded through the National Oceanic and Atmospheric Administration and in collaboration with coastal New England states, the MGS is installing several "living shoreline" projects to demonstrate the effectiveness of natural alternatives to armoring. Our subject area is Casco Bay, home to Maine's most populous city (Portland) and ringed by 34 miles of potentially unstable bluffs. The living shoreline approach attempts to recreate a fringing marsh environment at the base of an unstable bluff to act as a natural barrier to dissipate wave energy. We have installed and continued to monitor three



**Figure 1** Department of Agriculture, Conservation and Forestry Commissioner Amanda Beal (second from right) listens to MGS Marine Geologists Peter Slovinsky (third from right) and Stephen Dickson (right) discuss a living shoreline installation in Casco Bay.

projects that use fallen tree logs and woven coir bags filled with weathered oyster shells to buttress eroding banks and promote salt marsh growth (Figure 1).

### Groundwater Monitoring Network

We continue work begun in 2016 to augment Maine's groundwater monitoring network beyond the 24 wells maintained by the U.S. Geological Survey. In 2017, we added 32 existing high-quality wells to the network from 22 sites around the state, ensuring that Maine's fractured bedrock and surficial aquifer systems were well represented in the network. These were drawn from the Maine Department of Environmental Protection's Environmental and Geographic Analysis Database, which is used to manage all environmental information, including groundwater levels, at numerous permitted and remediated sites throughout Maine. In 2019, MGS hydrogeologists visited all the new well sites to confirm well locations and conditions, in preparation for downhole work scheduled for 2020.

# MARYLAND

## Maryland Geological Survey

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## INTRODUCTION

The Maryland Geological Survey (MGS) was founded in 1896 as an independent agency of the state housed at The Johns Hopkins University, with primary responsibilities to

- conduct topographic, geologic, hydrographic, and geophysical surveys;
- prepare topographic, geologic, and other types of maps to meet specific needs;
- prepare reports on the extent and character of the geology, minerals, and water resources; and
- periodically assess the paleontological resources of the state.

These responsibilities remain incorporated into the Code of Maryland Regulations. Since 1969, the Survey has been incorporated into the Department of Natural Resources, and many of the activities and functions that the Survey performs are conducted to support the management activities of the larger Department. The Survey additionally conducts studies in support of other regulatory agencies.

Currently, staffing levels are 18 scientists, one contractual scientist, one full-time support, and one part-time support. In 2020, Mr. Thomas Ulizio was hired as a hydrogeologist.

## GEOLOGIC MAPPING

### Bedrock Mapping

The MGS continued bedrock mapping through the STATEMAP program in 2020 and submitted draft geologic maps for the Oakland and Damascus Quadrangles at 1:24,000 and a GIS compilation of the Accident and McHenry Quadrangles at 1:24,000 with gas field data included. The geologic mapping continues our long-term strategy in the Appalachian Plateau, and the GIS compilation is an identified need from the State Mapping Advisory Committee.

The MGS began new geologic mapping in the Kitzmiller, Gaithersburg, and Relay Quadrangles in 2020. This new mapping continued with the Appalachian Plateau mapping and

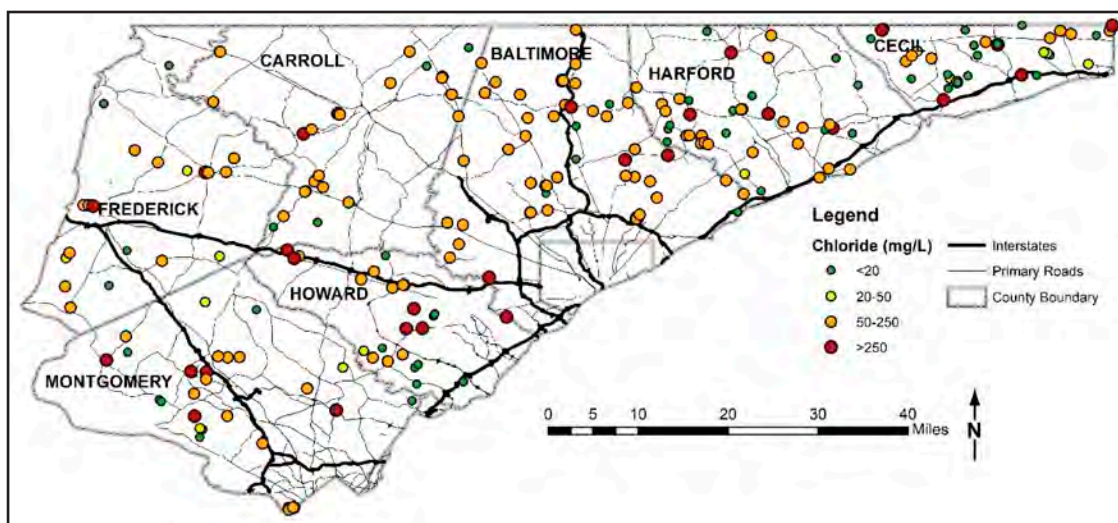
began a new strategy to map the Maryland Piedmont, which continues to develop at a very high rate.

The U.S. Geological Survey's (USGS's) Earth Mapping Resources Initiative (Earth MRI) project is funding geologic mapping of the Blue Ridge Summit Quadrangle at 1:24,000, which will complete the mapping of all of the Blue Ridge Province in the state. This funding is also allowing for the creation of several maps as Geologic Map Schema (GeMS)-compliant GIS maps. The supplemental funding provided by the USGS is allowing the MGS to create the second in our statewide bedrock map series of 1:100,000 regional maps covering Washington and Frederick Counties.

### Mineral Mapping

Through the USGS Earth MRI program, the MGS was awarded a grant to study the "Neoproterozoic Regolith and Rare Earth Elements (REEs) of the Maryland Blue Ridge." This project is the first mineral study project the Survey has performed in more than two decades. The purpose of this effort is to evaluate the distribution and character of the thick regolith overlying Neoproterozoic rocks of the core of the northern Blue Ridge in western Frederick County, Maryland. The thickness and distribution of this deposit will be compared with compositional variations within the underlying bedrock units of the Grenville-age Middletown complex and the Catoclin Formation's volcanogenic rocks. By precisely mapping these soils, and conducting widespread soil sampling, a volume of this surficial deposit can be calculated. This soil sampling will provide detailed mapping of the regolith distribution. The resulting GeMS maps will also be available to developers and engineers during housing and highway construction.

Chemical analysis of 100 samples ranging from 0 to 50 feet depth are currently being studied. Initial results indicate REE levels above normal in several bedrock samples and mobility and accumulation of REEs in the soil profile. New maps of regolith distribution at 1:24,000 scale have been produced as part of this study.



**Figure 1** Chloride concentrations from wells in the Maryland Piedmont.

## Land Subsidence Mapping

The MGS began working with the USGS in expanding the Maryland land subsidence network by two stations, for a total of 11 deep rod marks for GPS observations. These new marks are focused on low-lying coastal areas and diversifying the existing land subsidence network. The MGS conducted a GPS occupation of 9 marks in fall 2020. GPS data were processed using the National Geodetic Survey's Opus Projects for ellipsoid heights and the horizontal position of marks. Fall 2020 data were compared with historical GPS data for marks to assess changes in ellipsoid height and horizontal movement over time. Data were further analyzed to assess the degree of land subsidence across Maryland.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

### Triassic Rift Basins

The MGS completed Report of Investigations No. 88, *Exposed Triassic Basins as Proxies for the Understanding of Buried Rift Successions*. The report provides insight into areas suitable for long-term carbon dioxide sequestration in Maryland's Triassic Basins. The study of rocks exposed in the Culpeper and Gettysburg rift basins provides a foundation for understanding the buried Taylorsville rift basin. Deposition within Triassic rift basins did not form the layer cake geometries commonly portrayed, but rather laterally intergrading alluvial, fluvial, and lacustrine processes from basin margin to center. This revised internal stratigraphy indicated that areas suitable for long-term carbon dioxide sequestration exist within the coarse-grained, fluvial lithofacies associations that are concealed beneath thick intervals of fine-grained lake strata.

### State Highways Rockfall

The MGS completed a research project for the State Highways Administration titled "Highway Rock Cut Inventory and Fail-

ure Potential, Allegany County, Maryland." In this study, 195 roadway embankments in Allegany County, Maryland, were catalogued as to the effects of climate, vegetation, and geologic factors on slope stability. Observations included dimensions, weathering condition, and geologic structure. Recorded data were used to evaluate the potential for slope failure, such as by rockfall, rock roll, rockslide, or slumping. Rockfalls were determined to be likely on slopes of greater than 60 degrees and in massive lithologies on embankments displaying major levels of differential erosion. Rock roll was the most common potential slope failure on slopes that exceed 30 degrees of inclination. Rockslides were the dominant potential slope failure in outcrops where rock layering is inclined toward the highway. Roadside slumping or rotational dislocations were a prominent type of slope failure in highly weathered, relatively unconsolidated rock outcrops.

### Groundwater Chloride Concentration Monitoring and Assessment

The MGS is undertaking two groundwater chloride studies (Figure 1). The first is focused on fractured rock aquifers susceptible to contamination from road-deicing salts, agricultural amendments, and septic effluent or water softener effluent. The second is in the Appalachian Plateau, where there are concerns about the source of contamination being from natural brines, agricultural amendments, septic effluent or water softener effluent, or road-deicing salts. These studies will help in mapping the spatial distribution of chlorides in groundwater, evaluating the source of the chlorides, evaluating temporal variations, and determining any potential associations between elevated chlorides and other chemical constituents. This work will provide a foundation for developing guidance for private well owners, state and county transportation departments, and state and county health departments.

# MASSACHUSETTS

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### INTRODUCTION

The Massachusetts Geological Survey (MGS) is housed in the Department of Geosciences at the University of Massachusetts Amherst campus. The State Geologist reports to the Vice Chancellor for Research and Engagement. The mission of the Survey is to serve the needs of state government, industry, and the citizens of the Commonwealth of Massachusetts by providing earth science information and research relevant to natural resources, environmental quality, economic vitality, and public safety. Statutory authority for the Survey is in the Massachusetts General Laws, Chapter 21A, Section 7B.

The Survey receives no funding from the state and has no support staff. We rely on the Department of Geosciences for administrative help. The State Geologist is the only state-funded position. This year we had one undergraduate student working with the Survey on various project work.

### GEOLOGIC MAPPING

The MGS is continuing to work collaboratively with the U.S. Geological Survey (USGS) to complete the *Quaternary Geologic Map of Massachusetts*. The Quaternary map will be at 1:100,000 scale and based entirely on 1:24,000-scale field mapping. The USGS worked on unit descriptions this year, and the MGS began pulling together well data to produce 10- to 20-meter structure contours of the top of bedrock in the major river valleys.

Much of the year was spent editing well data and verifying well location information. Massachusetts has more than 250,000 wells from various public agencies, but the data have never been checked and validated. To date, the MGS has examined approximately 64,000 wells and verified them to an actual street address and unique parcel ID.

During the year, the MGS submitted three proposals to (1) help with validating existing well data, and (2) build a raster of the altitude of the bedrock surface across Massachusetts. This work is being done in concert with the New England Top of Rock project currently underway by Greg Walsh (USGS) via a FEDMAP project.

### WATER RESOURCES

The MGS continues to contribute to the Climate Response Network, a network of more than 70 wells used to monitor groundwater levels across the state. The MGS monitors 13 wells in the western part of the state on a monthly basis and reports results to the USGS. This work is done in collaboration with the Massachusetts Department of Conservation & Recreation (MA DCR) and the Department of Environmental Protection (MA DEP). Some of these wells have been in service since the 1950s. The data set is used by the state's Drought Management Task Force and provides a valuable time series of historic droughts against which current dry periods can be compared.

The MGS continues to assist Dr. David Boutt, hydrogeologist in the University of Massachusetts Department of Geosciences, with the collection of surface and groundwater samples for his stable isotope database project for Massachusetts. The goal of the project is to define flow paths and residence times of various components of the hydrological cycle within the Commonwealth.

The MGS continued to help the Massachusetts Department of Conservation and Recreation convert its daily rainfall records to digital data. Massachusetts has 132 citizen-run rainfall stations that have paper records dating back to 1966. Students have been hired to help with the digital conversion. This work was completed this year.



# MICHIGAN

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## INTRODUCTION

As of 2020, the Michigan Geological Survey (MGS) has been functioning in the Geosciences Department at Western Michigan University for 9 years. The base functions of the Survey include geologic investigation and technical support in regional areas of the state; the collection and archiving of samples, cores, and cuttings; and documentation of geologic investigations. We are currently conducting surficial and shallow geophysical surveys to support mapping of the glaciated terrain of the Lower Peninsula (LP) to identify potential buried water resources and will be supporting the mapping of critical minerals in selected areas of the Upper Peninsula (UP). The MGS mission is to serve the people of the state and governmental entities, the Client.

The MGS has received three \$500,000 legislative grants in the last 4 years, 2016, 2018, and now in October 2020, to assess natural resources and conduct additional subsurface and surficial 3-D mapping. The MGS has received additional grants in the last 15 months totaling more than \$1.3 million. These grant funds will support the assessment of natural resources and will be used both to conduct research and to compile geologic data in areas of Michigan where a new groundwater contamination issue is emerging—perfluoroalkyl substances (PFAS)—and for the validation of drilling data in the Michigan well drillers' database. The MGS is extremely grateful for these three legislative grants and recent project grants. However, without an annual funding mechanism, the MGS cannot hire full-time staff. As a result, the MGS is continuing to operate primarily on soft money. Like many other surveys, it will be affected by COVID-19, and most critical has been the layoff of University geologists who would be supporting MGS projects.

The MGS and all state surveys want to be recognized as the "go-to" resource for geologic information in the state, and marketing our capabilities is number one. The University has limited staff and will not be replacing the recently departed staff, so the MGS will be working with the University to fill those geologists' positions as soon as is practicable.

## SURFACE MAPPING, GROUNDWATER, AND NATURAL RESOURCES

The U.S. Geological Survey's (USGS's) National Cooperative Geologic Mapping Program has been actively funding state geologic mapping for more than 25 years, which in all the states has been focused on critical-need areas. Michigan is now faced with a new groundwater dilemma: emerging contaminants known as PFAS. Since early 2017, the identification of water-resource impacts by this carcinogen has multiplied from 35 to hundreds and perhaps thousands of locations in just over a year, with the state having confirmation analysis for many of these new areas. This includes community and individual drinking water supplies. Michigan has little to no compiled geologic knowledge of the many natural resources that may exist within its borders. Now the impacts of PFAS present a case in which most technical experts cannot say where groundwater is flowing because most of the subsurface geology has not been compiled and mapped in sufficient detail and consistency to predict the direction and rate of flow, further evidence of the continuous lack of focus on the geology by the state.

The MGS participates in both the USGS STATEMAP and Great Lakes Geologic Mapping Coalition projects under the direction of Dr. Robb Gillespie and John Yellich. Emphasis in the two USGS mapping programs is now concentrated in areas of accurate geologic data to quantify water resources and aquifer characteristics in the LP at a larger scale (1:100,000). This will provide geologic data on aggregate locations and extent. The LP studies are being done with a 3-D approach, which includes a combination of surface geologic mapping; utilizing lidar that is now available in many more areas of the LP; a limited rotasonic, wireline core, and (or) Geoprobe drilling program; downhole geophysical logs; and Tromino passive seismic, horizontal/vertical spectral ratio (H/VSR)-bedrock depth mapping, then incorporating the validated geologic logs from water-well drillers. All these components result in a more accurate geologic depiction of stratigraphic formations

and sections. This also increases the quality of the data set in assessing water-bearing strata and resource availability for high-production water users, primarily the agricultural community; identifying glacial units that have a high probability of producing aggregate resources; and determining the groundwater flow direction and projected rate of flow. This year, an expanded mapping program is being proposed to the state in sensitive high-water-use areas and areas having need of future aggregate resources so that these areas can be identified and not excluded from development by changing land use.

## CURRENT ACTIVITIES

The Director, John A. Yellich, has continued a road program, now virtual, to introduce the “reinvented” survey to the Client and to meet the critical stakeholders in the state. This includes meetings with the directors and chiefs in the Michigan Governor’s Departments of Environment, Great Lakes & Energy; Department of Natural Resources; Department of Agriculture and Redevelopment (MDARD); and local and regional economic development managers and business and municipal associations. The goal is to continue to identify the key geological issues currently facing the State of Michigan in all aspects of agriculture, industry, and rural growth. This includes identification, assessment, protection, and development, as well as data collection to support the management of critical natural resources (i.e., water and aggregate resources in populated areas). Outreach has also included formal presentations and formal and informal meetings and discussions in a number of areas of the state for all stakeholders, the general public, and legislators and to address K-12 science education requirements. Michigan has not been active in geological research for more than 30 years.

The MGS has had productive discussions during the past 3 years with the USGS Mineral Resources and Mapping groups in both Reston, Virginia, and Denver, Colorado. These discussions have resulted in being offered moral and technical support for an August 2018-completed aeromagnetic survey in the UP of Michigan, the first open file report on geophysical data for Michigan in decades. This mapping product will now be used to complete a critical minerals grant for surficial geologic mapping in Dickinson County of the UP. This is a collaboration with Michigan Technical University over the next 2 years. The second opportunity is a 2019–2022 collaborative program for a FEDMAP project in the Michigan Lowland Basin, which will include the Indiana, Illinois, and Wisconsin geological surveys and the investigation of shore, land, and bluff conditions, as well as a geologic and remote-sensing demonstration for the USGS and the MGS.

## MICHIGAN GEOLOGICAL REPOSITORY FOR RESEARCH AND EDUCATION SAMPLE AND DATE REPOSITORY

The Michigan Geological Repository for Research and Education (MGRRE), which has functioned for more than 30 years under the direction of Dr. William Harrison III, continues to be the strength of the MGS. Many requests for data review have been received by the MGRRE over the last 30 years.

Specifically, requests for review of geologic cores and data were incorporated into a collaborative carbon sequestration program, the Midwest Regional Carbon Sequestration Partnership (MRCSP) with Battelle national laboratories, Core Energy, and the U.S. Department of Energy (DOE). This technical review and field validation progressed significantly in developing enhanced oil recovery (EOR) with the capture and injection of CO<sub>2</sub>. The EOR program is one of the economic benefits of carbon capture and injection, and this has resulted in the secondary recovery of more than seven million barrels of entrained oil, providing millions of dollars in additional revenue for the Michigan economy. The MGRRE continues to receive funding for core and data storage from industry donations. The MGS and MGRRE are continuing to research and study CO<sub>2</sub> sequestration in Michigan through a DOE grant that has one year remaining.

The MGRRE has received grants from the USGS National Geological and Geophysical Data Preservation Program (NGGDPP), which has been functioning for more than 10 years. For the past few years of grant funding, the project scanned and inventoried gas chromatograph analyses. Paper copies of the data were reviewed for clarity and organized for scanning and data entry.

These hydrocarbon analyses provide near-immediate access to data, which can now be used to identify prospective wells and zones for secondary oil recovery and for safe underground CO<sub>2</sub> storage. Additionally, 3 years ago a state university was going to send its sample suites and cores to the dump, and the MGRRE rescued them. These are samples not seen for 30 years or more, and they are being cataloged and located in the MGRRE public database. There was no inventory of how many wells and core data were rescued, so we are currently compiling that data.

The USGS recognized the MGRRE as a national “poster repository” for the NGGDPP. The MGS–MGRRE was used to present the benefits of a core repository when, in 2008, core and data were rescued from a facility that was going to dispose of the core. These cores were brought to and stored at the MGRRE. NGGDPP funding allowed the MGRRE to catalog the core and data, which were then placed on the MGRRE website. This archived data resource was identified on the MGRRE website by a prospective mineral mining company/developer. The developer came to the MGRRE to examine the core and have it analyzed, which resulted in the 2013 rediscovery of the purest quality potash in the United States, deposited at 7,500 feet beneath the surface in Osceola and Mecosta Counties. This natural resource asset has an estimated in-place value of \$65 billion and is currently in the predevelopment and final permitting process. Following is the USGS article from January 2017: <https://www.usgs.gov/news/mineral-discovery-could-mean-billions-michigan>.

## OIL AND GAS

The MGS, through the Resource Center at the MGRRE, continues to be associated with the Petroleum Technology Transfer Council, which conducts day-long and multiple-day workshops on oil and gas production technologies in Michigan,

although COVID-19 eliminated the 2020 conference. These workshops and conferences focus on relevant topics in the petroleum industry and are attended by more than 150 industry professionals.

## **GROUNDWATER RESOURCES, ENVIRONMENTAL QUALITY, AND ENERGY**

The MGS has been asked to sit on the Governors' select water advisory group, the Water Use Advisory Council, which is supporting the adoption of the Great Lakes compact requiring permitting of large-capacity withdrawal water wells and quantifying their impact on stream flows. Local requests are being made to the MGS for information on the quantity of groundwater in certain areas of the state, but many of the requests do not have funding associated with any proposed study at this time.

## **GIS DATA MANAGEMENT AND MGS STORE**

Many maps and documents are being input into the MGS data management systems. A new functioning role of the MGS has been initiated, and it includes preparing documents and maps for distribution and sale through the MGS website.

The MGS continues to search for many older Michigan publications and paper resources that can be input into the docu-

ment archives and made available to the scientific community and general public. The MGS continues to update the compiled publications bibliography on Michigan geology from every library, university, and public resource in the United States. There are currently more than 8,000 publications, many of which have not been seen for years. Their locations have been noted in the bibliography on the MGS website.

## **OUTREACH AND K-12 PROGRAM**

The K-12 program at the MGS-MGRRE has had increasing interest by the Michigan educational community under the direction of Dr. Peter Voice. The emphasis is on the importance of earth science education starting with elementary students. For middle and high school students, greater emphasis is on models and demonstrations. Many teachers are now turning to the educational resources at the MGS-MGRRE facility. The number of contacts being made with students or the general public at presentations or sessions has continued to increase during the last 5.5 years to approximately 81,500 contacts, and the response from adults at gem and mineral shows has increased dramatically. The coordinator and staff have made more than 17,000 contacts during the last 3 years. Because of COVID-19, however, these personal interactions will be very limited for the foreseeable future. Teachers are seeing the benefits of these programs, and the MGS hopes to incorporate this into the state K-12 program going forward.



# MINNESOTA

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## INTRODUCTION

The Minnesota Geological Survey (MGS) is fulfilling its role primarily through 1:100,000 and 1:500,000 mapping of surficial geology, bedrock geology, subsurface geology, bedrock topography, and sediment thickness. New 1:100,000 mapping is being completed as County Geologic Atlases (CGAs) and is meant to be complete statewide within a decade or so. This mapping is focused on societal needs, with an emphasis on groundwater protection and management while taking a broad approach.

## GEOLOGIC MAPPING

A complete CGA consists of a Part A prepared by the MGS that includes the water-well database and 1:100,000-scale geologic maps showing the properties and distribution of sediments and rocks in the subsurface, and a Part B constructed by the Minnesota Department of Natural Resources (DNR) that includes maps of water levels in aquifers, direction of groundwater flow, water chemistry, and sensitivity to pollution. Atlases in most cases are initiated by a request from a county and an offer to provide in-kind service. A *Geologic Atlas User's Guide* helps nongeologists understand the information products and their uses. Atlases are available in print or in digital formats, including pdfs and GIS files.

The MGS priorities have been specified by a series of broadly consultative state resource planning exercises. In particular, the Minnesota Water Sustainability Framework advocated that a measure of our progress in obtaining a complete picture of groundwater resources in Minnesota should be the rate of completion of CGAs by the MGS and DNR. Atlases are complete for 41 counties and of these, 5 have been revised and 2 revisions are underway. Twenty-three new atlases are underway, and 21 counties have not yet been started. At the current pace and a completion rate of approximately 5 per year, statewide coverage will be achieved in less than a decade.

While MGS income tends to arrive in multi-year grants, we spent \$3.3 million this past year, similar to the level of the year before. MGS funding averaged \$2.4 million from 2003 to

2011, and the average since then has been \$3.2 million. The MGS relies on about \$1.3 million in base funding and approximately \$2.2 million in grants and contracts, primarily from the Environment and Natural Resources Trust Fund through the Legislative-Citizen Commission on Minnesota Resources (LCCMR). Additional funding from both sources covers non-personnel costs, such as travel, drilling, equipment, supplies, and services. Two years ago, a financial and administrative audit found no concerns.

MGS staffing was stable at 28 full-time equivalents (FTEs) from 2003 to 2011; since then, staffing has averaged 36 FTEs. Last year, the MGS was one of 17 state geological surveys in the United States whose staff were 40% or more female. This is compared with 38% nationwide. We currently employ 27 geologists, 3 information professionals, 2 administrative staff, and 6 students, equivalent to about 3 FTEs.

Mapping is focused on the CGA projects that are underway. The new *Quaternary Geologic Map of Minnesota* is complete. This is an update to the 1982 *Geologic Map of Minnesota, Quaternary Geology*, by H.C. Hobbs and J.E. Goebel. The work was largely funded by a 1:1 cost-sharing agreement with the Great Lakes Geologic Mapping Coalition of the U.S. Geological Survey (USGS). This multi-year project stitched together many maps created by the CGA program and other mapping programs, and filled in areas not yet mapped at the more detailed scale. New CGA mapping will be added to the digital database as it becomes available. The map follows construction of pilot statewide cross sections that depict the vertical and horizontal distribution of Quaternary sediment. At present, subsurface Quaternary geology is being mapped on a statewide basis as cross sections at a 5-kilometer spacing. This activity is in the third year of a 5-year program.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

The MGS manages several important geoscience databases that support our mapping and activities by others across the state. The largest and most commonly used is the County Well

Index, which includes records for more than 500,000 wells, of which about 60% have accurate digital locations. We interpret the drillers' description of the materials encountered in drilling and assign rock types and formation names. Our co-manager of this database, the Minnesota Department of Health, has contracted with the MGS to add additional data from historical records. Three years ago, Julia Steenberg and Andrew Retzler worked on the second of two projects to improve the usability of borehole geophysical and video data. They inventoried and digitally converted analog natural gamma logs, and then inventoried and updated the infrastructure for the multi-parameter, caliper, electromagnetic-flowmeter, and borehole video logs.

A significant development last year was a very successful implementation of till geochemical methods in stratigraphic characterization of till. In addition, the MGS undertakes much research that is needed to optimize our mapping, such as enhanced hydrogeological characterization of sediment and rock strata. Tony Runkel, for example, completed a 3-year project that used new techniques of borehole testing and rock fracture mapping in the Twin Cities to improve understanding of groundwater flow through fractured rock. Application of the results will improve the efficiency and effectiveness of remediation and monitoring at contaminated sites across the Twin Cities. Another project completed this past year evaluated links among southeastern Minnesota stream temperatures, trout habitat, and bedrock hydrogeology to improve trout

stream management. The goal of this project was to develop and apply a sensing method using fiber-optic cables along trout stream reaches to quantify the changes in temperature, flow, and trout distributions. Stream reaches were chosen based on geologic mapping, focusing on areas where different geologic conditions exist and information on trout distribution and abundance is available.

Three new groundwater projects were initiated by the MGS in the past year, in collaboration with University of Minnesota scientists, partner agencies, and consultants. One is an effort to better understand nitrate transport in southeastern Minnesota. This 3-year project will provide the information necessary to more accurately determine whether improvements in agricultural practices are improving groundwater quality in the region. A second project evaluates the feasibility of aquifer storage and recovery to alleviate groundwater quantity problems in areas such as Washington County, where aquifer drawdown is believed to impact base flow to streams and some lake levels. The third project focuses on groundwater contamination issues at the University of Minnesota Library Access Center. It targets bioremediation capacity and transport through fractured rock.

Principal funding sources are the Minnesota Legislature, state agency partners, the LCCMR, the Clean Water Fund, and the USGS National Cooperative Geologic Mapping Program.

# MISSISSIPPI

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**Figure 1** Test hole drilled on November 10, 2020, in support of the Ridgeland Quadrangle geologic map, showing geologists, drillers, GIS staff, and our Failing 1500 drilling rig and water truck with drill stems.

## INTRODUCTION

The Mississippi Department of Environmental Quality (MDEQ), Office of Geology was created by the state legislature as the Mississippi Geological Survey in 1850 and maintained that name up to 1980. In 1939, the Survey discovered the first and largest oil field in the state while mapping surface geology. The office is composed of four divisions: Environmental Geology (which includes drilling equipment and staff, geophysical wireline logging, and the core and sample library), Geospatial Resources (flood risk mapping, hydrography, orthoimaery, and lidar), Mining and Reclamation (state primacy over mining), and Surface Geology (the geologic mapping program).

## GEOLOGIC MAPPING

Published U.S. Geological Survey (USGS) STATEMAP-funded geologic maps include the Fayette, Gin Branch, and Union 7.5-minute quadrangle maps in Jefferson County in southeastern Mississippi at a scale of 1:24,000. These maps were a composite of bedrock and surficial units. Bedrock units mapped and correlated in the subsurface on cross sections include the Miocene-age Pascagoula Formation and Pliocene-age Graham Ferry Formation. Surficial units mapped include Pleistocene-age loess and river terraces and Holocene-age alluvium. Four test holes were drilled and logged in support of this mapping work, for a total of 870 feet drilled. A county geologic map of Jefferson County in progress is based on a compilation of STATEMAP grant work. Figure 1 shows the drill rig and crew.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Environmental Geology Division

The Environmental Geology Division staff pulled and restocked 150 boxes of cores and samples, representing 41 wells and 13,850 feet of well data, for study by oil exploration geologists and those in academia. They ran wireline geophysical logs on 42 test holes and water wells, collecting 23,759 feet of data.

### Geospatial Resources Division

The Geospatial Resources Division managed the Mississippi Flood Map Modernization Initiative and the Mississippi Digital Earth Model (MDEM). In FY 2020, Preliminary Flood Insurance Rate Maps covering portions of 23 counties were released for community review. The division also monitored and managed contractors completing work on MDEM data sets, includ-

ing hydrography, elevation/topography, lidar data, and high-resolution orthoimagery covering different areas of the state.

### Mining and Reclamation Division

The Mining and Reclamation Division performed 687 inspections, recommended to the MDEQ Permit Board the issuance of 26 initial and 12 amended permits, and received 60 Notices of Exempt Operations (less than 4 acres in size). A total of 1,493 bonded acres were completely reclaimed as a result of the division's oversight. A new surface coal mining permit was issued to the Red Hills Lignite Mine for 4,190 acres.

### Surface Geology Division

The Surface Geology Division has social media outreach through posts such as #FossilFriday and through the Ask a Geologist portal on the MDEQ website, and this was a large contributor to the office's 47 published works.

# MISSOURI

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## INTRODUCTION

The Missouri Geological Survey (MGS) was established in 1853 to provide earth science information and services that support stewardship and beneficial use of Missouri's natural resources and that benefit public health and safety. Functions of the Survey include geologic mapping, geologic resource assessment, groundwater protection through well construction, groundwater-level monitoring, major water-use monitoring, surface water observation and planning, dam and reservoir safety, and mined land reclamation. Goals for the year included coordination and collaboration of critical natural resource issues, providing better service, and balancing financial, scientific, and strategic coordination. These efforts better position the state for safe and timely resource assessment, protection, development, economic viability, and natural hazards planning. The MGS headquarters (Figure 1) is located in the city of Rolla, where the majority of staff have official domicile. Groups located there are the Geological Survey Program, Dam and Reservoir Safety Program, and groundwater functions of the Water Resources Center. Land Reclamation and surface-water resource functions are located in the Missouri Depart-

ment of Natural Resources main office building in Jefferson City. The McCracken Core Library and Research Facility is located off-site within a few miles of the Buehler Building in Rolla. The Survey was supported by 115 full-time equivalents and a \$25.8 million budget in FY 2020.

## GEOLOGICAL SURVEY

Amber Steele is Director of the Geological Survey Program, overseeing the activities of three groups with unique disciplines and 40 total staff. The Geologic Resources Section of 12 staff supports traditional geological activities, including geologic mapping through the National Cooperative Geologic Mapping Program, mineral and energy resource assessments, and data collection management and preservation. Geologic mapping activities continued in western Missouri to support infrastructure and transportation needs, among many others. Other information collected and managed involved industrial and metallic minerals, coal, geothermal, hazards, mining, and bedrock core and cuttings stored in the McCracken Core Library and Research Center. Staff supported activities of the State Oil and Gas Council, Industrial Minerals Advisory Council, and State Mapping Advisory Committee. The Environmental Geology Section of 14 staff provided geologic and hydrologic support for solid and liquid waste disposal, remediation of hazardous waste sites where aquifers are affected, and geologic hazards assessments involving karst features or mine collapse. The Well Installation Section of 14 staff oversaw construction and plugging of wells associated with water use, monitoring, minerals, and ground-source heat pumps through regulatory standards. The section provides technical assistance on well construction, aquifers, and hydrology to thousands of businesses, farmers, and citizens on an annual basis.

## LAND RECLAMATION

The Land Reclamation Program of 17 staff is managed by Larry Lehman to ensure proper stewardship of Missouri's resources during and after surface mining of minerals. The Industrial and Minerals Mining Unit issues permits and performs inspections for coal and industrial minerals (barite, tar sands, clay, limestone, sand and gravel, granite, and trap rock). This



**Figure 1** The Buehler Building, which is the MGS headquarters in Rolla, Missouri.

unit also implements the Metallic Minerals Waste Management Act (lead, iron, zinc, copper, cobalt, gold, and silver), which regulates the metallic minerals waste management disposal areas of mining operations. The Abandoned Mine Land and Permit Unit utilizes seven staff to oversee the implementation of the Surface Mining Control and Reclamation Act (SMCRA). This group designed coal reclamation projects left from past coal mining activities. They also worked to remediate two dangerous metallic mineral mine shafts. The Projects and Inspection Unit consists of two staff that provide oversight services to coal companies through permits to comply with U.S. Department of Interior SMCRA permitting and inspection requirements.

## **WATER RESOURCES**

The Water Resources Center is managed by Jennifer Hoggatt and is supported by 20 staff. Their mission is to understand water storage and availability based on water-use needs and protection vulnerabilities. The Center protects the interests of Missouri citizens as it relates to planning, operation, and use of the Missouri and Mississippi Rivers. The Center engaged in discussions with other states, federal agencies, and stakeholders to provide information; informed citizens; and made timely decisions regarding the state's policy on interstate water issues. The Center actively worked to provide citizens with security regarding adequate flood control and navigation flows on the Missouri River. The Center worked to implement the Missouri Water Plan by helping ensure that the quality and quantity of water resources in Missouri meet future needs. This was accomplished by implementing projects and initiatives at a state and local level and by serving as a guide for water-resource decision making, setting a clear vision for water-resource management for our state over the next 30 years. The Center provided financial, technical, and planning support for regional water-supply projects. It continued to provide assistance to develop two new drinking water reservoirs in north Missouri, a wholesale water pipeline project, and studies for a large water-resources coalition in southwest Missouri. The Center continued to provide real-time data regarding groundwater levels through one of the largest groundwater observation networks in the nation, by maintaining 151 wells across the state. It also tracks major water use across the state.

## **DAM AND RESERVIOR SAFETY**

This program is overseen by Professional Engineer Ryan Stack and is supported by three additional professional engineers and two support staff. The mission is to protect public safety through oversight of dam and reservoir construction, operation, and maintenance. The primary effort of the program is to permit dams in the state that meet regulatory standards. The program provided critical information to emergency responders and field staff in preparation for and during flood events. The program responded to potential overtopping and flood-related damage to dams, providing equipment and technical support in the case of serious structural threats; monitored reservoir and river or stream levels; and maintained awareness of actual flood levels and forecasts. The regular updates they provided enabled timely decision making and awareness of urgent on-the-ground conditions. The program continued to inventory regulated dams in Missouri to capture those that may have been built without a proper permit to ensure minimum standards are met.

## **ADMINISTRATION**

The MGS's administration program of eight staff provided operational support to the Survey. Administration staff responsibilities include operations management, budgeting, personnel management, building maintenance and improvements, custodial services, and the distribution of maps and publications, most of which is done electronically. Survey Director Joe Gillman fulfilled the duties of State Geologist, overseeing all activities of the Survey and representing it on several councils, boards, and commissions, including the State Oil and Gas Council, Board of Geologist Registration, Well Installation Board, and Missouri Mining Commission. Survey Deputy Director Jerry Prewett fulfilled the duties of Assistant State Geologist. He was responsible for oversight of program activities, legislative actions, and information technology governance and was involved in many other statewide initiatives. Nona Lancaster oversees the activities of five administrative support staff.

# MONTANA

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## INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG), founded in 1919, is a nonregulatory research agency and state geological survey within the Montana University System and a department of Montana Tech. The MBMG provides extensive advisory, technical, and informational services to the public and other agencies to inform responsible development and protection of Montana's mineral, energy, and water resources. Staff scientists conduct independent studies and typically have cooperative investigations with more than 70 different local, state, federal, and private organizations. The MBMG also responds to thousands of informal queries for information and assistance.

The MBMG's primary office is on the Montana Tech campus in Butte; a branch office is located in Billings. The staff comprise about 50 scientists and 15 technicians and support personnel; about 30 students work part time. The MBMG conducts research on all aspects of the geology of Montana, but groundwater dominates our work. Information for many of these projects can be found at <http://www.mbm.mtech.edu/>.

## GEOLOGIC MAPPING

### Bedrock Mapping

The first priority of MBMG's geologic mapping program is 1:100,000-scale digital coverage of the state's ninety-four 30 × 60-minute quadrangles. Including several U.S. Geological Survey (USGS) products, 77 quadrangles are now publicly available, and two more are imminent. Quadrangles lacking coverage are in the western part of the state. With support from STATEMAP, selected 1:24,000-scale quadrangles are being mapped (1) to resolve the complex structural features and immensely thick stratigraphic sequences of western Montana, leading to eventual 1:100,000-scale coverage, or (2) to provide more detailed mapping in valleys and urban areas that are experiencing high growth rates and land-use pressures. The inevitable encroachment of development on mountainsides is commonly accompanied by severe problems with water resources and slope stability. PDF versions of our digital

maps are viewable and downloadable from the MBMG website at <http://www.mbm.mtech.edu/>.

### Critical Minerals Mapping

In 2014, the MBMG's Economic Geology program began to reevaluate the potential for metallic mineral deposits in historic mining districts for future exploration. Currently, the MBMG is continuing to focus on mining districts associated with the Boulder Batholith. There is renewed interest in the mining industry to explore for critical metals used in batteries, high-tech electronics, renewable energy projects, and electric cars. Some of these elements include cobalt, cadmium, lithium, vanadium, germanium, gallium, tellurium, and rare earth elements. Since these elements are considered critical, because 100% of these elements are being imported into the United States, the USGS began a new program, the Earth Mapping Resources Initiative (Earth MRI), in 2019. The goal of the program is to conduct a nationwide inventory, identifying geologic environments favorable for critical mineral resources. Montana was included on the list to receive funding from the Earth MRI program. The first Earth MRI project was begun in 2020 in the Elkhorn Mountain Quadrangle, including the Elkhorn mining district in Jefferson County.

### Geologic Hazards Mapping

The Geologic Hazards program aims to provide high-quality information on landslides, potentially active faults, and earthquakes. The program's first goals are updating the map and database of active faults and creating a landslide map and database for Montana. Faults are considered active if they have produced an earthquake during the Quaternary Period (past 2.58 million years) and have the potential to generate a future earthquake. The previous map of active faults in Montana contained 116 faults and was published in 2000. The current version, updated by the MBMG, includes 608 faults and is undergoing review to determine which may be potentially active. The MBMG will continue to update the map and database as new geologic mapping and other data become available. The active fault database will be used to prioritize future

investigations of active faults and help assess seismic hazards throughout the state.

## Earthquake Studies

The MBMG's Earthquake Studies Office monitors earthquake activity in Montana and the surrounding area through a network of 42 in-state stations, as well as data from several networks in bordering states. Data are exchanged with seismic research centers in surrounding states and the USGS National Earthquake Information Center so that the public and emergency responders are rapidly provided with information about the location and severity of significant earthquakes affecting the state. As part of an effort to raise public awareness of the very real seismic hazards in Montana, the Montana Bureau of Mines and Geology has developed a web-based mapping application that displays more than 43,000 earthquakes recorded by the Montana regional seismic network since 1982. Also shown are significant historic earthquakes, potentially active faults, and seismic hazard zones. This site allows the public to explore their hometowns and see the level of seismic activity, hopefully raising awareness and preparedness. Visit the MBMG mapper at <https://www.mbmgt.mtech.edu/mapper/mapper.asp?view=Quakes&>.

## GROUNDWATER

### Ground Water Assessment Program

Montana's 1991 Ground Water Assessment Act provided a three-part program (groundwater characterization, long-term water-level monitoring, and a groundwater database) designed to systematically assess Montana's groundwater resources on a statewide level. **Characterization** studies are conducted on a drainage-basin scale and result in maps and atlases summarizing the hydrogeology of the basin. The core of the Ground Water Assessment Program's (GWAP's) **monitoring** program is a statewide network of about 950 wells where water levels are collected at least quarterly. About 75 wells are sampled for water-quality analysis annually. The **Ground Water Information Center (GWIC) database** contains all GWAP data, including that obtained from drillers' logs, published reports, field measurements, laboratory analyses, and other sources for about 250,000 sites; groundwater data collected from other MBMG projects; and more recently, groundwater data collected by some private entities. Water-well drillers can now submit their well records directly to the MBMG. The GWIC database is available publicly at <http://mbmggwic.mtech.edu>. Scanned images of well logs are also being added. GWIC users average about 44,000 queries per month from 31,000 registered users. At the end of 2018, the GWAP will have completed field work in 12 areas (30 counties) and released 800 maps and reports.

### Ground Water Investigations Program

Recognizing that competition for water resources and the lack of detailed information on groundwater-surface water interactions has challenged informed water-resource management and development in Montana, the 61st Montana Legislature

funded the Ground Water Investigations Program (GWIP). This program operates at the sub-basin scale to investigate local issues related to groundwater development. Since its inception in 2009, the GWIP has produced more than 16 MBMG publications related to seven project areas. Both groundwater programs, GWAP and GWIP, were strongly supported in recent meetings of basin advisory councils throughout Montana and are integral to the new Montana State Water Plan.

### Other Groundwater Projects

The MBMG works in concert with state and federal agencies, conservation districts, water-quality districts, tribes, and local communities across the entire state on many relatively short-term projects that address local issues, such as water supplies, water quality, or effects to groundwater resulting from land-use changes. These projects constantly change in response to need.

Longer term, the MBMG performs monitoring and local specific investigations in the Butte-Anaconda area through contracts with regulatory agencies and the Montana Department of Justice. This area has been subjected to releases from mining, milling, and other industrial sources over many decades, which has resulted in designation of the upper Clark Fork River basin as the largest superfund site in the United States.

Another long-term commitment is monitoring in the Controlled Ground Water Area along the northern and western boundaries of Yellowstone National Park that was established by compact between the National Park Service and the State of Montana to protect the geothermal resources in the Park. The MBMG is maintaining a long-term monitoring program with funding provided through the National Park Service.

The MBMG also continues monitoring that was begun in the 1970s in the Powder River coalfields. This serves a variety of purposes, from documenting the effects of coal mining on aquifers, to mine reclamation, to the effects of coalbed methane production on aquifers and surface waters.

## ENERGY RESEARCH

### Energy Resources

According to the U.S. Department of Energy, Montana ranks first among the states in its coal-reserve-base tonnage. The MBMG's coal-lands resources programs include geologic and hydrogeologic research, collection, and evaluation of data concerning the location, quality, and quantity of coal reserves and the dissemination of coal-related information. Historically, coal resources, mining, and their effects on aquifers were the focus of research, but in the last decade, questions related to coalbed methane have renewed impetus to the coal program and associated monitoring. The MBMG's National Coal Resources Data System database contains data on the stratigraphy, lithology, and thickness of coal resources for more than 6,800 locations throughout the state. More than 30 years of water-level and water-quality data, covering about 250 wells, are included in the hydrogeologic database, making this

the oldest continuous groundwater database available in Montana. A database containing geochemical information on the overburden in some areas is also available.

## **DATA PRESERVATION**

### **Mineral Resources and Data Preservation**

The MBMG provides technical information on mineral resources through our mapping and our archival records, as well as personal communications, mineralogical determinations, petrographic analyses, and information on recent developments in industry. The MBMG's mining archives contain more than 5,000 mineral property files and more than 20,000 entries in the historical claim-map and mine database. These documents are regularly used by the public for a wide variety

of interests, many of which are not geologic. In addition, the Anaconda Research Collection of specimens from the Butte mines is available to qualified researchers.

### **Mineral Museum**

Montana Tech's Mineral Museum, administered by the MBMG, houses one of the best mineral collections in the Pacific Northwest. About 1,500 fine specimens are on display, and new acquisitions are added based on their significance to the collection and to the region. The museum routinely sponsors workshops and lectures devoted to aspects of regional geology. In addition, schools and special interest groups may request tours and special workshops.



# NEBRASKA

## Conservation and Survey Division (Nebraska Geological Survey)

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## INTRODUCTION

The Conservation and Survey Division (CSD) of the University of Nebraska–Lincoln (UN–L) is a research, outreach/extension, and data-management organization that was established by state statute in 1921, although a state geological survey was established in 1893 and the first State Geologist was appointed in the 1870s. The CSD serves as Nebraska’s geological, ground-water, and soil surveys. Its existence is mandated in the Nebraska Revised Statutes. The CSD is unique in having been a part of the Institute of Agriculture and Natural Resources for decades, and it was merged into the UN–L’s School of Natural Resources in 2003. In 2019–2020, CSD staff consisted of 18 full-time equivalent employees. The CSD Geological Sample Repository receives new accessions (e.g., from petroleum exploration and in-house test-hole drilling) to its established collections each year and pursues improvements in preservation efforts and facilities.

## GEOLOGIC MAPPING

### Surficial Mapping

The CSD submitted two 7.5-minute surficial geologic maps during the June 2019 to June 2020 period. Mapping operations were suspended temporarily during the first half of 2020, but they are projected to be reactivated in the spring of 2021.

### Other Mapping

Two sets of important hydrogeological maps for areas of Nebraska with significant water-supply and water-management issues were also produced by CSD personnel. Furthermore, the annual *Nebraska Statewide Groundwater-Level Monitoring Report* for 2019 includes 10 maps portraying precipitation and groundwater changes in Nebraska.

## OTHER MAJOR ACCOMPLISHMENTS

CSD personnel were involved in approximately \$3.35 million in grant-funded research. Nearly 50 publications were produced by CSD personnel, almost half of which were

peer-reviewed journal articles. The subjects of these articles included social-science collaboration in water problems, socioeconomic impacts of drought, integrated water management, isotopes in aquifer systems, Quaternary eolian and glacial deposits on the Great Plains and Central Lowland, soil-science education, an exceptional Miocene boulder conglomerate in western Nebraska, and the potential for subsurface carbon dioxide storage in southwestern Nebraska.

Some 16,000 feet of test holes were drilled, logged, or both, including a significant expenditure of effort on the Omaha Clean Solutions for Omaha Deep Tunnel Investigation. CSD personnel provided more than 500 continuing education credits to regional professionals, supervised 21 graduate students, taught more than 800 credit hours in four different academic programs, and served more than 3,000 diverse stakeholders. CSD personnel also made dozens of technical presentations to local, state, national, and international audiences.

The CSD developed an online interactive mapping site that allows users to browse information for all of Nebraska’s 5,000+ test holes, water levels from more than 20,000 wells, location and geology data, and—through the cooperation of the Nebraska Department of Natural Resources—well-construction information for all registered water wells. Data are searchable and downloadable in a user-friendly, interactive Google Earth format. The CSD also finalized the Nebraska GeoCloud, a digital infrastructure for data related to geology, geophysics, and groundwater.

Two Geological Sample Repository facilities are undergoing upgrade improvements in organization. The Nebraska Hall facility has undergone asbestos removal. The remote facility in Mead, Nebraska, has received additional pallet racking, and the palletizing of core boxes has begun. The Oil & Gas Database Project has been awarded funding through the U.S. Geological Survey’s National Geological and Geophysical Data Preservation Program for three consecutive years. It will preserve geological sample metadata from an estimated 10,000 boreholes drilled across Nebraska over the past century. Additionally, volcanic ash samples from across the United States

and abroad are being organized, and analog metadata are being digitized.

CSD personnel manage and contribute to the Nebraska Water Leaders Academy. In its 10th year, the Academy is a year-long

program with components of leadership, policy and law, and natural resources. The Academy graduated 16 individuals in 2019 (contributing to an all-time total of 136 graduates) from diverse backgrounds.

# NEVADA

## Nevada Bureau of Mines and Geology

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## INTRODUCTION

The Nevada Bureau of Mines and Geology (NBMG) is a research and public service unit of the University of Nevada, Reno (UNR) and serves as the state geological survey for Nevada. The NBMG is a statewide agency that resides in the Mackay School of Earth Sciences and Engineering within the College of Science at UNR. As defined by state statutes, the NBMG is the state's official locus of data, analysis, and exchanges on Nevada's geology, natural resources, and geologic hazards. NBMG scientists conduct research and publish reports that facilitate economic development, public safety, and enhancement of the quality of life across the entire state. These include reports on mineral and geothermal resources, as well as earthquake, flood, landslide, and other geologic hazards. The NBMG disseminates this information to local, state, and federal agencies, major industries, engineers, educators, and the general public. As such, the NBMG has cooperative research and information programs with numerous local, state, and federal agencies. In addition, the NBMG hosts three major centers of excellence: (1) the Ralph J. Roberts Center for Research in Economic Geology (CREG), (2) the Great Basin Center for Geothermal Energy (GBCGE), and (3) the Nevada Geodetic Laboratory (NGL). The CREG and GBCGE are at the forefront of research in mineral and geothermal resources, respectively, and play important roles in education through teaching courses and workshops. The NGL has built a network of GPS stations across Nevada and parts of neighboring states. These stations track the motions of crustal blocks and help define earthquake hazards. The NGL is at the forefront of global research in geodesy. Programs are also underway to increase public awareness of earthquakes in Nevada and to prepare for an emergency response to a major earthquake. The NBMG effectively coordinated the response to the magnitude 6.5 Monte Cristo Range earthquake on May 15, 2020, in west-central Nevada (the largest earthquake in Nevada in 66 years) and spearheaded analyses of surface ruptures and displacements from the temblor. These efforts exemplify the NBMG's scientific and societal commitments to the state.

The NBMG employs approximately 28 geoscientists and support staff. This number includes 13 faculty positions in the geosciences, four specialists in support of publication production (cartography, GIS, and graphics design), two data managers, one information specialist, three management assistants

in support of publication sales and administrative and clerical needs, and one development technician. More than half of these positions are funded directly by the state through UNR, with nearly half funded by external grants and contracts. In addition, the NBMG employs about 20 graduate student assistants, several undergraduate students, and two postdoctoral scholars.

## GEOLOGIC MAPPING

Geologic mapping by the NBMG addresses the needs of a state that is the top producer of gold in the country, is rich in geothermal and other mineral resources, is the third most seismically active, is the fastest growing (tectonically speaking), and is the most urban (in terms of proportion of citizens living in large cities). The NBMG has three priority regions for geologic mapping: (1) Clark County in southern Nevada, which is home to Las Vegas and nearly three-fourths of Nevada's citizens; (2) the Reno-Carson City urban corridor in western Nevada and adjacent areas rich in geothermal and mineral resources; and (3) north-central to northeastern Nevada because of its wealth of mineral resources and classic setting for extensional tectonics. Northeastern Nevada contains the Carlin Trend, one of the richest regions on earth for gold production. All areas contain geologic hazards (e.g., earthquakes, floods, and landslides) that must be reckoned with for infrastructure planning and development. To date, we estimate that about 30% of the state has been mapped in sufficient detail (typically 1:24,000 scale) to adequately understand the geologic framework, hazards, and resources. Accordingly, significant work remains to produce high-quality, detailed geologic mapping for the state. The U.S. Geological Survey (USGS) STATEMAP program and other sources of funding generally permit publication of about five new quadrangles or areas per year. Although the arid climate greatly facilitates geologic mapping in Nevada, the complexity of the geology, with multiple overprinting tectonic episodes since the late Paleozoic, impedes more rapid progress. Mainly because of the large amount of public land (>85%), Nevada has lagged behind many states in the acquisition of high-resolution lidar and geophysical data that could expedite geologic mapping. However, this is changing, as evidenced by the ongoing Geoscience Data Acquisition for Western Nevada (GeoDAWN) project, which is a major collaborative effort between the USGS, the Geothermal Technologies Office of the

U.S. Department of Energy, and other federal agencies. Geo-DAWN will provide high-resolution lidar for nearly one-third of Nevada.

Some of the notable recent mapping projects include (1) quadrangle mapping and Quaternary fault studies in the Las Vegas metropolitan area, (2) a transect across highly extended, mineral-rich terrain in northeast Nevada, and (3) detailed mapping of geothermal systems in western to central Nevada. Most of these efforts have been funded by STATEMAP, but significant funding has also been obtained from Clark County, the U.S. Department of Energy, and the geothermal industry. In some cases, we have also developed detailed 3-D geologic maps of geothermal systems by integrating surface geologic maps with both geophysical and well data.

## **OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS**

### **Nevada Geothermal Play Fairway Project**

The Nevada geothermal play fairway project was a successful 5-year, multi-phase study that was completed in 2019. It was funded by the Geothermal Technologies Office of the U.S. Department of Energy. The primary goal of this project was to develop methodologies to identify blind or hidden geothermal systems in the Great Basin region. Studies suggest that most geothermal resources in the region are blind, with no surface hot springs or steam vents. The geothermal play fairway concept involves integrating geologic, geophysical, and geochemical parameters indicative of geothermal activity to identify promising areas for new development.

In Phase 1 of the project, 10 parameters were synthesized to produce a new detailed geothermal potential map of 96,000 square kilometers of Nevada. These parameters were grouped into subsets and individually weighted to delineate rankings for local permeability, intermediate permeability, regional permeability, and thermal potential, which collectively defined geothermal play fairways (i.e., most likely locations for significant geothermal fluid flow). Phase 2 involved detailed analysis of some of the most promising areas identified in Phase 1. Multiple techniques were used in the detailed studies, including geologic mapping, shallow temperature surveys, gravity surveys, lidar, geochemical studies, seismic reflection analysis, and 3-D modeling. The goal of the detailed studies was to identify areas with the highest likelihood for high permeability and thermal fluids such that drill sites could be targeted. Phase 3 involved more detailed geophysical surveys and temperature-gradient drilling at two highly prospective sites, with the goal of testing the play fairway methodology. Drilling sites were selected on the basis of collocated features indicative of geothermal activity, such as favorable structural settings, Quaternary faults, shallow (2-meter) temperature anomalies, favorable geothermometry from nearby wells, and geophysical anomalies (e.g., magnetic lows, intersecting gravity gradients, and low resistivity). Sites were drilled in southeastern Gabbs Valley and northern Granite Springs Valley, revealing temperatures as high as 124 °C at 152 meters and about 96 °C at approximately 250 meters, respectively, at the two sites. These findings suggest the presence of two hitherto unknown blind geothermal systems and provide initial validation of the play fairway methodology.

# NEW HAMPSHIRE

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## INTRODUCTION

The New Hampshire Geological Survey (NHGS) was established by legislation in 2001 to “collect data and perform research on the land, mineral, and water resources of the state, and disseminate the findings of such research to the public through maps, reports, and other publications.” This substantially redefined the preexisting Office of the State Geologist, which was established in 1839. The NHGS is a unit within the Commissioner’s Office of the New Hampshire Department of Environmental Services. Three of the five full-time staff are fully supported by external funds, as are temporary part-time positions that are assigned to specific grant-funded projects on an as-needed basis. One part-time, state-funded position serves as the education and outreach coordinator. A number of volunteers provide ongoing critical services as part of the geologic mapping and groundwater-level monitoring programs.

## GEOLOGIC MAPPING

The NHGS continues to participate in the cooperative U.S. Geological Survey (USGS) STATEMAP program and increase the number of 1:24,000-scale quadrangles with completed surficial and bedrock geologic maps.

### Bedrock Mapping

The area surrounding the Presidential Range of the White Mountains continues to be a focus area for new bedrock mapping. One objective is to complete an east-west transect along U.S. Route 2 from near the Vermont border at the Connecticut River to the border with Maine. The Berlin Quadrangle is the latest in this sequence. This mapping is key to revealing critical relationships between Ordovician intrusive and volcanic rocks of the Bronson Hill Belt and Silurian and Devonian metasedimentary rocks of the Central Maine Belts in the northern Appalachians. The first 1:24,000-scale quadrangle was also completed in the Indian Stream project area above the 45th parallel in the northernmost part of the state. The Pittsburg Quadrangle is the first of seven quadrangles to be mapped as part of the project, which is largely the work of a

dedicated team of retired professional geologists serving as NHGS volunteers.

### Surficial Mapping

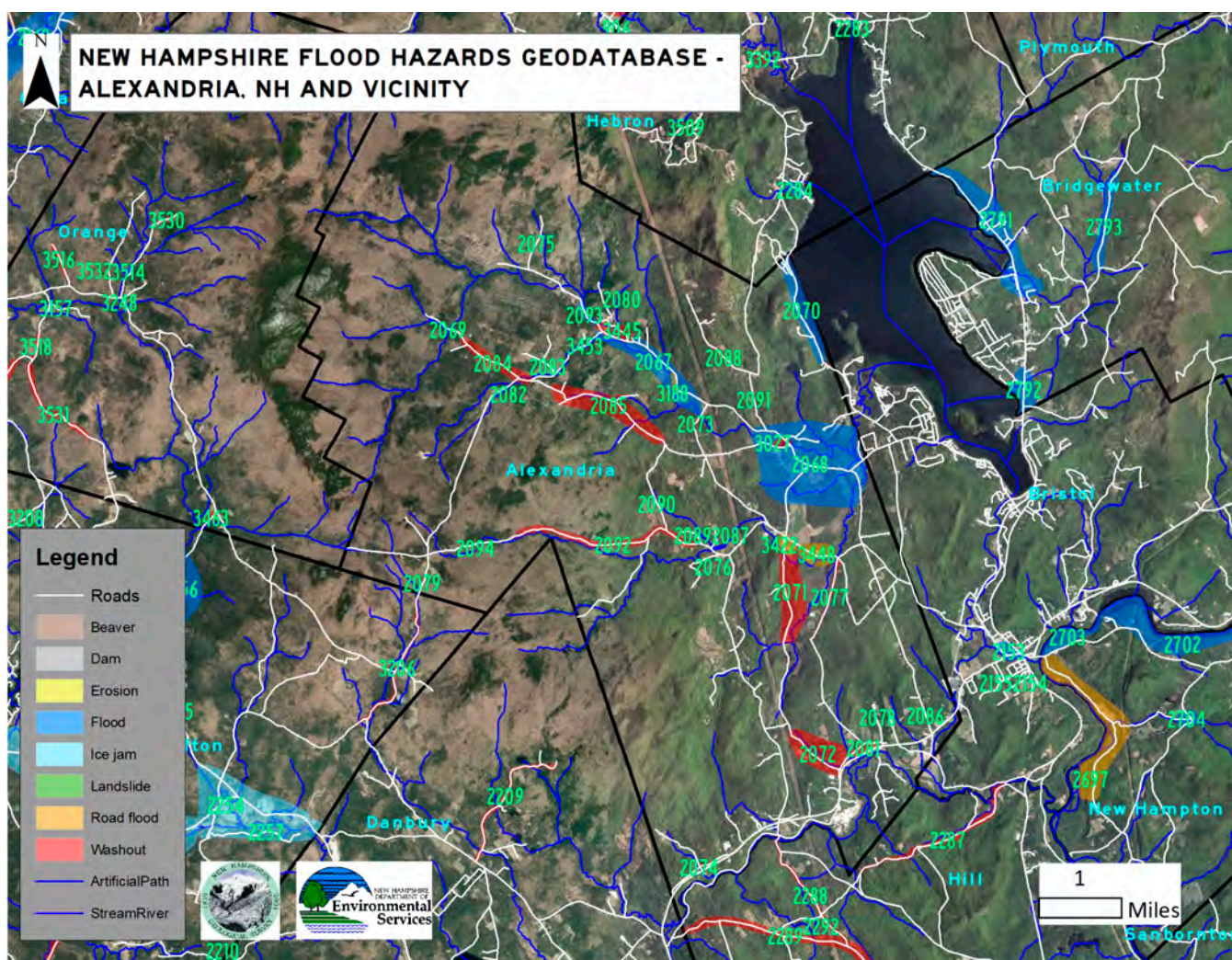
Recent mapping has been focused on completing surficial geology for the entire Lake Winnepesaukee watershed in the central part of the state, south of the White Mountains. This popular tourist destination was planned to be the focus of the 2020 Northeast Friends of the Pleistocene trip, which was postponed because of COVID-19 concerns. Discovery of topographic features that do not align with the expected, predominant northwest-to-southeast ice flow in the upper part of the watershed are of special interest. Another focus area has been the southern tier immediately along the state’s border with Massachusetts. Recent completion of the last remaining unmapped quadrangles allowed the NHGS to undertake its first 100,000-scale surficial geologic map compilation of all the quadrangles within the Lowell 30 × 60-minute sheet. This compilation was able to take advantage of lidar data, which did not exist at the time most of the quadrangles were originally mapped, as well as subsurface data for hundreds of new water wells that had been added to the statewide database.

### 3-D Mapping

The NHGS expanded its capability to map the thickness of surficial deposits with the acquisition of a Tromino instrument for measuring depth to bedrock by using passive seismic energy. Unfortunately, COVID-19 concerns prevented its deployment during the 2020 field season.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

The NHGS’ Flood Hazards activities continued to be focused on stream-crossing assessments in support of the state’s culvert assessment initiative. Despite COVID-19-induced budgetary challenges, the NHGS hired six interns for the summer of 2020, four of whom performed stream-crossing assessments



**Figure 1** Example of the New Hampshire Flood Hazards Geodatabase for the Town of Alexandria, New Hampshire, and adjacent communities.

across New Hampshire all summer. The challenges notwithstanding (i.e., interns in their own vehicles, social distancing masks), the NHGS interns successfully collected data for 681 culverts this summer. In addition, the statewide Flood Hazards Geodatabase, a joint project with New Hampshire Homeland Security and Emergency Management, “officially” came online in August with two well-attended WebEx gatherings by local officials and emergency management directors across the state (Figure 1).

Acquisition of new lidar data was completed under the latest cooperative USGS 3-D Elevation Program project with the NHGS. This includes tide-coordinated Quality Level (QL) 1 data for the Seacoast region, which supersedes a QL3 data set

that was originally acquired in 2010–2011. New Hampshire now has QL2 or better data for the entire state, a major milestone with significant benefits for a broad range of stakeholders.

Automated techniques developed by the NHGS for extraction of headwater streams were applied in the White Mountain National Forest as part of a cooperative project with the U.S. Forest Service to enhance the National Hydrography Dataset (NHD). Validation of predicted stream channels by field inspection in the Peabody River watershed revealed that headwater streams are dramatically underrepresented by the NHD, by as much as 300%.

# NEW JERSEY

## New Jersey Geological and Water Survey Department of Environmental Protection

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### INTRODUCTION

The New Jersey Geological and Water Survey (NJGWS) has a wide range of responsibilities. These include management of water supply allocation and well permitting; water supply planning and modeling; groundwater resource assessments; mapping onshore and offshore geology; evaluating natural hazards; advising on energy issues (geothermal, natural gas, and wind), with their related infrastructure issues; conducting site evaluations; and providing earth science information to government agencies and the public to address economic, environmental, and public health and safety issues. The Survey also provides technical expertise and direction for New Jersey on numerous strategic programs, including the State Hazard Mitigation Team, Board of Licensed Site Professionals, Board of Licensed Well Drillers and Pump Installers, Pine-lands Commission, Highlands Commission, Delaware River Basin Commission, and Delaware River Decree Parties.

### GEOLOGIC MAPPING

#### STATEMAP

Five quadrangle maps were completed and submitted in June 2020: Jenkins (surficial and bedrock), Green Bank (surficial and bedrock), Medford Lakes (surficial and bedrock), Lakewood (surficial), and Pitman East (bedrock). Because of COVID-19, the six NJGWS geologic mappers were not allowed to conduct any field work and worked at home to finish the deliverables. They relied on interpretations of electronic information without the final ground-truthing that field work normally provides.

An offshore geologic map for the inner continental shelf between Corson Inlet and Absecon Inlet was delayed owing to difficulties in accessing office software remotely because of the COVID-19 shutdown beginning in mid-March 2020.

NJGWS received a no-cost time extension until December 2020 for this deliverable.

### WATER QUALITY

#### Ambient Groundwater Quality Network

Data from the New Jersey Ambient Groundwater Quality Monitoring Network, part of the National Ground-Water Monitoring Network, are used to evaluate and track trends from non-point-source impacts on the water table. Fifty monitoring wells are sampled each year.

#### Public Health Outreach

The NJGWS continued partnering on a public health outreach study, sponsored by the New Jersey Department of Health and the federal Centers for Disease Control and Prevention. A series of outreach events were conducted to determine public health impacts, using water quality data from New Jersey's Private Well Testing Act. The goal is to increase private well testing and water treatment in areas identified as high risk from geogenic impacts. Radionuclides were the targeted compounds, and the outreach was focused in areas where radionuclide concentrations are known to exceed New Jersey's Safe Drinking Water Standards.

### WATER SUPPLY

#### Hydrogeologic Analyses

The NJGWS completed reviews of six proposed new water withdrawals to determine the potential impacts on existing users, streamflow depletion, and movement of saltwater and anthropogenic contaminants. In addition, the NJGWS completed a review of 11 aquifer test proposals to ensure that the

proposed testing met with established criteria and would provide the data necessary to accurately determine the effects of the requested diversions to area users and the environment.

## **Water Supply and Modeling**

The NJGWS provided technical support to water-resource planning and permitting groups within and external to state government. Projects during the reporting period included updates and enhancements to water-use databases, review and modeling of water supply permit modification requests, modeling support for reservoir construction projects, water quality and water supply condition monitoring, review of regional water supply and drought operation plans, negotiation of interstate water management agreements, and research into the effects of climate change on water availability.

## **DATA PRESERVATION**

The NJGWS has participated in the National Geological and Geophysical Data Preservation Program for more than 10 years. During the reporting period, 36 field notebooks from three retired Survey geologists and 93 field maps from various Survey geologists were scanned. Most of the field books and maps date back to the mid-1900s.

## **GEOPHYSICS**

The NJGWS provided programmatic support by collecting and interpreting downhole and near-surface geophysical data. These capabilities are utilized in support of the NJGWS STATEMAP program and other NJDEP programs, such as Green Acres and Site Remediation.

## **REGULATORY ACTIONS**

For the period from July 1, 2019, to June 30, 2020, the NJGWS issued 10,669 new well permits, received 10,452 well records, and received 7,159 well abandonment reports. For this period, the NJGWS also issued 13 modifications to agricultural certifications, 77 new or renewed agricultural certifications or registrations, 9 temporary dewatering permits, 16 minor or major

modifications to water allocation permits, 36 new or renewed water allocation permits or equivalencies, and 36 new or modified water-use registrations. The various categories are based on use of the water and the volume needed. The NJGWS also granted 6 aquifer test waivers.

New Jersey currently has six bedrock storage caverns used to store liquified petroleum gas that operate under a 1950s-era law. No regulations are in place for either the construction or operation of these caverns. The NJGWS is participating in a rule-writing effort to develop new regulations to protect public safety by ensuring sound installation, management, operation, maintenance, and decommissioning on any such cavern.

## **PRINCETON GEOTHERMAL**

Princeton University is taking steps toward “going green” by constructing geothermal wells throughout its campus to provide for all heating and cooling needs. The university installed a 1,500-foot test well in late 2019 to investigate site geology. On the basis of data from this well, Princeton plans to install more than 1,000 closed-loop geothermal wells at depths of about 850 feet in sandstone and shale of the upper Jurassic Stockton Formation. Drilling began in March 2020.

The number of geothermal wells associated with this project, coupled with the reality of having multiple drillers on site simultaneously, further complicates NJGWS inspection and oversight. Because of these considerations, all well permits associated with this geothermal project have a condition that requires a certified geothermal inspector to be on site for the duration of the project and to report findings to help ensure regulatory compliance.

## **PUBLICATIONS AND WEB**

The NJGWS published four STATEMAP products from previous years. The quadrangles published were the bedrock geology of the Mendham Quadrangle and the surficial geology of the Cassville, Lakehurst, and Newfield Quadrangles. The [Survey website](#) averages 67,300 hits per month.

# NEW MEXICO

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### INTRODUCTION

Established by legislation in 1927, the New Mexico Bureau of Geology & Mineral Resources is a nonregulatory state agency that serves as the geological survey for the State of New Mexico. Through our offices, museum, store, laboratories, publications, and website, our staff serve the diverse population of New Mexico. From elementary students to research and industry scientists, there is something at the Bureau of Geology for everyone who has an interest in the exceptional geology and natural resources of New Mexico. Our multifaceted organization consists of a number of interwoven programs, including geologic mapping; energy, mineral, and water resources; basic geologic research; archiving and disseminating mining, petroleum, and rock core data; assessing geologic hazards; and public education and outreach. During the past year, we had a staff of approximately 60 full- and part-time employees, supported by a mix of state appropriations and funds obtained from grants and contracts.

### GEOLOGIC MAPPING

Geologic mapping provides the underpinning of most research carried out by our organization. Our mission is to provide state-of-the-art geologic maps of sufficient detail to be of practical benefit to the State of New Mexico. These maps address a wide range of specific topics, such as the location of geologic hazards and geologic resources, including mineral and petroleum resources and groundwater, which are all relevant to natural resource use, city planning, and education. Partial funding for our mapping program was provided by the National Cooperative Geologic Mapping Program. Our goal is to have a variety of geologic and resource maps accessible online, via direct download for viewing in our new interactive web-based application.

During this year, our geologic mapping group completed approximately 600 square miles of mapping, partially funded by the STATEMAP program. We were able to hire three new mappers, all with PhDs, to support our mapping and research programs. Our minerals group continued a geologic mapping initiative, funded by the U.S. Geological Survey (USGS) Earth Mapping Resources Initiative (Earth MRI) Critical Miner-

als Program, on rare earth element deposits in the Gallinas Mountains of New Mexico and began work on another Earth MRI project on rare earth element deposits in the Cornudas Mountains in Otero County, New Mexico.

On the GIS and production end of the mapping program, 6 maps were completed and 13 maps were digitized. Our geologic mapping program website received a large number of visits (588,602) and supported 1,922 gigabytes of downloaded data. Our mapping personnel also taught an ArcGIS class to 24 New Mexico Tech students and employed 5 students to digitize geologic maps.

We maintained productivity through COVID-19 time among both staff and students. Our governor granted our organization a waiver to carry out field work during New Mexico's stay-at-home order, so field work has continued to move forward. We supported our staff and students' productivity throughout the COVID-19 crisis by facilitating at-home work and granting access to our building (with its fast internet!) on an as-needed basis.

### OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

#### Hydrology

Efforts were ongoing on nine regional and three statewide active hydrology projects, with a state funding allocation of \$285,000 supplemented by \$430,000 of other federal, state, or private funds. Bureau scientists interacted extensively with community members and leaders to help understand, and react to, an imminent groundwater shortage. This program supported four graduate students and two undergraduates, contributing to New Mexico's future workforce.

#### Water Data Act

In our efforts to support a legislative initiative intended to make water data in New Mexico accessible and interoperable, we accomplished critical targets for FY 2020, including development of a governance structure, a vision, and an online data service.

## Energy

We hired a new junior petroleum geologist using expansion funds granted to us during the last fiscal year. We were successful in securing a donation of state-of-the-art scientific software for use by the entire New Mexico Tech campus. We developed several collaborative projects with the New Mexico Oil Conservation Division and are involved in two large U.S. Department of Energy grants focused on carbon sequestration.

## Minerals

We received funding from the USGS to further investigate critical minerals in New Mexico and were able to hire an economic geologist specializing in rare earth element mineral research by using a budget expansion provided during the last fiscal year.

## Geologic Hazards

We published, through our website and print publications, accessible information about a range of geologic hazards in New Mexico. Continued focus on seismicity, rockfalls and landslides, and volcanism in New Mexico contributes to our citizens' safety and security.

## Laboratories

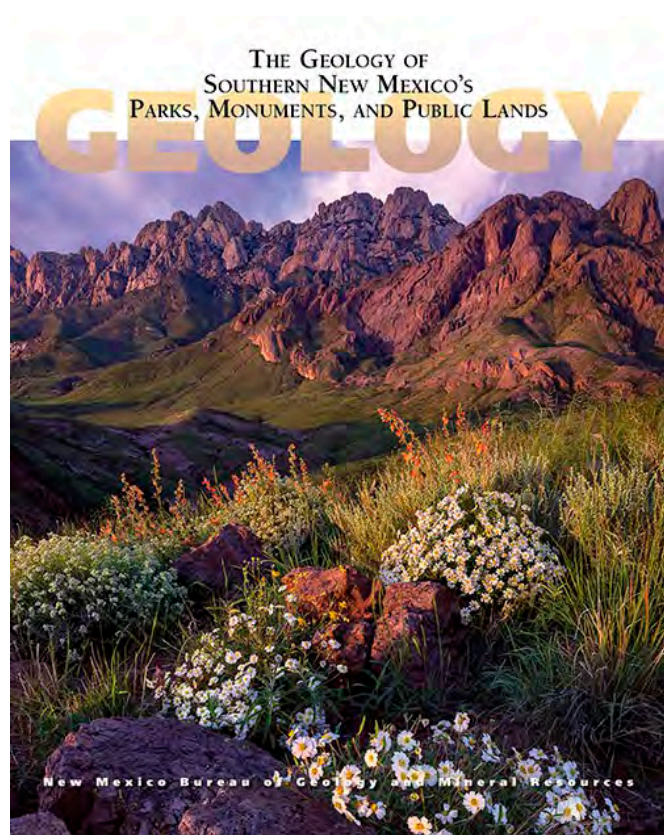
Our laboratories supported research work for 31 New Mexico Tech students, as well as 35 from other universities as part of the 168 laboratory users who worked with us to obtain high-quality geochemical and geochronological data supporting a wide range of research projects. The laboratory income of \$284,000 in the past year supports a number of professionals and students.

## Publications

We published a new popular-interest book titled *The Geology of Southern New Mexico's Parks, Monuments, and Public Lands* (Figure 1) and reprinted the award-winning sister volume, which focuses on northern New Mexico. We also published 37 peer-reviewed publications, several open file reports, a technical journal, and two outreach periodicals supporting research, education, and outreach in New Mexico.

## Web Presence

Our efforts to make information and interactive maps available through our website have resulted in more than 600,000 individual visitors to our website during the past year, many from other state agencies. These visitors downloaded a total of 37.5 terabytes of data.



**Figure 1** Cover of our latest book, *The Geology of Southern New Mexico's Parks, Monuments, and Public Lands*.

## Museum

Our spectacular museum continues to grow in visitorship. Despite COVID-19 challenges, we hosted more than 15,000 visitors this year, which included 800 students.

## Outreach and Education

During the past year, in addition to our many recurring outreach activities, we hosted a virtual geology workshop, "Rockin' Around New Mexico," to support New Mexico educators during the COVID-19 crisis.

## Academic Support

Eighteen of our staff members are adjunct faculty in New Mexico Tech departments. During the past year, our staff served on 15 graduate committees and taught 171 credit hours at the 400 and 500 level, generating \$189,000 in formula funds.

# NEW YORK

## New York State Museum/Geological Survey

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## INTRODUCTION

The New York State Geological and Natural History Survey was established by the New York State Legislature in 1836. Geological research has been conducted continuously since then and has remained an important component of the State Cabinet of Natural History, established in 1842 and later renamed the New York State Museum in 1870. The New York State Geological Survey (NYSGS) is a bureau of the State Museum in the State Education Department. Our mission is to conduct geologic research, evaluate mineral resources and geologic hazards, and make the data and advice derived from that research available to state agencies, the educational community, and the public for the health, safety, and economic welfare of the citizens of the state. Presently, the NYSGS has a staff of eight and is conducting research statewide. Geologic mapping and paleontology are the two most active programs, and substantive discoveries continue to be made.

## GEOLOGIC MAPPING

Geologic mapping remains the principal scientific research function at the NYSGS. In the last 10 years, working closely with our advisory group, we have launched long-term mapping projects focused on the production of county-scale geologic maps that will provide utility to a variety of county and state agencies. Emphasis in recent years has been placed on surficial geologic mapping to improve understanding of the complex glacial geologic framework related to water resources. Recently, a new and exciting discovery of rare earth-bearing rocks near the Adirondacks has us poised to launch a new bedrock mapping project to address national priorities for critical minerals mapping. The COVID-19 lockdown in New York almost brought mapping to halt in 2020, but fortuitously, we were able to adapt projects and modify plans to streamline travel and still accomplish map deliverables.

### Bedrock Mapping

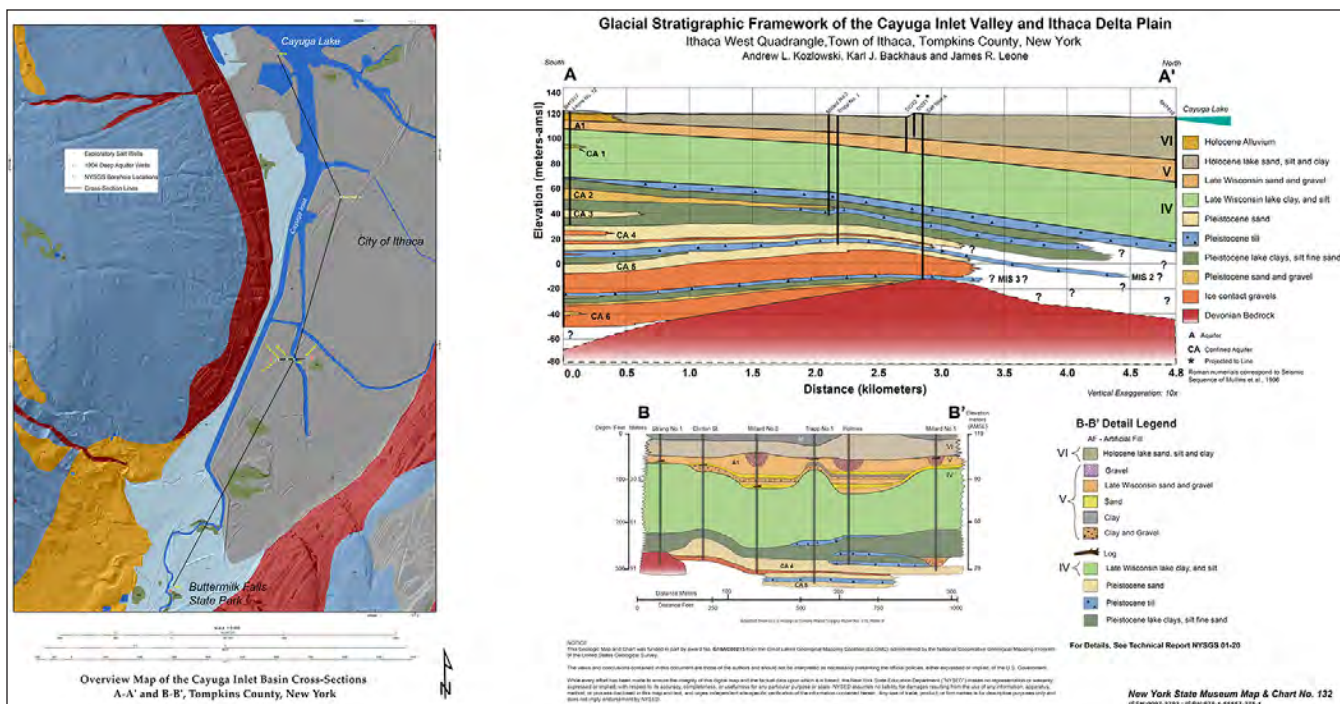
No bedrock mapping was completed in 2019–2020.

## Surficial Mapping

Surficial geologic mapping focused on the glacial geology in the eastern Finger Lakes in Cayuga and primarily Tompkins Counties along Cayuga Lake, the second largest and deepest of the Finger Lakes. Our mapping focused on identifying new groundwater resources. Despite literally being surrounded by water, the regional freshwater resources of the Finger Lakes have been adversely affected by harmful algal blooms (HABs). The HABs adversely affect surface water quality and prove difficult and expensive to treat with existing water treatment techniques. Bedrock aquifers in the region are also typically unsuitable and are saline or of poor quality because of interaction with evaporite deposits in the Salina Group. We are focusing our efforts on mapping and exploring thick glacial deposits in previously undocumented buried bedrock valley systems. For the most part, the deposits contained within the buried valleys have never been systematically mapped by geologists. They contain a complex record of glaciation and consistently contain aquifer-bearing units.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

In the fall of 2019, the NYSGS completed the second of two deep exploration cores to collect continuous cores of Pleistocene sediment. This effort resulted in a new publication documenting the complex glacial stratigraphic framework of the Inlet Valley, a Delta Plain near Ithaca, New York (Figure 1). This element of our 3-D mapping program sought to collect high-resolution drill core of thick Pleistocene deposits in an area of public concern. The controversy centered around a long-standing underground salt mine at the south end of Cayuga Lake. Many citizens had environmental concerns about the potential impacts of mining on groundwater–surface water resources in Cayuga Lake. The absence of high-quality geologic information resulted in speculation and unsubstantiated claims that aquifers and the lake bottom interface might be adversely affected. However, the existing subsurface and surficial geologic data were of such poor quality and so limited that a very simple three-layer aquifer model was believed to be present.



**Figure 1** Map showing surficial geology of the Ithaca Delta Plain (left) at the south end of Cayuga Lake and stratigraphic framework (right) of complex glacial geology, including multiple aquifers.

The completion of the continuously cored wireline boreholes in Buttermilk Falls State Park extended to a depth of 560 feet without reaching bedrock and penetrated seven stratigraphically different glacial aquifers, six of which were confined and five of which displayed flowing artesian conditions. The aquifers and aquicludes present were the product of multiple cycles

of glacial advance and retreat and include lithologies ranging from boulder gravel to laminated silt-clay rhythmites. None of the aquifers appeared to be saline, and the lowermost aquifers have the potential to serve as a municipal water supply for the City of Ithaca.

# NORTH DAKOTA

## North Dakota Geological Survey Department of Mineral Resources

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## INTRODUCTION

The North Dakota Geological Survey (NDGS) was established in 1895 and serves as the primary source of geological information in the State of North Dakota. From 1895 to 1985, the State Geologist was also chair of the Geology Department at the University of North Dakota in Grand Forks. In 1989, the Geological Survey was placed under the North Dakota State Industrial Commission and moved to Bismarck. In 2005, the Geological Survey became a division, and both it and the North Dakota Oil and Gas Division were placed within the newly formed Department of Mineral Resources.

## GEOLOGIC MAPPING

### Bedrock Mapping

We published several maps over this time period regarding potential zones for produced water injection (Inyan Kara Formation) and potash resources (Prairie Formation).

### Surficial Mapping

COVID-19 severely curtailed field work during the spring and summer of 2020. Much of the mapping planned for the greater Fargo metropolitan area was placed on hold because of quarantines and travel restrictions (one person per vehicle and avoidance of overnight stays). Surface mapping of two quadrangles east of Bismarck was continued because of the proximity to the office.

### Landslide Mapping

With the surface mapping curtailed, three of our four surface geologists accelerated their landslide mapping by using aerial photographs, Google Earth images, and lidar. As a result, we published 336 quadrangles, identifying 5,500 landslides with a combined total area of 16,500 acres. We project that we will complete the initial phase of landslide mapping in late 2021. We have also flown gridded drone flights over a half dozen landslides. We established elevation control points around these slides and have flown repeated gridded drone flights

to generate surface elevation models so we could identify areas within the slide body that are moving and calculate the volume of failed material.

## Critical Minerals Project

In 2019, we continued collecting lignite samples for our 6-year project on rare earth elements, while at the same time expanding the scope of the project to include most of the remaining critical elements (without the platinum group elements). We have now had more than 1,100 lignite samples analyzed for rare earth elements and 425 samples for the other critical elements. In January 2020, we mined 44 tons of lignite containing an average concentration of 480 ppm of rare earth elements. The high rare earth coal was blended with 200 tons of lignite containing lower rare earth element concentrations, enabling it to meet the minimum concentration requirements for a U.S. Department of Energy grant. The Institute for Energy Studies (University of North Dakota) is currently processing that lignite in a rare earth pilot plant. We did no sample collection from April 1 to June 30, 2020, because of COVID-19.

## Proppant Sand Project

In 2019 and 2020, we collected 50 sand samples from wind-blown deposits located primarily in the central part of North Dakota. Those samples were analyzed for a series of proppant criteria: grain size, sorting, roundness, sphericity, quartz content, crush resistance, acid solubility, and turbidity. We generated a handful of maps and reports from these results, which were then used by industry to establish proppant sand mines in two locations.

## OTHER HIGHLIGHTS

### Core Workshop

The Geological Survey held two consecutive two-day-long core workshops from October 7 to 10, 2019, in the Wilson M. Laird Core and Sample Library. We initially planned the workshop for 40 participants, but then had to cap registration at 100 after an overwhelming response. The strong response was not

entirely unexpected because the oil and gas industry is undergoing a large employee turnover. Those first employed during the peak in activity in the late 1970s are retiring, and their replacements typically do not have a strong background in core studies. More than half of the attendees were in their 20s or early 30s and new to the Williston Basin. We were planning an August 2020 core workshop, but that has been postponed because of COVID-19.

### **Paleontology Virtual Lecture Series**

As soon as the North Dakota public schools closed in mid-March in response to COVID-19, the Paleontology Section decided to create a series of lectures to give students suddenly stranded at home a chance to tune in for a dose of science. The paleo chats were broadcast over the Zoom webinar platform from 10:00 to 11:00 am CST, Monday through Friday. On March 25, after six very successful presentations on mosasaurs, coprolites, ammonites, sabertooth cats, amber, and hadrosaurs, the Heritage Center closed because of COVID-19 and the paleo crew had to gather their fossils, grab their computers, and set everything up at home. Even before the Heritage Center closed, the paleontologists knew they would need to reach out to guest presenters to keep the paleo chats going without creating too much of a burden on themselves. They ended up securing 20 guest speakers from a wide variety of institutions spread across the United States (North Dakota State University, Cleveland Museum of Natural History, Raymond F. Alf Museum of Paleontology in Claremont, California, Washing-

ton University School of Medicine, University of Tennessee, Oklahoma State University, and the John Carroll Museum in Ohio). Also participating were scientists from the Royal Saskatchewan Museum in Regina, the Museum für Naturkunde in Berlin, and the Instituto de Geología in Mexico City. As schools improved their virtual classrooms, the paleo chats were scaled back to twice a week (Tuesdays and Thursdays) and were then discontinued as the school year was coming to an end. In total, 30 live lectures were presented from March 18 to May 14 and then posted on YouTube ([www.youtube.com/c/NDGSPaleo](https://www.youtube.com/c/NDGSPaleo)) for future use by teachers and other educators or the general public interested in paleontology. Under trying circumstances, the paleontologists initiated a new lecture series, learning as they went, in an attempt to fill a void and perhaps create a diversion for students from what was going on in the world around them.

### **Public Fossil Dig Program**

Our 2019 Public Fossil Digs once again ran at full capacity, with several hundred people on the waiting list. Unfortunately, the occupancy rate for our Medora Public Fossil Dig plummeted to 51% in June 2020 as half the registrants dropped out because of the COVID-19 pandemic. Although that made it easier to socially distance in the vehicles and on the outcrop, we also incurred additional costs for masks, hand sanitizer, and additional digging tools because we could no longer allow tool sharing between dig participants.

# OHIO

## Ohio Department of Natural Resources Division of Geological Survey

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### INTRODUCTION

The Ohio Department of Natural Resources (ODNR), Division of Geological Survey was founded in 1837 and has been continuously authorized since 1869. The Division's mission is to provide the geologic information and services needed for responsible management of Ohio's natural resources. It researches and reports on the geology of the state and is Ohio's archive for geologic information. Main offices are located on the ODNR main campus in north Columbus and at the Horace R. Collins Laboratory (HRC) at Alum Creek State Park. The Division's staff of 37 provide technical expertise to citizens, industry, and other agencies of government concerning coal, oil and gas, minerals, and geologic hazards. During the FY 2020 reporting period, the Division's budget consisted of severance tax income on fuel and nonfuel commodities, federal and state grants, departmental-allocated funds, and income generated from the sales of publications and data.

The Division is organized into seven groups: Administration and Fiscal, Energy Resources, Geologic Mapping and Industrial Minerals, Groundwater Resources, HRC/Lake Erie Science (HRCLES, or "Hercules"), the Geologic Records Center (GRC) and Archives, and Publications & Outreach.

### ADMINISTRATION AND FISCAL

The outbreak of the COVID-19 virus in March 2020 caused a major shift in the daily workflow and priorities for the Administration and Fiscal section. Much energy was devoted to helping set up remote work and handling numerous personnel and technology issues associated with this transition. The Administration and Fiscal section was also occupied with several large procurements, including hiring a contractor to develop a new database system for our water-well logs, obtaining subsurface mapping software for our Energy Resources Group, and contracting an architect to design a remodeled office facility at our Fountain Square headquarters. Currently, staff are housed in Building C of our complex, and records, archives, and maps are stored in Building B. The plan is to substantially remodel Building B and occupy the new space

by early 2022. This will allow the entire staff and records to be housed under one roof and to be arranged in a more logical floorplan. An additional purchase was the acquisition of a 25-foot steel-hulled boat, outfitted for doing research along the shore of Lake Erie. Additionally, Fiscal Officers May Sholes and Toni Rahaman developed a new method for billing labor to grants and other projects when ODNR transitioned to a new timekeeping system.

### ENERGY RESOURCES GROUP

The current staff of the Energy Resources Group includes five members. Jim McDonald is the group's supervisor and has experience in petroleum geology, CO<sub>2</sub> sequestration, coal resources, and abandoned underground mines. Erika Danielsen's focus is on Silurian and Devonian bio- and chronostratigraphy. Sam Hulett works as a geochemist who also specializes in detrital-zircon age dating. Michael Solis is a petroleum and structural geologist, and Chris Waid works as a Silurian bio- and chronostratigrapher.

One of the largest efforts for the Energy Resources Group involved the Eastern Section American Association of Petroleum Geologists (AAPG) Annual Meeting held in Columbus, Ohio, in October 2019. The group led three field trips and one core workshop. Sam Hulett led a field trip on the Upper Devonian Berea through the Pennsylvanian sandstones of central Ohio. Erika Danielsen was a co-leader on the field trip to the Devonian Ohio Shale in central Ohio. Finally, Chris Waid led the Lower Silurian field trip and core workshop in central and western Ohio. The staff also gave several presentations. Jim McDonald gave a presentation on the history of structure contour mapping in the Appalachian Basin from 1870 to 1917. Michael Solis gave a talk on the structural framework of the Cambridge Arch and the Parkersburg syncline using new seismic reflection data. He also presented a poster on the Silurian through Middle Devonian far-field tectonics during the Appalachian Orogen in Ohio (co-authored with Julie Bloxson, former staff member who is an assistant professor at Stephen F. Austin University in Texas). Chris Waid and Erika Danielsen

were co-authors on a poster presentation with an Ohio State University undergraduate student, examining the porosity in the Trenton Limestone in northwestern Ohio. In addition to the Energy Resources Group staff, Jeff Deisher, of the HRC, gave a presentation on the history of the Pennsylvanian-age Macksburg oil field in Ohio. Staff were also involved in the meeting's Honors and Awards ceremony. Chris Waid received an award for his 2018 presentation on Lower Devonian Shale cyclicity. Jim McDonald received a Certificate of Merit for being part of the meeting organizing committee. Later in the year, Jim McDonald was informed that his petroleum history paper would be awarded the A.I. Leverson Award, which is given for the best scientific paper at the Annual Meeting. The award will be presented at the next Eastern Section AAPG Annual Meeting in October 2021 in Pittsburgh, Pennsylvania.

The 2019–2020 time period marked a significant transition for the Division's participation in CO<sub>2</sub> sequestration research. The Midwest Regional Carbon Sequestration Partnership (MRCSP) came to a close at the end of December 2019, after a 17-year period of operation. During that time period, the Survey led the effort to characterize the CO<sub>2</sub> sequestration capacity in the midwestern and eastern United States, along with more detailed characterization of the CO<sub>2</sub> sequestration capacity in Ohio. In place of the MRCSP, a larger, expanded partnership was formed, the Midwest Regional Carbon Initiative (MRCI). The MRCI includes states in the eastern United States, the Appalachian Basin, and the Michigan Basin, along with states from the Illinois Basin area, such as Illinois and Iowa. The kick-off meeting for the MRCI occurred in the spring of 2020, with Jim McDonald being Ohio's principal investigator and Chris Waid acting as the lead geologist for the Division.

The Energy Resources Group began a new project, in partnership with Battelle Memorial Institute, to examine the regional enhanced oil recovery potential of the Utica Shale/Point Pleasant Formation unconventional shale play in Ohio. The project will support Battelle's effort to conduct a pilot project to inject natural gas liquids to increase production in the oil window of the Utica/Point Pleasant play. Lead Ohio Geologist Michael Solis and Geologist Erika Danielsen are involved with establishing the stratigraphic framework and mapping the geologic units of the play. Chris Waid is tasked with completing the organic source rock analyses, mineralogical analysis, and calculation of the mineral brittleness indices. Sam Hulett is responsible for mapping and analysis of the elemental composition of the geologic units, mapping of the total organic carbon (TOC), and mapping of the porosity and permeability of the geologic units associated with the Utica/Point Pleasant play. Progress on the project has been hampered by the COVID-19 pandemic, lack of access to the ODNR network, and lack of access to GIS and subsurface mapping software. This has led the staff to be creative in the data analysis and mapping portions of the project.

Several other projects are ongoing. The Energy Resources Group has a project to convert geophysical well logs from scanned images to LAS format. Sam Hulett is the project manager for this project. Erika Danielsen has a project to examine the TOC distribution in Devonian Ohio Shale in the Appalachian Basin of Ohio. Data indicate that these rocks may

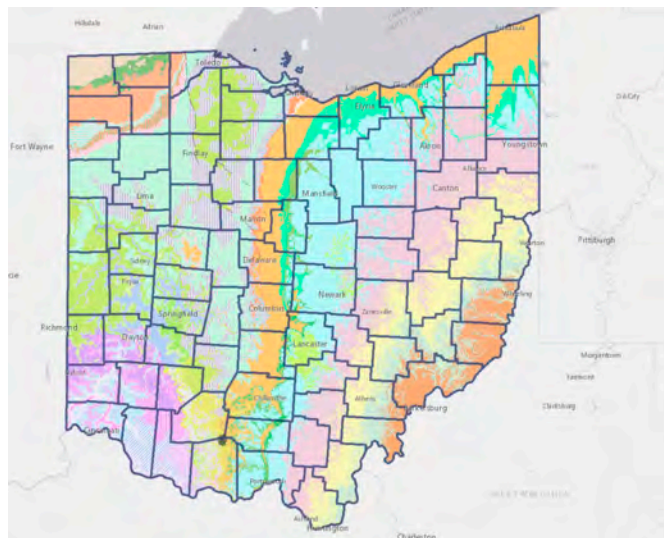
support important future economic potential. This project work is dependent on data from an LAS conversion project. Sam Hulett has worked on a variety of projects researching the occurrence of zircons in Ohio's deep subsurface Cambrian and Precambrian sandstones. The zircons would help with both age dating and determining provenance. Chris Waid continues to build expertise with the Silurian carbonates in Ohio. He continues work on a PhD program at The Ohio State University, revising the stratigraphic correlation for Ohio's complex Silurian sequences.

A new initiative, headed by Jim McDonald, is to provide staff field trips to learn about Ohio's stratigraphy. The first field trip was to the Serpent Mound meteorite impact crater. This field trip was led by Curtis Coe, of the Groundwater Resources Group and co-led by Jim McDonald. These educational field trips have been put on hold because of COVID-19 pandemic travel restrictions.

## GEOLOGIC MAPPING AND INDUSTRIAL MINERALS GROUP

The Geologic Mapping Group (Figure 1) continued detailed bedrock mapping for the 2019–2020 U.S. Geological Survey (USGS) STATEMAP project. Senior Geologist Frank Fugitt performed detailed mapping of Mississippian- and Pennsylvanian-age units in eastern and southeastern Ohio. Frank mapped the Hallsville, Laurelville, and South Bloomingville 7.5-minute quadrangles at 1:24,000 scale. This region is of great importance as it constitutes the heart of Ohio's Hocking Hills Region, which is a major draw for tourism and investment.

The USGS-sponsored Great Lakes Geologic Mapping Coalition is another long-term funding source for the Division. In 2019–2020, several projects were funded by the Coalition. Geologists Douglas Aden and Brittany Parrick did active karst mapping



**Figure 1** The new Ohio Geology Interactive Map released on the Division website in 2020.

in Hamilton County and created a karst interactive map that depicts the location of karst features statewide ([https://gis.ohiodnr.gov/website/dgs/karst\\_interactivemap/](https://gis.ohiodnr.gov/website/dgs/karst_interactivemap/)).

Geologist Andy Nash completed an ambitious project to determine the Late Pleistocene environmental conditions of central Ohio. The research culminated in the creation of a new Quaternary map for Clinton County. Andy Nash, Douglas Aden, Brittany Parrick, and Tyler Norris completed mapping of the surficial geology, creating stack maps for eight 7.5-minute quadrangles in the Coshocton area of eastern Ohio. Detailed bedrock topography mapping utilizing Tromino-based passive seismic surveys is being used to help create and verify the bedrock topography associated with the Teays River Valley trunk stream in western Ohio. Trominos are small passive-seismic devices that allow shallow seismic data acquisition. The goal is to map the area immediately adjacent to Indiana and then coordinate with the Indiana Geological and Water Survey to determine the depth of the Teays River Valley at the state border. Work for the Tromino surveys and related work with the Indiana Survey was slowed by the COVID-19 restrictions on field work.

Staff also performed surficial stack mapping as part of a 5-year plan to complete the surficial geologic mapping of Ohio. Efforts were focused along the Ohio River in far southeastern Ohio and in Brown County in southwestern Ohio. Dr. Mohammad Fakhari is an expert structural geologist and has been working on overturned beds in Lorain County west of Cleveland and on tying these structures to orogenic events. Geologist Chris Wright and Assistant Chief J.D. Stucker compiled the 2018 *Report on Ohio Mineral Industries*, which was released in November 2019. Chris is finalizing the 2019 report to be released in November 2020.

The group finalized a map coauthored with Dr. Paul Potter, emeritus professor from the University of Cincinnati. Dr. Potter was internationally recognized for his research in sedimentology, including textbooks on sandstone and shale. His concepts helped lay the groundwork for sequence stratigraphy. The published map, *Little Miami River Watershed*, features the geomorphology of this complex stream system in southwestern Ohio. Dr. Potter tied the landscape and stream morphology into a combination of glacial geology influences and the regional tectonics that controlled lineaments in the bedrock, and in turn the many twists and meanders of the river.

Overall, the transition to work from home brought about many technological and IT challenges that the staff rose to solve. It also created many opportunities for the staff to help create virtual outreach efforts and webinars.

## GROUNDWATER RESOURCES GROUP

The Groundwater Resources Group added Hydrogeologists Tom Valachovics and Devon Goeller to the group in late 2019 and early 2020, respectively. Tom works primarily with groundwater vulnerability mapping. The group is in the second year of a 3-year Ohio Water Development Authority grant project to complete the mapping of the groundwater vulnerability (pollution potential) and to create a statewide seamless map. This grant will be completed by December 31, 2021.

During this time period, 8 of the existing 11 counties left to be mapped were mapped. Twenty counties were added to the statewide seamless map. In adding counties to the statewide map, all county boundary issues are resolved, and all polygon attributes are checked and standardized.

Devon works primarily with the Water Well Observation Program, which presently consists of 141 wells dispersed across the state that provide continuous water-level readings. The wells monitor groundwater-stressed areas with high water usage and ambient conditions for various aquifers in different physiographic areas. These wells are critical for monitoring climate changes, especially incipient drought conditions. Hydrologist Scott Kirk has nearly 40 years of experience monitoring the Water Well Observation Network and knows every site. Scott and Devon work to produce a monthly Water Inventory Report that discusses the water levels and trends. The group finished the second year of a 2-year USGS-awarded National Ground-Water Monitoring Network grant. During the second year, the group slug tested 38 observation wells and supervised the installation of two new observation wells (in Scioto County and Fulton County). This brings the total number of wells maintained in the Water Well Observation Program to 141 wells (2 were added, but one was lost to redevelopment of an industrial site in Montgomery County). The group was awarded another 2-year grant to slug test 60 existing observation wells, which began on July 2, 2020.

The group oversees one of the most critical databases in the state, the Ohio Water Well Log System. This database includes the images and data for more than 800,000 water-well logs (about half of which have GIS locations). The database also accepts newly completed water-well and sealing report records. More than 6,400 new water-well records and 4,600 new well-sealing reports for abandoned wells were added over the period. The group has been working extensively with the ODNR, Office of Information Technology to bid and contract a provider to construct a new database platform that will be upgradable, secure, and more efficient. The group responded to more than 50 public service requests for groundwater information, and the website averages around 60,000 hits for information each year. Group Supervisor Jim Raab brings 30+ years of experience to the group, and geologist Curtis Coe handles the bulk of the public service requests.

The Groundwater Resources Group manages investigations pertaining to groundwater quantity in water-stressed areas, and it reviews mining permits for the ODNR, Division of Mineral Resources Management to determine whether the mining will affect the water table for nearby residents. The group completed groundwater models for two of these potential mining sites. Hydrogeologists Krista Hardin and Tom Valachovics also perform environmental reviews for the Division. These are for a wide variety of sites, including wind and solar farms and sewage plants.

The group participated in several outreach events, including the Ohio State Fair, the Farm Science Review, and Earth Science Week, during the summer and fall of 2019. All these events were cancelled during 2020 because of the pandemic. The staff also helped provide training to the Ohio Environmental Protection Agency regarding groundwater properties.

## HRCLES (H.R. COLLINS AND LAKE ERIE SCIENCE), OR “HERCULES” GROUP

D. Mark Jones is the supervisor of this group, which includes four other full-time geologists. The H.R. Collins Core and Sample Repository (HRC) continued to acquire core and sample collections to augment the more than 300,000 linear feet of core currently stored at the facility. This group was one of the most highly affected by the pandemic, as most outlying facilities were closed for a substantial period. Visitors were limited to a few graduate students and their advisors examining and sampling core. We have been restricted from conducting regular tours, hosting meetings in our classroom, or holding any workshops or other technical events. Geologist Jeff Deisher serves as curator and made a presentation during a series of webinar events featuring core repositories from various state surveys that was organized initially by Harvey Thorleifson of the Minnesota Geological Survey.

In early 2020, the Division took delivery of a new, custom-built 25-foot research vessel built by Metal Shark of Jeanerette, Louisiana. With state-of-the-art side-scan sonar, a sub-bottom profiler, and autopilot, this vessel will be a platform from which the Survey will continue its long history of research into the physical properties of Lake Erie. Unfortunately, the pandemic curtailed our 2020 Lake Erie field season, but we are planning to get the vessel onto the water as soon as conditions permit. Before taking delivery of the new boat, the Division also collected side-scan sonar in the lake off Conneaut, Ohio, in partnership with the State of Pennsylvania, to study erosion mitigation from the Ohio-Pennsylvania border to Presque Isle, Pennsylvania. Future plans will include side-scan sonar and sub-bottom profiling for portions of the coast in northeastern Ohio.

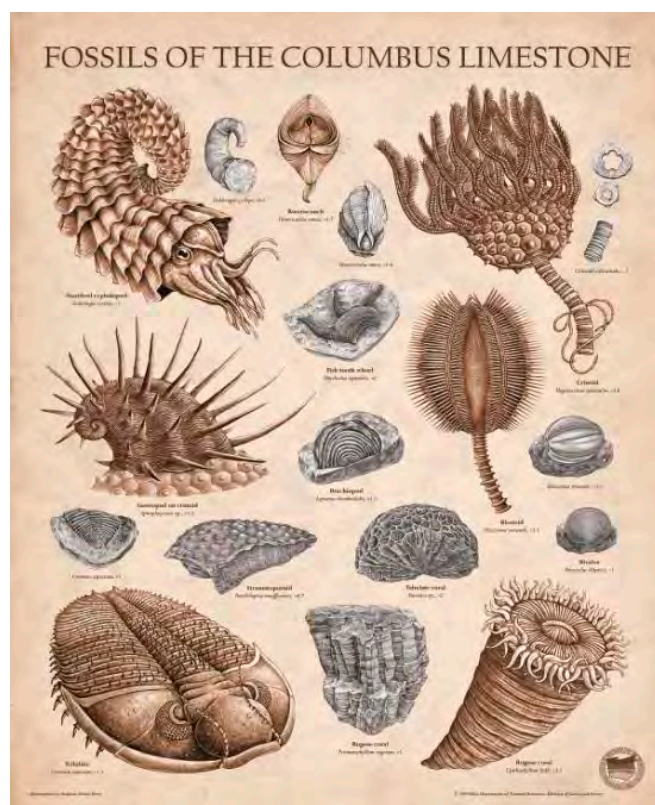
The Ohio Seismic Network (OhioSeis), headquartered at the HRC, continued its mission of monitoring for earthquakes. The OhioSeis group is staffed by Geophysicists Jeff Fox, Daniel Blake, and Jacqueline Mills. The group has installed more than a half dozen high-sensitivity Guralp seismometers in shallow vaults, primarily in remote areas of state lands, including parks, forests, and natural areas. These areas were selected as being “quiet,” with less background noise to interfere with the sensitive seismic signal.

When a seismic event occurs, staff must determine whether it is an actual event; identify the exact location, depth, and magnitude; and help decide whether the event was naturally occurring or perhaps induced. They work closely with the ODNR, Division of Oil & Gas on these determinations. Senior geophysicist Jeff Fox has been working on numerous outreach-related activities. The group also helped with editing and publishing an Earthquake Catalog that captures information on every major recorded seismic event throughout Ohio’s history. The catalog reflects several years of hard work by the now-retired founder of OhioSeis, Dr. Michael Hansen. All events are now placed into the catalog.

## PUBLICATIONS & OUTREACH GROUP

The Publications & Outreach Group is responsible for the design, production, and release of reports, maps, and popu-

lar publications; managing the Division’s social media and website; and planning and coordinating various outreach and educational programs. Chuck Salmons, the Division’s former publications editor, has been promoted to supervise this group and help expand its mission. The goal of this group is to organize the outreach and education efforts and publication releases for the Division. Despite limitations imposed by the coronavirus pandemic, the group was very active and achieved several milestones. Group Supervisor Chuck Salmons, and Editor Tony Bresnen spearheaded the effort to launch a new Division website, which went live in August 2020. The group also established a new Facebook page for the Division. The account officially went live on June 1, and since that time has reached thousands of Facebook users with information about Ohio geology, new publications, fun facts, and events. Because in-person events were not possible, the group and its staff were featured in or helped produce a dozen free webinars, including 10 special presentations in a series called Ohio Rock Talks. These webinars reached more than 1,600 people when first broadcast live. They are now available to people around the world on the [ODNR YouTube channel](#). The group released several new publications and maps, including the beautiful *Fossils of the Columbus Limestone* poster, which was created by Madison Perry, the Division’s graphic illustrator (Figure 2). Her work in creating the poster is just one of the reasons the Division staff selected her as our Employee of the Year for 2020. Madison’s work was guided by fellow group



**Figure 2** *Fossils of the Columbus Limestone* poster illustrating fossils and showing interpretations of their living appearance from the Devonian-age Columbus Limestone.

member Mark Peter, the Division's paleontologist. Illustrations from the poster were used in a new publication he authored: *Statehouse Fossils: A Guide to Fossils of the Ohio Capitol*. The guide was released on the Division website last December and will be available in print in January 2021. Mark also presented several webinars in 2020, including three Ohio Rock Talks.

## GEOLOGIC RECORDS CENTER AND ARCHIVES

All staff in this group transitioned to telework in March 2020. Beginning in May 2020, all members of the group began scheduling one day a week to be in the office to accommodate public service requests, mail processing, and collections processing. Customer service changed at this time, but it was maintained and supported through new digital deliveries that had not previously been available for use. Many products and publications that had previously been available for purchase were made freely accessible through partnerships with other institutions and electronic delivery at no cost to the customer. In-person services at the GRC were discontinued during the March through June 2020 time frame, which affected the number of face-to-face interactions and distribution of free publications for the 12-month period. Group Manager Lisa Long did extensive planning to help create a new archival space in an adjacent building. This space will hold all of the Division's records and feature modern shelving and better lighting, among other amenities.

The GRC is the Division's direct connection with Ohio citizens and industry. Customer Service Assistant Madge Fitak has more than 35 years of experience with the Division and oversees the GRC, managing the Division's sales office and records center and handling incoming requests for information and publications. Maps, geologic records, and data are made available to walk-in and online customers as well as via phone and email requests. The GRC has assisted 132 counter customers (pre-pandemic), processed 475 miscellaneous sales transac-

tions, taken more than 625 phone calls, responded to more than 500 emailed requests, and distributed more than 8,000 free handouts, such as leaflets, pamphlets, and geologic maps on various topics. Income from the sale of maps, reports, and digital information totaled more than \$14,250 for the July 2019 to June 2020 period. In autumn of 2019, Madge began compiling a biographical directory of Ohio Geological Survey staff covering the time period from 1837 to the present.

The Division also has three librarian-archivists (two full time and one part time) to help identify, file, preserve, and catalog the Division's extensive records. Lisa Long manages the work of examining Division files and records at both the Columbus office and the HRC. Lisa began working on a major space planning project that will establish a formal library and archives storage area and a collections access record center on the ODNR campus in Columbus. Sylvia Halladay has made great strides in organizing the Division's numerous physical collections, along with evaluating digital files and looking for duplicate files and corrupt files. Sylvia catalogued 1,170 items during the July 2019 through June 2020 time frame. Kim Dorian joined the group as a contract archivist in January 2019, with the specific task of organizing more than 900 linear feet of material donated to the Dr. Ann G. Harris Deep Mine Research Collection for eastern Ohio and western Pennsylvania. Dr. Harris is professor emeritus from Youngstown State University and is one of the region's foremost experts on abandoned underground mines. The work of processing the Dr. Ann Harris Deep Mine Research Collection continues, with significant progress on rehousing the manuscripts and identifying books for the Pauline Smyth Geological Library Collection.

Christopher Thoms continues assisting the group with processing and organizing the physical paper files in the Ohio Water Well Log Collection. He also helps Administration with contracts, memoranda of understanding, and other legal agreements.



# OKLAHOMA

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## INTRODUCTION

The Oklahoma Geological Survey (OGS) is a state agency for research and public service located on the Norman campus of the University of Oklahoma. The OGS is charged with investigating the state's land, water, mineral, and energy resources, and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources consistent with sound environmental practices.

This year, the OGS performed a nationwide search and successfully selected a new director for the agency beginning July 2020. COVID-19 lockdowns in March 2020 resulted in the relocation of all researchers and staff to a teleworking environment. The agency was successful, however, in continuing most public service virtually and in conducting research and field activities while maintaining proper health and safety protocols. Laboratory research was conducted under strictly monitored conditions, and field work proceeded only in areas that were remote and where interaction between geologists and the public could be minimized.

## GEOLOGIC MAPPING

### Bedrock Mapping

Using Oklahoma-specific sites, OGS seismologists are determining regional basement fracture characteristics via 3-D seismic (where available) interpretation. Research on microstructural analysis and laboratory samples will determine relative contributions of microfracturing and stress-induced anisotropy. Synthesized results will be provided to update project-derived regional geologic and velocity models. Algorithms and methodologies derived from this project will be applied to Oklahoma data sets. Contributions to multiple peer-reviewed publications will result.

### Surficial Mapping

The OGS continued field activities through its statewide surficial mapping program known as STATEMAP. This current effort supports the launch of Phase Three of the National Geologic Map Database through funding from the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program. The result will be an integration of detailed national-

and continental-resolution 2-D and 3-D information produced throughout the survey and by federal and state partners. The information collected is an essential underpinning of the USGS Earth Map and Earth Mapping Resources Initiative (Earth MRI). It will enhance drinking water protection, hazards resilience, infrastructure design, and natural resource management and will support a wide range of fundamental research applications. Current map areas include central and northwestern Oklahoma.

## ENERGY RESEARCH

The OGS is participating in a U.S. Department of Energy 4-year program to establish the Caney Shale Field Laboratory in southern Oklahoma. The effort will include conducting a comprehensive field characterization experiment and validating cost-effective technologies that will lead to a detailed development strategic plan for the Caney Shale. The first step is to develop an open, collaborative, and integrated program to characterize geophysical, geological, petrophysical, reservoir fluid, and geomechanical properties and further perform a baseline analysis of current well production performance and total well economics. The second step involves performing detailed analysis of core drilled during the project to improve our understanding of hydraulic fracture creation, fracture and proppant embedment, and fracture and fluid interaction in the Caney Formation. The third step will be to validate the findings and recommendations from the first phase to drill and stimulate a horizontal well. A development plan will be prepared for the Caney Shale in southern Oklahoma based on the initial results from this well, leading to the expected outcome of an accelerated development of the play. OGS geologists will be collaborating with Oklahoma State University scientists to perform this work.

## OTHER HIGHLIGHTS

The OGS has entered into an important new research arena by making plans to host a regional National Science Foundation Convergence Accelerator workshop in August 2020. The workshop will facilitate meaningful conversations about carbon capture and storage (CCS) and will engage scientists, engineers, and policy makers from a wide spectrum of vested stakeholders. Oklahoma's unique solutions to a regional and

world problem will be in view as participants look for various ways to mitigate the excess carbon problem. Storage utilization of Oklahoma's depleted subsurface reservoirs coupled with OGS's distributed seismic monitoring of sealing efficiency are just some of the ways that can point to economical long-term CCS solutions. Accelerated application of community-based CCS approaches will result from these discussions for the benefit of Oklahoma and the nation.

Another valued asset of the OGS is the volume of geological and geophysical data collected during its more than 100 years of existence. Examples include various types of well

data—logs, completion reports, aerial photographs, production reports, scout tickets, completion reports, and completion cards—as well as several warehouses full of rock cores and cuttings. The collections, the bulk of which are located in storage, reside in a 192,000 square foot warehouse facility known as the Oklahoma Petroleum Information Center (OPIC). Processing, cataloging, and archiving these data to make them accessible, and consequently useful, is a principal activity at the OGS OPIC facility. A project is underway to develop a comprehensive database of preserved geoscience data by generating scanned digital content and making those data available to the public through an online map-based application.

# OREGON

## Oregon Department of Geology and Mineral Industries

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### INTRODUCTION

The Oregon Department of Geology and Mineral Industries (DOGAMI), established in 1937, increases understanding of Oregon's geologic resources and hazards through science and stewardship. The agency's mission is to provide earth science information and regulation to make Oregon safe and prosperous. Our Geological Survey & Services Program develops maps, reports, and data to help Oregon manage natural resources and prepare for natural hazards, such as earthquakes, tsunamis, landslides, floods, volcanoes, and coastal erosion. Our Mineral Land Regulation & Reclamation Program oversees the state's mineral production and works to minimize impacts of natural resource extraction and to maximize the opportunities for land reclamation. An independent executive agency of the State of Oregon, DOGAMI assists in the development of state policy related to geologic materials, natural resources, and hazards, as well as policy related to mining, oil, gas, and geothermal exploration, production, conservation, and reclamation. DOGAMI's current funding supports 39 positions.

### GEOLOGIC MAPPING

#### Bedrock Mapping

Between June 2019 and June 2020, DOGAMI continued geologic mapping projects in the Middle Columbia Basin and the Walla Walla Basin of Oregon. This work is significantly refining current understanding of stratigraphic and structural controls on groundwater availability and the potential for geologic hazards, such as earthquakes and landslides, and is identifying potential new rock resources. Work was supported in part by the U.S. Geological Survey's (USGS's) STATEMAP component of the National Cooperative Geologic Mapping Program.

#### Surficial Mapping

To better understand the spatial and temporal variability of changes taking place on the coast as well as their causes, DOGAMI geologists established the Oregon Beach and Shoreline Mapping Analysis Program. This work has provided important insights into the response of U.S. West Coast beaches to the effects of major El Niños and with respect to multi-decadal changes in the alongshore movement of sediment on the northern Oregon beaches. Funding is provided

through a partnership with the Northwest Association of Networked Ocean Observing Systems.

DOGAMI continues to map landslide hazards and risks throughout the state. In response to the wildfires of 2020, DOGAMI is participating on the Erosion Threat Assessment and Reduction Team and in the Geotechnical Extreme Events Reconnaissance Association to conduct primary landslide and debris flow assessments in the burn areas.

Multi-hazard and risk analyses are provided to communities that will use detailed earthquake, flood, landslide, channel migration, and tsunami hazard data and Hazus software to estimate losses from multiple hazards.

#### 3-D Mapping

Airborne lidar-based 3-foot digital elevation models and derivatives (slopesshade, hillshade, contours) are a fundamental 3-D base data set used by DOGAMI for geologic mapping. To date, more than 24 million acres of data have been collected, covering more than 98% of the state's population, and 53% of the state is now mapped at USGS Quality Level 2 or better, equivalent to 1-foot contour accuracy. Quantitative definitions of rock types, structure, and other critical surfaces are based on surface geology and subsurface geologic information. Subsurface geologic information remains geographically restricted in the state. When available, observations of surface exposures are supplemented with drillhole data, gravity and magnetic modeling, and seismic reflection and refraction profiles. In 2020, standard 2-D geologic maps were published with a 3-D geodatabase.

### OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

The biggest hazard facing the Oregon coast is a great earthquake and accompanying tsunami on the Cascadia Subduction Zone. To address this hazard, DOGAMI completed 89 new tsunami inundation maps covering the entire Oregon coast, along with 42 tsunami evacuation maps. Mapping was fully completed in June 2013. Since then, DOGAMI coastal staff have focused on completing new evacuation modeling for coastal communities to identify the best and fastest routes out of harm's way. This modeling, in the form of "Beat the Wave"

tsunami evacuation maps, shows residents of coastal communities how fast they need to travel from any starting point to reach safety ahead of the wave. Modeling is currently ongoing. Major work has also been completed to evaluate maritime tsunami hazard guidelines for the Oregon coast and the Columbia River system. These studies examined the offshore current tsunami velocities and potential for wave amplification as a

result of both local and distant tsunami hazards to identify offshore staging areas for maritime evacuation. This latter study involves an entirely new modeling effort that incorporates dynamic tides, different river flow regimes, and friction, providing the most realistic understanding of both a Cascadia earthquake and a tsunami hazard to date.

# SOUTH CAROLINA

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## INTRODUCTION

The mission of the South Carolina Geological Survey (SCGS) is to provide reliable geologic information to decision makers as part of the Earth Science group of the South Carolina Department of Natural Resources—Land, Water, and Conservation Division (DNR). The Geological Survey has five geologists on staff, and three staff are assigned to the drill crew. Three grant-temporary geologists also are employed.

## GEOLOGIC MAPPING

The SCGS is the sole-source provider of geologic map information to the public in the state. Geologic mapping is partially supported by the U.S. Geological Survey's (USGS's) STATEMAP program. Geologic mapping, which represents original research, and digitization of that geologic information, are competencies. The collection and distribution of geologic information also continue to be long-term baseline measures in the operation plan.

### Piedmont Mapping

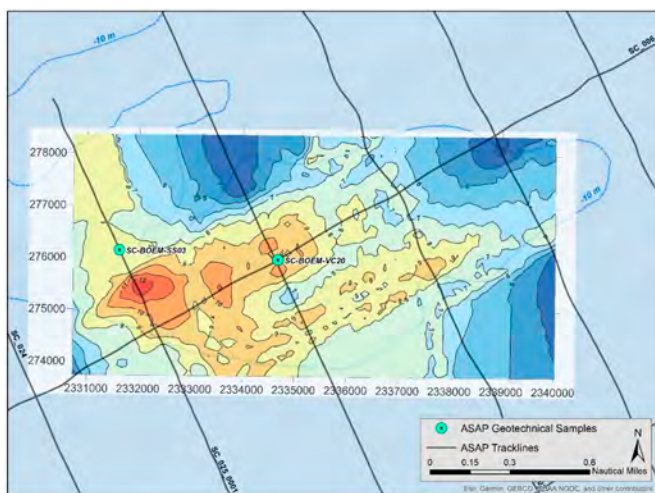
Piedmont mapping is a priority for the SCGS. Under STATEMAP, two quadrangles were completed within the Carolina terrane. New STATEMAP work is focused on delineating relations between the Carolina terrane and the Modoc shear zone, which marks the southern boundary of the Carolina terrane and may have direct implications for SCGS's Earth Mapping Resources Initiative (Earth MRI) work. Map compilations are an additional goal of our Piedmont program, particularly in the Carolina and Charlotte terranes. Digitization of reconnaissance mapping in both terranes is complete, and efforts continue to be directed toward increasing the number of detailed 1:24,000-scale maps and field checking. With the increased popularity of outdoor recreation in South Carolina in recent years, the SCGS has provided geologic information for popular recreation areas in the Piedmont and Upstate regions. The development of first-pass Inner Piedmont and Blue Ridge map compilations is an additional benefit resulting from these projects.

### Coastal Plain Mapping

Recent SCGS mapping in the Coastal Plain has focused on the Lower Coastal Plain in Horry County from the coastline to the northwest along the North Carolina state line. To date, 24 of the 32 quadrangles in Horry County have been completed. These new maps were done through the STATEMAP program. The impetus for this work came from a request by the South Carolina Department of Transportation because the department is seeking information on local sources of borrow material for the planned construction of Interstate 73, connecting Myrtle Beach into the interstate highway system. New mapping will move to the northwest along the proposed Interstate 73 corridor into the Middle Coastal Plain. This recent mapping has provided insight into the geomorphic evolution of Pleistocene barrier systems and the Little Pee Dee and Waccamaw Rivers.

### Offshore Mapping

The SCGS completed two multi-year projects in collaboration with the Bureau of Ocean Energy Management (BOEM) to characterize offshore sand resources for potential beach renourishment and to address questions related to the shallow geology of the near Outer Continental Shelf (3–8 nm) in the southeastern United States. Project partners included three South Carolina universities (College of Charleston, University of South Carolina, Coastal Carolina University) to process and interpret geophysical (side-scan sonar, Chirp seismic) and geotechnical (vibracore) data sets collected during the Atlantic Sand and Gravel Assessment Project (ASAP). Work also included digitizing historical seismic data from the USGS that was provided to BOEM's Marine Minerals GIS online data portal. Volumetric estimates and potential compatibility of sand resources were identified offshore of South Carolina (Figure 1). An offshore sand-shoal predictive model was created using the ASAP data set along with historical geophysical data sets and detailed bathymetry data. A regional cooperative project involved work with researchers in Georgia (Skidaway Institute of Oceanography) and North Carolina (East Carolina



**Figure 1** Sand thickness contours for a shoal in the Folly–Kiawah, South Carolina, compartment (based on interpretations from ASAP VC20). Thicker deposits are delineated in red and orange. Sand thickness contours are indicated in feet.

University) that focused on the shallow regional stratigraphy. Using age-dating techniques (amino acid racemization,  $^{14}\text{C}$ , and U-Pb detrital zircon) combined with detailed core lithology, grain-size, and mineralogical analyses, a large data set was generated to understand the composition and depositional history of offshore sand deposits. Both projects provided opportunities for undergraduate and graduate students to participate and contribute.

The SCGS also provides shoreline-change studies to identify geomorphological changes along the coast and quantify patterns of erosion and accretion. The need for information about coastal geomorphology has become apparent at several coastal properties that are managed by the South Carolina

Department of Natural Resources. SCGS staff convey the dynamics of local geomorphology to other researchers, managers, and members of the public through in-person and virtual presentations and the creation of ArcGIS StoryMaps.

## Geologic Information and Data Management

The SCGS has developed mapping standards and procedures for their Piedmont, Coastal Plain, and Offshore mapping projects. Digital field-data collection procedures are in place for Piedmont mapping, and the Coastal Plain mapping program is developing a similar data collection system for logging borehole cuttings using ESRI's Survey123 application. The USGS Geologic Map Schema (GeMS) data model is being integrated into these mapping procedures and will be the standard data model for SCGS geologic GIS data. The SCGS is now developing Level 3 GeMS databases and streamlining the map digitization process. A recent GIS data migration project digitized the Hydrogeologic Framework of the South Carolina Coastal Plain, a compilation of geophysical, lithologic, and stratigraphic logs from boreholes used to generate cross sections of hydrogeologic units interpolated between boreholes. The SCGS is experimenting with 3-D subsurface models.

## Earth Mapping Resources Initiative

The USGS Earth MRI program funded new, high-resolution aeromagnetic and radiometric surveys in the South Carolina Upper Coastal Plain between the Orangeburg Scarp and the Fall Line, which are being used to identify potential heavy mineral placer deposits. As part of this project, the SCGS is producing two new 1:24,000-scale quadrangle maps, upgrading existing 1:62,500-scale quadrangle maps to 1:24,000, and providing a 10-quadrangle map compilation within the footprint of the new geophysical surveys. Geochemical samples and geochronologic data collected as part of the project will help to ground truth the radiometric data and delineate the source materials for identified critical minerals deposits.

# TENNESSEE

## Tennessee Geological Survey Department of Environment and Conservation

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### INTRODUCTION

The Tennessee Geological Survey (TGS) encourages and promotes prudent development and conservation of Tennessee's geological, energy, and mineral resources by developing and maintaining databases and maps, providing geologic hazard assessments and technical services, and disseminating geologic information through publications and educational outreach. The TGS is part of the Bureau of Environment. The State Geologist reports directly to the department's Deputy Commissioner for Environment. Established in 1831, the TGS advises state agencies and federal and local organizations on matters related to Tennessee's geology, energy, and mineral resource issues. The Survey also maintains a well cuttings and core samples library and seismic station and a map and publication sales office. Survey staff include six geologists and an administrative services assistant, with expenditures of \$831,800 during FY 2019–2020, of which \$299,400 came from state appropriations. The remaining \$532,400 came from federal cooperative projects, interdepartmental funds, and the sale of maps and publications.

### GEOLOGIC MAPPING

Geologic mapping is the Survey's primary legislative mandate, and the TGS is the only Tennessee state agency that produces and distributes geologic maps. Survey staff perform basic geologic mapping on-the-ground field traverses using GPS technology. Survey staff then input geologic field data into a GIS that is used in conjunction with graphics editing software to produce geologic map products. The resulting maps are printed on demand or distributed electronically.

The TGS has been engaged in detailed geologic mapping at the 7.5-minute quadrangle scale (1 inch = 2,000 feet) since

1960 and has completed 538 to date. These maps are the basic source of information for people engaged in environmental regulatory work, mineral and (or) oil and gas exploration, geologic hazard assessment and mitigation, building site evaluation (including dams and highways), and many other practical and scientific uses that provide for human needs with respect to water, energy, materials, and security.

During FY 2019–2020, the TGS completed work under a FY 2018–2019 \$76,575 cooperative agreement from the U.S. Geological Survey (USGS) under the State Geological Mapping Program component (STATEMAP) of the National Cooperative Geologic Mapping Program (NCGMP). During FY 2019–2020, the TGS was approved for funding under a \$79,893 STATEMAP cooperative agreement. Since 1994, the Survey has received nearly \$1.1 million, completing 57 new geologic maps and converting 24 previously completed geologic maps to digital coverages under this program. The TGS website has a NCGMP fact sheet updated through September of 2019 under the STATEMAP fact sheet link on the Geology Programs page: <https://www.tn.gov/content/dam/tn/environment/geology/documents/geology-statemap.pdf>.

### Bedrock Mapping

The purpose of the FY 2018–2019 project was to complete the Pall Mall (335-SW), Tennessee, 7.5-minute geologic map in Fentress and Pickett Counties. The purpose of the FY 2019–2020 project was to map the geology of the southeast half of the Avondale (162-SW), southeast half of the Douglas Dam (156-NE), and all of the Robbins (128A-SE), Tennessee, 7.5-minute quadrangles in Claiborne, Grainger, Jefferson, Hamblen, and Sevier Counties and make a digital compilation of the Gravelton (146-NE), Tennessee, 7.5-minute quadrangle in

**Table 1** Quadrangle geologic maps released in FY 2019–2020

Quadrangle	Counties	Authors
Bonicord (421-NE)	Dyer, Crockett, and Lauderdale	Vince Antonacci
Pall Mall (335-SW)	Fentress and Pickett	Ronald J. Clendening and Albert B. Horton

Knox and Union Counties. Chief Geologist Dr. Peter Lemiszki and Staff Geologist Barry Miller from the Survey's Knoxville office worked on the Douglas Dam and Avondale Quadrangles. Staff Geologist Ron Clendening and Assistant State Geologist Albert Horton from the Survey's Nashville office were responsible for the Dyer and Robbins Quadrangles. Martin Kohl, who was formerly with the TGS and is currently in the Oil and Gas Program in the department's Division of Water Resources, was responsible for Graveston.

## Surficial Mapping

The purpose of the FY 2018–2019 project was to complete the Bonicord (421-NE), Tennessee, 7.5-minute geologic map in Crockett, Dyer, and Lauderdale Counties. The purpose of the FY 2019–2020 project was to map the geology of the Dyer (436-SW), Tennessee, 7.5-minute quadrangle in Gibson County. Vince Antonacci and Albert Horton were responsible for the Dyer Quadrangle.

## OTHER ACTIVITIES

### Data Preservation

The TGS worked under a \$39,105 cooperative agreement for FY 2019–2020 from the USGS under the National Geological and Geophysical Data Preservation Program (NGGDPP). In January 2020, the Survey completed a proposal for more than \$40,000 for work to be completed during FY 2020–2021. Since 2007, the Survey has received nearly \$164,000 under this program. The NGGDPP is a federal grant program designed to preserve state geological survey data collections and provide a means for potential users of those data to determine what is available. The holdings of each collection will be accessible through an internet-based catalog, the National Digital Catalog (NDC).

Work during FY 2019–2020 consisted of four projects:

1. To revise information appearing on the NDC and to update existing metadata records.

2. To create metadata for 450 documents in the Mineral Resources Collection.
3. To create metadata and convert to a digital format 500 documents in the Coal Geology Maps Collection and 200 documents in the Coal Exploration Core Hole Logs Collection.
4. To make documents from the Zinc Mining Reports and Maps Collection and the Coal Geology Maps Collection available to the public through FileNet.

### Seismic Station

Since April 1997, the TGS has been operating a seismic station inside its core storage facility at Waverly, Tennessee. The station has three broadband sensors, a secondary broadband sensor, and a strong-motion sensor. Designated as WVT, this station is part of a national seismic network designed to improve earthquake monitoring in the New Madrid Seismic Zone (NMSZ). It is operated under a cooperative agreement with the USGS National Earthquake Information Center and St. Louis University. Because of its quiet location, which allows for better seismometer response in the low-frequency range, and its proximity to the NMSZ, WVT is an important part of the Global Seismic Network. Albert Horton maintains this facility.

### Subsurface Geologic Repository

The TGS manages the state's only repository of subsurface geologic samples in the form of well cuttings and rock cores. This rock repository is an important source of subsurface information that is made freely available on request and has been used for a wide range of geologic investigations. The TGS considers it a high priority to acquire rock core when it becomes available because of the time, effort, and expense that companies have undertaken to collect it. Storing and managing our expanding inventory is an ongoing task that requires foresight and flexibility.

# TEXAS

## Bureau of Economic Geology

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## INTRODUCTION

The Bureau of Economic Geology (Bureau) is the state geological survey of Texas and the oldest organized research unit at The University of Texas at Austin (UT Austin). The Bureau is one of three units in the John A. and Katherine G. Jackson School of Geosciences at UT Austin.

The Bureau curates the largest volume of subsurface core and cuttings in the United States, and perhaps the world, at three major centers located in Austin, Houston, and Midland. The Bureau's Austin Geophysical Log Facility maintains a major collection of well logs, having nearly 2 million Texas well records on file.

The Bureau owns and operates an airborne laser terrain and bathymetric mapping (lidar) system, a high-resolution offshore 3-D seismic imaging system, an array of ground-based and borehole geophysical tools to explore the shallow subsurface, and 20 major laboratories. Research projects are well supported by appropriate hardware and advanced software for data analysis and modeling, and its scientists apply related technologies in GIS, GPS, and remote sensing.

## GEOLOGIC MAPPING

The Bureau provides Texas with geologic maps and related information that serve as a primary data source for applied earth science investigations. The Bureau's geologic mapping program is jointly supported by STATEMAP, which is part of the National Cooperative Geologic Mapping Program administered by the U.S. Geological Survey, and the Bureau's State of Texas Advanced Oil and Gas Resource Recovery (STARR) program, which focuses on geologic hazards, geologic mapping, and earth and mineral resources.

Between June 2019 and June 2020, Bureau researchers completed one Miscellaneous Map and six Open-File Maps as part of the STATEMAP and STARR mapping effort. These maps focus on bedrock and surficial geology, but they also include subsurface data where appropriate. Miscellaneous Map 53 is a 1:50,000-scale map of part of central Texas west of Austin. Three of the 1:24,000-scale Open-File Maps depict part of the Texas coastal plain (Flake Quadrangle on the upper Texas coast and Placedo and Port Lavaca West Quadrangles on the

middle Texas coast), one depicts the central Texas urban-growth corridor (Pedernales Falls Quadrangle), and two in south-central Texas (Rossville and Leming Quadrangles) support sand resource mapping.

## Map Citations

Caudle, T.L., and Paine, J.G., 2019, Geologic map of the Flake Quadrangle, Texas Gulf of Mexico coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 238, scale 1:24,000.

Elliott, B.A., 2019, Geologic map of the Leming Quadrangle, Texas Gulf of Mexico coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 242, scale 1:24,000.

Elliott, B.A., 2019, Geologic map of the Rossville Quadrangle, Texas Gulf of Mexico coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 241, scale 1:24,000.

Paine, J.G., and Costard, L., 2019, Geologic map of the Placedo Quadrangle, Texas Gulf of Mexico coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 239, sheet 1, scale 1:24,000; sheet 2, digital elevation model, time-domain electromagnetic induction soundings, and frequency-domain electromagnetic induction measurements.

Paine, J.G., and Costard, L., 2019, Geologic map of the Port Lavaca West Quadrangle, Texas Gulf of Mexico coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 240, sheet 1, scale 1:24,000; sheet 2, digital elevation model, time-domain electromagnetic induction soundings, and frequency-domain electromagnetic induction measurements.

Woodruff, C.M., Jr., and Collins, E.W., 2019, Geology of the lower Lake Travis and Lake Austin vicinity, Texas: The University of Texas at Austin, Bureau of Economic Geology, Miscellaneous Map No. 53, map scale 1:50,000, and accompanying text booklet.

Woodruff, C.M., Jr., Costard, L., and Barnes, V.E., 2019, Geologic map of the Pedernales Falls Quadrangle, Blanco County, Texas: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map 243, scale 1:24,000.



**Figure 1** The new Bureau of Economic Geology Core Research Facility.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

The Bureau of Economic Geology built a remarkable new Core Research Facility that was formally dedicated in November 2019 (Figure 1). The Facility features a spacious core-analysis room to be utilized by researchers and students as they unlock the secrets of the Bureau's rocks. The new building includes a specially designed Scanning Electron Microscopy Laboratory and several other laboratories. It is topped by the Chuck Williamson Family Terrace, an airy covered-rooftop terrace suitable for all types of gatherings. Adjoining the building is the tree-shaded Stoneburner Family Rock Garden, an elaborate exhibit laid out like the geologic map of Texas, hosting huge rock specimens from across the state, each with an information station accessible in 11 languages.

Bureau of Economic Geology Director Scott W. Tinker spent several months on sabbatical in 2019 traveling the world to produce a new film, *Switch On*. The documentary illustrates the dire energy poverty that billions of people face each day and offers hopeful solutions. He formed the Switch Energy Alliance, a nonprofit organization established to inspire an energy-educated future.

Dr. Kenneth Wisian joined the Bureau as Associate Director of the Environmental Division in May 2020. Before joining the

Bureau, Dr. Wisian, a retired two-star general in the Air Force, served as the Executive Director of the Disaster Research Program at The University of Texas at Austin's Center for Space Research and as co-investigator of the U.S. Department of Energy-funded Geothermal Entrepreneurship Organization. Ken replaces Dr. Michael Young, who decided to focus again on research. Mike has stayed on at the Bureau in his role as a Senior Research Scientist and is leading several new programs.

Bureau Senior Research Scientist Dr. Jeffrey Paine was made Fellow of the Geological Society of America (GSA) in 2019. The GSA Hydrogeology Division awarded Bureau Senior Research Scientist Bridget Scanlon its 2019 O. E. Meinzer Award.

The STARR program for oil and gas recovery is proud to report that in 17 months, it has generated more than \$80 million in severance tax and royalty revenue for the State of Texas—an 810% return on the funding STARR receives from the state to operate.

TexNet, the Bureau's statewide seismometer network, formed in 2015, now comprises more than 150 seismometers and provides earthquake information in real time to the public.

# UTAH

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## INTRODUCTION

In 1949, the Utah Geological and Mineralogical Survey was created within the University of Utah's State School of Mines and Mineral Industries. Today, the Utah Geological Survey (UGS) is a state executive branch applied science agency within the Utah Department of Natural Resources. The UGS comprises five technical programs: Energy & Minerals, Geologic Mapping & Paleontology, Geologic Hazards, Groundwater & Wetlands, and Geologic Information & Outreach. Most of our approximately 70 employees work out of our main office in Salt Lake City, and two geologists work out of our satellite office in Cedar City.

In spite of the significant challenges presented by the COVID-19 pandemic, the UGS fared well and continued to be effective in accomplishing our mission. Our staff transitioned to remote work situations, and we maintained a high level of productivity in our research, mapping, field work, publications output, grant proposal writing, and day-to-day operations.

## GEOLOGIC MAPPING

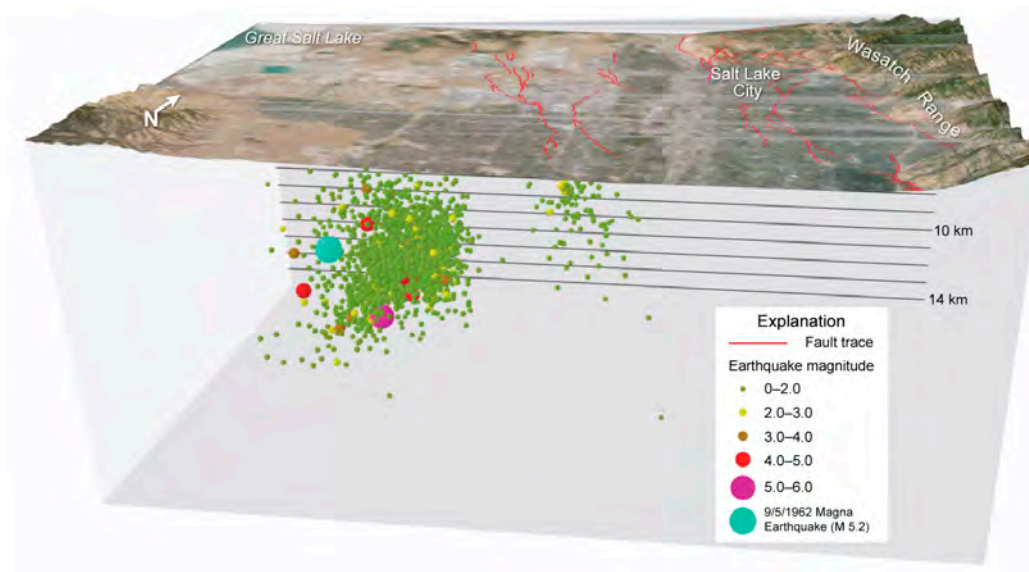
The Geologic Mapping Program (GMP) produces printed and digital GIS geologic maps at popular intermediate (30 × 60-minute series at 1:62,500 to 1:100,000) and detailed (7.5-minute at 1:24,000) scales. Two decades ago, the Utah State Mapping Advisory Committee (SMAC) set goals to complete mapping of the entire state at intermediate scale to meet regional land management, resource exploration, scientific research, and other goals. They also set goals to map the entire state in high detail, with shorter-term goals focused on geologic hazard, geotechnical, and water issues associated with Utah's large population centers, high-growth areas, major transportation corridors, and high recreation-use areas. Thanks to the new National Cooperative Geologic Mapping Program funding, our projects will significantly expand in FY 2021.

This fiscal year, in the 30 × 60-minute quadrangle series, the GMP continued work on four multi-year projects: the Bonneville Salt Flat, Loa, Beaver, and Salina Quadrangles; year 2 on the Bonneville Salt Flat was our STATEMAP project. The U.S.

Geological Survey (USGS)-authored Newfoundland Mountains Quadrangle worked its way through final review for publication by the UGS and will be published in early 2021. The USGS mappers are now working on final revisions to the Tremonton Quadrangle. We also open-filed parts of two quadrangles to make recent mapping in multi-year projects available pending completion of the final maps. We continue to conduct projects on various older maps to temporarily fill holes in our 30 × 60-minute series GIS database coverage pending future new mapping projects—this fiscal year, we released new GIS versions of five older maps. These maps do not meet many of our current standards for accuracy or precision, but they provide better data than our state 1:500,000-scale map. Currently, about 80% of the state now has at least preliminary geologic map coverage, and about 70% has intermediate-scale GIS coverage.

In the 7.5-minute quadrangle series (1:24,000-scale mapping), the GMP published or produced open files of five geologic maps, slightly fewer than the previous year, partly because of COVID-19 and partly because of normal fluctuations. We are now in the seventh year of a SMAC priority emphasis to significantly increase detailed mapping in the Wasatch Front area, the most populated part of the state. In this high-priority block of 120 quadrangles, 70 are considered complete to our higher standard; of these, 24 were mapped or improved in this effort. We completed combined bedrock-surficial maps of two quadrangles and a surficial map as STATEMAP projects in this area. We also actively support and encourage EDMAP mapping projects, with one to two new projects each year.

As part of our effort to make geologic maps more accessible to our users, we continue to post new and old maps to our online interactive [Geologic Map Portal](#). Recent improvements to our geologic map interface on the UGS website, including a separate interactive search tool showing available GIS data, have been very popular and have significantly increased hits on geologic maps. We began adapting our Utah geologic map schema to the national Geologic Map Schema (GeMS), which included hiring a new GIS analyst whose primary duty is to train our staff and develop procedures to convert our older maps.



**Figure 1** Following the March 18, 2020, moment magnitude 5.7 Magma earthquake, the UGS created an [interactive 3-D web scene](#) to display the main shock and aftershock hypocenter locations (data provided by the University of Utah Seismograph Stations). This image (view looking north) shows an update from July 9, 2020, and includes more than 2,300 aftershocks. The 2020 earthquake main shock is represented by the large purple circle near the bottom of the western aftershock cluster, and the main shock hypocenter from a 1962 magnitude 5.2 earthquake (large blue circle) is shown for comparison. The web scene proved helpful for technical discussions regarding the causative fault(s) of the 2020 earthquake sequence and for general public understanding of the concepts of earthquake hypocenter and epicenter locations relative to surface fault traces in the context of normal faulting in an extensional tectonic setting.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

In spring 2020, the UGS led scientific and outreach responses to the moment magnitude 5.7 Magma earthquake, which struck Salt Lake Valley on March 18 and caused more than \$70 million in damage. We activated our Emergency Operations Center to coordinate response activities, and our Geologic Hazards Program established a web-based clearinghouse to collect, distribute, and archive important data. UGS field teams documented geologic effects of the earthquake, including ground cracking, rockfall, liquefaction, and lateral spread, and we began a collaborative effort with the University of Utah Seismograph Stations to determine the causative fault(s) for the earthquake and subsequent aftershocks (Figure 1). Our Geologic Information & Outreach Program partnered with the Utah Division of Emergency Management to develop the [earthquakes.utah.gov](http://earthquakes.utah.gov) website, to answer questions specific to the Magma earthquake, and to provide a single online point of access for scientific, preparedness, and response information provided by multiple state and federal agencies addressing earthquakes in Utah.

Additionally, staff across the UGS contributed to several other significant projects. Our Paleontology Section coordinated a move of the nine-ton *Utahraptor* “megablock” fossil assemblage from the Museum of Ancient Life at Thanksgiving Point to its new home in renovated space in our Utah Core

Research Center. The move allowed our chief preparator to continue working on the block amid COVID-19 restrictions. Bones of approximately 12 individuals have been exposed in the “quicksand” block. The Geologic Hazards and Geologic Information & Outreach Programs launched the online [Utah Geologic Hazards Portal](#), which supports community resilience by providing statewide geologic hazards information for improved land-use development and management. Our Groundwater & Wetlands Program made substantial progress on several ongoing projects. Work by the Groundwater Section included hydrogeologic studies of Juab Valley and Emery Valley (near Bryce Canyon National Park), hydrologic monitoring of environmental restoration projects, hydrogeologic studies for a geothermal energy demonstration project, and an evaluation of groundwater flow to Great Salt Lake. Work by the Wetlands Section included developing an online [Wetland Plant Application](#), mapping wetlands in the Cache Valley, developing a wetland reference network and baseline condition assessment in the Central Basin and Range ecosystem, and monitoring wetland water levels in the Snake Valley. Our Energy & Minerals Program published two important reports: *Critical Minerals of Utah*, which highlights and summarizes Utah’s current and potential critical minerals production, and *Utah’s Energy Landscape, 5th Edition*, which reviews Utah’s energy economy as it continues to evolve and as the balance between fossil fuels and renewable energy changes.

# VIRGINIA

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## INTRODUCTION

The Division of Geology and Mineral Resources (DGMR) is part of the Department of Mines, Minerals and Energy (DMME), a Commonwealth of Virginia agency whose mission is “to enhance the development and conservation of Virginia’s energy and mineral resources in a safe and environmentally sound manner to support a more productive economy.” The DGMR serves as Virginia’s geological survey. Located in Charlottesville, the DGMR performs geological and mineral resource investigations aimed at reducing the risk from geologic hazards and encouraging sustainable economic development through the wise use of mineral, land, water, and energy resources. Division staff include seven full-time geoscientists, six part-time support staff, and several external contractors. In FY 2020, funding for the DGMR came from state-appropriated recurring general funds (65%) and federal grants (33%).

## GEOLOGIC MAPPING

Most of the DGMR’s geologic mapping is conducted under the STATEMAP program, funded by the U.S. Geological Survey’s (USGS’s) National Cooperative Geologic Mapping Program with a 50%-50% state-federal match. Projects are prioritized pursuant to the Division’s long-range mapping plan and approved by our Geologic Mapping Advisory Committee, a panel composed of representatives from the mining industry, academia, the consulting community, land-use planners, and state and federal government agencies. Two continuing mapping projects are underway: the Interstate 81 corridor and the greater Richmond Metropolitan Statistical Area (MSA). In the past year, the DGMR completed geologic maps for the Eagle Rock, Max Meadows, and Snowden Quadrangles in the Interstate 81 corridor. In the Richmond MSA, geologic maps were completed for the Cartersville, Hopewell, and Midlothian Quadrangles. All mapping was at 1:24,000 scale and compiled in ArcGIS version 10.7 using the Geologic Map Schema (GeMS) geodatabase data model. All mapping used the statewide lidar data set, which is especially helpful for interpreting surficial deposits, landslides, and, in some areas such as the Valley and Ridge Province, bedrock structure. All maps depicted bedrock geology and surficial deposits, and all included at least two

structural cross sections. Although the COVID-19 pandemic resulted in travel restrictions and mandatory teleworking, none of our mapping staff members was directly affected and we completed all our deliverables on time.

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

Rain-induced landslide events continue to be Virginia’s single greatest geologic hazard, in terms of potential loss of life and infrastructure. With a Pre-Disaster Mitigation Grant from the Federal Emergency Management Agency, DGMR geoscientists are currently mapping prehistoric and historic landslides in Albemarle and Nelson Counties, two of the more populous counties in the Blue Ridge. Our geoscientists continue to work with emergency responders, local government, and the Virginia Department of Emergency Management to update regional hazard mitigation plans to address geologic hazards. Virginia’s inventory of landslides is approaching 8,000 features.

The Economic Geology Section focused much of its effort this year on Earth Mapping Resources Initiative (Earth MRI) activities funded by the USGS. With funding from the National Cooperative Geologic Mapping Program, we are collaborating with the USGS and the North Carolina survey on mapping placer heavy mineral sands that contain critical minerals in the western part of the Atlantic Coastal Plain. With funding from the USGS through the National Geological and Geophysical Data Preservation Program (NGGDPP), our economic geologists produced web pages showing the potential in Virginia for all 35 of the critical mineral commodities identified by the Department of the Interior. Four of the critical minerals were determined to have high potential, 13 were determined to have moderate potential, and 18 were determined to have unknown potential. We also delivered descriptions of 40 credible critical mineral deposits in the commonwealth and digital maps of prospective areas for 9 critical minerals. High-resolution photographs of critical mineral district cores in our repository were uploaded to the National Digital Catalog. We also produced a new depth-to-basement structure map for Virginia and eastern West Virginia.

With funding from the USGS under the traditional Data Preservation priorities, the DGMR NGGDPP team scanned field maps and field notebooks and linked the Economic Geology

Section's abandoned mine files to the Reclamation program's extensive records of abandoned sites.

# WASHINGTON

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### INTRODUCTION

Since 1890, the Washington Geological Survey (WGS) has provided geological data and services that benefit the people of Washington. The Survey's vision is to foster a safer, more productive, and resilient society that incorporates geology into its regular thought and decision-making processes. The WGS is Washington's primary state science agency for earthquake, tsunami, volcano, and landslide research; environmental geology; geologic mapping; lidar acquisition; and earth resources. Its mission is to collect, develop, use, distribute, and preserve geologic information to promote the safety, health, and welfare of the citizens of Washington, protect the environment, and support the economy of the state.

To carry out its responsibilities during the period of June 2019 to June 2020, the WGS employed approximately 45 full-time staff. The Survey consists of several programs, including Geologic Hazards; Landslide Hazards; Geologic Mapping; Surface Mine Reclamation; Lidar; and GIS, Editing & Publications, and it is home to the Washington Geology Library.

### GEOLOGIC MAPPING

The Survey's Geologic Mapping Program consists of four mappers, two geophysicists, four field assistants, and a manager. In 2019–2020, the Program continued its participation in the STATEMAP initiative and mapped three and a half quadrangles at 1:24,000 scale. This work added to recent mapping in southwestern Washington and began a new 5-year project in the Kittitas Valley of central Washington. New geophysical data collection (gravity and ground-based magnetics) were also collected in these areas and used to model geologic cross sections.

The Program also continued its work on a topical neotectonic study of the Willapa and Doty Hills areas in southwestern Washington. The project is aimed at understanding the uplift and faulting history of the area as it relates to the proposed siting of a flood retention structure on the upper Chehalis River. This year, work focused on mapping approximately five quadrangles at 1:24,000 scale and obtaining a large collection of gravity data. The mapping and gravity were used to develop

cross sections and test possible geometries of major faults. Two 500-meter-long active seismic lines were collected to image potentially active fault strands. The seismic data will be processed this fall.

### OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

The WGS has also been active in publishing reports, maps, videos, graphics, web pages, and other content related to geologic hazards. The Landslide Hazards Program published a GIS inventory of landslides and alluvial fans in Whatcom County. The Geologic Hazards Group continued their work on the School Seismic Safety Project, an effort to understand how Washington public school buildings could be affected by earthquake shaking. The team is conducting seismic surveys at about 340 school buildings across the state. The WGS released five tsunami simulation videos that show how a tsunami might affect communities along the Washington coast. The team also released a series of four tsunami pedestrian walk-time maps showing the time required to evacuate on foot from within the inundation area of a tsunami triggered by a Cascadia subduction zone earthquake. The Survey released a *Homeowners Guide to Tsunamis* and a *Homeowners Guide to Earthquakes*, two booklets that inform the public about the hazards and how to prepare for them. The Survey published six issues of *TsuInfo Alert*, the National Tsunami Hazard Mitigation Program newsletter.

The Geothermal Program completed drilling of two test holes, one south of Mount Baker (total depth of 1,200 feet), and another northwest of Mount St. Helens (total depth of 1,050 feet). The holes were drilled as a validation of the play fairway method developed in collaboration with industry and the U.S. Department of Energy. Multiple temperature profiles run during and after drilling identified that the hole near Mount Baker had an elevated gradient, as predicted by the play fairway model. Core collected from the bottom half of each hole will be used to evaluate the history of fracture development and alteration. Future work will characterize the core and use geochemistry to assess possible reservoir temperatures.

The WGS made progress on data preservation activities conducted under the National Geological and Geophysical Data Preservation Program. This included updating the National Digital Catalog, converting the Survey's statewide 1:100,000-scale geologic mapping database into the U.S. Geological Survey's Geologic Map Schema, or GeMS, and gathering information on critical minerals (part of the Earth Mapping Resources Initiative, or Earth MRI). The funding also supported the

publication of scans of more than 100 field notebooks, many of which were degrading and at risk of being lost.

The Washington Lidar Program collected about 8,100 square miles of airborne lidar data through the federal 3-D Elevation Program, including large swaths of the Olympic Peninsula. Once several ongoing projects are completed, Washington will have about 75% coverage of Quality Level 1 or equivalent lidar data.

# WEST VIRGINIA

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## INTRODUCTION

Fiscal year 2020 was marked by significant changes at the West Virginia Geological and Economic Survey (WVGES) as the agency entered the Great Crew Change generational gap in the geosciences. Three staff members retired between June 2019 and June 2020, with an additional four staff members (including WVGES Director Mitch Blake) stating their intention to retire by the end of the calendar year. These retirements constitute turnover of nearly 20% of the staff and represent a considerable loss of institutional knowledge. The loss of institutional knowledge is mitigated somewhat by the opportunity to recruit highly trained individuals exiting the coal and natural gas industries as well as by the hiring of well-educated young geoscientists eager to gain hands-on experience. Compounding this problem is the fact that all these events occurred during the COVID-19 pandemic, which necessitated alternate approaches to initiation and early training protocols.

## GEOLOGIC MAPPING

Geologic mapping continued in West Virginia, primarily using funds awarded to the WVGES under the U.S. Geological Survey's (USGS's) STATEMAP program. WVGES geologists were heavily affected by COVID-19 travel restrictions, which significantly curtailed the spring field season. Work to compile the final geologic map products was also affected by mandatory telework policies, as the agency was not initially equipped for full-scale remote work. To remedy these issues, the WVGES requested and received a no-cost extension from the USGS to complete the STATEMAP products, which extended the initial May 15, 2020, deadline to July 31, 2020. Staff turnover also affected field work, and the impending loss of senior field mappers will almost certainly create a gap in the continuity of mapping operations. The WVGES has been fortunate to receive permission to fill staff vacancies, and the agency hopes to increase geologic mapping in the state in the future. However, it will take several field seasons for new employees to learn the geologic section.

Karst continues to be a geologic mapping priority in West Virginia. The WVGES was instructed by the West Virginia Department of Environmental Protection to produce maps of

areas containing karst. This initiative was designed to identify regions where oil and gas drilling or pipeline construction may impact groundwater resources. Past, current, and future quadrangles are chosen with this in mind.

Finally, the WVGES is in the initial stages of developing a workflow to create Geologic Map Schema (GeMS)-compliant databases for delivery to the USGS. This will require significant changes to the entire data collection, geologic map, and database construction process. The WVGES will continue this process through consultation with the USGS and through staff training conducted by the West Virginia GIS Tech Center (WVGISTC). The directed training will be funded in part through FY 2021 Supplemental STATEMAP funds.

## Bedrock Mapping

The WVGES was awarded STATEMAP FY 2020 funds to deliver three 1:24,000-scale quadrangle bedrock geologic maps from locations in southeastern West Virginia. These quadrangles were the Denmar, Lobelia, and Woodrow Quadrangles in Greenbrier, Pocahontas, and Webster Counties. Each deliverable includes a geologic map, cross section, stratigraphic column, technical report, correlation of map units, and description of map units.

## Surficial Mapping

The WVGES surficial mapping projects are limited, but they include initial discussions with the WVGISTC to field check landslides identified and characterized by the WVGISTC using lidar and machine-learning applications.

## 3-D Mapping

The WVGES does not have a dedicated 3-D mapping initiative but is working to compile data to satisfy Phase III of the National Map. This effort includes the identification of all West Virginia map products, as well as exposure to training opportunities held by other federal and state geologists and GIS professionals to introduce staff to 3-D mapping development tools and workflows.

Additionally, WVGES geologists have begun to use the 3-D options available in ESRI's ArcPro software as the agency transitions from ArcGIS Desktop to ArcPro. Initial investigations suggest that the 3-D tools available in ArcPro will allow for more robust geologic map construction in the office to connect field data points.

## ENERGY RESEARCH

Energy research in West Virginia is multifaceted and covers not only traditional energy sources, such as coal and natural gas, but also new and novel topics, including carbon capture, utilization, and storage (CCUS) applications, mine pool geothermal and pump storage investigations, and critical minerals exploration.

Coal research forms a cornerstone of WVGES operations and is conducted primarily through the legislatively mandated Coal Bed Mapping Program. During FY 2020, this research included quality control of a GIS-based data model containing maps of 85 coal seams and associated splits. In addition, the WVGES worked with the West Virginia Office of Miners' Health Safety & Training to acquire and process 381 new mine maps representing 1,801 individual mines. These mine maps were included in a study conducted with the West Virginia Office of Energy to identify stacked mines with potential for pump storage applications. Although mine-based pump storage does not appear to be viable in West Virginia, the volume of water held in the mines is sufficient for geothermal applications, such as providing cooling for large data centers.

Several cores collected during mining operations were also targeted for sampling for the USGS's Earth Mapping Resources Initiative (Earth MRI). In FY 2020, the WVGES was awarded funding to coordinate an eight-state reconnaissance study of high-alumina underclays. Travel restrictions imposed because of the COVID-19 pandemic precluded field sampling, but the WVGES coal sample collection contains greater than 10,000 samples and constitutes a valuable source of data for the Earth MRI project.

Hydrocarbon research is also a mainstay of WVGES research programs, and work in FY 2020 included geologic framework studies of Middle and Upper Devonian shale units as well as estimates of in-place resources and recovery efficiencies. The number of horizontal well permits dropped by nearly 30% from FY 2019 (317 permitted wells, down from 461 in FY 2019), but the number of horizontal well completions remained more consistent, with 167 completions (down from 198 in FY 2019). A majority of wells targeted the Middle Devonian Marcellus Formation, but the Ordovician Utica Shale/Point Pleasant Formation is also an active exploration and development target.

Finally, carbon storage research continues with the inception of the U.S. Department of Energy-funded Midwest Regional Carbon Initiative (MRCI), a coalition of 21 states dedicated to advancing geologic framework studies, infrastructure modeling, and stakeholder engagement related to CCUS applications. The MRCI project follows the successful conclusion of the Midwest Regional Carbon Sequestration Partnership. The WVGES looks forward to continuing to work with other states in the mid-Atlantic and Midwest on CCUS and other energy initiatives.

# WISCONSIN

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### INTRODUCTION

The Wisconsin Geological and Natural History Survey (WGNHS) provides objective information about Wisconsin's geological, mineral, and water resources. The WGNHS was created by the Wisconsin Legislature in 1897, with earlier state surveys in Wisconsin dating back to 1854. The Survey is part of the Division of Extension at the University of Wisconsin–Madison. In 2020, the staff of the WGNHS consisted of 29 science and support staff and a number of students. They were involved in a variety of mapping, research, and educational projects in the areas of geology, hydrogeology, and mineral resources.

Locations and details of WGNHS projects are available as [StoryMaps](#) linked to the [WGNHS website](#). Highlights from the year are as follows.

### GEOLOGIC MAPPING

#### Bedrock Mapping

The Survey completed new 1:100,000-scale bedrock geology and topography mapping in Dodge County and initiated new mapping in neighboring Jefferson County. In this part of southeastern Wisconsin, the bedrock geology is composed of a Precambrian bedrock surface characterized by regional-scale folding and topographic relief overlain by upper Cambrian siliciclastics and Ordovician through Silurian dolostone and siliciclastics. In Dodge County, fold geometry and preferential sulfide mineralization along fold limbs is similar to that observed in the Upper Mississippi Valley Lead-Zinc District, suggesting similar controls on deformation and mineralization for southwestern and southeastern Wisconsin. The Survey also initiated new 1:100,000-scale bedrock mapping in Grant County in southwestern Wisconsin.

WGNHS geologists developed new 1:24,000-scale maps of the surface and subsurface [Precambrian geology of the Baraboo Hills](#), Sauk and Columbia Counties (Figure 1). This work is



**Figure 1** WGNHS geologist Esther Stewart doing cold-weather mapping in the Baraboo Hills. Photograph by Carsyn Ames.

constraining the location of several newly identified and previously recognized folds and faults, suggesting minor Paleozoic reactivation of Precambrian structures.

Working with USGS scientists, we are integrating two-dimensional reflection seismic lines with aeromagnetic and gravity data and onshore geologic constraints to characterize the geometry of volcanic packages of the 1.1 billion-year-old Midcontinent Rift beneath western Lake Superior.

### Quaternary and Surficial Mapping

The WGNHS completed an 8-year project mapping the surficial geology of all of the lower Wisconsin River valley. The resulting 1:100,000-scale maps and accompanying report, which are in preparation for publication, will provide new insights into the nature and distribution of unconsolidated sediments at the earth's surface throughout this portion of Wisconsin's unglaciated Driftless Area. In addition to producing new maps, this project is providing important insights into the history and reorganization of midcontinent rivers and the chronology of the Green Bay Lobe of the last major glaciation. To complement surficial geologic mapping, the WGNHS has become a leader in collecting Geoprobe cores from places where lakes formerly existed along the margin of the last great ice sheet. These cores are providing new chronologic control on the timing of the advance and retreat of the Green Bay Lobe and providing new insights into the behavior of the glacier during the peak of the last Ice Age.

The Survey also completed new 1:100,000-scale Quaternary mapping in Oneida and western Waushara Counties and progressed on mapping in Jefferson County. In addition, Survey geologists initiated new Quaternary mapping in Bayfield County.

## OTHER MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

### Southwest Wisconsin Groundwater

In partnership with the U.S. Department of Agriculture, U.S. Geological Survey (USGS), and county staff, the WGNHS participated in the [Southwest Wisconsin Groundwater and Geology \(SWIGG\)](#) study, which is sampling private wells in three southwestern counties (Iowa, Lafayette, and Grant) for agricultural contaminants and pathogens in groundwater. This study has fostered additional new work to understand and map the Rountree Formation, a shallow unlithified unit that might help protect groundwater in the region.

### Springs of Wisconsin

WGNHS hydrogeologists completed a statewide inventory of Wisconsin's larger springs and developed an [online application](#) to view spring data and locations. The Survey released a [publication](#) on methods and best practices for spring surveys in the state based on this work.

### Northern Wisconsin Groundwater

In cooperation with the USGS and the U.S. Forest Service, the Survey developed a [hydrogeologic database, maps of hydrogeologic properties, depth to bedrock, and the water table configuration](#) for national forests in northern Wisconsin. In related work, WGNHS hydrogeologists completed the [Bayfield County Groundwater Atlas](#) as an educational resource, with information about the source of groundwater to wells, streams, and rivers, to inform land-use discussions, decisions, and planning.

### Central Sands Lakes Study Monitoring

As part of a legislatively mandated initiative to evaluate groundwater in Wisconsin's Central Sands agricultural area, the WGNHS conducted field studies of groundwater-surface water relationships near several lakes in the central part of the state.

### Door County Wetlands: Water Quality Indicators of Human Impacts

In most of Door County, private septic system effluent and landscape or agricultural chemicals have the potential to move through the thin soil layer into the underlying karst bedrock and groundwater aquifer. WGNHS scientists are collaborating with The Nature Conservancy to determine the impacts of non-point-source pollution on the biodiversity and function of these coastal wetlands [and recently published](#) some of their findings.

### Data Collection, Management, and Preservation

The WGNHS continued to play major roles in the collection, management, and preservation of geologic data and samples, including collection of downhole geophysical logs, participation in the [statewide Groundwater-Level Monitoring Network](#), management of well construction reports, and maintenance of an online data viewer. In addition, the WGNHS [Research Collections and Education Center](#) maintains thousands of geologic samples and records and houses examination space. Finally, a new [Publication Catalog](#) on the WGNHS website offers quick access to our archive of digitized publications and provides an infrastructure that will expand access to geologic data and publications going forward.

# WYOMING

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## INTRODUCTION

Since 1933, the Wyoming State Geological Survey (WSGS) has performed the important and critical function of interpreting Wyoming's complex geology. The mission of the WSGS is to promote the beneficial and environmentally sound use of Wyoming's vast geologic, mineral, and energy resources while helping make the public aware of geologic hazards. Wyoming natural resources are managed to maximize the economic, environmental, and social prosperity of current and future generations.

The WSGS is on the University of Wyoming campus in Laramie, Wyoming, and has 20 full-time benefited staff positions. The WSGS works to (1) study, examine, and understand the geology, mineral resources, and physical features of the state; (2) prepare, publish, and distribute reports and maps of the state's geology, mineral resources, and physical features; and (3) provide information, advice, and services related to the geology, energy, and mineral resources; hazards; and physical features of the state.

## GEOLOGIC MAPPING

### Bedrock Mapping

- 1:24,000-scale *Preliminary Geologic Map of the Garden Gulch Quadrangle*, Open File Report 2019-3, Carbon County
- 1:24,000-scale *Preliminary Geologic Map of Horatio Rock Quadrangle*, Open File Report 2019-5, Albany and Carbon Counties
- 1:100,000-scale *Preliminary Geologic Map of the Chugwater 30' × 60' Quadrangle*, Open File Report 2020-1, Goshen, Platte, and Laramie Counties, Wyoming, and Scotts Bluff and Banner Counties, Nebraska
- 1:24,000-scale *Preliminary Geologic Map of the Earnest Butte Quadrangle*, Open File Report 2020-2, Sweetwater County
- 1:24,000-scale *Preliminary Geologic Map of the Lion Bluffs Quadrangle*, Open File Report 2020-3, Sweetwater County
- 1:24,000-scale *Preliminary Geologic Map of the South Baxter Quadrangle*, Open File Report 2020-4, Sweetwater County

### Surficial Mapping

- 1:24,000-scale *Preliminary Surficial Geologic and Landslide Maps of the Blind Bull Creek and Pickle Pass Quadrangles*, Open File Report 2020-5, Lincoln County

## OTHER MAJOR ACCOMPLISHMENTS/ HIGHLIGHTS

### Energy Research

#### 2019 Oil and Gas Map of Wyoming

The WSGS updated its *Oil and Gas Map of Wyoming* (September 2019), which is one of the agency's most widely used publications.

### Mineral Research

#### Stream-Sediment Samples Reanalyzed for Critical and Economic Minerals Potential

The WSGS released geochemical data (June 2020) from a reanalysis of archived stream-sediment samples originally collected under a federal uranium exploration program. The new data will help establish modern baseline geochemistry for future studies of mineral systems and deposits across Wyoming.

#### Geology and History of Wyoming's Top-Producing Uranium Mining District

The WSGS released a Public Information Circular (July 2019) about uranium geology and resources of the Gas Hills District, which has significant unmined uranium reserves. Uranium is a highly valued energy resource that plays a significant role in Wyoming's history and economy.

### Hazards Research

#### Interactive Map Detailing the Geology of Yellowstone

The WSGS developed an interactive map (May 2020) that provides researchers and the general public an opportunity to

view multiple geospatial data sets related to the geology of Yellowstone National Park.

## Hydrology Research

### Groundwater Salinity in Wyoming

The WSGS published a report (June 2020) that examines the salinity of groundwater that occurs throughout Wyoming and explores the relationship between salinity and depth-of-sample in selected geologic formations.

### Groundwater Resources in Northeast Wyoming

The WSGS published a groundwater study (December 2019) of the Powder/Tongue/Northeast River Basins in northeast Wyoming for the Wyoming Water Development Commission. The study is part of an overall effort to assess groundwater in river basins throughout Wyoming.

## Outreach

### State Park Pamphlets

The State Park pamphlets are part of a series focused on the geology of Wyoming's various state parks, thus enhancing park visitors' experience. These include the following:

- *Buffalo Bill Park Geology* (March 2020).
- *Glendo State Park Geology* (January 2020).
- *Edness K. Wilkins State Park Geology* (October 2019).
- *Bear River State Park Geology* (October 2019).
- *Keyhole State Park Geology* (July 2019).

### Annual Summary Reports

The WSGS has published a series of summary reports highlighting issues and opportunities related to the state's energy industry in the last couple of years (January 2020). The two publications provide synopses of Wyoming's oil, natural gas, and coal industries.

# AWARDS

## JOHN C. FRYE MEMORIAL AWARD

Environmental geology has steadily risen in prominence over recent decades, and to support the growth of this important field, the John C. Frye Memorial Award was established in 1989 by the Geological Society of America (GSA) and AASG. John C. Frye joined the U.S. Geological Survey (USGS) in 1938, he went to the Kansas Geological Survey in 1942, he was its Director from 1945 to 1954, he was Chief of the Illinois State Geological Survey until 1974, and he was GSA Executive Director until his retirement in 1982, shortly before his death. John was active in the AASG and on national committees and was influential in the growth of environmental geology. The John C. Frye Memorial Award is given each year to a nominated environmental geology publication released in one of the three preceding calendar years, either by GSA or by a state geological survey.

The nominated publications identify a geologically based environmental issue, provide sound and substantive information pertinent to the problem, relate geology to the issue, and present information directly usable by geologists, by other professionals such as land-use planners and engineers, and ideally by informed laypersons. The Selection Committee assesses the uniqueness, significance as a model, and overall worthiness of the publication. The 2020 award was presented to James W. Duley and Cecil Boswell of the Missouri Geological Survey for the report *Revised Recharge Areas of Selected Large Springs in the Big Four Region of the Ozarks* (2017, Water Resources Report No. 76).

## CHARLES J. MANKIN MEMORIAL AWARD

Geological survey agencies play an essential role in the provision of comprehensive, jurisdiction-wide geoscience information. Whereas the Frye Award recognizes work on environmental geology issues, such as water resources, engineering geology, and hazards, the Mankin Award recognizes state geological survey publications in regional, energy, or mineral resource geology, with an emphasis on surface or subsurface geologic mapping, compilations, and associated reports.

Charlie Mankin (1932–2012) earned a Ph.D. from the University of Texas in 1958, he joined the University of Oklahoma in 1959, and from 1967 to 2007 he was Director of the Oklahoma Geological Survey. He was AASG President in 1975–1976, American Geosciences Institute (AGI) President in 1978–1979, and Campbell Medalist in 1987. Charlie played a key role in establishing STATEMAP, a program crucial to the state geological survey role in geologic mapping.

The Mankin Award is given each year to a nominated geologic map, compilation, or report on regional, energy, or mineral

resource geology published in the current year or one of the three preceding calendar years by a state geological survey. The winners of AASG's 2020 Charles J. Mankin Memorial Award are C. Robin Mattheus, Kelvin W. Ramsey, and Jamie L. Tomlinson of the Delaware Geological Survey for their publication *Geologic Map of Offshore Delaware* (2020, Geologic Map No. 25).

## PICK AND GAVEL AWARD

The Pick and Gavel Award was initiated by the AASG in 1999 to recognize distinguished friends of geology who have made or are making major contributions to advancing the role that geoscience plays in our society. The Pick and Gavel Dinner is held in Washington, DC, in mid-March at the Cosmos Club, whose history is steeped in geology.

One of its founders and first presidents was John Wesley Powell, 1881–1894, USGS Director and explorer of the Grand Canyon, and its membership has included many renowned geologists. The Award consists of a mounted mineral, fossil, or rock with a symbol that includes a geologist's pick, a policy-maker's gavel, and the Capitol, where geologists and policy makers work together to respond to the needs of the nation.

The Pick and Gavel Award is presented to Senator Joe Manchin for his support of earth sciences and understanding of its importance and inclusion in public policy. Senator Manchin has been very involved in coal, oil, and natural gas production and balancing our nation's energy industry with critical minerals for renewable energy. He supports the issues that surround the implementation of CO<sub>2</sub> sequestration and the geologic research that is needed to develop this industry. His excitement and involvement in these geologic topics and his support of public policy to support these industries is greatly appreciated by the AASG.

## AASG PRESIDENTIAL AWARD

The AASG Presidential Award is presented by the AASG President to particularly helpful, constructive, and worthy members or friends of the AASG for extraordinary service to the objectives of the AASG. In 2020, AASG President Richard Ortt presented the AASG Presidential Award to Richard C. Berg, Illinois State Geologist. Dick Berg has provided dedicated service to the AASG as well as excellent mentorship, has served on many committees, and in general has volunteered to help whenever needed. Dick's smile and guidance have significantly enhanced the AASG throughout the year. The list of Presidential Awards can be found here: <https://www.stategeologists.org/award/presidential>.

