



Association of American State Geologists

State Geologists Journal
Volume LXXIII
July 2021–June 2022

Journal edited and produced by the Washington Geological Survey

AASG Editor: Casey Hanell

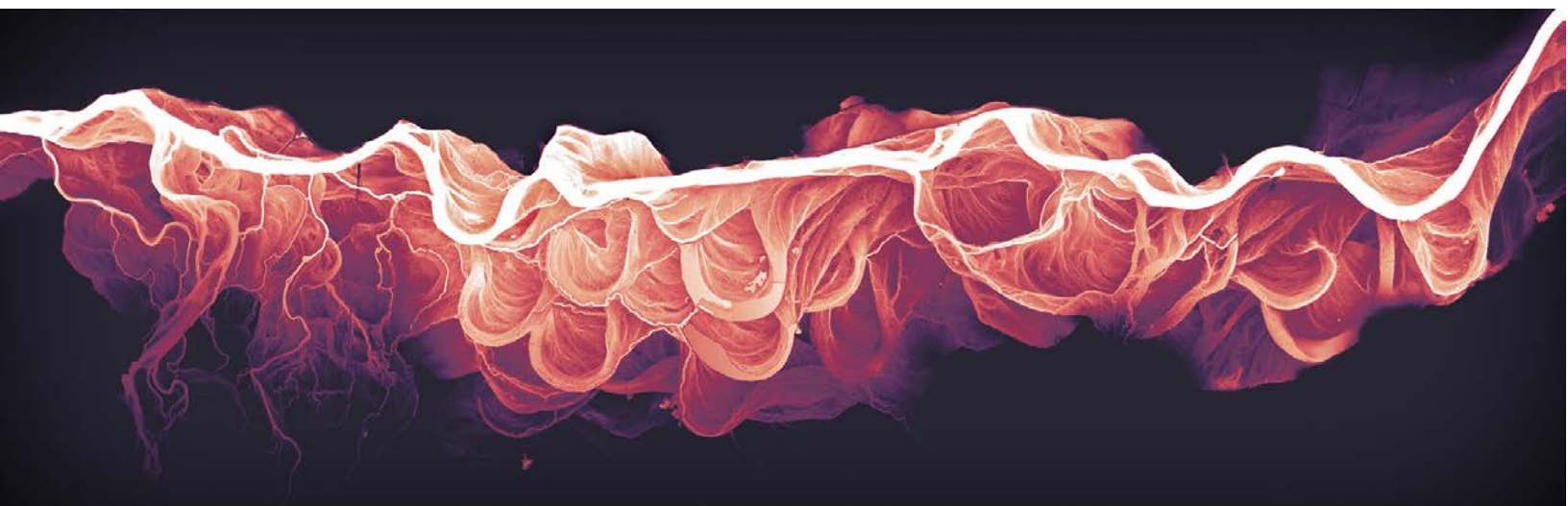
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Front Cover Photo: View of the Puget Lowland and Mount Rainier from Mount Erie, Washington.
Credit: Nikolas Midttun, Washington Geological Survey.

Contents Page Photo: Lidar-derived image of the Skagit River, Washington.
Credit: Daniel Coe, Washington Geological Survey.

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PRESIDENT'S LETTER



Erin A. Campbell

The 2021–2022 year brought a return to normal, a new normal, for AASG, with our first in-person annual meeting since 2019. But we have carried the lessons from COVID quarantine with us as we continue to offer virtual options that increase participation for more states and associates and open new doors of communication with our federal partners.

This past year saw implementation of the federal Infrastructure Investment and Jobs Act which led to greatly enhanced funding for the earth sciences. Our strong relationship with the U.S. Geological Survey (USGS) enabled AASG to help coordinate and efficiently implement this funding, as well as broaden the scope of programs to benefit more state geological surveys. The willingness of the USGS to address our preferences and needs has allowed more states to participate and new and important work to be undertaken. We truly appreciate the leadership and vision of our friends at the USGS.

AASG includes geological surveys that range from staffs of one to nearly two hundred. Some surveys are part of a university, while others are independent state agencies. However, we all work toward similar missions—furthering understanding and knowledge of earth sciences for the benefit of our state's residents and nation's citizens. When we work together, we are stronger, more effective, and have a greater impact.

The demand for earth science expertise is rising during a time when the number of earth science graduates are decreasing. Critical minerals, water, geologic hazards, and climate and energy issues are on the front page both nationally and globally. We in the geological surveys recognize a need to improve access to geoscience for underrepresented groups. Workforce issues including diversity, equity, inclusion and justice continue to be a focus for AASG, and we look forward to progress in that realm.

I want to thank President-Elect Jim Faulds and the Nevada Geological Survey, and Vice-President John Metesh for a wonderful AASG Annual Meeting at Lake Tahoe this year. It was a joy to reunite with old friends and meet those we have been interacting with virtually. It should be noted that Dr. Faulds hosted not one, but three annual meetings, two of which were virtual. Additionally, during this year's in-person meeting, Dr. Faulds was President-Elect as well as annual meeting host. He and his staff deserve recognition and deep gratitude for this extraordinary contribution.

This year would not have been as successful without the knowledge, skills, efforts, and support of the AASG Executive Committee. To Past President John Yellich, President Elect Jim Faulds, Vice President John Metesh, Treasurer Phil Pearthree, and Secretary Nelia Dunbar, I offer my sincere gratitude and admiration for your commitment to AASG and your excellent work.

The State Geologists Journal highlights the accomplishments of state surveys during this past year, and I'm sure you will share my amazement at the breadth of the geologic work conducted. We continue to have a notable impact in the field of earth science, and AASG facilitates and enhances much of that work. Please enjoy this year's edition of the State Geologists Journal.

Respectfully submitted,

A handwritten signature in blue ink, appearing to read 'Erin A. Campbell'.

Erin A. Campbell

AASG President

ALABAMA

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INTRODUCTION

The Geological Survey of Alabama (GSA), established in 1848, 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 (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, as well as the geologic storage of carbon dioxide and other gases.

GEOLOGIC MAPPING

The Geologic Investigations Program (GIP) researches, documents, and maps Alabama's geology, non-fuel minerals, paleontological resources, and geologic hazards. The GIP conducts projects to (1) generate geologic and geospatial information and data used in groundwater, environmental, and urban planning; (2) increase natural hazards situational awareness; and (3) educate the public on Alabama's mineral, rock, and paleontological resources.

Bedrock with Minor Surficial Mapping

The GSA generally produces bedrock geologic maps; however, quadrangle maps also include surficial units, such as alluvium, terrace, artificial fill, and paleokarst deposits as needed. The GeMS GIS data for these maps are provided in two layers, but this method may change in the future.

The GSA's primary source of map funding has been the STATEMAP component of the National Cooperative Geologic Mapping Program (NCGMP), administered by the U.S. Geological Survey (USGS).

Three 7.5-minute quadrangle maps in northeastern Alabama were completed for STATEMAP in September 2021: Centre and Sulphur Springs (Gadsden area) and Triana (Huntsville area). Additional 2021 deliverables included GeMS data for previously mapped 7.5-minute quadrangles of the Coosa deformed belt in central Alabama rescaled to 1:100,000 scale. A third part of GSA's STATEMAP deliverables in September 2021 consists of a supplemental project documenting stratigraphic and map unit inconsistencies across state lines. Beginning in September 2021, GSA started the next STATEMAP project: new field mapping and map production for three 7.5-minute quadrangles: Cedar Bluff, Farley, Jamestown, and Lim Rock.

The GSA also receives funding from the USGS NCGMP Earth Mapping Resources Initiative (Earth MRI) program. In September 2021, GSA completed a 2-year project to map the Milltown, Roanoke West, Wadley South, and Roanoke East 7.5-minute quadrangles in the Piedmont in east-central Alabama. Deliverables included draft maps, GeMS data, and a report with chemistry results reflecting critical minerals measured in 106 regolith samples overlying metagranitoids in the quadrangles. In September 2021, GSA also began a second Earth MRI project mapping the Mitchell Dam and Flag Mountain quadrangles in the graphite belt of the Alabama Piedmont. This project also contains a critical minerals sampling and analyses component: quantifying levels of high-quality graphite. Deliverables for this project will also include maps, GeMS GIS data, and a report.

Reasons for Mapping in Locations

STATEMAP mapping projects are based on multiple criteria and STATEMAP Advisory Committee (SMAC) discussions. The SMAC, led by the GIP Geologic Mapping Section manager, meets twice a year to review geologic mapping projects, urban development, water resources, mineral resource needs, and other characteristics, and identifies Alabama's mapping priority areas.

Earth MRI mapping projects are chosen by GSA and the USGS and reflect critical minerals of particular national interest. Regional discussions among the USGS and other state geological surveys are also held annually to examine geologic mapping needs and domestic critical minerals priorities. Geophysical data acquisition activities are also discussed, in support of the Earth MRI's geologic mapping needs.

Outcomes

For the reporting period July, 2021, to June, 2022, GSA published the Dunaway Mountain quadrangle map and its report (GSA Quadrangle Series Map 73), which was previously mapped under STATEMAP.

OTHER PROGRAM HIGHLIGHTS

In September 2021, the GSA completed 1,164 fossil meta-data records and 2,005 fossil specimen digital photos for the USGS's National Geological and Geophysical Data Preservation Program (NGGDPP). The fossil data were uploaded to the National Digital Catalog.

The Coastal Resources Program (CRP) is engaged in assessment of offshore sand deposits, monitoring of gulf-fronting beaches, coastal area multidisciplinary GIS development, and assessment of sediment characteristics in coastal waters. Reports for beach monitoring are generated annually. Current investigations funded through the Bureau of Ocean Energy Management and the RESTORE Act enable the recovery of legacy data, such as shallow sediment core,

surficial samples, and geophysical data, new data acquisition, and the development of a comprehensive geodatabase of geophysical and sediment data in support of the delineation of significant offshore sand resource areas. Through funding provided by the Gulf of Mexico Energy Security Act, sediment within estuarine areas is being sampled for sediment characteristics and geochemistry to further our understanding of their geospatial and temporal distribution.

The Groundwater Assessment Program (GAP) is continuing to develop WaterSTAR, a new geospatial database in conjunction with the Groundwater Protection Council and Coordinate Solutions. WaterSTAR is currently in its third beta release and the GAP is evaluating a new feature of the database that will allow drillers to submit an electronic version of the state's notification of intent to drill for new wells. The GAP completed two projects: a 2-year study, conducted in conjunction with the Alabama Department of Environmental Management, to evaluate the contribution of groundwater to surface water quality for the purpose of establishing Total Maximum Daily Load limits for impaired streams, and a project in conjunction with the Ecosystems Investigations Program to evaluate groundwater controls on listed species habitats on Redstone Arsenal in north Alabama. Personnel from the GAP are currently working with the GIP on Cenozoic and Mesozoic stratigraphic correlations across the eastern Gulf of Mexico basin to refine the hydrostratigraphy across the region.

The Ecosystems Investigation Program (EIP) has conducted scores of aquatic biodiversity studies, including basin-wide surveys of fishes, mussels, crayfishes, cave shrimp, and other aquatic invertebrates, and status surveys of federally listed threatened and endangered species and state conservation priority species, as well as water and sediment quality and land uses that affect those populations. The comprehensive book *Crayfishes of Alabama*, co-authored by an EIP staff member, was published in April by the University of Alabama Press. Other initiatives include leadership of the newly created Southeast Aquatic Resources Partnership statewide Stream Assessment Team and initiation of an assessment of the springs in the Cahaba River watershed in support of a federally listed aquatic snail.

The Geochemical Laboratory continues 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.

The Energy Investigations Program works on carbon capture, utilization, and storage (CCUS) projects, supporting geologic models, permitting requirements, regulation needs, and community engagement. Energy staff are working on CCUS assessment projects in the northern Gulf of Mexico and across the southeastern US. A critical minerals assessment in the southern Appalachian basin is underway. The Program is responsible for our core facility, which serves students, academics, and industry interested in the subsurface geology of Alabama. In August of 2021, a web search of our database of over 12,000 cores and cutting sets and

7,000 thin sections was published, allowing researchers and the general public to see what is in the collection.

ALASKA

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INTRODUCTION

Mission

Determine the potential of Alaskan land for production of metals, minerals, fuels, and geothermal resources, the locations and supplies of groundwater and construction material, and the potential geologic hazards to buildings, roads, bridges, and other installations and structures (AS 41.08.020).

Background

The Alaska Division of Geological & Geophysical Surveys (DGGS) is part of the Alaska Department of Natural Resources (DNR) and is organized into seven program sections: Energy Resources, Mineral Resources, Engineering Geology, Volcanology, Geologic Information Center (GIC), Alaska Geologic Materials Center (GMC), and the Alaska Geospatial Office (AGO). In fiscal year 2022, the division had 40 full-time, permanent positions, 11 part-time positions, and 11 non-permanent staff. The total fiscal year 2022 expense budget for the division was \$11.2 million, consisting of \$3.91 million in state general fund receipts, \$2.72 million in federal receipts, \$3.07 million in capital improvement projects and interagency receipts, and \$1.52 million in designated general fund and publication sales. DGGS maintains a website at dggs.alaska.gov, which provides access to its publications (78 in fiscal year 22) and petabytes of digital data. DGGS also administers websites for the Alaska Volcano Observatory (avo.alaska.edu), the Alaska Seismic Hazards Safety Commission (seismic.alaska.gov), and the Alaska Geospatial Council (agc.dnr.alaska.gov).

MAPPING

Geologic

Detailed geological and geophysical maps of Alaska at scales needed for resource exploration, land-use management, and geologic-hazards assessment are scattered geographically and currently available for only about 21 percent of the state, but our field programs are increasing this coverage gradually each year. The survey prioritizes the selection of new mapping areas in consultation with other state agencies, appropriate state boards and commissions, its Geologic Mapping Advisory Board, industry resource-interest groups, and other stakeholders. The survey is committed to delivering the results of its extensive field mapping programs to the public in a timely manner. The total area of published mapping in fiscal year 2022 was 2,603 square miles with an annual average area of 3,144 square miles of published, peer-reviewed geologic mapping over the last 10 years. Major mapping efforts included a total of 10 weeks of helicopter-supported fieldwork, including more than

500 square miles and 1,700 square miles in the central North Slope and Western Tanacross regions, respectively.

Geophysical Surveys

Much of Alaska's lands with high mineral-resource potential have poorly exposed geology due to tundra and tree cover. Airborne geophysical surveys measure physical properties of the earth; these properties correspond to various geologic features and measurements are not affected by vegetation. Airborne geophysical survey data are invaluable for guiding subsequent ground-based geologic mapping, sampling, and associated mineral-assessment work. Only about 28 percent of prioritized mineral-bearing state lands have been geophysically surveyed, and DGGS is committed to acquiring data in remaining areas of the state that have high mineral-resource potential, subject to availability of funding.

In fiscal year 2022, DGGS released the 3,757-square-mile Eagle and 5,183-square-mile White Mountains magnetic and radiometric surveys, funded by the U.S. Bureau of Land Management (BLM) and U.S. Geological Survey (USGS), respectively. DGGS also released the Icy Cape magnetic survey funded by the Alaska Mental Health Trust Land Office, covering 201 square miles of beach sands with the potential to host critical minerals.

USGS Earth MRI funding from federal fiscal years 2019 and 2021 will support the collection of 7,984 square miles of fixed-wing magnetic and radiometric data in Central Yukon-Tanana Upland and 4,741 square miles in Western Yukon-Tanana Upland, respectively. Surveying started in May 2022 and these surveys are scheduled for publication in fiscal year 2023.

OTHER PROGRAM HIGHLIGHTS

The Geologic Information Center (GIC) provides information technology, GIS, and publication support services that allowed the division to publish 78 new geologic reports, maps, and datasets. The survey served 29.5 terabytes of digital geologic data and information from the division's website (dggs.alaska.gov) and geoportals. The GIC also manages DGGS's public outreach efforts, which include 4,281 followers on Twitter, 530 subscribers to the Division's news feed, 1,566 followers on its Facebook page, and responding to hundreds of in-person, phone, and email information requests.

The Alaska Geospatial Office (AGO) continues to coordinate closely with the Alaska Mapping Executive Committee. This long-standing relationship is critical to modernizing Alaska's spatial data infrastructure, recently resulting in the completion of the state's first consistent elevation dataset, second statewide imagery product, the start of a 10-year project to map the state's hydrography, and nearly completing statewide wetland mapping. The AGO coordinated with the U.S. Fish and Wildlife Service and USGS to procure

\$5.4M for mapping hydrography and wetlands in the Exxon Valdez Oil Spill region.

As part of a sand and gravel resource assessment, in support of the Arctic Strategic and Transportation Resources Project (ASTAR), DGGs contracted with ASRC Energy Services to complete terrain unit and geohazards mapping covering an area of ~51,500 square miles (~83,000 square kilometers) across Alaska's North Slope. Detailed mapping, which was lacking in this area, guided our summer 2019 helicopter-supported fieldwork over an area of ~8,900 square miles (~14,300 square kilometers) in the northeast National Petroleum Reserve-Alaska.

DGGs Alaska Volcano Observatory (AVO) staff responded to volcanic unrest at Makushin volcano and the Atka Volcanic Complex and eruptions at Cleveland, Pavlof, Semisopchnoi, Veniaminof, and Great Sitkin volcanoes. Response activities include issuance of volcanic eruption alerts in collaboration with USGS and University of Alaska Fairbanks (UAF) colleagues, 24/7 seismic and satellite monitoring,

detailed record-keeping of eruptions and impacts, and ash sample collection for hazard analysis. Field crews installed four new web-cameras: two at Semisopchnoi that returned dramatic images of the explosive ash eruptions, one at Okmok with a view inside the caldera, and one at Great Sitkin volcano near Adak.

The survey published 22 new reports and peer-reviewed publications on geologic hazards. DGGs completed more than a dozen airborne lidar surveys, covering over 3,500 square miles, to collect high-resolution elevation data needed to assess geologic hazards and support resource assessments all over the state, including 70 square miles evaluated on the active volcanoes Makushin and Shishaldin. In fiscal year 22, DGGs launched an immediate response to the Barry Arm unstable slope in Prince William Sound that was identified in May 2020 and is a potential source for a damaging tsunami if the slope fails. We continue our role as co-lead on a multi-agency (federal and state) science and technical response team tasked with assessing the current state of the slope.



Figure 1. State of Alaska DGGs engineering geology scientists describe and profile coastal bluffs while assessing gravel potential on the North Slope. The work will help validate terrain unit mapping, identify potential material resources along proposed transportation corridors, and gather information to inform more detailed helicopter-supported drilling investigations in 2022.

ARIZONA

ARIZONA GEOLOGICAL SURVEY

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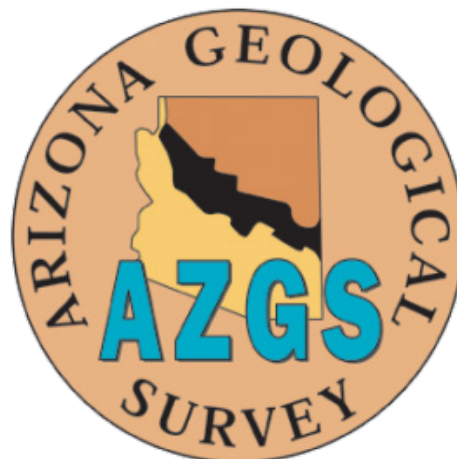
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INTRODUCTION

The Arizona Geological Survey (AZGS) and its predecessors have been providing critical geologic information to the people of Arizona since 1893. Other than the period of 1988–2016 when it was a separate state agency, AZGS has been part of the University of Arizona in Tucson. AZGS receives a base funding appropriation from the state legislature; we complement this by pursuing diverse external funding opportunities and cooperative partnerships with federal, state, and local agencies, and the private sector. AZGS increased its budget and personnel in 2021–2022, taking advantage of expanded funding opportunities for geologic mapping, mineral resources research, and basin/subsurface analyses. We have a wide range of expertise with particular emphasis on geologic mapping, geologic resources, geologic hazards, digital geologic data, and public outreach.

GEOLOGIC MAPPING

AZGS conducted integrated bedrock and surficial geologic mapping at detailed (1:24,000) and intermediate (1:100,000) scales in several areas across Arizona during 2021–2022. In the past two years our geologic mapping efforts expanded substantially in response to increases in available federal and state funding. Most of our geologic mapping was conducted as part of the STATEMAP program. Under this program we have undertaken more and larger projects due to funding levels that are nearly double what they have been historically. In addition, we have an Earth MRI project to understand the framework of lithium-rich deposits in northwestern Arizona. This project includes geologic mapping that dovetails with nearby STATEMAP mapping projects. We have also continued efforts funded by the Arizona Department of Water Resources to map young alluvium along perennial streams to assist with adjudication of water rights. Finally, we completed detailed geologic mapping along a Quaternary fault zone near Flagstaff in northern Arizona with funding from the U.S. Geological Survey (USGS) Earthquake Hazards Program.

We work closely with our technically diverse and supportive State Mapping Advisory Committee (SMAC) to set our STATEMAP mapping priorities. SMAC members work in the metallic and aggregate resource industries, environmental geology, and geologic hazards; public sector geologists represent state and federal agencies and academia. In 2021 we met virtually with our SMAC in October to receive their feedback and guidance before we prepared the fiscal year 2022 STATEMAP proposal. We discussed the increasing emphasis given to intermediate-scale mapping and solicited their recommendations for compilation mapping areas. We submitted our proposal to the USGS in December 2021 and received our largest STATEMAP award ever beginning in September 2021.

AZGS was able to maintain mapping productivity through challenges presented by the Covid pandemic. Fieldwork continued with no significant interruptions because our mappers were nearly entirely camping, so risk of contracting Covid while in the field was low. Our computer and network infrastructure facilitated a relatively seamless transition to remote work in 2020 and we have maintained this option for staff; thus, we were able to complete our geologic map deliverables through a combination of remote and in-office work and did not require contract extensions. In the past year we released final versions of 1:24,000-scale geologic maps in northwestern Arizona (two maps) and southeastern Arizona (two maps), from mapping done in previous STATEMAP cycles (Figure 1). In the current STATEMAP cycle we completed draft versions of three Geologic Map Schema (GeMS) compliant 1:100,000-scale maps in central and western Arizona and four 1:24,000-scale maps in northwestern Arizona. We began work and made substantial progress toward completing two other 1:100,000-scale maps in southern Arizona and four 1:24,000-scale maps in northwestern Arizona, complementing our mapping efforts from the previous year. We also utilized STATEMAP funding to develop the AZGS GeoMapMaker toolbar for use in the digitization of geologic maps using the USGS GeMS standard and ESRI ArcGIS Pro software.

OTHER PROGRAM HIGHLIGHTS

Geologic Hazards

Post-wildfire hazards are of particular importance in Arizona given the size and frequency of wildfires in the past few decades. In 2021–2022, flooding and debris flows from burned areas caused substantial damage in northern and eastern Arizona. AZGS research in collaboration with colleagues in the Department of Geosciences in the University of Arizona and the USGS has focused on understanding triggering mechanisms for post-wildfire debris flows, factors that influence where debris flows may occur, and how large they might be. Building on this research, 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.

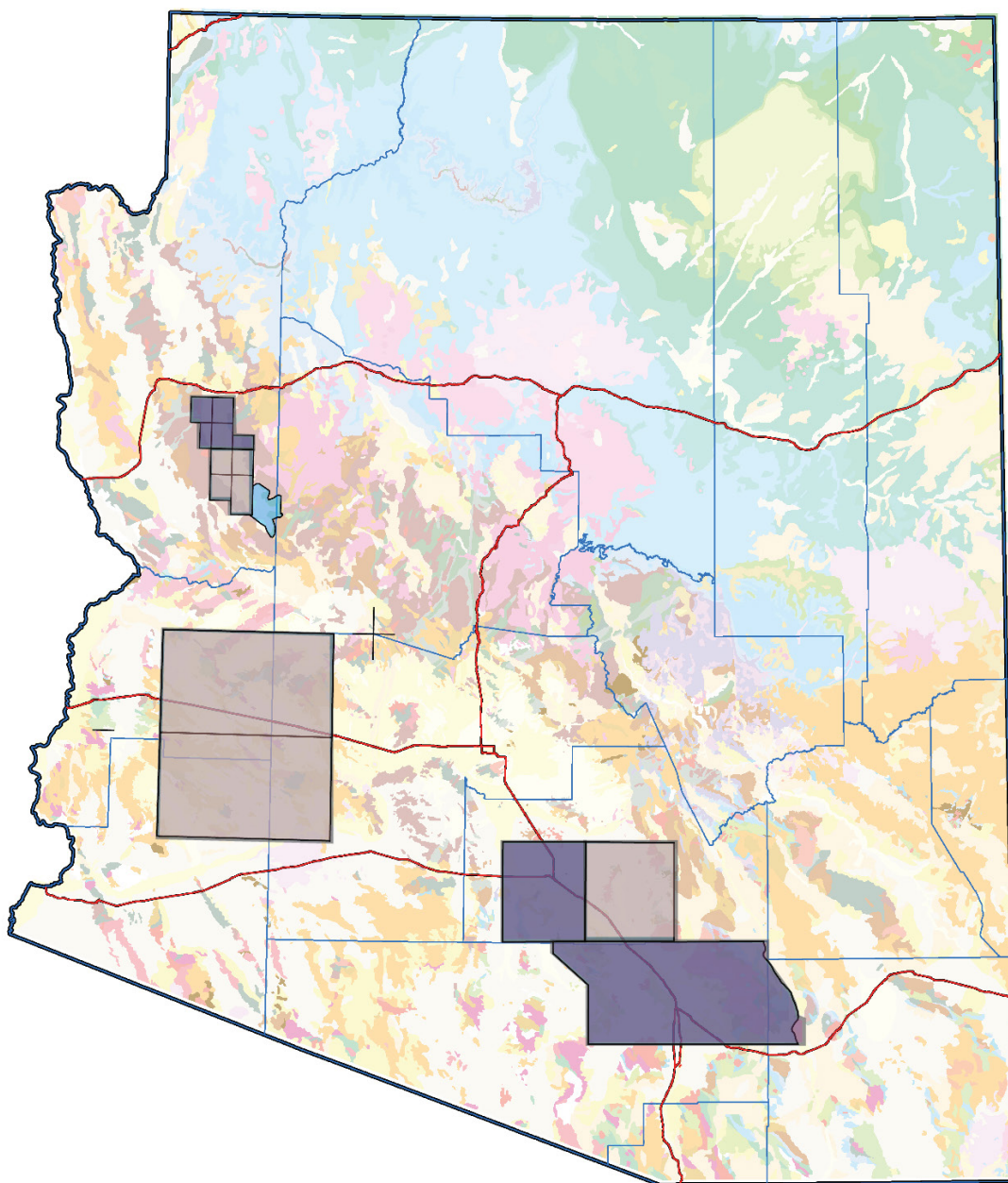
Critical Minerals

We began a new 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 STATEMAP detailed mapping project in the same area.

Carbon Sequestration and Underground Storage

AZGS is participating in the Carbon Utilization and Storage Partnership (CUSP) led by New Mexico Tech to characterize, catalog, analyze, and rank carbon capture, utilization, and storage options for Arizona. The CUSP partnership comprises 13 states and 3 national laboratories, and is one of 4 regional initiatives funded by the U.S. Department of Energy. We are analyzing several deep sedimentary basins in central and western Arizona and relatively thick Mesozoic and Paleozoic strata on the Colorado Plateau in more detail to characterize their potential for carbon storage. Complementary to this project there is increasing interest from electric power utilities and private sector manufacturers in Arizona to investigate the potential for underground hydrogen storage. The need for better subsurface information is a common factor in these investigations.

Figure 1. Map showing primary Arizona Geological Survey mapping areas in 2021–2022. Areas shown in light brown were mapped in 2022; these products were released to the public after June 2022. Mapping in areas shown in purple began in 2021. The area shown in light blue is an Earth MRI mapping project.



ARKANSAS

ARKANSAS GEOLOGICAL SURVEY

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GEOLOGICAL SURVEY

INTRODUCTION

The Arkansas Geological Survey (AGS) is a non-regulatory agency that has been responsible for the collection and dissemination of unbiased and sound geologic data and information pertaining to the State of Arkansas since 1857. In April of 2019, Governor Asa Hutchinson signed the Transformation and Efficiencies Act of 2019 that authorized the reduction of the number of cabinet-level agencies from 42 to 15 and accomplished the largest reorganization of state government in almost 50 years. The AGS was merged into the Division of Energy and Mineral Resources of the Department of Energy and Environment (E&E). The AGS headquarters is now co-located with the Arkansas Oil & Gas Commission and the Arkansas Department of Environmental Quality at the recently designated E&E building in North Little Rock, Arkansas.

GEOLOGIC MAPPING

Bedrock Mapping

The Arkansas Geological Survey conducted two geologic mapping projects in North Arkansas during 2021–2022: Earth Mapping Resources Initiative (EMRI) and STATEMAP. The federally funded EMRI project, which focused on producing detailed geologic mapping of the historic Batesville Manganese District (Figure 1), was officially completed in January 2022 after a six-month extension. The STATEMAP project was completed in June 2022 by mapping the remaining halves of the 7.5-minute quadrangles from the EMRI project.

The EMRI project highlights the outcrop belt of the Cason Formation, a thin, discontinuous, clastic unit historically mined for phosphate and manganese. It has become the subject of renewed interest due to recent analyses indicating that it contains significant percentages of rare-earth elements. The new 1:24,000-scale geologic maps are divided into west and east parts and are available on the AGS website. AGS spent approximately 372 days collecting and recording data in the field at nearly 6,000 locations. Eighty-seven Cason samples were collected and sent to the U.S. Geological Survey (USGS) to determine content of rare-earth elements over a large area. These new maps will be useful to landowners interested in developing these resources for personal or commercial purposes, to scientists seeking a better understanding of landscape evolution and geologic history, and to local and regional planners responsible for the orderly development of natural resources and recreational opportunities, and their associated environmental impacts.

The STATEMAP project received \$126,115 in August of 2021, to complete the southern portions of the Bethesda, Batesville, Sulphur Rock, and Charlotte 7.5-minute quadrangles in the Batesville area. Another component of this grant

was to compile a 1:100,000-scale digital geologic map of the Mountain View quadrangle. This involved digitally compiling 32 individual 7.5-minute quadrangles that were previously mapped over a span of 15 years from 2001 to 2016.

CRITICAL MINERALS

Lithium Sampling

As the shift to clean energy continues and demand for batteries and other electronics increases, the production of the critical mineral lithium will be vital to meet future needs of the United States. A state-of-the-art pilot facility is already extracting lithium from bromine brines produced from the Jurassic Smackover Formation in south Arkansas. The anticipated increase in extraction of lithium from Smackover brines will require improved knowledge of host-rock geology, geochemistry, and its interconnectivity over a broader region of this formation.

The Arkansas Geological Survey, in partnership with the USGS Geology, Energy, and Minerals Science Center and the USGS Energy Resources Program, completed a successful sampling campaign in August of 2022 to collect produced water samples from oil and brine wells in southern Arkansas. The goal of the sampling was to expand on historical datasets to characterize lithium resources in the brines of southern Arkansas, which is recognized as a region of significant mineral occurrence for lithium. The team collected 35 brine samples from 26 wells operated by 7 different companies representing Jurassic through Cretaceous geologic formations. The team also adapted specialized sampling techniques to sample “sour” wells, or wells with hazardous levels of hydrogen sulfide gas. The sampling effort could not have been completed without a cooperative partnership with the USGS, including collaboration across two mission areas of the USGS, and the support of private industry.

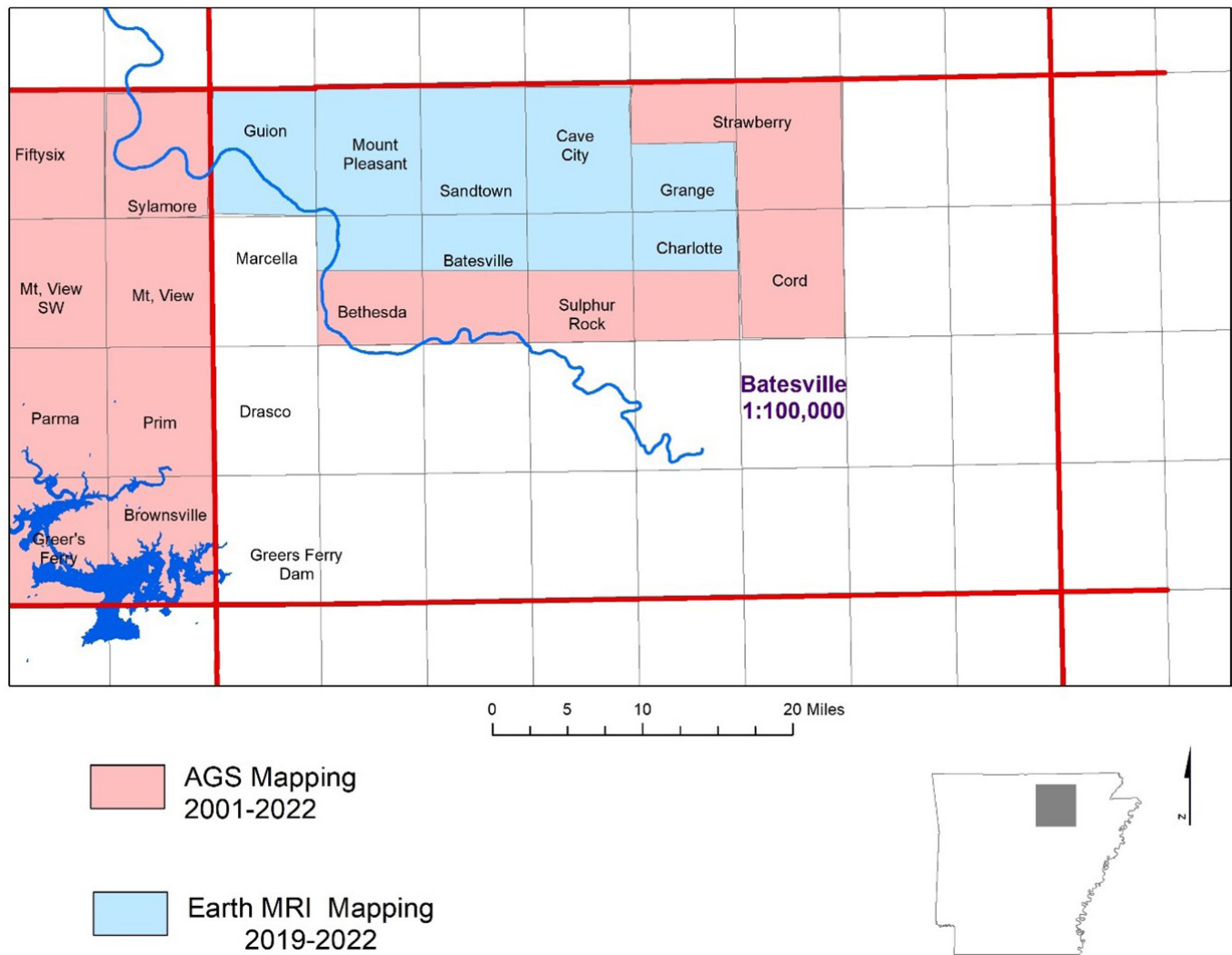


Figure 1. Map showing the Earth Mapping Resources Initiative (Earth MRI) and STATEMAP mapping in the Batesville Manganese District in north Arkansas.

CALIFORNIA

CALIFORNIA GEOLOGICAL SURVEY

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INTRODUCTION

The mission of the California Geological Survey (CGS) is to provide scientific products and services about 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 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 five field offices throughout the State. The CGS employs 139 geologists, engineers, seismologists, GIS cartographers, field instrument technicians, and administrative staff.

GEOLOGIC MAPPING

Geologic mapping is completed by the Regional 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 USGS Earth Mapping Resources Initiative (MRI) program. Each year, CGS completes new geological mapping, compiles geologic maps into regional maps, and works to publish geologic maps of California. The CGS prepares inventories of both climate (rainfall) and seismically induced landslides and presents them in a statewide landslide inventory database.

The Regional Geologic and Landslide Mapping Program completed four and one-half 7.5-minute quadrangle geologic mapping projects within Mendocino, Los Angeles, Kern, and San Bernardino counties, covering over 280 square miles, and two 30' x 60' quadrangle GeMS-compliant geologic map compilations within Stanislaus and Merced counties, covering over 3,800 square miles. Mineral Resources Program staff collaborated on the San Bernardino County geologic map to target pegmatites that potentially host beryllium, niobium, fluorine, lithium, tantalum, and rare earth elements to improve our understanding of the mineral systems in the area (Figure 1).

The Mineral Resources Program completed preliminary geologic mapping of four 7.5-minute quadrangles in the Mountain Pass Rare Earth Elements Focus Area in San Bernardino County.

3D Mapping

Three-dimensional geologic framework maps are a fundamental data source for modeling changes over time, managing risk to life-safety, public and private infrastructure, and economic welfare. In 2021, the California governor and legislature approved funding for the CGS to develop a multi-benefit 3D geologic framework mapping pilot project

(3D Geo) to support the state in sustainable groundwater management, seismic hazard mitigation, carbon sequestration, and mineral resource evaluations. Through collaboration with state partners and stakeholder groups, the CGS developed a scope of work for a pilot project in the southern San Joaquin Valley based on the needs of project stakeholders and data availability, density, and quality required for 3D geological mapping and modeling. The project duration is from July 2021 to June 2024.

OTHER PROGRAM HIGHLIGHTS

Forest and Watershed Geology Program and Regional Geologic and Landslide Mapping Program staff co-led Watershed Emergency Response Teams (WERT), assessing seven wildfires which impacted more than 1.2 million acres for post-fire life and safety hazards such as debris flows, rock falls, flooding, and sedimentation. Additionally, staff from the Forest and Watershed Geology Program completed a multiyear statewide assessment of the existing stream-gaging network and prepared a technical report, the California Stream Gaging Prioritization Plan, outlining the locations of, and prioritization for installing new and upgrading existing, stream gages across the state.

Post-fire runoff and debris bulking can be multiple times larger than pre-fire conditions and has resulted in damaging flood and debris flow events that have caused significant impacts to infrastructure and loss of life. To better address post-fire hazards, in 2022 the CGS implemented a new Burned Watershed Geohazards Program. The Program will focus on providing pre- and post-fire assessments to characterize the magnitude and spatial extent of fire-induced hazards related to flooding and debris flows, perform burned area monitoring to identify opportunities to refine or improve post-fire assessment processes, and conduct public outreach and education to elevate public awareness of post-fire hazards.

Mineral Resources Program staff prepared a California Statewide Indoor Radon Potential Report summarizing indoor radon potential information available for counties throughout California. The report provides information about radon measurement geographic distribution and statistics, describes radon and geologic unit relationships, and priorities for future radon testing and investigations.

Seismic Hazards Program staff completed updated tsunami hazard maps for emergency planning for San Francisco, Contra Costa, Santa Clara, San Luis Obispo, Santa Barbara, and Orange counties.

The Strong Motion Instrumentation Program (SMIP) upgraded 40 monitoring stations to real time. SMIP now operates 240 strong motion stations in real time. SMIP currently has 134 stations that contribute to the California Earthquake Early Warning (ShakeAlert) System. The SMIP generated ShakeMaps for 131 California earthquakes and processed 4,014 station records from 217 earthquakes of magnitude 3 and above.



COLORADO

COLORADO GEOLOGICAL SURVEY

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INTRODUCTION

The Colorado Geological Survey (CGS) is a state agency responsible for evaluating geologic hazards, assessing mineral and water resources, and conducting basic geologic studies across the entire state. We are under the umbrella of the Colorado School of Mines, with our main office located in Golden, Colorado. The CGS was established by the Colorado legislature in 1907 and went out of existence sometime around 1925. The CGS was then re-established in 1967. To support our mission, we have a diverse staff of about 30 scientists that work in many different disciplines such as mapping, groundwater, minerals, geologic hazards, and GIS.

GEOLOGIC MAPPING

The CGS continues an active STATEMAP mapping program that began with the inception of the STATEMAP program in 1993 and has generally seen increased funding for geologic mapping since then. The CGS will reach a milestone of 150 geologic quadrangles mapped at the 1:24,000 scale by the 2022–2023 fiscal year. Currently, the CGS maps about six 1:24,000-scale quadrangles each year, prioritized by the Geologic Mapping Advisory Committee, in specific project areas of Colorado shown in Figure 1. The CGS always maps both surficial and bedrock units on their 1:24,000-scale geologic maps. Both have importance depending on the project location.

Bedrock Mapping

The sedimentary strata include extensive areas of weak clay- and silt-rich Cenozoic and Mesozoic bedrock. These shales and mudstones may be susceptible to adverse mass wasting, including landsliding in moderate to steep sloped areas, and erosion from slaking, rilling, and debris-flow flood channelization. All very steep areas of Colorado bedrock are also exposed to gravity rockfall hazards, especially along steep valleys of the Uncompahgre and Animas rivers. Resources such as coal, oil and gas, and mining have a rich history in Colorado so where bedrock is exposed, a cursory resource assessment is made for each quadrangle that may include discussion of coal resources, oil and gas, and minerals. The San Juan project area in Colorado includes the northern San Juan basin that has extensive mineral-fuel resources.

Surficial Mapping

Unconsolidated surficial deposits (soils) can be problematic for a number of reasons, so they are prioritized in Colorado. Colorado has a semi-arid to arid climate and problematic moisture-sensitive swelling and collapsible soils are widespread where derived from the weak clay- and silt-rich geologic terranes mentioned above. Valley side alluvial fans and valley floor alluvial soils also may indicate areas that are

threatened by periodic debris-flow and mud-flow flooding. Eolian deposits are also well known for susceptibility to hydrocompaction (collapsible soils). The same is true for clay-rich alluvial fans and mud alluvium, which may also be corrosive and prone to dispersion and pseudokarst formation. Steeper slopes of clay-rich colluvial deposits may also be prone to landsliding. Unconsolidated materials may also be an important resource. Alluvial sand and gravel may have high value for aggregate and CGS mapping is used to help delineate those resources.

OTHER PROGRAM HIGHLIGHTS

During 2021–2022, the CGS continued to develop of a geologic map of the Wet Mountains in Central Colorado. This project is supported by the U.S. Geological Survey (USGS) Earth Mapping Resources Initiative (Earth MRI) program and will result in a 1:50,000-scale geologic map and analytical (inductively coupled plasma mass spectrometry) data for approximately 165 rock samples with a focus on critical minerals. In late 2022, we received Earth MRI funding for a 3-year geologic mapping and sampling project in the La Plata Mountains in southwest Colorado; field work began in late fall of 2022. The CGS is also partnering with the University of Wyoming and University of Utah on two Department of Energy funded Carbon Ore, Rare Earth, and Critical Minerals (CORE-CM) projects. The aim is to assess coal and coal waste-stream byproducts for critical minerals and to stimulate economic growth through the new development of resources centered on current coal mining and related industries.

With National Geological and Geophysical Data Preservation Program (NGGDPP) funds, the CGS updated our statewide inventory of nonmetallic mining and processing operations in Colorado, created an inventory of uranium exploration data from the Tallahassee Creek Mining Area, and converted four county geologic maps (Gunnison, Park, Lake, Saguache) to the USGS Geologic Map Schema (GeMS) format.

These data were uploaded to the USGS ReSciColl, the NGMDB, and the CGS bookstore and are available for public download.

In 2022, our Groundwater Resources Program received funding from the Colorado Department of Public Health and Environment to conduct a 5-year water quality study of portions of Fremont and Custer counties. The area is known to have elevated levels of radionuclides and metals in groundwater and this program will analyze drinking water samples provided by residents.

To assist with sound management of existing and increasingly scarce water resources, the CGS began producing comprehensive county-wide geology and groundwater reports beginning in the mid-2010s. Counties completed thus far include Douglas, Park, Chaffee, Mesa, and Elbert.

Nearly complete is La Plata County. These reports and data are available as downloads on the CGS website.

In early 2021, the CGS partnered with the Colorado Water Conservation Board (CWCB) and a private consultant to identify salinity sources within the South Platte River Basin. Upper basin salinity has been steadily increasing, and salinity also continues to increase through the lower basin with average annual salinity that can decrease crop yields and requires treatment for municipal use. The study utilized water-quality sampling from rivers and groundwater during irrigation and non-irrigation seasons. Streamflow and groundwater baseflow estimates were used to estimate salt loading from irrigated agriculture and geologic sources. Lab results are pending, and a final report is expected in 2023.

The CGS’s involvement with geologic hazards is partly mandated by state law requiring land-use reviews for local governing agencies. These reviews typically include verification that site-specific investigations have correctly interpreted the geology, identified the hazards and constraints associated with the geologic conditions, and provided appropriate mitigation measures. Additionally, if requested, the CGS responds to emergencies related to geologic hazards with direct and immediate threats to public safety. Emergency response can lead to funded work which this past year has included research partially paid for by the CWCB and Boulder County. This work involves post-fire debris flow assessments and research into early warning systems for these types of debris flows. Other funded work in 2022 includes detailed mapping of alluvial fan systems to predict and prepare for post-fire debris flows in Pitkin County.

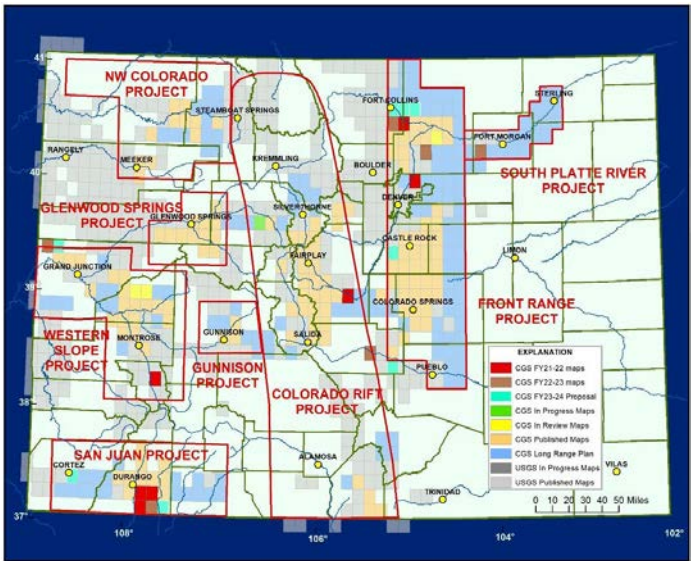


Figure 1. Mapping status map of Colorado showing quadrangles mapped during the fiscal year 2021–2022 season.

Table: The seven 1:24,000-scale quadrangles mapped by CGS in fiscal year 2021–2022.

Quadrangle	Project Area	Bedrock	Surficial Deposits
Brighton	Front Range	Cenozoic to Cretaceous Denver Formation	Alluvial sand, gravel terrace, extensive eolian sediments
Windsor	Front Range	Cretaceous Fox Hills and Pierre Shale	Alluvial sand and minor gravel, extensive eolian sediments
Spinney Mtn.	Colorado Rift	Faulted Cenozoic volcanic/volcaniclastic rocks and Proterozoic crystalline rocks.	Gravel, alluvial fans, colluvium
Dallas	Western Slope	Cenozoic San Juan volcanic rocks, Cretaceous and Jurassic Mancos Shale, Dakota/Burro Canyon, Morrison, and Entrada Sandstone)	Glacial moraines, glacio-fluvial gravel terraces, mud alluvium, colluvium, and landslides
Loma Linda	San Juan	Cenozoic and Cretaceous Nacimiento, Animas, and Kirkland Formations	Glacio-fluvial gravel terraces, alluvial fans, colluvium, eolian deposits, and landslides
Bondad Hill	San Juan	Cenozoic San Jose and Nacimiento Formations	Glacio-fluvial gravel terraces, alluvial fans, colluvium
Gem Village	San Juan	Cenozoic San Jose, Nacimiento, and Animas Formations	Glacio-fluvial gravel terraces, alluvial fans, colluvium, eolian deposits

CONNECTICUT

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY OF CONNECTICUT

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INTRODUCTION

The Connecticut Geological and Natural History Survey was established in 1903 by the Connecticut Legislature. The Survey is responsible for 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 (Chapter 462, Sections 24-1 to 24-4). In 2022, the Department of Energy and Environmental Protection reorganized the Geological Survey within the Bureau of Central Services Engineering & Field Support Services Division. The Natural History Survey has remained in the Bureau of Natural Resources (BNR) Wildlife Division since 2006. This report pertains to the Connecticut Geological Survey. The Connecticut Geological Survey Program is coordinated by Meghan Seremet, State Geologist.

GEOLOGIC MAPPING

Bedrock Mapping

The Connecticut Geological 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 STATEMAP and EDMAP components of the National Cooperative Geologic Mapping Program, the Connecticut Survey is actively working with federal and academic partners to update the Connecticut Bedrock Map. The strategic plan was developed in 2021 by the State Geologist in consultation with scientists representing mapping expertise in Connecticut's crystalline rocks of the eastern and western uplands, and Mesozoic rocks of the central valley. In conjunction with the goals of the previously adopted long-range plan, the 7.5-minute quadrangles in Connecticut were assigned mapping and digital compilation priority ratings. Each 7.5-minute quadrangle was given high, medium, or low priority ratings for both bedrock mapping and development of GIS databases in the USGS Geologic Map Schema (GeMS) format. For mapping, an assessment of the magnitude of field mapping, geochemistry, geochronology, and structural analysis required for individual quadrangle areas was used to determine priority ratings. The detailed Bedrock Map Revision Strategic Plan will be available online through the Connecticut Geological Survey.

Completed map products and geologic reports are available online at www.ct.gov/deep/geology and ngmdb.usgs.gov

Surficial Mapping

1:24,000-scale surficial and Quaternary geologic mapping, developed cooperatively by the Connecticut Geological 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). The digital geologic data is one of the primary resource layers used in environmental analysis by the Connecticut Department of Energy and Environmental Protection (DEEP), and is available for download through the Connecticut DEEP GIS Open Data portal (ct-deep-gis-open-data-website-ctdeep.hub.arcgis.com/).

OTHER PROGRAM HIGHLIGHTS

The Connecticut Bedrock Mining Sites Database (2022) is a comprehensive inventory of active and historic bedrock mines and quarries for the State of Connecticut. This work is integral to the mission of the Connecticut Geological and Natural History Survey, and contributes to the National Assessment of Critical Minerals for the USGS National Earth Resources Mapping Initiative and the National Geological and Geophysical Data Preservation Program. This database is used for routine technical assistance to DEEP programs, consultants, state & federal agencies, and citizens. The geologic sites database is also a central resource for Connecticut Geological Survey land acquisition reviews within DEEP. The Connecticut Bedrock Mining Sites Database is available as a downloadable geodatabase in GeMS format; an interactive map is in preparation.

COLLECTIONS & DATA PRESERVATION

As a participant in the National Geological and Geophysical Data Preservation Program, the State Survey is making information about its collections 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 scientifically important rock cores 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 through the DEEP website (www.ct.gov/deep/geology) and the USGS Digital Catalog (www.sciencebase.gov/catalog/). Access to the Connecticut Survey library and the Randolph P. Steinen Collections Facility by 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 non-profit 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.

LINKS

Publications:

portal.ct.gov/DEEP/Geology/Publications

On-line publication sales:

www.ctdeepstore.com

(860) 424-3555 or email deep.store@ct.gov

DELAWARE

DELAWARE GEOLOGICAL SURVEY

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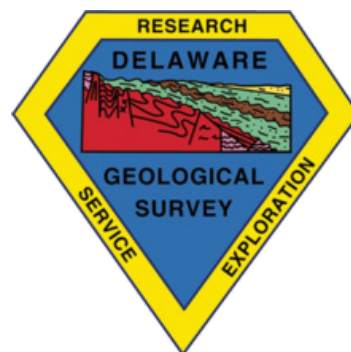
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INTRODUCTION

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

The DGS is a unique agency within 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 of Delaware. 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. Within the University, the DGS is affiliated with the College of Earth, Ocean, and Environment (CEOE), and 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 impact 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 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 geologic mapping program is to map surficial geology of the First State at the detailed scale of 1:24,000. The U.S. Geological Survey (USGS) STATE-MAP 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 DGS is completing the work on the Frederica and Bennetts Pier Quadrangles from our previous mapping project area, and field data is being collected from our current surficial geology mapping study area, which is the Wyoming quadrangle. These quadrangles were chosen with input and guidance from the Delaware Geologic Mapping Advisory Committee (DGMAC), which convenes annually to review the DGS mapping program, and provide input regarding the geological mapping needs of stakeholders, such as state agencies,

local government agencies, non-profit organizations, federal partners, and the general public.

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 the eastern coast of the United States, and has been recently utilized by parties anticipating possible future interest in potential offshore east coast energy (for example, wind) resources. The DGS is currently partnering with our Department of Natural Resources and Environmental Control (DNREC) to have vibracores taken in the Delaware Bay. One completed, splits of the cores will be stored in our core repository for future research and mapping studies.

The DGS also partnering with the Bureau of Ocean Energy Management (BOEM), investigating historical sand usage rates to better estimate regional sand resource demand over the 21st century. By coupling the sand needs of different beach communities with the sand availability in known offshore deposits, the team hopes to establish a timeline of when new sand deposits, likely in federal waters, may need to be utilized. This work will help guide coastal resilience planning and BOEM's decision making pertaining to offshore leasing activities along this stretch of coastline.

The DGS is also leading an effort by the State of Delaware to apply for USGS 3-D Elevation Program (3DEP) cost-sharing funds to have statewide Lidar flown in 2022–2023 timeframe. Our last statewide Lidar was flown in 2013–2014 timeframe following Super Storm Sandy, and using supplemental funds provided by Congress following the disastrous storm that affected much for the mid-Atlantic coast.

OTHER PROGRAM HIGHLIGHTS

Surface water and groundwater are among Delaware's most important natural resources. 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. Currently we manage a groundwater monitoring network with 90 dedicated monitoring wells. We also manage the state's stream and tide gaging network in cooperation with the USGS. Currently we have 10 stream gages, and 7 tide gages in our network. More than 32 million records have been collected to date. Data are reviewed by the DGS for quality control and then are available from DGS online sources. The DGS advises water-resource management decisions through ongoing monitoring of water conditions,

summarized monthly in a Summary of Water Conditions available on the DGS website.

The DGS also became a node in the National Ground-Water Monitoring Network through a non-competitive funding agreement with the USGS. 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's National Network Framework Document.

LINKS

For data and information from the Delaware Geological Survey, visit our public website:

www.dgs.udel.edu

For a more complete listing of DGS programs, projects, and activities, the DGS Annual Report of Programs & Activities for 2021–2022 can be viewed at:

www.dgs.udel.edu/sites/default/files/annual_report/DGS_Annual_Report_2021-2022.pdf



Figure 1. University of Delaware geology students participate in DGS drilling exercise to map subsurface geology at the University of Delaware farm in Newark, Delaware.

FLORIDA

FLORIDA GEOLOGICAL SURVEY

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INTRODUCTION

The Florida Geological Survey (FGS) was established as an autonomous state agency in 1907 by the Florida Legislature. Today, the FGS is a division within the Florida Department of Environmental Protection (DEP), the state's lead agency for environmental management and stewardship, protecting our air, water, and land.

After 33 years of service to the State of Florida and 13 years as FGS Director and State Geologist, Dr. Jon Arthur retired in July 2021. Guy "Harley" Means was appointed as the new FGS Director and State Geologist.

From July 2021 through June 2022, the FGS conducted research on the state's geology, geomorphology, hydro-geologic systems, and geohazards. The FGS continued its education and outreach activities, reaching thousands of customers through field trips, presentations, and [newsletters](#). Staff members served on the [Water Science Technology Board](#) of the National Academies, the [Florida Board of Professional Geologists](#), the American Society for Testing and Materials Karst Subcommittee, the Bureau of Ocean Energy Management's Gulf Coast Geology Working Group, the STATEMAP Advisory Committee, and the steering committee of the [Florida Coastal Mapping Program](#).

GEOLOGIC MAPPING

The Florida Geological Survey Mapping Initiative (FGSMI) was designed and implemented to accelerate the completion of a new statewide surficial geologic map of Florida. The FGSMI includes the Florida Geologic Mapping Program (FLAGMAP), which works in areas adjacent to U.S. Geological Survey (USGS) STATEMAP-funded quadrangles to maximize mapping efforts. FLAGMAP is internally funded. The USGS Earth Mapping Resources Initiative, discussed below, also contributes to FGSMI goals.

Surficial & Bedrock Mapping

The Florida Geologic Mapping Program (FLAGMAP) works with the STATEMAP program to conduct new geologic mapping within adjacent non-STATEMAP-funded areas. The density of data collected outside STATEMAP areas varies based on local topography and stratigraphy. Data sources include strategically selected borehole samples from the Florida Geologic Sample Collections Facility, including newly drilled boreholes, to establish a network of wells used for surficial and subsurface geologic modeling.

The USGS National Cooperative Geologic Mapping Program (NCGMP) provided project extensions to the [FGS STATEMAP Program](#) for federal fiscal years 2019, 2020, and 2021 due to COVID delays in drilling, sample description, and fieldwork. Between July 2021 and June 2022, the FGS STATEMAP Program completed its fiscal year 2019 mapping

project for the Vero Beach 30 x 60-minute USGS quadrangle. With a funding amount of \$161,029, the FGS mapped 1,211 square miles at \$265.98 per square mile (including matching funds). The Vero Beach mapping project deadline was extended to March 2022 and resulted in the publication of seven geologic cross-sections, a geologic map, a geomorphic map, and explanatory text. The FGS STATEMAP program also completed a large portion of the fiscal year 2020 project to map the Fort Pierce 30 x 60-minute USGS quadrangle with \$164,127 in grant funds. The FGS mapped 1,631 square miles at \$201.26 per square mile (including matching funds) for this project, which was extended to August 2022.

For federal fiscal year 2021, the FGS STATEMAP Program received \$293,599 from the USGS to map the West Palm Beach and Cape Canaveral 30 x 60-minute USGS quadrangles. Due to previous project delays and doubled mapping efforts for fiscal year 2021, this project was extended to March 2023.

OTHER PROGRAM HIGHLIGHTS

The USGS awarded the FGS \$100,000 to complete a distribution and geochemistry study of heavy mineral placer deposits adjacent to and along Trail Ridge in northeastern Florida. This funding came through the U.S. Geological Survey's Earth Mapping Resources Initiative (Earth MRI) based on interest in mineral commodities hosting rare earth elements (REEs). The two-year study began in December 2020. Project deliverables will include a surficial geologic map of the [Florida Focus Area](#), over 750 square miles adjacent to the Georgia border, and geochemical analyses of samples containing heavy mineral sand.

FGS received \$5,649 from the USGS National Geological and Geophysical Data Preservation Program (NGGDPP) to preserve some of Florida's coastal borehole data. Work on this project, which included participation in the Data Rescue and Preservation Workshop, began in July 2021, and the deliverable was nearly finalized in June 2022. The final product included the audit, revision, and verification of borehole and lithologic metadata, which was uploaded to the USGS National Digital Catalog and made available for public consumption.

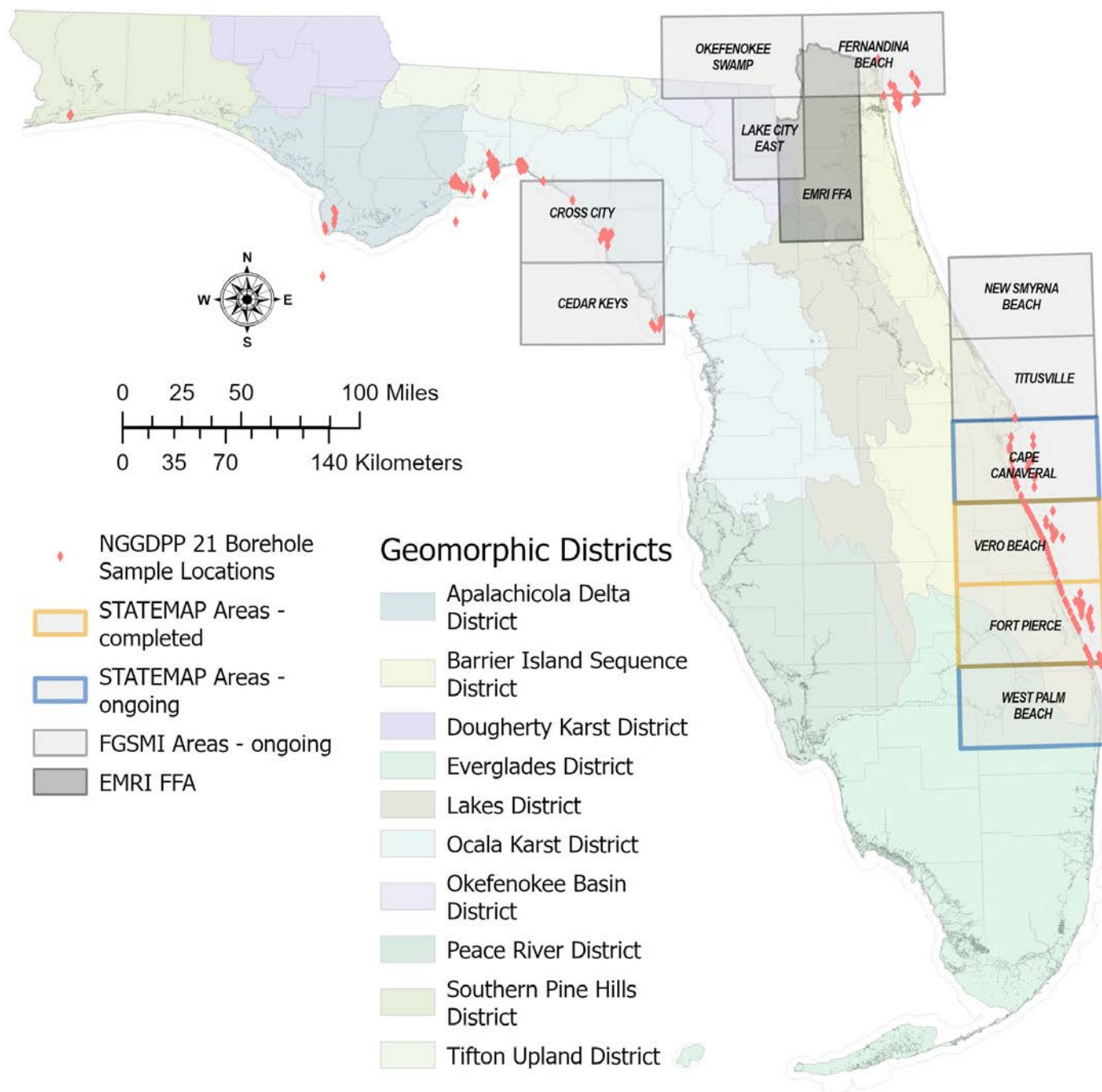


Figure 1. Florida project areas for fiscal year 2021–2022.

ILLINOIS

ILLINOIS STATE GEOLOGICAL SURVEY

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I ILLINOIS

Illinois State Geological Survey
PRAIRIE RESEARCH INSTITUTE

INTRODUCTION

The Illinois State Geological Survey (ISGS) was first formed in 1851 but has been continuously operational since 1905, when it was officially established as a state agency by an Act of Illinois' General Assembly. It is located on the campus of the University of Illinois at Urbana-Champaign. In 2008, when the University of Illinois State Scientific Surveys Act was passed by the General Assembly, the ISGS and other scientific surveys became an institute within the University of Illinois. The Prairie Research Institute (PRI) now houses the ISGS, Illinois Natural History Survey, Illinois State Water Survey, Illinois State Archeological Survey, and Illinois Sustainable Technology Center—together employing over 1000 scientists, support staff, and students. The ISGS has about 170 scientists and support staff.

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, minerals exploration, energy and water resources, environmental protection, and overall scientific understanding of Illinois' geology.

GEOLOGIC MAPPING

Bedrock Mapping

For the 2021–22-year Illinois bedrock mapping included four original 7.5-minute quadrangles: Andalusia, Port Byron, Green Rock in the Quad Cities area, and Galena in Jo Daviess County. Three county compilations at the 1:48,000-scale was also produced for Alexander, Pulaski, and Massac Counties. The mapping followed the U.S. Geological Survey (USGS) geologic mapping schema (GeMS), tracking information such as contact line confidence and data sources. This mapping has continued under the USGS-ISGS cooperative STATEMAP program.

The main finding in the Port Byron mapping was that a large area on the Kolata et al. (2005) bedrock geology of Illinois map will be changed from Silurian to Pennsylvanian because over 100 water wells showed Tradewater Formation overlying the Silurian in the northeastern quarter of this quadrangle. On the Andalusia quadrangle, an old abandoned quarry was found three-quarter mile east of Andalusia on the Mississippi River that was previously unknown to the ISGS. It contained an angular unconformity within the Cedar Valley Formation. This may be a collapse breccia that is associated with barite mineralization across the river in the Iowa Linnwood Mine. In the Galena quadrangle, a 280-foot stratigraphic test boring was drilled through the Late Upper Ordovician Maquoketa Shale, Middle Upper Ordovician Galena, Decorah, and Platteville formations of the Sinnipee Group for stratigraphic investigations at the Einsweiler's property.

An important find occurred during field checking for the Alexander County compilation. An extremely rare endocerid cephalopod fossil was found in the Thebes Sandstone Member of the Maquoketa Formation. This zone also has abundant phosphate nodules, and correlates to other areas in Illinois and Missouri. No marine fossils were known from the Thebes Sandstone until now. This find was due to historically low water levels of the Mississippi River.

Surficial Mapping

The ISGS began a new compilation of the surficial (Quaternary) geology of Illinois in 2020–2021, the first phase of a 5-year project with USGS STATEMAP funding. During 2021–22, Phase 2 was completed. It included much of southern and northeastern Illinois. This new Quaternary map updates the four-decade old map of 1979 with findings from much detailed quadrangle and county mapping (1:24,000 to 1:62,500 scales) during the interim. The availability of lidar elevation data and digital U.S. Department of Agriculture Natural Resources Conservation Service soil maps also aided the project. The mapping followed the USGS geologic mapping schema (GeMS), tracking information such as contact line confidence and data sources. Contact lines were drafted in a GIS at 1:80,000 or 1:100,000 scale, with anticipated map publication at 1:250,000 or 1:500,000 scale. New data acquired to address statewide stratigraphic issues included 21 shallow test holes, 2 electrical resistivity transects, 26 radiocarbon ages, particle-size data, and mineralogical and elemental analyses. One new geologic finding was that many hills in Jasper, Clay, and Marion Counties (south-central Illinois), formerly mapped to contain ice-contact sediments (Hagarstown Member), are now interpreted as bedrock-controlled hills with Pennsylvanian sandstone or mudstone within 8–20 feet of land surface. A major addition was dozens of ice-walled lake polygons mainly in northeastern Illinois, which previously were not recognized. Finally, the new Quaternary map has a 10-mile (16-kilometer) buffer zone into surrounding states, to show the full width of the Mississippi, Wabash, and Ohio River valleys and to facilitate collaboration with adjacent state geological surveys.

Large-scale (1:24,000) mapping of surficial geologic quadrangles has continued under the USGS-STATEMAP program. Quadrangles mapped over 2020–2021 occurred along the Illinois-Indiana border south of Chicago and along the southern Wabash River, as well as in east-central Illinois over the Mahomet Aquifer. Notable findings included a detailed radiocarbon-dated chronology of retreat of glacial Lake Chicago–Lake Michigan over 17.2–2.8 ka, further discovery of early Wisconsin Episode (marine isotope stage 3) slackwater lake deposits, and the constraint of the extents of and connections between units of the Mahomet Aquifer.

3D Mapping

The 3D geologic mapping program at the ISGS continued to focus on the Chicago metropolitan area for the 2021–2022 mapping year and has been twofold. First, the bedrock to-

pography in northeastern Illinois (including 8 collar counties) was updated to include new data from recent mapping at 1:24,000 and 1:100,000 scales. This was completed during the first year of a 2-year project to update the statewide bedrock topography map, which has not been newly compiled since 1994. The statewide bedrock topography will be updated and completed in year two of the project. Second, a 3-year 3D geologic mapping project was initiated in Boone County, Illinois. The first year included database management and field data collection. The locations and recorded lithologies of 4,696 water-well records and engineering borings were reviewed and corrected. Furthermore, 69 one-dimensional seismic soundings were collected in the field along with 6,500 meters of 2D seismic data and 4,500 meters of 2D electrical resistivity tomography data. More field data will be collected in sequential project years, and they will be compiled and interpreted using 3D geologic modeling software and distributed with an online geologic model viewer. The resulting 3D geologic model will benefit local and regional decision makers with long-term natural resource management and protection planning.

OTHER PROGRAM HIGHLIGHTS

Progress on Energy

The ISGS Subsurface Energy Resources Section conducted impactful applied U.S. Department of Energy (DOE)-funded research on safe and permanent carbon storage, low-carbon oil production, and energy storage in support of the global energy transition. Two new characterization wells were drilled, and seismic reflection surveys were conducted in southwestern and east-central Illinois at a coal fired power plant and a large ethanol plant, respectively, as part of the CarbonSAFE Illinois Storage Corridor project. Data from the wells (cores, geophysical logs, and injection test results) and the seismic surveys characterized potential carbon storage reservoirs and seals, but also contributed to a broader understanding of the deep stratigraphy and structure of the Illinois Basin. For the Residual Oil Zone (ROZ) Fairways project, 1,000 tons of CO₂ were injected into an ROZ and successfully produced approximately 65 barrels of oil while storing approximately 650 tons of CO₂, demonstrating the potential for carbon-negative oil production with associated CO₂ storage. In collaboration with industry partners, evaluation projects were completed to advance the development of compressed air and hydrogen storage in porous reservoirs, technologies intended to help stabilize energy production to the grid caused by unplanned outages or normal diurnal fluctuations of renewable energy output.

Lake Michigan Coastal Program

The ISGS Coastal Geology Group continued its State-funded, multi-year monitoring effort along the Lake Michigan shoreline using aerial drones and precision topographic surveying. Priority sites included all remaining stretches of

natural shoreline along Illinois Beach State Park and the urban pocket beaches of Chicago, for which high-resolution orthoimages and digital elevation models were rendered using Structure from Motion Photogrammetry derived from 99 drone flights. These products were supplemented with bathymetric point datasets (from single-beam sonar) from 25 offshore surveys, with all geospatial data available through the ISGS Data Clearinghouse. These high-resolution datasets provided valuable insights to coastal stakeholders (including the Chicago Park District) regarding short-lived coastal morphodynamics. Other achievements included the acquisition of nearly 40 kilometers of ground-penetrating radar data across Chicago beaches for sand assessment (part of a National Oceanic and Atmospheric Administration Sea Grant project), acquisition of 10 vibrocores from the Zion ridge plain for shallow stratigraphic assessment and OSL dating for an improved geochronology of this unique coastal lithosome, and hydrodynamic monitoring using instrument cage deployments surrounding a new Great Lakes Restoration Initiative Healthy Port Futures site at Illinois Beach State Park.

National Benefit Cost Study of Geological Mapping

The Nevada Bureau of Mines and Geology, with the ISGS as a Co-PI, are conducting a national benefit cost study to assess the value of geological mapping conducted between 1994 and 2019. Retired ISGS Minerals Economist Subhash Bhagwat, is the lead investigator. Cost data by State Geological Surveys and the USGS total \$1.99 billion (inflation adjusted 2020 USD). Preliminary benefits data, obtained by sending a lengthy questionnaire to more than 81,000 stakeholders, revealed, among other things, a greater than 21% cost and time savings over a 5-year period when using geologic maps, and a “willingness to pay” and expected payment for one map averaging from \$28,000 to \$56,000. There are two advisory groups helping with the effort. One consists of current and retired state geologists and the other of economists and statisticians. Project completion is scheduled for the middle of 2023.

Critical Minerals

The USGS Earth EMRI program supported detailed mapping, map compilation, and geochemical sampling for critical minerals, that has led to ISGS discoveries of multiple distinct rare earth element (REE) enriched rock types surrounding the Hicks Dome (southeast Illinois) volcanic structure in the Illinois Basin. Additionally, the ISGS conducted petrographic and geochemical analyses of individual minerals and has identified numerous REE bearing phases at Hicks Dome. In addition, the ISGS steadfastly continued pursuing new funding opportunities with the U.S. Department of Defense with respect to these REE enrichments.

Geothermal

In Spring 2022, the ISGS geothermal program was awarded two grants. One will foster collaboration with several DOE National Laboratories and universities to develop geothermal energy systems at federal facilities. The other will host workshops with USGS scientists and international collaborators at the USGS Powell Center on the theme "Geothermal Energy in Cities." ISGS geologists are also leading the development of a statewide technical, educational, and outreach program for geothermal energy with faculty and students from the University of Illinois at Urbana-Champaign and the University of Illinois Extension.

INDIANA

INDIANA GEOLOGICAL AND WATER SURVEY

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INTRODUCTION

The Indiana Geological and Water Survey (IGWS) is a research institute of Indiana University (IU). Its mission is to provide geological information that contributes to the wise stewardship of energy, mineral, and water resources and mitigates potential geologic hazards. Indiana residents continue to benefit from focused research initiatives; geologic sample and data collection and archiving; and dissemination of information through databases, outreach programs, and the peer-reviewed Indiana Journal of Earth Sciences.

During summer and fall 2021, the IGWS finished moving out of temporary office space and back into our 57-year-old headquarters after a 2½-year renovation funded by IU. In June 2022, a hands-on museum and classroom, the Learning Lab, opened to showcase IGWS collections and introduce students to geologic specimens and technology. The IGWS hosted an open house which was attended by around 100 people—including several state legislators—and a proclamation was awarded in recognition of our 185th birthday.

GEOLOGIC MAPPING

The IGWS's long-range geologic mapping goal is to map the state at 1:100,000 scale and its metropolitan areas at 1:24,000 scale by the IGWS bicentennial in 2037. Indiana is among several U.S. midcontinent states not yet wholly mapped at 1:100,000. The IGWS was granted \$559,505 from STATEMAP to continue working toward mapping all quads south of the 40th parallel at the target scale, to develop associated geodatabases, and to improve enterprise database infrastructure. The IGWS also received funding from the Great Lakes Geologic Mapping Coalition (GLGMC).

Two STATEMAP-funded maps were published in the Indiana Journal of Earth Sciences (IJES) in December 2021, and seven other draft products—four databases, two maps, and one pamphlet to accompany a map—are to be published in fiscal year 2023.

Bedrock Mapping

Bedrock Geologic Map of the Northern Half of the Bedford 30- x 60-Minute Quadrangle, Indiana (1:100,000 scale) ([link](#))

This quad contains abundant natural resources including natural gas, dimension and crushed limestone, groundwater, gypsum, and extensive public lands used for recreation. It also has been the site of extensive construction work for Interstate 69. Because of widespread karst landscapes, corridor planning requires a broader understanding of underlying geology and its relationship to engineering design and natural hazards.

Six new drill hole cores, 93 outcrop surveys, 25 data points from previous employees' field notes, four Indiana

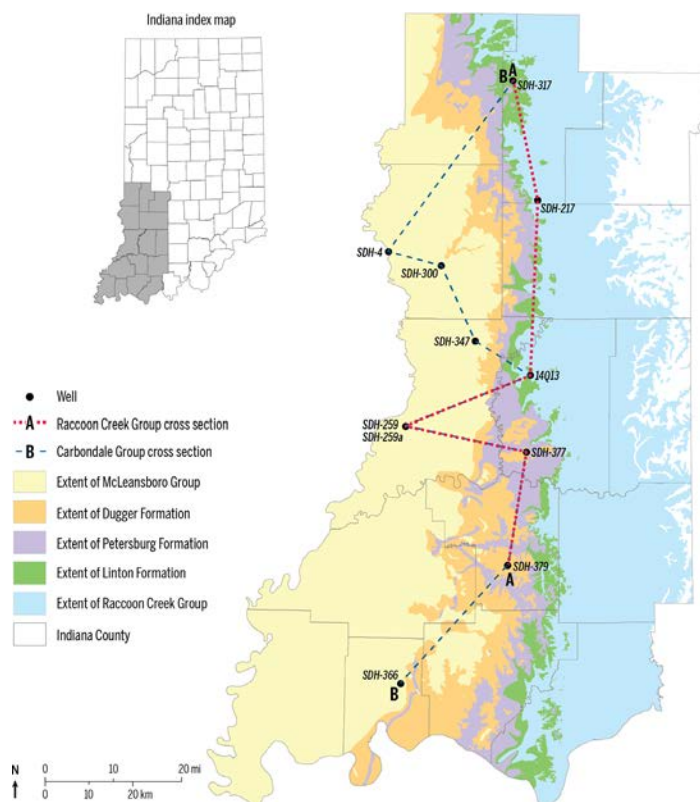


Figure 1. Map of southwestern Indiana showing locations of boreholes analyzed for rare earth elements and lithium. From *“Characterization of Pennsylvanian Paleosols in Indiana with a Special Reference to Rare Earths (REE) and Lithium,”* Indiana Journal of Earth Sciences, Vol. 4.

Department of Transportation (INDOT) cores, and data pulled from 1,400 records in the IGWS Petroleum Database Management System informed the points. That data, along with records from 326 outcrop exposures and 111 IGWS drill holes, was amalgamated into a single database used for this map.

A map of the southern half of the quad was published separately in fiscal year 2021 ([link](#)).

Surficial Mapping

Quaternary Geology of the Indiana Portion of the Western Extent of the South Bend 30- x 60-Minute Quadrangle (1:100,000) ([link](#))

This Lake Michigan-adjacent area of northern Indiana is a unique region where interplay among three lobes of a continental ice sheet can be assessed: the Michigan, Huron-Erie, and Saginaw Lobes. Their chronology has only partially been determined in neighboring southwestern Michigan and northeastern Indiana, while large areas in northwestern Indiana lacked chronology.

IGWS researchers gathered more than 950 feet of unconsolidated core from 25 sites to delineate surficial geologic units and investigate glacial stratigraphy. Ten samples also

were processed for optically-stimulated luminescence (OSL) dating in the newly established IGWS Luminescence Geochronology Laboratory.

A map of the eastern extent of the quad and an associated geodatabase were published separately in fiscal year 2021 ([link](#)).

New fault extension

While gathering data for another project, IGWS researchers Don Tripp and Sarah Burgess discovered that the Mt. Carmel Fault in Washington County likely extends several miles further south of where it was previously mapped. A [news story](#) about this research was picked up by a statewide wire service and received front-page treatment in at least three counties.

HIGHLIGHTS

Legacy data accessibility

The IGWS has amassed literal tons of data. However, due to multiple moves and lack of collections staffing and space, most items haven't been accessible to researchers—who may not know they exist due to data siloing—let alone to the public. In April, the IGWS was awarded \$142,582 through the USGS National Geological and Geophysical Data Preservation Program (NGGDPP) to transform unused rooms into a record center and convert 26,000 paper records to digital assets. A separate, ongoing project has digitized and placed more than 1,000 historical IGWS publications in an open-access repository for free download, with hundreds more to go.

Legislative changes

State legislation reorganized the IGWS into two centers, The Center for Water and the Center for Energy, and reconstituted the IGWS advisory board. Details of new continuing education requirements are being discussed.

Outreach expands reach

The IGWS resumed and expanded its Discovery Trunk program. Loaned to educators, the trunks cover Topographic Maps; Ice Age Indiana; Fossils of Indiana; Rocks of Indiana; and Shake, Rumble, Roll.

The IGWS hosted its first [Limestone Month Festival](#) in June, teaching Indiana's quarry history and why Salem Limestone—better known as Indiana Limestone—is deservedly “The Nation's Building Stone.”

The Learning Lab, opened in June 2022, would go on to host more than 1,800 visitors by the end of the calendar year through events like Storytime with the Survey, the GeoCre-

ate art program, and trick-or-treating. A sold-out Master Naturalist series graduated 30 participants.

A [news section](#) also was launched on the IGWS website, highlighting stories from the monthly E-Geo News newsletter and allowing for easier link-posting on social media.

New equipment

Five instruments were purchased with grant or internal funds: Mt. Sopris downhole geophysical probes; an auto-titrator and an ion chromatograph for the water lab; and a micropore physisorption analyzer and a carbon analysis coulometer for the energy lab.

Diverse publications

In addition to STATEMAP-funded maps, the Indiana Journal of Earth Sciences rereleased an updated version of a 60-year-old favorite, [“Caves of Indiana,”](#) to mark the International Year of Caves and Karst.

IGWS researchers published two papers on rare earth elements and critical minerals: [“Rare Earth Elements: A brief overview”](#) (our most-downloaded publication of the year), and [“Characterization of Pennsylvanian Paleosols in Indiana with a Special Reference to Rare Earths \(REE\) and Lithium.”](#)

Those joined a diverse collection published earlier in the calendar year: two projects on the composition and safety of wood-based and charcoal-based grilling fuels; a trans-disciplinary study regarding water resource information; and a paper on the pre-mortem crinoid-coral interaction from the Silurian of southeastern Indiana.

Newcomers and legends

Eight new staff members were hired, while 10 left due to retirement or other opportunities. Researcher Maria Mastalerz co-authored a paper [published in the journal Science](#) and was awarded the Reinhardt Thiessen Medal from the International Committee for Coal and Organic Petrology. Retiree Henry Gray [turned 100](#) in March 2022; three weeks later, he turned in a research paper co-authored with IGWS staff and a former mentee.

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INTRODUCTION

The Iowa Geological Survey (IGS) was established by the Iowa legislature in 1855. The IGS is a part of IHR-Hydroscience and Engineering, a research institute within the University of Iowa's College of Engineering (formerly the Iowa Institute of Hydraulic Research). 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, ten full-time professional positions and one 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 (USGS) STATEMAP program included three subprojects in vastly different geologic areas of the state with a focus on impaired watersheds and developing areas. Following six years of quadrangle mapping in southeast Iowa, surficial and bedrock geologic maps of Lee County were completed at 1:100,000 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. Quaternary mapping efforts focused on refining the characterization of the glacial deposits, improving the location of the Illinoian moraine boundary, better understanding of the nature of the Des Moines and Mississippi rivers and tributary alluvial systems and terrace deposits, confirming loess thickness in the region, and delineating areas of shallow bedrock. Bedrock mapping subdivided the Augusta Group of the 2010 bedrock map (Witzke and others) into the Warsaw, Keokuk, and Burlington formations and refined the distribution of Pennsylvanian outliers. Research objectives included determining whether the McCraney Formation is correlative to the type McCraney in Illinois; assessing the relationship between the Prospect Hill Formation and the type Hannibal Formation in Missouri; and evaluating whether some of the "St. Louis" Formation strata should be reassigned to the Ste. Genevieve Formation. 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.

The IGS also continued much needed surficial and bedrock geologic mapping of the Cedar River watershed by beginning a multi-year mapping effort in Muscatine County. This initial phase produced 1:24,000-scale bedrock geologic

maps of the Muscatine and Illinois City quadrangles which subdivided the Middle Devonian Wapsipinicon and Cedar Valley groups and initiated cross-state collaborations with the Illinois State Geological Survey (ISGS) to begin addressing lithostratigraphic nomenclatural issues across the border. Surficial geologic mapping was completed for the Wilton Quadrangle and focused on characterization of Illinoian glacial deposits and terrace mapping in the Cedar River. The IGS will continue mapping efforts in Muscatine County for the next several years.

A third project focused on surficial geologic mapping of a Hydrologic Unit Code (HUC 12) watershed in northwest Iowa by mapping the Outlet Creek HUC 12 watershed in Buena Vista County. Many questions and applications of surficial geologic mapping in Iowa are directly related to watershed issues, and therefore, the traditional quadrangle boundary is not always most useful. This approach received wide support from the IGS stakeholders. The Outlet Creek HUC 12 watershed straddles the Des Moines Lobe (DML) and Northwest Iowa Plains (NIP) landform regions (Prior and Kohrt, 2006). The DML encompasses the area that was most recently glaciated in Iowa during the late Wisconsin and is dominated by subdued topography and poorly integrated drainage networks. Extensive agricultural activity in this area has led to a host of environmental issues including elevated agrichemical and sediment load inputs to surface water bodies. The map project included the area around Storm Lake, which experiences a high volume of tourism and is also the focus of many environmental improvement programs. Ongoing projects in Powell Creek and Outlet Creek have significantly benefitted from this geologic mapping and unit characterization.

OTHER PROGRAM 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. Geophysical surveying is used alongside geologic mapping, groundwater modeling, and drilling to characterize shallow well-fields. These investigations allow water managers to make informed management decisions, assess the state of their well-fields, and help address concerns. Geophysical surveying is also used to inform geologic hazard efforts, including imaging sinkholes, karst terrain, underground mines, and landslide slopes. Passive seismic methods and seismic refraction are used by the IGS to help determine the depth to bedrock in areas lacking existing information. The IGS has also taken part in seismic monitoring with respect to induced seismicity.

Data Preservation

The IGS is working on three distinct data preservation projects. All are scheduled to be completed in June 2023.

The first project is to incorporate a dataset of over 3,800 sites containing detailed, regional alluvial stratigraphic nomenclature into IGS databases. The dataset will aid IGS geologists in the creation of surficial geologic maps and other researchers for a myriad of other research projects.

The second project is to expand its cutting storage repository area. The IGS' current cutting storage area is full. The expansion is anticipated to provide sufficient shelving space for the IGS to inventory and store cutting samples for the next 10 years.

The third project is to convert scanned geophysical logs to LAS (Log ASCII Standard) format. The IGS has scanned JPGs of over 3,000 unique geophysical logs in its archive. The conversion of scanned geophysical logs to LAS format will allow the IGS staff and others to access geophysical data in a format compatible with a variety of geologic software platforms for data modeling. Furthermore, the conversion of these data preserved in these archived geophysical logs into LAS format will be a great contribution to the search for critical minerals in the state.

Water Resources

The Water Resources Management program of the IGS evaluates the availability and sustainability of Iowa's groundwater resources and drinking water supplies. Methods employed include aquifer mapping, drilling, soils testing, well logging, geophysical surveys, water-level pumping tests, hydrogeology evaluations, groundwater modeling, and groundwater flow budget and flow path analysis. Numerical methods and modeling are used extensively to assess the feasibility of potential new well locations and well field development scenarios, simulate drought mitigation measures, and predict and reduce water level drawdown impacts, including aquifer mining and well interference conflicts between water users. The identification, characterization, and long-term management of groundwater resources is essential to promote economic growth, and to preserve Iowa's unique and vulnerable water resources for future generations.

The Iowa Geological Survey serves Iowans. The City of Decorah enlisted IGS to perform hydrogeologic mapping, geophysical surveys, aquifer pumping tests, and numerical modeling to better delineate the municipal utility's well head protection area (WHPA). Once refined, the WHPA served to focus the community's attention and limited funding on a smaller area, thereby accomplishing more cost efficient and effective source water protection. IGS provided specialty wells siting services for the City of Iowa Falls by completing a desktop survey and hydrogeologic mapping of potential groundwater supply within a proposed city annexation, along with several private sector firms and municipalities. IGS serves Iowans and industry in a variety of other ways,

including identifying potential karst features in relation to proposed mining operations, conducting groundwater modeling of quarry dewatering and its drawdown impact on nearby water wells, generating aquifer boundaries and elevation surfaces for university modeling of climate-groundwater interactions.

The Iowa Geological Survey also partnered with a variety of state and federal agencies to gain a better understanding where groundwater is most vulnerable to contamination (aquifer vulnerability mapping), provide shallow alluvial aquifer water level updates during drought, determine where conservation practices should be located in watersheds, and help quantify the effectiveness of conservation practices once they have been installed. Research focused on evaluating sediment delivery in Iowa watersheds, the performance of a saturated buffers, grass buffers, tile drainage export, and conservation siting in karst terrains.

MAINE

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INTRODUCTION

The Maine Geological Survey (MGS) was founded in 1836 with a single State Geologist. In 2022, the State Geologist oversees a staff of seven geologists, two on bedrock, one on surficial, two on hydrogeology, and two on marine and coastal geology. An eighth staff member manages GIS, web outreach, and databases in support of all geological data, map production, and USGS-compliant databases. Within a larger bureau, the survey receives part-time executive secretarial and financial support administering grants. The survey closely collaborates with (a) Floodplain Management, (b) Land for Maine's Future, (c) Land Use Planning Commission, (d) Natural Areas Program, and (e) Municipal Planning and Assistance which are all within the Bureau of Resource Information and Land Use Planning.

GEOLOGIC MAPPING

Bedrock Mapping

The focus of bedrock mapping was driven by both the U.S. Geological Survey (USGS) STATAMAP and Earth Mapping Resources Initiative (Earth MRI) programs. Bedrock investigations at the 7.5-minute quadrangle level focused on 3 different regions in Maine. In northern Maine, continued mapping of the Munsungun-Winterville Belt identified two new formations and faults. Collaboration with Chunzeng Wang of the University of Maine at Presque Isle led to two new maps, improved geochronology, and ground support for airborne geophysics flown in 2021 by the USGS Earth MRI program. A new post-Acadian St. Froid Lake Formation (Dsf) was established from this work and represents a Devonian marine or estuarine setting with terrestrial and marine fossils. A second new formation consisting of greywacke, slate, and conglomerates was named the Ferguson Brook Formation (Ofb) and is of Ordovician age. Geochronology revised the tectonic setting from peri-Gondwanan to peri-Laurentian with accretion to North America during the Taconic Orogeny.

In central Maine, the Lewiston area was a second area of bedrock focus. Urban field work and sampling helped better define stratigraphic relationships, fault types, and sequences of igneous intrusions, metamorphism, and deformation spanning from the Ordovician up through the Permian and thus spanning most of Maine's bedrock history. Igneous intrusions were dated in this region from 420 to 278 Ma. This effort helped build detailed maps for compilation in smaller scale 1:100,000 Portland, Lewiston, and Bath maps.

Coastal Maine was the focus of the third bedrock mapping effort. The mid-coast region has many peninsulas that owe their origin to complex thrust faulting, folding, igneous intrusions, and differential weathering. Ordovician volcanic arc and sedimentary sequences about Silurian flysch, and all underwent extensive metamorphism up to amphibolite

facies. Structural relations are complex and exposed along the ocean shoreline (Figure 1). MGS collaborated with David West of Middlebury College to enter over 60 years of Bowdoin College professor Arthur Hussey's field observations and maps into a digital database and merged the earlier data with new field observations to produce 4 new 7.5-minute quadrangles with detail and geologic complexity in the Bath 1:100,000-scale quadrangle.

Surficial Mapping

In central Maine, surficial mapping focused on the Unity Pond and the Belgrade Lakes areas where Quaternary deposits created hilly topography and multiple lakes. The Belgrade area, just north of the state capitol in Augusta, was made famous in the movie *On Golden Pond* and is the source of commercial aggregate extracted from glacial till, moraines, and eskers. Exposed bedrock striations helped reconstruct the history of Laurentide ice flow. Mapping the extent of pro-glacial lakes and glacial marine mud identified the extent of late-glacial marine incursion around 12,000 radiocarbon years ago into interior Maine. Along unconfined slopes, such as river meanders, these unconsolidated marine sediments are prone to landslides so surficial mapping helps identify potential geohazards. This effort was funded through STATEMAP and resulted in both surficial geology and surficial materials maps three 7.5-minute quadrangles: Norridgewock, Unity, and Unity Pond. These maps help fill in the Skowhegan 1:100,000-scale quadrangle.

OTHER PROGRAM HIGHLIGHTS

Critical Mineral Discovery

Years of bedrock geologic mapping in northern Maine led to an Earth MRI-funded project led by Anji Shah of the USGS in the summer of 2021. An airborne geophysical survey identified a radiometric anomaly at Pennington Mountain about 40 miles northwest of Presque Isle. Elevated concentrations of 17 rare earth elements plus the elements niobium and zirconium were found in a brecciated trachyte. The geophysical data led to a more thorough field effort to map the extent of the minerals at the surface, collect samples for laboratory study, and to better understand the genesis and nature of mineralization. Swift scientific collaboration among USGS, MGS, and academic institutions produced results to be published in the December 2022 issue of the journal *Economic Geology*.

Rock Core Archives

Maine reviewed needs for improved drilled rock core storage, preservation, and scientific access. MGS is a repository of 75,000 linear feet of core in Augusta with another 66,000 feet in Presque Isle. This archive is estimated to have a value of around \$200 million and represents some locations that could no longer be redrilled should the existing samples be

damaged or lost due to neglect. With a national interest in critical minerals and metallic commodities, the existing archive needs improved curation and a facility that can accommodate further investigations, analysis, and accessibility.

Coastal and Marine Mapping

Collaboration with the National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management led to geomorphic maps of the Gulf of Maine seafloor along the Maine coast. Marine geologic mapping produced a digital layer of “Geoforms” interpreted from bathymetry, multibeam backscatter, and sediment samples. These data compliment the Coastal Marine Ecological Classification scheme used for habitat mapping. The effort included joint mapping off New Hampshire and Massachusetts to make a regional map of features and bottom types in an area of multiple uses including ground fishing, lobstering, species migrations, shipping, and potential offshore wind energy. Results will be available through the Northeast Ocean Data Portal in 2023.

Coastal erosion monitoring resulted in synthesis of dune changes, migration of the high-water line, and shore-normal beach profiles. Results and trends were released in a State of Maine’s Beaches in 2022 report along with online access to custom mapping. In addition to erosion, multiple online tools allow analysis of high-resolution inundation mapping of storm surge and sea level rise scenarios. Additional hazards can be evaluated by comparing water levels in the Federal Emergency Management Agency Flood Insurance Rate Map with elevations of coastal engineering structures for overtopping vulnerability. Another mapping option is to examine the suitability of shorelines for possible living shoreline construction. The Maine Geological Survey also posts monthly verified NOAA tide gauge data on a sea level rise ticker and a more in-depth dashboard with sea level rise trends and projections. Geologists helped produce the Maine Climate Science Update 2021 for the Maine Climate Council.

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 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
- Periodically assess the paleontological resources of the State

These responsibilities remain incorporated into the Code of Maryland Regulations. In 1969, the Survey was 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 19 scientists, 1 full-time support, and 1 part-time support. In 2021, MGS had a significant turnover with the loss of several scientists moving on in their careers, deciding to further their education and follow their passions. MGS was able to recover with the hiring of Kirk Marks, Rubina Firdous, Anthony Reisinger, and Joe Allman.

GEOLOGIC MAPPING

Bedrock Mapping

MGS continued bedrock mapping through the U.S. Geological Survey (USGS) STATEMAP program in 2021–2022 with the submission of draft geologic maps for the Kitzmiller, Relay, and Gaithersburg 1:24,000-scale quadrangles. The geologic mapping continues our long-term strategy in the Appalachian Plateau and Piedmont physiographic provinces.

MGS began new geologic mapping in the Rockville, Savage, Gorman, and Mt. Storm quadrangles in 2021. This new mapping furthers work in the Appalachian Plateau as well as the Maryland Piedmont which continues to experience suburban development at a very high rate.

The STATEMAP USGS program is also funding the compilation and conversion of geologic maps to GIS formats including a 1:100,000-scale regional map covering Washington and Frederick Counties and 1:24,000-scale geologic maps of Emmitsburg and Taneystown.

Mapping funded by the USGS Earth Mapping Resources Initiative (EarthMRI) continues in the Blue Ridge Summit

quadrangle at 1:24,000 scale, which will complete the mapping of all of Maryland's Blue Ridge province. This funding is also being used for the conversion of six other 1:24,000-scale Blue Ridge geologic maps into GIS format using the USGS GeMS database format.

Mineral Mapping

Through the USGS EarthMRI program, Maryland Geological Survey initiated work on a grant to study volcanogenic mineralization in the Westminster Terrane in Maryland's western Piedmont. This project is the second EarthMRI study undertaken by the survey. Geologists are currently mapping and sampling mineralized zones in interlayered carbonate and volcanogenic rocks and overlying soils of eastern Frederick County and western Carroll County, Maryland. Mineralization consists of a broad range of copper, iron, zinc, and magnesium minerals formed mainly at or near the contact of these two units that is interpreted to be the result of emplacement by primary fluids associated with volcanism. Initial results from portable X-ray fluorescence (XRF) testing indicate high manganese content in soils overlying carbonate rocks and near contacts with volcanic rocks. New maps of bedrock distribution and mineralization at 1:24,000 scale are in process and will be completed using new aeromagnetic data flown by the USGS Appalachian transect. Once completed, the resulting maps will be made available as GIS shapefiles and in the USGS GeMS geodatabase format.

Land Subsidence Mapping

MGS continues to work with other government agencies and universities to collect high-precision GPS satellite observations at 55 geodetic benchmarks surrounding Chesapeake Bay annually. Data from multiple years' surveys will be used to better isolate short-term changes in land subsidence due to human activities such as groundwater extraction, from long-term geologic signals such as glacial cycles and deep Earth processes. The findings will be used to produce revised maps depicting the variability of land subsidence, and will also be used to improve models that predict possible effects of land subsidence and aquifer management decisions on critical wetland habitat.

OTHER MAJOR ACCOMPLISHMENTS

Riverine Impounded Sediment Characterization

MGS staff completed a study of the subsurface geologic conditions and sediment properties within the Daniels Dam impoundment located on the Patapsco River in Howard and Baltimore Counties, Maryland. Similar work was previously completed prior to the removal of two downstream dams, Simkins Dam in 2010 and Bloede Dam in 2019. The Patapsco River Valley containing the Daniels Dam impoundment

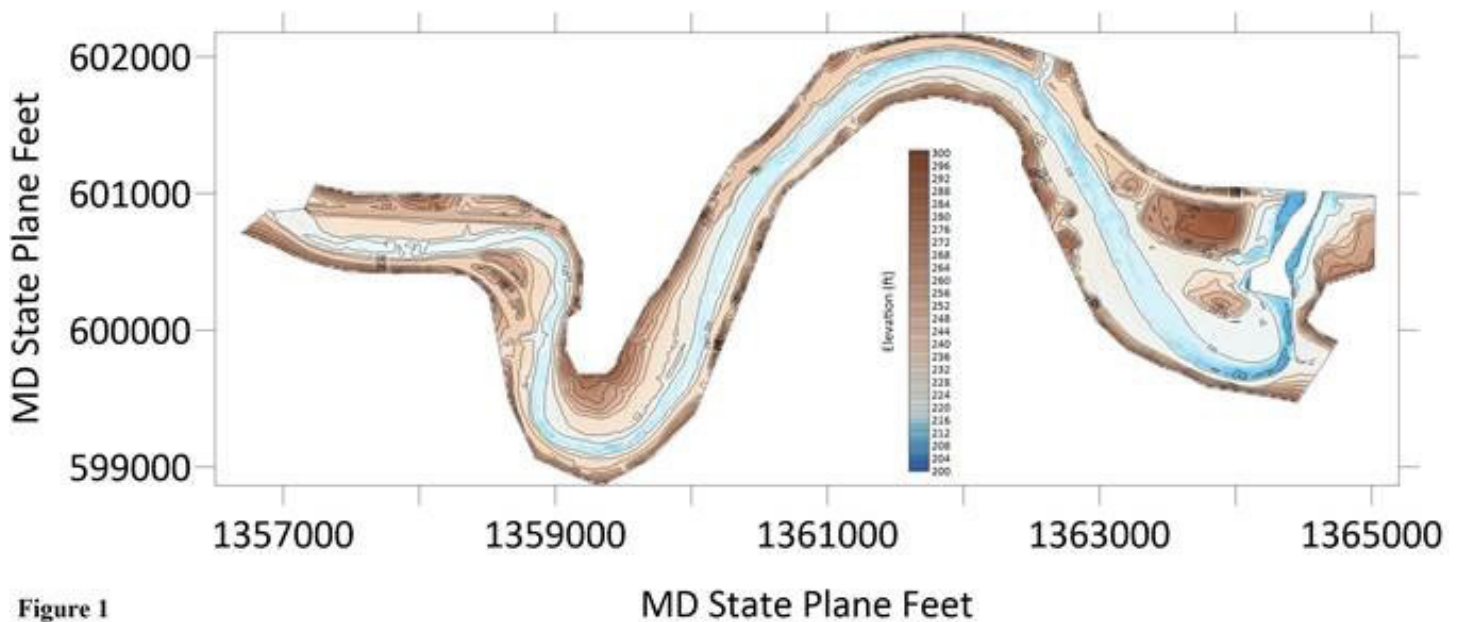


Figure 1

Figure 1. Map showing the current surface elevations of the Daniels Dam impoundment and surrounding area. The Patapsco River flows from west to east with the dam located to the east.

is underlain by ancient, hard, crystalline formations. The Daniels Dam impoundment itself crosses through three major rock formations: The Precambrian-age Baltimore Gneiss, the Setters Formation Schist/Quartzite and the Loch Raven Schist, the latter two both of latest Precambrian to Ordovician age. The Daniels Dam itself takes advantage of an outcrop of the erosion-resistant Setters Formation along its eastern edge. Within the immediate vicinity of the Dam, bedrock formations dip steeply to the North, although the submerged areas and impoundment have filled in with sediments. Subsurface data were collected within the impoundment using acoustic seismic equipment. Seismic data were analyzed in an attempt to determine the depth-to-bedrock underlying the unconsolidated sediments. The current surface elevations were mapped using a combination of bathymetry, traditional total station surveys, and high-resolution lidar (Figure 1). Bathymetry data were collected for the entire navigable extent of the impoundment with traditional total station data collection performed in the unnavigable extent. Lastly, lidar data were used to identify emergent floodplain deposits along the river banks. Cores were then collected at twelve locations to characterize the physical and chemical properties of the sediment, and to test for the presence of specific pollutants. The fieldwork for this study occurred between November 2021 and July 2022. The resulting data will be utilized by State and Federal agencies to determine the feasibility of potential dam removal and release or removal of the impounded sediments.

National Groundwater Monitoring Network

MGS and the USGS work together under an annual Joint Funding Agreement to collect water level data from approximately 460 wells throughout Maryland. We share

the concerns of other agencies and organizations which monitor our nation's groundwater – that the collected data should be reliable, consistent, and comparable. Many of the wells used to collect water-level data are valuable long-term data sources, but for this reason, they are also vulnerable to deterioration or blockage related to their old age and lack of pumping. To help accomplish our goal of collecting and presenting quality data, MGS has received funding in recent years through the USGS National Groundwater Monitoring Network (NGWMN) grant to conduct GPS and total station surveying and well integrity testing on a subset of 112 wells that compose the Maryland NGWMN network. Slug testing and well-camera surveys conducted with help from the grant have identified numerous problem wells that will require repair, redevelopment, or replacement.

Mid-Atlantic Stratigraphic Reconciliation Initiative (MAtStrat)

MGS geologists continue to participate in an effort to identify known conflicts in regional stratigraphy, create strategies for reconciliation, and determine implications for the correlation of regional aquifers and geologic resources. In the past year, MGS geologists collaborated with our counterparts at the Delaware Geological Survey to conduct continuous coring at two sites in Maryland in order to better define the coastal plain stratigraphy near our common border.

A similar project is being conducted in western Maryland between Virginia, Pennsylvania, West Virginia, Maryland, and the USGS.

MASSACHUSETTS

MASSACHUSETTS GEOLOGICAL SURVEY

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INTRODUCTION

The Massachusetts Geological Survey (MGS) is housed in the Department of Earth, Geographic and Climate Sciences (recently changed name) at the University of Massachusetts Amherst campus. The State Geologist reports ultimately 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 state geologist is the only state-funded position. There is no state support for staff or operations. This reporting year the focus was working on the Massachusetts Top-of-Rock Project.

GEOLOGIC MAPPING

During the year MGS continued to collaborate with the U.S. Geological Survey to complete the statewide Quaternary Geologic Map of Massachusetts as a companion to the statewide bedrock geologic map. The Massachusetts Geological Survey's contribution to the map is to provide 20-meter structure contours of the bedrock surface in the major river valleys and areas of thick glacial stratified deposits. The Quaternary map will be at 1:100,000 scale and based entirely on 1:24,000-scale mapping.

Most of the year was spent building a database of subsurface points described in drill holes and geophysical surveys and beginning the work of creating a map of the altitude of the top of bedrock surface. Over 107,700 subsurface points from 28 different data sets and over 65,000 mapped bedrock outcrops were entered in the database. In addition, a model was created of the shallow-to-bedrock areas (areas where bedrock is less than 10 feet deep, or where there are so many outcrops that they are too numerous to map at 1:24,000 scale) using curvature and slope providing a total of 681,000 data points with bedrock altitudes. The state was discretized into a 100-meter grid and bedrock altitudes assigned in the grid cells according to a prescribed allocation scheme. The next step is to test and evaluate various automated techniques of modeling the bedrock surface. A data release of the well and geophysical data will be published soon.

Building the database of subsurface points also included collecting passive seismic survey data (Horizontal to Vertical Spectral Ratio, HVSr) to estimate depth to bedrock in areas where well data were sparse. Five students were hired to fan out across the state and collect passive seismic survey data during the summer of 2021. A total of 401 measurements were made and added to the database of subsurface points.

The Massachusetts Top of Rock Project work is being done in concert with the New England Top of Rock effort by the USGS and, also supports the U.S. GeoFrameworks Initiative currently underway.

WATER RESOURCES

Well Driller's Database

Massachusetts requires every driller that completes a test boring, test hole, water supply well, geothermal well or monitoring well to complete a well completion report and submit it to the Massachusetts Department of Environmental Protection (MADEP). This report provides information such as total depth, depth to bedrock, water level, casing length and some stratigraphic information, etc. There are currently 204,432 wells in the database. However, only 65,855 (32%) have actual street addresses and can be matched to the statewide parcel data. MGS is working with MADEP to help verify street addresses for the remaining wells with no or invalid addresses. The work involves going town by town, one well record at a time, and tracing well owners and property transfers in the Registry of Deeds and examining assessor's data and subdivision plans until the homeowner of record is verified with a valid street address. The well is then manually moved to the correct parcel using an online mapping tool provided by MADEP. About 12 percent of MGS time was spent helping with this validation process. The validation process, though tedious, has raised the percentage of wells in the database with valid street addresses from 32 percent to 73 percent. When the project is complete, it is estimated that this will provide an additional 80,000 wells to the Massachusetts Top of Rock database. This information will help the U.S. GeoFrameworks and the National Borehole Inventory initiatives.

Climate Response Network

The MGS continues to contribute to the Climate Response Network, a network of over 70 wells, used to monitor ground water levels across the state. 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 Recreation and Conservation and the MADEP. 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.

OTHER PROGRAM HIGHLIGHTS

Hazards

The Brimfield schist and Partridge Formation are part of an extensive pyrite-pyrrhotite-bearing sulfidic schist belt that stretches across eastern Connecticut and central Massachusetts into New Hampshire. Concrete batched from aggregate containing pyrrhotite has caused severe damage to tens of thousands of homeowner foundations in northeast Connecticut and south-central Massachusetts. Originally it was thought the tainted aggregate came from one quarry in Connecticut. New data show crumbling foundations in central Massachusetts, a distance that is too far from the Connecticut quarry. It is now believed some pyrrhotite-bearing aggregate is sourced in Massachusetts. A new bill was submitted in January 2022 requiring testing of aggregate from Massachusetts quarries. MGS provided written testimony to the appropriate committees.

Earth MRI

A proposal was submitted in collaboration with the Connecticut Geological Survey in fall 2021 to the Earth Mapping Resources Initiative (Earth MRI) program requesting funds to conduct airborne geophysical surveys in eastern Connecticut and central Massachusetts. The surveys focus on the mafic magmatic, basin brine path, granite-related porphyry and metamorphic mineral systems. Geophysical targets are deposits of the Central Atlantic Magmatic Province that include conduit style mineralization from the various basalt extrusives, epithermal base metal and barite vein deposits, as well as stratabound and fault breccia occurrences in Mesozoic basin fill deposits, pegmatite districts in both states with known past mining for Li and Be, and Ordovician to lower Devonian metamorphic rocks of the Brimfield schist (Connecticut) and Partridge Formation (Massachusetts) that comprise the sulfide belt of Connecticut and Massachusetts and contain known occurrences of graphite that have been mined in the past. The proposal was not funded but will be resubmitted in 2022.

New England States Geologic Mapping Coalition

In fall 2021, the Maine Geological Survey received a grant on behalf of the Coalition from the USGS National Collaborative Geologic Mapping Program (NCGMP) Phase 3 Geologic Synthesis project. The purpose of the grant is to identify, research, and summarize cross-border stratigraphic inconsistencies and recommend strategies to address these inconsistencies; all in an effort to support the USGS Geoframeworks Initiative. Massachusetts will subcontract with the Maine Geological Survey. Work is expected to commence in early 2023.

MICHIGAN

MICHIGAN GEOLOGICAL SURVEY

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INTRODUCTION

As of 2022, the Michigan Geological Survey (MGS) has been functioning in the Geosciences Department at Western Michigan University for 11 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 the first annual funding for the survey in over 30 years and this will allow MGS to hire professionals to support the current societal needs for the State of Michigan going forward. This includes mapping and data compilation not done in a formal manner during that 30 years. The MGS had received incremental state appropriations and awarded grants totaling more than \$1.3 million in the last three years. These grant funds helped focus MGS to present the initial assessment of natural resources and were used to conduct research and 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, Wellogig. The MGS is extremely grateful for these legislative and recent project grants and these programs can now be expanded with annual funding to meet the societal benefits. Like many other surveys, MGS was impacted by COVID-19. Most critical was the layoff of university geologists who would have supported MGS projects, something we have recovered from at this time, but will going forward with funding.

The MGS, like all state surveys, wants to be recognized as the “go-to” resource for geologic information in the state, so marketing our capabilities is a top priority.

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 (per- and polyfluoroalkyl substances). 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 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. The impacts of PFAS present a case in which most technical experts cannot say where groundwater is flowing because most of the subsurface glacial 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 John Yellich supported by Dr. Robb Gillespie. 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 (1:62,500). This will also 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 rotosonic or wireline core, and (or) Geoprobe drilling program; downhole geophysical logs; and Tromino passive seismic, horizontal to 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 water and aggregate resources; and determining the groundwater flow direction and estimated projected rate of flow. The past two years, MGS has expanded the mapping program and has presented this to the state stakeholders in sensitive high-water-use areas and areas having need of future water and aggregate resources so that these areas can be identified and not impacted or excluded from development by changing land use.

CURRENT ACTIVITIES

The Director, John A. Yellich, has continued road and virtual presentations in 2021 and 2022 by attending 140 meetings in the last six months, making six PowerPoint presentations (virtual and in person), testifying to three State legislative committees, and the Michigan House and Senate, to both introduce the reinvented survey and present the need for quality data to meet the needs of critical stakeholders in the state and the US. This includes meetings with the directors and chiefs in the Michigan Governor's Department of Environment, Great Lakes, and Energy; Department of Natural Resources; Department of Agriculture and Redevelopment; 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 and city growth. This includes identification, assessment, protection, and development of natural resources and the new assessment: Critical Minerals. This is data collection to support the management of natural resources (specifically, 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 functional geological resource research for more than 30 years, and all of these presentations and meetings for the last nine years has provided justification for annual funding for the Survey.

The MGS has had productive discussions during the past five years with the USGS Mineral Resources and Mapping groups in both Reston, Virginia, and Denver, Colorado. These discussions have resulted in a USGS aeromagnetic survey in the UP of Michigan, the first open file report on geophysical data for Michigan in decades. This geophysical mapping product will now be used to support a critical minerals grant for surficial geologic mapping in Dickinson County of the UP. This is a collaboration with Michigan Technical University over two years. A second opportunity to support Critical Minerals assessment of the UP of Michigan will be in 2023–2025, mapping in areas with new airborne geophysical data to better quantify the location of the geology in the UP. The third opportunity is a 2019–2022 collaborative program for

a USGS FEDMAP project in the Michigan Lowland Basins, 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 DATA 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 CO₂. 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 nine 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

MGS - geologic projects, today, Eastmanville Farm



Coring, monitor well installation, purging well



Drift/till-
130'
Marshall

1

Figure 1. Michigan Geological Survey, mapping, coring, installing monitor wells for statewide groundwater monitoring network.

research and study CO₂ sequestration in Michigan through a DOE grant and new federal bipartisan infrastructure law funding, creating additional opportunities to assess carbon sequestration and hydrogen storage in Michigan, one of the largest gas storage areas in the US.

The MGRRE has received grants from the USGS National Geological and Geophysical Data Preservation Program (NG-GDPP), which has been functioning for more than 11 years. For the past few years of grant funding, the project scanned and inventoried gas chromatograph sample analyses. Paper copies of the data were reviewed for clarity and organized for scanning and data entry and thin sections have been scanned to a database.

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 CO₂ storage. Additionally, six 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 and 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 final stages of development and permitting. Following is the USGS article from January 2017: [link](#).

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 and MGRRE had a program in October 2022. These workshops and conferences focus on relevant topics in the petroleum industry and are attended by more than 110 industry professionals.

GROUNDWATER RESOURCES, ENVIRONMENTAL QUALITY, AND ENERGY

The MGS has been asked to sit on the Governor’s select water advisory group, the Water Use Advisory Council (WUAC), 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. The WUAC presented recommendations to the Governor and Legislature in December 2020 and included in a Michigan signed budget bill in April 2022 was \$10 million for WUAC projects and \$3.0 million for MGS to initiate geologic mapping projects in Michigan.

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 through the MGS website, now free because MGS has staff to support data requests.

The MGS continues to search for many older Michigan publications and paper resources that can be input into the document 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 8,500 publications on Michigan geology, 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 eight 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 five years. Teachers are seeing the benefits of these programs, and the MGS hopes to incorporate this into the state K–12 program going forward.

MINNESOTA

MINNESOTA GEOLOGICAL SURVEY

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INTRODUCTION

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

We spent \$3.4 million this past year, similar to the level of the year before. MGS annual funding averaged \$2.4 million from 2003 to 2011, and the average since then has been \$3.2 million. MGS relies on about \$1.2 million in base funding and about \$2.2 million in grants and contracts, primarily from the Environment and Natural Resources Trust Fund (ENTRF). Additional funding from both sources covers non-personnel costs such as travel, drilling, equipment, supplies, and services. Funding also is provided by U.S. Geological Survey (USGS) data preservation, geological mapping, and minerals programs.

MGS staffing was stable at 28 full-time-equivalents (FTE) from 2003 to 2011; since then, staffing has averaged 36 FTE. Last year, MGS was one of 14 state geological surveys in the United States whose staff is 40% or more female. This compared to 38% nationwide. We currently are 24 geologists, 4 information professionals, 2 administrative staff, and 6 students equivalent to about 4 FTEs.

After being formed in 1872, MGS was on the University of Minnesota campus in Pillsbury Hall from 1890 until 1970. After a brief stay in Jones Hall, MGS moved off campus in 1970 to a building on Eustis Street in Saint Paul, followed by relocation to University Avenue in Saint Paul in 1983. In 2015, we moved to our current location on Territorial Road in Saint Paul. The new building has worked out well. Nearly every desk is in use, and the fit and function of the facility are very good.

GEOLOGIC MAPPING

Mapping at a resolution of 1:24,000 and a publication scale of 1:100,000 is focused on the CGA projects that are underway. Mapping is being compiled as seamless 1:100,000 surficial and bedrock databases that only cover counties with a complete Atlas, and also as consistent statewide 1:500,000 maps and incrementally updated databases. The most recent state bedrock map was published in 2011, and a Precambrian map followed in 2012. In 2020, a database for a state basement map, from which Precambrian cover rocks had been removed, was released. A new state Quaternary map was published in 2019, largely funded by a 1:1 cost-sharing agreement with the Great Lakes Geologic Mapping Coalition of the USGS. This multi-year project stitched together many maps created by the CGA program and other mapping programs, and also filled in areas not yet mapped at the more detailed scale. New CGA mapping will be added to the database. Subsurface Quaternary geology is being mapped statewide as cross-sections at a 5-kilometer spacing.

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 the Minnesota Department of Natural Resources (DNR). Atlases are complete for 45 of 87 counties and of these, 5 have been revised and 2 revisions are underway. There are 26 new atlases underway; 16 counties have not yet been started. At the current pace and a completion rate of approximately 5 counties per year, statewide coverage will be achieved within a decade. We then plan to focus on ongoing updating of statewide databases at two levels of resolution.

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



Figure 1. Minnesota Geological Survey Staff, May 2022.

distribution of sediments and rocks in the subsurface, and a Part B constructed by DNR that includes maps of water levels in aquifers, direction of groundwater flow, water chemistry, and sensitivity to pollution. We also coordinate with DNR aggregate mapping, and with Natural Resources Research Institute (NRRI) mineral potential research.

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.

graphic units. A noteworthy recent discovery is evidence for a buried meteorite impact crater near Inver Grove Heights, Minnesota. This was found by MGS geologists while mapping the bedrock geology of Dakota County for the County Geologic Atlas.

OTHER PROGRAM HIGHLIGHTS

In coordination with state agencies, MGS manages several important geological and geophysical databases and collections that support our mapping, and activity by others across the state. The largest and most commonly used is the water well database, which includes records for more than 600,000 wells, of which about 70 percent have accurate digital locations. We interpret the driller's description of the materials encountered in drilling and assign rock types and formation names. We work closely the co-manager of this database, the Minnesota Department of Health (MDH). As another example, we are in the third year of a comprehensive enhancement of the MGS collection of ~5,860 sets of drill cuttings.

MGS undertakes much research that is needed to optimize our mapping, such as enhanced hydrogeological characterization of sediment and rock strata. Our research most commonly is funded through state sources, as the results have direct applications to societal issues. We continue to support multiagency efforts to address PFAS contamination in the eastern metro by providing maps, data, and guidance for the construction of models to inform how to best provide clean drinking water for people in the region. This work was funded via the Minnesota Pollution Control Agency from the 3M PFAS/PFC settlement with the State of Minnesota. We also are continuing with efforts to better understand nitrate transport in southeastern Minnesota, by providing information necessary to more accurately determine whether improvements in agricultural practices are improving groundwater quality in the region. We are working with university colleagues on the feasibility of aquifer storage and recovery to alleviate groundwater quantity problems where aquifer drawdown has impacted baseflow to streams and lakes. We also are collaborating with university and federal partners on drainage issues in the Twin Cities. We are supporting MDH watershed planning under the Groundwater Restoration and Protection Strategies (GRAPS) - including compilation of Quaternary and bedrock geology for five watersheds—Zumbro, St. Louis, Cannon, Missouri, and Redeye. We also are supporting USGS work in coordination with the Department of Defense regarding a groundwater flow and transport model for the Twin Cities Army Ammunition Plant (TCAAP), by providing 3D geology to support definition of hydrostrati-

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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 comprised of four divisions: Environmental Geology (includes drilling equipment and staff, geophysical wireline logging, and core and sample library), Geospatial Resources (flood risk mapping, hydrography, orthoimagery, and lidar), Mining and Reclamation (state primacy over mining), and Surface Geology (geologic mapping program).

GEOLOGIC MAPPING

Ten STATEMAP-funded and National Park Service-funded geologic maps were published in fiscal year 2022, including 7.5-minute geologic map of Ridgeland (revised), 7.5-minute geologic map of Widows Creek; 7.5-minute geologic map of Raymond; 7.5-minute geologic map of Clinton; 7.5-minute geologic map of Pocahontas, 7.5-minute geologic map of Baldwin, 7.5-minute geologic map of Fulton NE, 7.5-minute geologic map of Cranfield, 7.5-minute geologic map of Kirby; and the 7.5-minute geologic map of Red Lick 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, varied from Late Cretaceous to Miocene in age. Surficial units include Pleistocene loess and river terraces and Holocene alluvium. A county geologic map of Jefferson County is in progress based on a compilation of STATEMAP grant work.

OTHER PROGRAM HIGHLIGHTS

The Environmental Geology Division ran wireline geophysical logs on 43 test holes and water wells during fiscal year 2022, collecting 23,145 feet of data. The Core and Sample Library hosted 12 visitors; most were from oil and gas companies. Cores and cuttings representing 32 wells were requested. Staff pulled and restocked 235 boxes of cores and cuttings representing 23,700 feet of well data. Staff re-boxed 98 boxes of cores and samples representing 23,700 feet of well data. Sample splits were done on three wells amounting to 8,000 feet of samples shipped to interested entities. The Geospatial Resources Division managed the Mississippi Flood Map Modernization Initiative and the Mississippi Digital Earth Model (MDEM). In fiscal year 2022, Preliminary Flood Insurance Rate Maps covering portions of eleven counties were released to the local communities for review, and eight counties had their new mapping become effective for the flood insurance and flood plain management purposes. In fiscal year 2022, the Division took delivery of color 12-inch

and 6-inch orthoimagery from contractors covering six counties collected in the 2020–2021 Mississippi Coordinated County Orthoimagery Project and three counties collected by MDEQ's contractor. Late in fiscal year 2022, the Division received its copy of over 6,600 square miles of Quality Level 2 (QL2, 0.7 m) lidar collected and processed by U.S. Geological Survey contractors and funded by the Natural Resource Conservation Service as part of the National 3D Elevation Program (3DEP). The Mining and Reclamation Division preformed 662 inspections in fiscal year 2022 and recommended to the MDEQ Permit Board the issuance 20 initial and 7 amended permits and received 50 Notices of Exempt Operations (less than 4 acres in size). A total of 1,627 bonded acres were completely reclaimed as a result of the Division's oversight. The state currently has 601 permits covering approximately 34,515 acres. The Surface Geology Division has a social media outreach through posts such as #FossilFriday and through the Ask a Geologist portal on the MDEQ website, and was a large contributor to the office's 32 published works.



Figure 1. Core hole through the Cretaceous–Paleogene boundary (Prairie Bluff Chalk–Clayton Formation contact) drilled on August 1, 2022, in support of the Starkville 7.5-minute quadrangle geologic map. The image shows geologists, drillers, GIS staff, and our Failing 1500 drilling rig and water truck with drill stems.

MISSOURI

MISSOURI GEOLOGICAL SURVEY

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INTRODUCTION

The Missouri Geological Survey (MGS) is one of five Divisions of the Missouri Department of Natural Resources. Since 1853, MGS has provided essential geoscience information to steward decision-making that helps protect Missouri's natural resources and encourage economic development. These efforts are provided via 115 full time employees that support six organizational programs. General functions of these programs include:

- Administration
- Geologic activities such as bedrock mapping, mineral and energy resource assessments, geologic hazards, and groundwater protection
- Dam and reservoir safety
- Reclamation of surface coal, metallic, and industrial minerals mines
- Safe water resource planning
- Soil and water conservation cost-share practices

GEOLOGIC MAPPING

Bedrock Mapping

Through the National Cooperative Geologic Mapping Program (NCGMP) STATEMAP Program, MGS completed bedrock mapping of 11 7.5-minute quadrangles (Fayetteville, Higginsville, Knob Noster NW, Lexington East, Lexington West, Mayview, Odessa North, Odessa South, Pittsville, Warrensburg East, and Warrensburg West) along the western I-70 corridor in the Kansas City metropolitan area. New mapping refined existing, generalized mapping of Pennsylvanian-age stratigraphy and geologic structures. In addition, MGS implemented the 1:500,000-scale geologic map of Missouri into a database compliant with the U.S. Geological Survey (USGS) Geologic Map Schema (GeMS). This project addresses the USGS GeoFramework Initiative to construct a multi-resolution and seamless national 2D and 3D geologic model.

USGS Earth Mapping Resources Initiative (Earth MRI)-funded bedrock geologic mapping of the Fredericktown 7.5-minute quadrangle was completed in August 2021. The quadrangle contains major mines of the Fredericktown-Mine La Motte lead-zinc subdistrict, which produced cobalt and nickel in the past. The area also contains the current operations of Missouri Cobalt, currently working to recover cobalt from tailings and potential new underground mining. New mapping addresses sedimentary facies, previously undefined igneous units, geologic structures, and mineralization indicators. MGS will be continuing this mapping in three

quadrangles contiguous to the Fredericktown 7.5-minute quadrangle, also with Earth MRI funds.

As part of an ongoing Challenge Cost-Share Agreement with the U.S. Forest Service – Mark Twain National Forest (MTNF), MGS completed reconnaissance field mapping for two 7.5-minute quadrangles (Bardley and Many Springs) in the Eleven Point Ranger District located in south-central Missouri. Detailed geologic mapping of this District is critical to the work of the MTNF Terrestrial Ecology Inventory Unit.

OTHER PROGRAM HIGHLIGHTS

MGS hosted the first in-person Digital Mapping Techniques (DMT) workshop since 2019. The event was held May 22–25, 2021, on the Missouri University of Science and Technology campus. DMT was attended by almost 70 geology professionals from USGS, state surveys, and other professional organizations.

Earth MRI funding, passed through the National Geological and Geophysical Data Preservation Program (NGGDPP), supported entry of 1,000 core logs into an MGS core log database. Logs entered were in prospective critical mineral areas, contained intercepts of Precambrian igneous rocks, or had associated geochemical data. The logs contain unit descriptions and contacts, as well as descriptions of mineralization or associated indicators. Numerous logs contain associated geochemical assays. The data are useful for stratigraphic modeling, support 3-D framework initiatives, and can aid development of structure contours for both subsurface and surface geologic mapping and models. MGS is continuing this work, and is adding an additional 1,000 core logs in the current grant cycle.

MGS is also participating in a multi-state, Earth MRI-funded project to look at critical mineral potential in Ordovician phosphate rocks, and will begin a similar project for Pennsylvanian black shales. In addition, MGS is working with multiple states on a Department of Energy-funded project for critical mineral potential in coals.

NGGDPP funds supported scanning and indexing of MGS Mineral Resource files, which contain unpublished data on multiple commodities, including critical minerals found in Missouri. The files contain a wide variety of data unavailable elsewhere, including logs, maps, unpublished reports, geologic notes, chemical analyses, photographs, and correspondence related to the commodities. Numerous critical mineral occurrences are only noted within these files. MGS is continuing this project in the current NGGDPP grant cycle.

MGS is currently involved in a multi-state project to reconcile Pennsylvanian stratigraphic nomenclature across state boundaries.

NEBRASKA

CONSERVATION AND SURVEY DIVISION

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**CONSERVATION AND
SURVEY DIVISION**

School of Natural Resources

INTRODUCTION

The Conservation and Survey Division (CSD) is Nebraska's geological, groundwater, and soil survey. CSD is unique in that it is part of the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln. CSD personnel include ten faculty and six professional staff. During the past year, CSD personnel were involved in more than \$3 million of external funding for research, outreach, and extension work. They answered more than 300 requests for data and analyses and served approximately 3,000 stakeholders and dozens of organizations and programs. CSD personnel also produced 20 peer-reviewed scientific journal articles and numerous other publications. The Nebraska Water Leaders Academy, a year-long program for professionals, is managed and supported by CSD faculty. CSD faculty also teach multiple courses at the university.

GEOLOGIC MAPPING

CSD personnel completed 1:24,000-scale surficial geologic maps during the year as part of the STATEMAP Cooperative Geologic Mapping Program. CSD cooperated with U.S. Geological Survey personnel in the compilation and digitization of bedrock and surficial geological maps of the state at scales of 1:250,000 and greater. Every year, CSD publishes the Nebraska Statewide Groundwater-Level Monitoring Report, which includes multiple maps depicting groundwater levels and groundwater-level changes over various time scales. CSD personnel also produced the educational story maps "Sand Hills Groundwater and Streams" and "Red Pivots and Nitrate." The latter corresponds to a peer-reviewed journal article investigating the correlation between rust-coated irrigation pipes and groundwater nitrate concentrations in parts of the state.

OTHER PROGRAM HIGHLIGHTS

CSD unveiled its first-ever online Interactive Data Map (snr.unl.edu/csd/map), which includes data sets such as airborne electromagnetic (AEM) flight lines (see Nebraska GeoCloud, below), aquifer outlines, groundwater levels, groundwater-level changes, test-hole data, registered wells and bedrock and basement geologic maps. More data sets will be added soon. The CSD Geological Sample Repository provides data and access to geological sample analysis to academics and to petroleum, carbon capture and storage, and critical minerals; the core database was augmented with metadata, part of improvements funded through grants from the U.S. Geological Survey. CSD also released new data and developments in Nebraska GeoCloud ([link](#)), a web platform for 2D and 3D visualization of subsurface data and models. CSD personnel published research on a variety of subjects, including geophysical surveys of underground

mines, the Cenozoic hydrostratigraphy of western Nebraska (Figure 1), geogenic contaminant mobilization, the effects of microbial activity and temperature on the formation of vesicular pores in soils, far-traveled glacial erratics, and integrated water management in the Nebraska's Platte River basin. CSD personnel continue to research the morphology and evolution of dunes in the Nebraska Sand Hills, regional Pennsylvanian stratigraphy, critical minerals in the Forest City Basin, High Plains Cenozoic stratigraphy and ancient rivers, Pleistocene to Holocene evolution of the Platte River system, Nebraska structural geology and basement rocks, human dimensions of natural resources, machine learning applications in hydrology, and numerous other subjects.

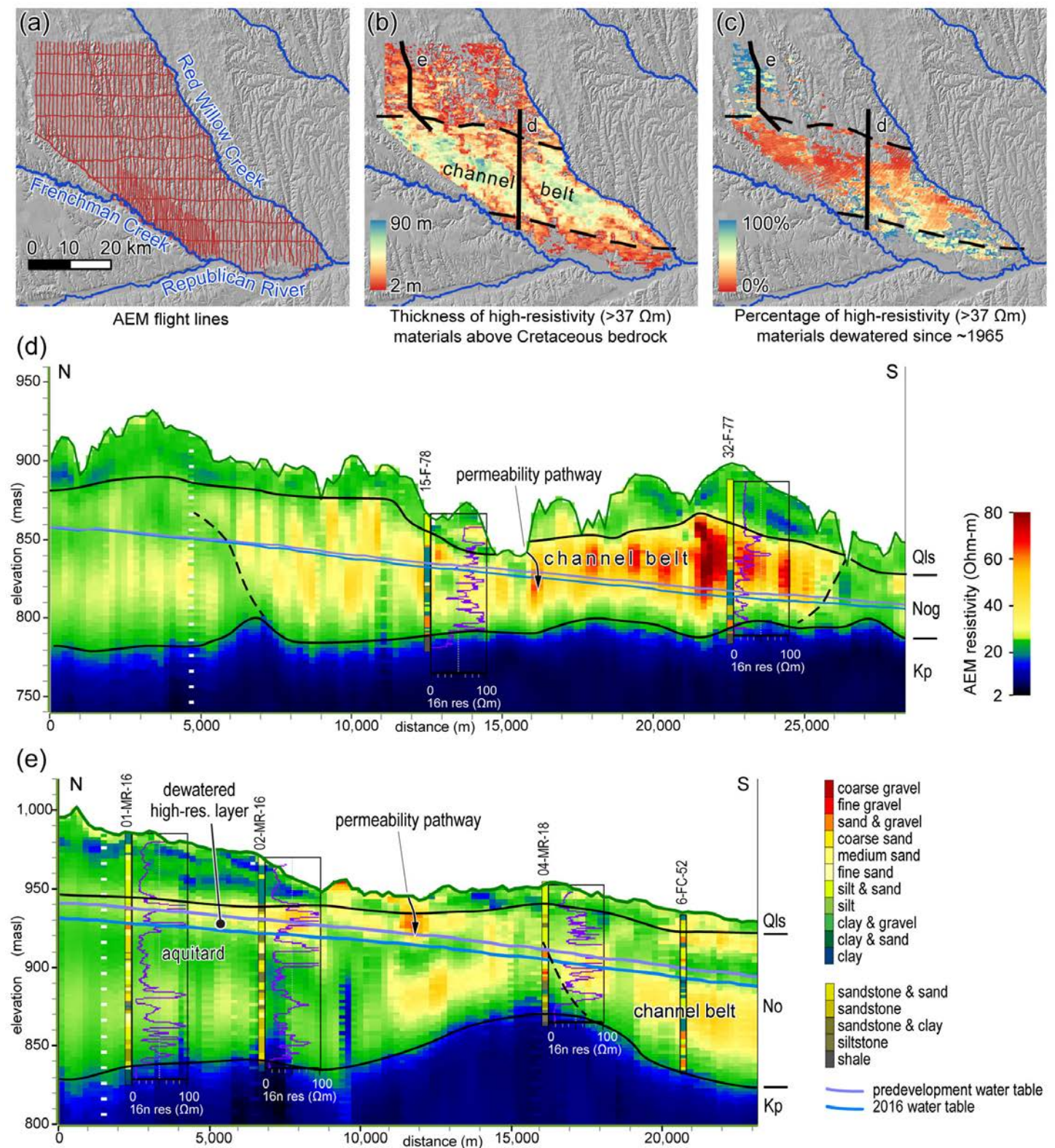


Figure 1. Example of the application of airborne electromagnetic (AEM) surveys to the mapping of aquifers in southwestern Nebraska. Maps and cross sections showing: (a) AEM flight lines; (b) thickness of high resistivity (>37 ohm m) materials above Cretaceous bedrock; (c) percentage of those materials dewatered since 1965; (d) and (e) cross sections showing aquifer-hosting sandstone bodies in the Ogallala Group (Miocene). From: Korus, J.T., Joeckel, R.M., 2022. Sandstone-Body Geometry and Hydrostratigraphy of the Northern High Plain Aquifer, USA, Quarterly Journal of Engineering Geology and Hydrogeology 55(3): qjehg2021–171, doi: [10.1144/qjehg2021-171](https://doi.org/10.1144/qjehg2021-171)

NEVADA

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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. 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, NBMG is the state's official locus of data, analysis, and exchange 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. NBMG products include geologic maps and reports on mineral and geothermal resources, as well as earthquakes, floods, landslides, and other geologic hazards. NBMG disseminates this information to local, state, and federal agencies, major industries, engineers, educators, and to the general public. As such, NBMG has cooperative research and information programs with numerous local, state, and federal agencies. In addition, 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)
3. The Nevada Geodetic Laboratory (NGL)

CREG and GBCGE are at the forefront of research in mineral and geothermal resources, respectively, and also play important roles in education through teaching courses and workshops. NGL has built a network of great than 400 global positioning system (GPS) stations across Nevada and parts of neighboring states. These stations track the motions of crustal blocks and help to define earthquake hazards. NGL is at the cutting edge of global research in geodesy. Programs are also underway to increase public awareness of earthquakes in Nevada and to prepare for emergency response to a major earthquake.

NBMG employs approximately 30 geoscientists and support staff. This includes 14 faculty positions in the geosciences, five 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 over one third funded by external grants and contracts. In addition, NBMG employs about 25 graduate student assistants, several undergraduate students, and two post-doctoral scholars.

GEOLOGIC MAPPING

Geologic mapping by NBMG addresses the needs of an extraordinary state. For example, Nevada commonly leads the nation in non-fuel mineral production, is the top producer of gold in the country, and is rich in geothermal and critical mineral (for example, lithium) resources. Nevada is also the third most seismically active, fastest growing (tectonically speaking), and most urban state (in terms of proportion of citizens living in large cities). NBMG has three priority regions for geologic mapping:

- Clark County in southern Nevada, which is home to Las Vegas and nearly three-quarters of Nevada's citizens
- The Reno-Carson City urban corridor in western Nevada and adjacent areas rich in geothermal and mineral resources
- North-central to northeastern Nevada due to 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 regions contain geologic hazards (for example, earthquakes, floods, and landslides) that must be reckoned with for infrastructure planning and development. To date, we estimate that approximately 32% 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 permit publication of several new quadrangles/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 rapid progress on geologic mapping. However, recent increases in funding for the STATEMAP program have accelerated the pace of detailed geologic mapping by NBMG in the state, including publication of "legacy" maps. Legacy maps are previously unpublished, but largely completed high-quality geologic maps produced by authors outside NBMG (for example, USGS geologists and university professors). Some of the notable recent mapping projects include:

- Quadrangle mapping and Quaternary fault studies near the Las Vegas metropolitan area
- Additional quadrangles in a transect across highly extended, mineral-rich terrain in northeast Nevada
- Cretaceous basins in northeastern Nevada
- Areas containing geothermal systems in western to central Nevada.

In addition, an assessment of the quality of all existing geologic maps in Clark County was completed to help prioritize unmapped or poorly mapped areas in ongoing efforts to eventually complete detailed mapping of all critical areas in southern Nevada. Most of NBMG's mapping efforts have been funded by the aforementioned STATEMAP program, but significant funding has also been obtained from Clark County and the U.S. Department of Energy.

Due mainly to the large amount of public land (approximately 85%), Nevada has, until recently, lagged behind many states in the acquisition of high-resolution lidar and geophysical data that could expedite geologic mapping. However, this is rapidly changing, as evidenced by the recently completed Geoscience data acquisition for western Nevada project (GeoDAWN), a major collaborative effort between the USGS, Geothermal Technologies Office of the Department of Energy, and other federal agencies. GeoDAWN and related projects will provide high-resolution lidar and relatively detailed aeromagnetic data for over one-third of Nevada. Notably, the federal fiscal year 2023 budget contains funding for acquisition of high resolution lidar for most remaining parts of Nevada.

NEW HAMPSHIRE

NEW HAMPSHIRE GEOLOGICAL SURVEY

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INTRODUCTION

The New Hampshire Geological Survey (NHGS) was established 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 redefined the Office of the State Geologist, established in 1839. NHGS has five authorized full-time positions, four of which are filled. One permanent part-time position serves as NHGS’ outreach coordinator. Three project specific part-time, and six summer intern positions round out the staffing of NHGS. While geologic mapping remains central, New Hampshire has experienced its third consecutive year of drought in 2022. Thus, NHGS staff ensured timely measurements from NHGS’ Groundwater Level Monitoring Network (NH-GWLMN), and updated dissemination infrastructure to provide timely data to the public and stakeholders. The NH-GWLMN is a critical tool that has become integrated into statewide drought-related decision making during the past year.

GEOLOGIC MAPPING

NHGS continues to perform bedrock and surficial geologic mapping as part of the U.S. Geological Survey (USGS) STATEMAP program. During 2022, the Geologic Resources Advisory Committee (GRAC), which serves as the STATEMAP mapping advisory council for New Hampshire, was reconstituted. Consequently, NHGS is undergoing transitions in the priority order for 1:24,000-scale surficial and bedrock mapping of the State’s 213 quadrangles, as recently redefined by GRAC.

BEDROCK MAPPING

To date, bedrock mapping has continued to be focused in the White Mountains, a popular tourist destination visited by many thousands each year. Although mapping products allow the visiting public to learn more about the natural history and geologic processes of the White Mountains, many questions remain regarding the timing and sequences of the mountains’ formation. A second area of focus for bedrock mapping has been the Indian Stream area of far northern New Hampshire on the border with Quebec. This latter effort is being conducted by a contract bedrock geologic mapper to answer questions posed by an earlier effort by the same mapper in the 1980s. Though these efforts will be maintained while existing contract mappers remain with us, NHGS, as charged by GRAC, will be making the pivot to performing bedrock mapping in the more populated areas of southern New Hampshire, an area that has not been extensively mapped at the 1:24,000 scale. These areas of the state have experienced groundwater contamination and availability concerns in recent years. Also, an area in central

New Hampshire has been the focus of recurring small (<4.5 magnitude) earthquakes. GRAC charged NHGS with seeking to add this area to its priorities for 1:24,000-scale bedrock mapping as well.

Surficial Mapping

At the end of 2021, NHGS and its contract mappers completed portions of five 1:24,000-scale quadrangles focused largely in the White Mountains, and also completed a 1:24,000-scale coverage cap in southwest New Hampshire. Given New Hampshire’s considerable focus to date on completing surficial geologic mapping, and its needs for aquifer mapping and groundwater availability identification, GRAC has charged NHGS with maintaining program focus on completing the 1:24,000-scale surficial geologic mapping of the state. The story of the surficial geology of New Hampshire revolves around the effects of the Wisconsin glaciation, and our surficial geologic mapping efforts continue to raise new findings in the reconstruction of the processes by which the glaciers advanced and receded. New surficial mapping and 1-meter lidar visualization has identified the presence of two separate dynamic ice lobes flowing around the White Mountains as ice thinned after the Last Glacial Maximum, which challenges the stagnation model of deglaciation in that part of the state. As mapping continues elsewhere, it is apparent that both models of deglaciation can operate across the state at approximately the same time due to topographic controls.

3D Mapping

In 2022, NHGS began to incorporate use of the Tromino digital tomographic passive seismic unit into surficial geologic mapping efforts. Application of the passive seismic method has allowed NHGS to successfully model bedrock depth in areas without boring or well data to detect buried bedrock valleys.

OTHER PROGRAM HIGHLIGHTS

NHGS continues its long-standing role as steward of the statewide New Hampshire Groundwater Level Monitoring Network (NH-GWLMN). New Hampshire experienced its third consecutive year of drought in 2022. Making current and historical data more readily accessible to the public and stakeholders has been a key focus of NHGS’ efforts in late 2021 into 2022. These efforts included a new web viewer for online access to the data. Data and graphs from well measurements in the statewide network are used regularly by the Water Division at the New Hampshire Department of Environmental Services (NHDES), State Drought Management Team, federal partners at the National Weather Service Forecast Office in Gray, Maine, and local media. NHDES has instituted a financial assistance program for well owners affected by natural disasters (for example, wells going dry because of drought). NH-GWLMN data have served as an

input into decisions made regarding the financial assistance program.

In 2022, NHGS' Flood Hazards were once again largely focused on stream crossing (culvert) assessments in support of a larger statewide multi-agency Stream Crossing Initiative. NHGS hired four summer interns in 2022 to continue assessments, primarily collecting data in the southwest part of the state. Additionally, NHDES contracted with the University of New Hampshire on a project to complete culvert assessment work in southeast New Hampshire. As part of this effort, NHGS oversaw two additional interns who performed the QA/QC review of the incoming data as part of that project. In total, the six interns surveyed 619 crossings throughout the state. The New Hampshire Silver Jackets continues to be chaired by NHGS. In 2022, the Silver Jackets team continued efforts on an existing project to install manual staff gages on streams in the state and to have citizens report the values as a supplement to the state's existing stream gage network. A gage was recently installed in Keene, and discussions have been ongoing with town officials in Pelham.

NHGS continues a partnership with the NHDES Coastal Program and the University of New Hampshire's Center for Coastal and Ocean Mapping, which are currently focused on a long-term beach profiling project. Coastal Program staff and trained volunteers regularly survey the contour profiles of select beach sites on New Hampshire's Seacoast to understand their change over time. Data are used to identify trends in beach erosion and accretion, which play an important role in beach resource management. NHGS manages the collected data and the web data access portal for the project. In 2022, NHGS worked collaboratively with project partners to update the web page and data loading and handling procedures to maximize the utility of public access to the information.



Figure 1. NHGS staff, contract geologists and members of the New Hampshire geology community investigating the landscape during the Mount Trip pyramid Quadrangle mapping field conference, Summer 2022. Photo courtesy of Rebecca LeCain.

NEW JERSEY

NEW JERSEY GEOLOGICAL AND WATER SURVEY

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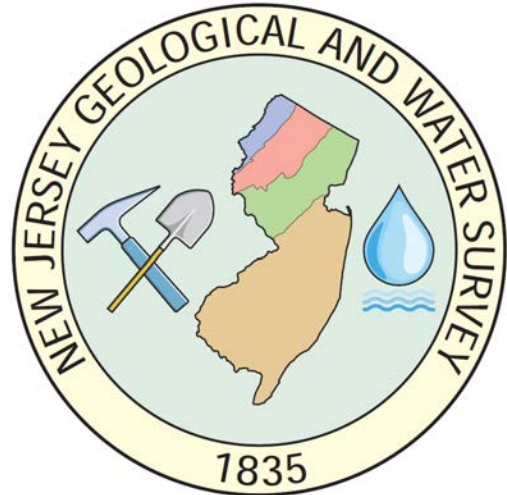
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INTRODUCTION

The New Jersey Geological and Water Survey (NJGWS) has a wide range of responsibilities. These include: mapping onshore and offshore geology; management of water supply allocation and well permitting; water supply planning and modeling; groundwater resource assessments; evaluating natural hazards; advising on energy issues (geothermal, natural gas and wind) with their related infrastructure issues; site evaluations; and providing earth science information to government agencies and the public to address economic, environmental, 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 Professional, Board of Licensed Well Drillers and Pump Installers, Pinelands Commission, Highlands Commission, Delaware River Basin Commission, and the Delaware River Decree Parties.

GEOLOGIC MAPPING

The Geologic Mapping and Coastal Geology Section completed three STATEMAP deliverables and met all Geologic Map Schema (GeMS) federal requirements: Bedrock and surficial map of the Cedarville Quadrangle, bedrock and surficial maps of the Egg Harbor City Quadrangle, karst features map of the Newton East Quadrangle.

Bedrock Mapping

The NJGWS published bedrock maps of ten quadrangles: Flatbrookville, Cassville, Califon, Portland, New Gretna, Pitman West, Newton West, Clementon, Pitman East, and Medford Lakes.

Surficial Mapping

The NJGWS published surficial geologic maps of 11 quadrangles: Atsion, Belvidere, Ship Bottom, New Gretna, Flemington, Easton-Bangor, Lakewood, Clementon, Frenchtown-Riegelsville, Washington, and Medford Lakes.

OTHER PROGRAM HIGHLIGHTS

Data Preservation

NJGWS scanned and digitally preserved and created associated metadata for three sets of historic geologic data for a total of 182 documents. The first collection contains 17 maps, of which six are engineering drawings with boring locations and information for construction of a proposed section of the Intracoastal during the early twentieth century. The rest consists of 11 maps with historic quarry locations by the NJGWS. The second collection included scanning 164

field maps from 1880–1985, 132 of which are south Jersey surficial maps by G. N. Knapp mapped during the early part of the twentieth century. The rest consists of 16 surficial and glacial field maps and 16 bedrock field maps by various Survey geologists. The third collection consists of one field notebook from a more recently retired Survey geologist.

Publications and Web

NJGWS published 18 STATEMAP products, six in the Geologic Map Series, and 12 Open File Maps. The Survey website had 145,359 downloads of 145 geologic maps.

Water Supply Modeling

NJGWS provided technical support to water resource planning and permitting groups within and external to State government. Projects during the reporting period include: enhancement of a land phase hydrologic model to evaluate potential impacts of climate change on groundwater recharge; modeling and monitoring of hydrologic conditions for a water supply drought which emerged in June; initiating an updating the State's water supply plan; and estimating detailed spatial distributions of water use for private domestic wells.

Water Allocation, Hydrogeologic Analysis, and Well Permitting

The NJGWS is responsible for issuing permission for analyzing and permitting major water withdrawals and wells in NJ. For this period NJGWS issued 16 new or major modifications to agricultural certifications or registrations, 44 renewed or minor modification agricultural certifications or registrations, 11 temporary dewatering permits, six new or major modifications to water allocation permits, 65 renewed or minor modification water allocation permits or equivalencies, 23 new or modified water use registrations. NJGWS also granted four aquifer test waivers and approved four aquifer test proposals. NJGWS completed 12 reviews of proposed new and (or) increased withdrawals to determine the potential impacts on existing users, streamflow depletion, and movement of saltwater and anthropogenic contaminants.

For the period July 1, 2021 to June 30, 2022 the NJGWS issued 10,710 new well permits, reviewed 10,949 well records, and reviewed 10,233 well abandonment reports. Thirteen test well future potable use permits were issued, which are then redesignated to public supply. There were also two new public supply well permits issued during this time period.

Groundwater Quality

NJGWS completed sampling fifty monitoring wells as part of the New Jersey Ambient Groundwater Quality Monitoring Network. Samples taken from this network are analyzed for; field parameters, nutrients, major ions, trace elements, pesticides, volatile organic compounds (VOCs), twenty eight

per- and polyfluoroalkyl substances (PFAS), and 1,4 -dioxane. Work also began on installation of a saltwater inundation/intrusion monitoring network in the unconfined Kirkwood-Cohansey aquifer along the Delaware Bay in cooperation with the U.S. Geological Survey.

Publications completed or being finalized during this reporting period include:

- Investigation of Elevated Sodium and Chloride in Well Water, Village of Columbia, Knowlton Township, Warren County, NJ
- Efficacy of Using Marine Seismic Data to Map the Potential Use of Offshore Sheet Sands for Beach Replenishment in New Jersey
- Compilation and Analysis of Radiocarbon Dates Offshore New Jersey
- Organic wastewater compounds in shallow groundwater downgradient from large-facility septic-tank-wastewater disposal fields in New Jersey, 2009–2011

NEW MEXICO

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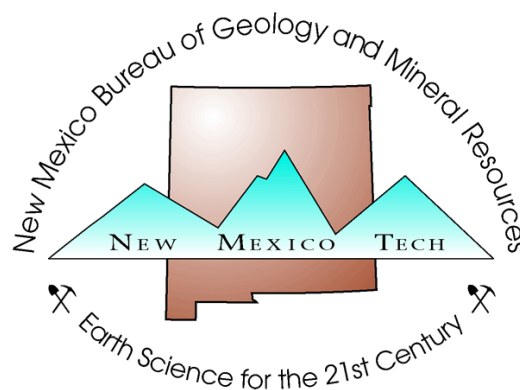
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INTRODUCTION

Established by legislation in 1927, the New Mexico Bureau of Geology and Mineral Resources is a non-regulatory 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 70 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 foundation of most research conducted by our organization. Our mission is to provide modern, digital, geologic maps that are beneficial for applications in New Mexico. These maps address a wide range of specific topics, such as the location and abundance of geologic resources, including energy and mineral resources and groundwater, as well as geologic hazards. Our geologic maps are a critical component for natural resource management, infrastructure planning, and research, thus serving a wide audience. Our goal is to provide a variety of 2D and 3D geologic and resource maps online in an interactive web-based application.

Our mapping program continues to grow in size and scope as new funding opportunities become available. Partial funding for our mapping is provided by the STATEMAP component of the National Cooperative Geologic Mapping Program. This year our program secured \$668,850—the top award recipient for this year's STATEMAP grant opportunity. Classic mapping of 7.5-minute quadrangles continues in our three long-term target areas of the Rio Grande watershed, Lower Pecos watershed, and San Juan basin. Under the U.S. GeoFramework Initiative, new mapping priorities were set including compilation of 30 x 60-minute quadrangles, 3D mapping of the economically significant areas such as the Delaware basin, and development of a geochronology database featuring results from our $^{40}\text{Ar}/^{39}\text{Ar}$ facility. Additional mapping focused on the rare earth element (REE) deposits of the Cornudas Mountains and erosional hazards impacting infrastructure on the Jicarilla Apache Nation. In total, 480 square miles were mapped, six maps were digitized and served, and 23 maps were completed in ArcGIS layout. Nearly 900 Gb of data were downloaded from our mapping

program and 81 Gb of data were downloaded from our web map application. Lastly, 18 students were trained in GIS by our staff, ensuring the next generation of geologists are prepared for geological mapping in the 21st century.

3D Mapping

Utilizing existing subsurface data, the 3D mapping effort has published geologic models that cover approximately 18,700 square miles of New Mexico, and an additional 14,800 square miles are currently under development. Together these ArcGIS models will depict the freshwater bearing zones of depths up to 10,000 feet of over 28 percent of the State. This work is supported through multiple of funding sources, initiated with philanthropic funding, and built upon with funding from state agencies and now USGS StateMap funding. The process of developing these models is iterative and changing as the team moves from regions of higher to lower subsurface data density. The Bureau is currently developing a model that will capture the Delaware Basin, in southeast New Mexico, from the surface to the basement, however an accurate model of this magnitude is only possible due to the wealth of existing oil and gas subsurface data in the region. For mapping in data poor regions, the Bureau is developing a diverse 3D modeling team of petroleum geologists, field and structural geologist mappers, geophysicists, and hydrogeologists to support this work. Products are available as ArcGIS Map Packages, ESRI Story Maps, and soon as 3D interactive PDFs.

OTHER PROGRAM HIGHLIGHTS

Hydrogeology

In a desert state, a detailed understanding of our aquifers is critical, especially in the face of a changing climate. Regional studies of aquifers and their changes have been supported by approximately \$275,000 of annual state funding, leveraged with an additional \$500,000 of grant, contract and gift funding. Products are all publicly available, and frequently used for water management decisions in regulatory agencies, as well as supporting consulting services.

Water Data Act

Following the 2019 statute, the Bureau of Geology is the convening agency of the New Mexico Water Data Act, coordinating with numerous state, federal, and regional data providers. Building funding to support this work has been a concerted effort, growing state funding and using it to match federal cooperative grants. This work is focused on improving access to data using standardized application programming interfaces (APIs), where data are persistently updated and available for multiple map and data visualization applications.

Energy

We continue to collaborate on two U.S. Department of Energy (DOE) funded projects studying carbon sequestration in the San Juan Basin. As part of these projects, a characterization well was drilled through Jurassic formations, collecting samples and geophysical logs in December 2022. Through a U.S. Geological Survey (USGS) data preservation grant, we have been working to make our extensive subsurface log, core, and cuttings library more accessible online. This effort includes setting up a core photography laboratory.

Minerals

The Bureau's Minerals Group has completed two Earth Mapping Resources Initiative (Earth MRI) mapping and geochemical studies in the Gallinas and Cornudas Mountains, where potential REE, Nb, and Zr deposits are found. The Bureau is continuing data preservation and creating databases of critical minerals. The USGS has awarded two new projects: 1) critical minerals in the Laramide porphyry systems and 2) evaluating mine wastes for critical minerals. The Bureau was also awarded a DOE grant evaluating REE and critical minerals in coal and related strata. These field studies are complimented by the Bureau's Critical Minerals experimental laboratory, which receives funding from the DOE and National Science Foundation for thermodynamic studies to better understand critical mineral formation.

Laboratories

Our laboratories supported research work for 207 users including 55 students from New Mexico Tech and beyond covering a wide-range of research topics. The laboratories supported several graduate and undergraduate projects, including salary and analytical support for the students. Total income to bureau lab service centers was approximately \$275,000 that is used to pay salaries, maintain and expand equipment, and facilitate research on societally relevant projects. The laboratories support the entire mission of the bureau by contributing analytical data to all research programs.

Outreach and Education

Our spectacular Mineral Museum continues to grow in visitorship. We hosted more than 20,000 visitors this year, which included 800 students; strengthening one of our primary missions – to inspire interest in Science, Technology, Engineering, and Mathematics disciplines (STEM). In addition to our mineral museum, we continued our many recurring outreach activities, such as "Rockin Around New Mexico," to support New Mexico educators and general audience journals including Earth Matters and Lite Geology. We also published a new report entitled "Climate Change in New Mexico over the Next 50 Years: Impacts on Water Resources," which is available for free on our website (Figure 1).

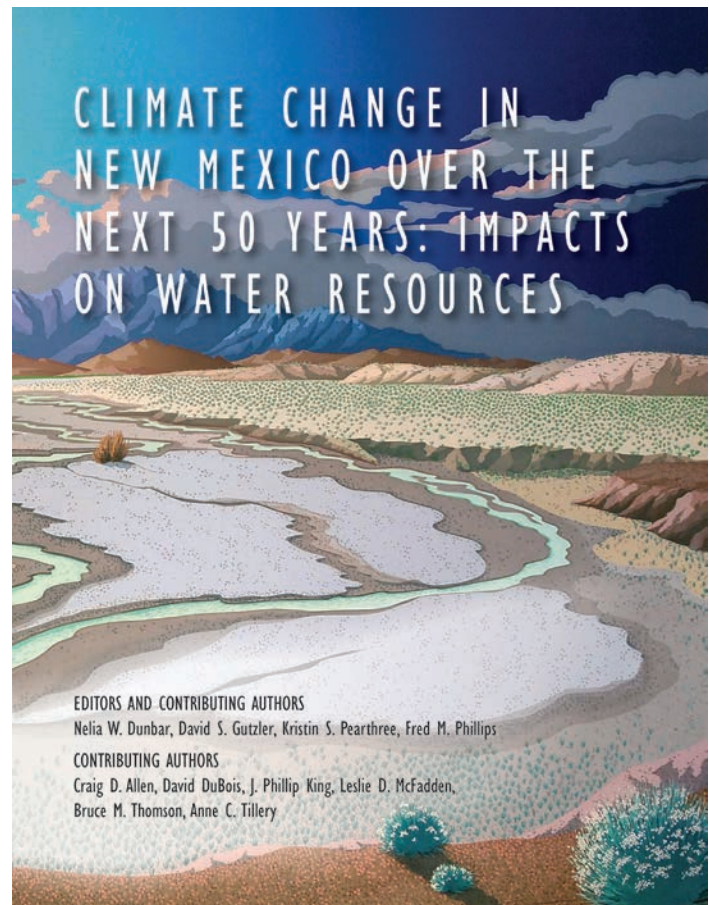


Figure 1. Cover image of a new comprehensive report entitled "Climate Change in New Mexico over the Next 50 Years: Impacts on Water Resources."

geoinfo.nmt.edu/ClimatePanel/report/home.html

NORTH DAKOTA

NORTH DAKOTA GEOLOGICAL SURVEY

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INTRODUCTION

The NDGS was established in 1895 under the administrative guidance of the State Board of Higher Education. The State Geologist also served as Chairman of the Department of Geology at the University of North Dakota in Grand Forks. This dual role was maintained until 1985. In 1941, ten years before oil was discovered in North Dakota, the Survey was charged with enforcing the oil and gas conservation law for the North Dakota State Industrial Commission (the Governor, Attorney General, and Agriculture Commissioner). The NDGS was given authority over the state's subsurface mineral program in 1969, through which we regulate the exploration and production of all minerals other than oil and gas, coal, and sand and gravel. We also regulate coal exploration (since 1975), geothermal energy production (1984), Class III underground injection control wells (1987), paleontological resources (1989), underground storage and retrieval of nonhydrocarbons (2019), and high-level radioactive waste (2019). In 1981, the North Dakota Industrial Commission Oil and Gas Division was split from the Geological Survey. In 1989, the Geological Survey was placed under the North Dakota State Industrial Commission and moved to Bismarck. In July 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 (DMR). The State Geologist is director of the Survey and an assistant director within the DMR. The State Geologist reports to the Industrial Commission on a quarterly, or as needed, basis. The NDGS shares an office and warehouse with the North Dakota Oil and Gas Division in Bismarck. We also maintain the Johnsrud Paleontology Laboratory in the North Dakota Heritage Center and State Museum in Bismarck. The NDGS operates the Wilson M. Laird Core and Sample Library on the campus of the University of North Dakota in Grand Forks.

GEOLOGIC MAPPING

Bedrock Mapping

We completed maps of three shallow salts in the North Dakota portion of the Williston Basin, the Dunham (Piper Formation), the Pine (Spearfish Formation), and the Charles A (Charles Formation). These maps were published as North Dakota Geologic Investigation numbers 256, 264, and 267. These salts are being investigated for gas storage.

Surficial Mapping

New geologic mapping during this time occurred in south-eastern North Dakota and resulted in the completion of a new surface geologic map and subsurface database for the Hickson quadrangle. This quadrangle is in eastern Cass County just south of rapidly expanding urban areas near

Fargo. This new geologic mapping was completed to better characterize the surficial and near-surface geologic units as well as any geohazards present in the study area. The depths and extent of subsurface sediments that have the potential to be problematic for the construction of infrastructure projects were delineated.

OTHER MAJOR ACCOMPLISHMENTS

Critical Minerals

Since 2015, the NDGS has collected more than 2,000 rock samples (primarily lignites) and measured 306 geologic sections in western North Dakota. During the reporting period, we collected 215 rock samples and measured 31 geologic sections. These samples were analyzed for rare earth elements as well as roughly a dozen of the other critical elements that our previous analyses had demonstrated were promising. So far, 17 percent of our samples contain rare earth element concentrations above 300 ppm (the U.S. Department of Energy's economic threshold) and the highest concentration that we found in a North Dakota lignite in 2022 was 2,800 ppm (Figure 1). During the reporting period, we published four reports regarding this project (a white paper to the North Dakota Lignite Research Council and Reports of Investigation numbers 128, 130, and 131).

Landslide Mapping

Late in 2021, we completed mapping landslides across the entire state of North Dakota at a scale of 1:24,000. Under this program, we mapped approximately 50,000 landslides (primarily rotational slumps) in 1,400 quadrangles. This sporadic mapping program began in the 1990s by interpreting a stereo-pair set of 1957–1963 U.S. Department of Agriculture black-and-white aerial photographs (Phase I). In 2016 we ramped things up and added interpretation of lidar and Google Earth imagery along with the aerial photographs (Phase II). We placed three of our four surface mappers into the program and dedicated 50% of their time, each completing roughly 100 quadrangles per year over the next five years. In 2021, we started a Phase III landslide mapping program which identifies recent slope movement by comparing lidar coverages (typically 2018 versus 2008 in eastern portions of North Dakota).

Paleontology Program

In October of 2021, our three paleontologists unveiled a new exhibit of an Edmontosaurus (duck-billed dinosaur) in the North Dakota Heritage Center and State Museum. Dakota the dino-mummy, as it is called, contains preserved skin across most of its tail, right arm, left foot, and part of its body. Our senior paleontologist also recently coauthored a paper describing how Dakota came to be preserved in such exquisite detail. Their research revealed that after Dakota died the carcass was partially consumed by crocodiles and

likely some small meat-eating dinosaurs. That scavenging allowed the internal tissues to rot away, leaving the remaining skin and nails to dry out and mummify. Once dried, the skin was stable and survived until the animal was buried and was fossilized. They were able to make that interpretation because Dakota is the only dinosaur specimen in the world that preserves tooth and claw marks in the original skin, allowing them to reconstruct what, when, and how different animals fed on the carcass. The paper was published in the Public Library of Science journal PLOS ONE on October 13, 2022. For years, our paleontology program has accounted for most of our outreach. To date, 72 news outlets from across the world have published articles on the study, ranging from the New York Times, the Wall Street Journal, National Geographic, and Science Magazine. Additionally, the renewed attention has resulted in multiple research groups from across the world reaching out to our paleontologists to discuss adding this specimen to other ongoing studies on the anatomy and preservation of these kinds of fossils.



Figure 1. The HT Butte lignite, visible to the left between the underlying brightly colored rocks of the Bullion Creek Formation and the overlying gray and brown rocks of the Sentinel Butte Formation, has burned to the right baking the overlying rocks to form clinker (known locally as scoria). The HT Butte is but one of many Fort Union Group (Paleocene) lignites targeted for sampling under the North Dakota critical minerals project. The photograph, along East River north of Medora, was taken by Ed Murphy in 1981.

OHIO

OHIO DIVISION OF GEOLOGICAL SURVEY

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INTRODUCTION

The Ohio Department of Natural Resources (ODNR), Division of Geological Survey (the Division) 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. The main office is located on the ODNR main campus in north Columbus. The Horace R. Collins Laboratory in Delaware County houses the Survey's core and sample archive and the offices of the Lake Erie and seismic researchers. The Division has a full-time staff of 37 with currently one vacancy, arranged into seven groups: Geologic Mapping and Industrial Minerals, Groundwater Resources, Energy Resources, Geologic Hazards, Publications and Outreach, Library and Records Center, and Administration and Fiscal. The Division's typical budget consists of severance tax income on fuel and nonfuel commodities, federal and state grants, department-allocated funds, and income from the sales of publications and data.

GEOLOGIC MAPPING

Geologic Mapping and Industrial Minerals published seven new geologic maps and one annual report during the period. Two new county-scale (1:62,500) surficial geology maps of Jackson and Lawrence counties were published with partial funding from grants from the STATEMAP component of the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program (NCGMP) and from the Great Lakes Geologic Mapping Coalition (GLGMC). These two maps cover a significant portion of the area in Ohio that lacks surficial geology map coverage. The surficial geology of Jackson and Lawrence counties is dominated by residuum and colluvium derived from regional Pennsylvanian bedrock. Although these counties are outside the glacial margin, there are still significant unconsolidated materials that were better defined by this mapping. The regional extent and thickness of Quaternary clays (Minford Formation), which can be prone to landslides, has been fully defined as a result of this mapping effort. This mapping also led to a better understanding of drainage modifications that occurred by the creation and collapse of the early-Quaternary glacial Lake Tight. Also produced was a county-scale bedrock topography map of Lawrence County, helping to better define the thickness of all Quaternary deposits in the county. The Division also published four new bedrock topography maps at 1:24,000 scale. These maps of the Troy, Piqua East, Fletcher, and Christiansburg 7.5-minute quadrangles were funded in part by the GLGMC. Over 500 new passive seismic horizontal-to-vertical spectral ratio (HVSr) data points were collected to measure the depth to bedrock across this four-quadrangle area in a continuation of the Division's long-term goal to remap the bedrock topography of our largest buried valley system, the

Teays River. Through these new bedrock topography maps, part of the Teays River and some of its tributaries have been more clearly defined. The Division also continues to assess geologic hazards through our karst inventory mapping program. Potential karst features of Delaware and Franklin counties were identified via remote sensing and digital mapping techniques before being field verified. During the 2020 field season, a total of 214 new karst features were added to the statewide inventory. Of these, 206 were field-visited. Karst inventory mapping is crucial to the sustainable development of both counties as population growth leads to new construction in areas where karst features are active. Franklin County is the most populous county in Ohio (over 1.3 million residents according to 2020 census) and Delaware County is the fastest growing county in the state (almost 23% increase in population between 2010 and 2020 census). The Division maintains a karst features database with a nearly 19,000 mapped features linked directly to a publicly-available interactive map. Yearly updates to this database are now detailed via an annual report that describes the mapping results and updates the status of the karst inventory mapping program.

OTHER PROGRAM HIGHLIGHTS

The Energy Resources Group released an Open-File Report, Conducting research to better define the sequestration options in Eastern Ohio and the Appalachian Basin, which summarizes the data availability and potential stratigraphic targets for CO₂ sequestration in Ohio. The group is also part of a carbon capture, utilization, and storage partnership, the Midwest Regional Carbon Initiative (MRCI), which encompasses 20 states in the Midwest and northeastern United States. The Energy Resources Group participated in the Association of Earth Science Editors Annual Meeting in Columbus in 2021, leading and releasing a field trip guidebook titled Reefs to Rivers – Evidence of the Acadian Orogeny in Central Ohio: AESE 2021 Annual Meeting Field Trip Guidebook. The group also was awarded a new grant from the USGS Earth Mapping Resources Initiative (Earth MRI) program, Pennsylvanian Marine Black Shales, a project being led by the Kansas Geological Survey. Finally, two staff members were given awards for presentations at the 2019 Eastern Section annual meeting of the American Association of Petroleum Geologists (AAPG), the A.I. Leverson Award for Best Scientific Paper, the Pittsburgh Geological Society Award for the Best Paper on Appalachian Geology, and the Vincent E. Nelson Memorial Best Poster Award.

The Groundwater Resources Group released new Groundwater Vulnerability maps, which depict vulnerability to groundwater contamination based upon hydrogeologic, topographic, and soil media characteristics. Three years in the making, the maps are the culmination of a decades-long effort to create a statewide, seamless map of Ohio's hydrogeology. This mapping has identified forty hydrogeologic settings in the state and will be used by government agencies and land-use planners to inform their decisions, and

by citizens seeking to understand their local groundwater resources.

At the Geologic Hazards Group, the Division's newest research vessel, the *Erigon*, began its first full season of field work on Lake Erie, collecting about fifteen miles of sidescan and subbottom survey data off the coast of northeast Ohio, to further efforts to understand the distribution of lakebed materials and the role they play in coastal dynamics. Our seismic group installed new seismometers at eight locations, placing the instruments in dedicated boreholes at least 10 feet below grade to attenuate surface noise, improving upon earlier shallow vault seismometers and enabling lower earthquake detection thresholds. The Library and Records

Center answered about 1,650 public inquiries and archived about 2,000 geophysical logs, and the Publications and Outreach Group distributed about 41,000 free handouts and maps. The Division also funded capital improvements at the Glacial Grooves Geological Preserve (Kelleys Island) which protects the largest and most easily accessed glacial grooves in the world.



Figure 1. Aerial view of capital improvements taking place at Glacial Grooves Geological Preserve, Kelleys Island, Lake Erie.

OKLAHOMA

OKLAHOMA GEOLOGICAL SURVEY

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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 (OU) and affiliated with the OU Mewbourne College of Earth and Energy. The Survey is chartered in the Oklahoma Constitution, and 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. OGS currently has 25 staff members, about half of whom are PhDs. OGS coordinates with both state and federal agencies, the university community, as well as industry groups, on research and service for Oklahoma.

GEOLOGIC MAPPING

Over the last fiscal year, the STATEMAP program of OGS was involved in extensive bedrock and surficial mapping of the Muskogee 1-degree sheet in eastern Oklahoma. Mapping procedures encompassed reconnaissance mapping of 32 individual 7.5-minute quadrangles over a period of four months. Field quadrangles were then finalized, digitized, and imported into ArcGIS mapping software. Individual quadrangle geology was then refined and merged into a final 1-degree geologic map, complete with detailed field description and correlation of geologic units. Besides continued

1-degree sheet mapping that will deliver 1:100,000-scale map coverage of Oklahoma, plans for the STATEMAP program include a detailed mapping program along the Oklahoma-Kansas border to answer stratigraphic problems within the Marmaton Group (Desmoinesian) as outlined by the Pennsylvanian Reconciliation committee between the state surveys of Oklahoma, Kansas, and Missouri.

OTHER PROGRAM HIGHLIGHTS

The Oklahoma Geological Survey (OGS) hosts an extensive core and logging-data repository. In 2022, OGS launched a beta version of a new online web portal, our 'well viewer', providing the public a free viewer for all of our geologic data. This well viewer accompanies our existing seismic network portal offering real-time information on the state's earthquakes. The OGS continues to expand in the science and service of net-zero, planning ahead for carbon capture and sequestration efforts in the state, as well as onramps for the hydrogen and electric vehicle economies. These efforts include research into the state's critical minerals. The net-zero approach is entirely consistent with OGS's ongoing support for the oil and gas production economy, who we serve through workshops, publications, regional compilations, site-specific studies, and data stewardship. Additionally, in our research of the Oklahoma environment, OGS began a new National Aeronautics and Space Administration (NASA) program in 2022 on shallow landslides in the state.

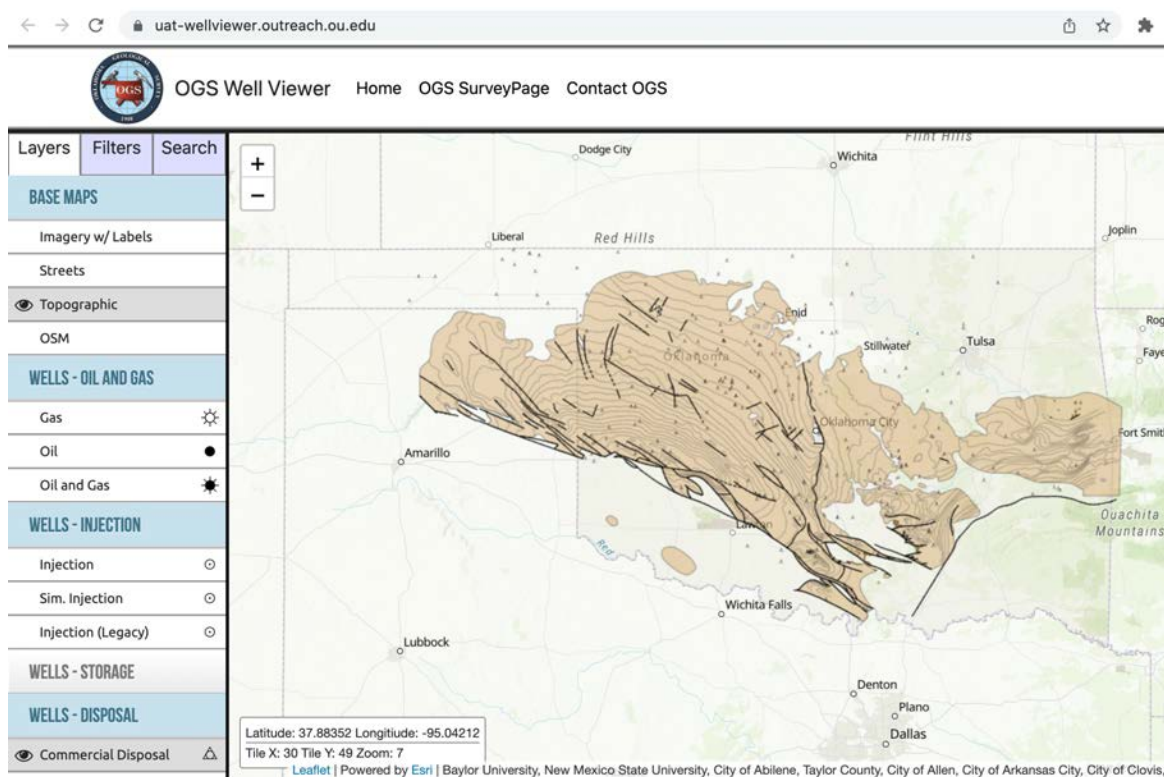


Figure 1. Beta version of the Oklahoma Geological Survey (OGS) well viewer, allowing public access to the OGS maps and data.

OREGON

OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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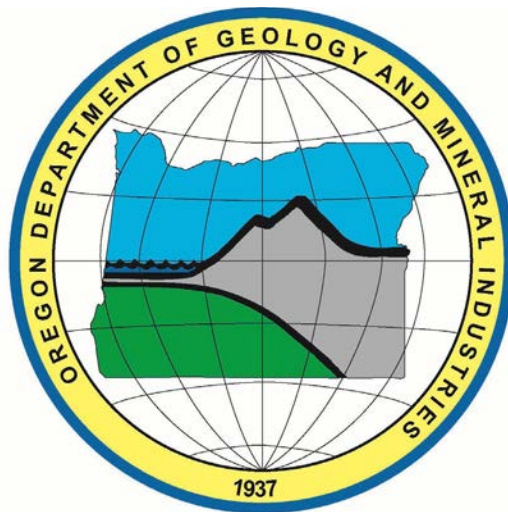
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INTRODUCTION

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 and 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 and Reclamation program oversees the state's mineral production and works to minimize impacts of natural resource extraction and 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 34 positions.

GEOLOGIC MAPPING

Bedrock Mapping

DOGAMI geologic mapping projects between July 2021 and June 2022 were focused on the Middle Columbia Basin of north-central Oregon as well as the Walla Walla sub-basin of northeast Oregon. This geologic mapping, supported by grants from the STATEMAP component of the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping Program (NCGMP), was a high priority of the Oregon Geologic Map Advisory Committee. The chief objective of these investigations was to provide an updated and spatially accurate geologic framework for key parts of the state. Focus topics for DOGAMI included developing a better understanding of the stratigraphic and structural controls on groundwater, mineral resource potential, areas of geologic hazards such as earthquakes and landslides, and rock resources. DOGAMI used these STATEMAP projects to build and refine Agency capabilities in order to consistently produce new geologic maps in a digital format compliant with the USGS NCGMP level 3 Geologic Map Schema (GeMS).

Surficial Mapping

DOGAMI maps landslides and studies landslide risks and mitigation strategies in individual Oregon communities. Landslides in the form of rapidly moving debris flows are a significant public-safety issue in Oregon's upland terrains, particularly following major forest fires. These types of debris flows are referred to as post-fire debris flows. After major wildfires in Eagle Creek in 2017 and the Western Cascades in

2020, DOGAMI committed resources to map, monitor, and make assessments of post-fire debris flows and landslides. This long-term research effort will help DOGAMI to map hazard zones, evaluate the risk, and work on risk reduction. In early January 2022, northwestern Oregon experienced a series of long-lasting rain and snow events (known as atmospheric rivers), after an already wet December. Over 5.25 inches of rain was recorded in the Columbia River Gorge from January 4th to 6th, triggering many landslides and debris flows from parts of the Eagle Creek Burn (Figure 1). DOGAMI's post-fire debris flow mapping is being supported with funds from both the Federal Emergency Management Agency (FEMA) Cooperating Technical Partners program and the USGS.

3D Mapping

Airborne-lidar-based 3-foot Digital Elevation Models (DEMs) and derivatives (slopes, hillshade, contours) are a fundamental 3D base dataset used for geologic mapping by DOGAMI. To date, over 37 million acres of data have been collected, covering over 98 percent of the state's population and 60 percent of the state is now mapped at USGS quality level 1 or better, equivalent to 1-foot contour accuracy. Repeat lidar acquisitions are also providing detailed measurements of topographic change related to processes such as landslides and coastal and fluvial erosion and deposition. Quantitative definition 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.

OTHER PROGRAM HIGHLIGHTS

During 2022 DOGAMI released several reports detailing pedestrian tsunami evacuation studies along segments of the Oregon coast. To make this information as accessible as possible, DOGAMI, in partnership with the Northwest Association of Networked Ocean Observing System (NANOOS), researchers at the University of Oregon (UO) Infographics Lab, and the UO Safety and Risk Services Location Innovation Lab, have developed the ability to automatically generate evacuation routes for any location on the Oregon coast within the tsunami zone via a web portal (nvs.nanoos.org/TsunamiEvac). Users can enter an address for a specified location and an evacuation route is automatically generated from that starting point to the nearest high ground outside of the tsunami zone. Additional information such as the distance to safety and travel speed needed to "Beat the Wave" is also included.

Channel migration zone maps identify areas within which a given river is most likely to laterally move over time. The mapping components include historically occupied areas,

the 30-year erosion area, 100-year erosion area, avulsion hazards, recently eroded banks, and channels adjacent to landslides. Currently DOGAMI staff are focusing on making channel migration zone maps for the McKenzie and Middle Fork Willamette Rivers in Lane County. The upstream end of the McKenzie study area has been heavily impacted by the 2020 Holiday Farm Fire. New channel migration maps are

essential to support on-going local projects and to make key decisions regarding natural hazard planning and risk reduction, hazard awareness, land-use planning and conservation, and overall river health. The FEMA Cooperating Technical Partnership Program is funding this work.



Figure 1. Image showing an example of a small debris flow track and deposit with woody debris. Eagle Creek Burn in the Columbia River Gorge of Oregon. (Photo credit: Bill Burns; January 12, 2022)

PENNSYLVANIA

BUREAU OF GEOLOGICAL SURVEY

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INTRODUCTION

While we are commonly known as the Pennsylvania Geological Survey (PaGS), our official title is the Bureau of Geological Survey, a bureau within the Pennsylvania Department of Conservation and Natural Resources (DCNR). PaGS has been examining Pennsylvania's geology since 1836 under various organizational structures. The present organization dates to 1919, when it was authorized by the General Assembly "to serve the citizens of Pennsylvania by collecting, preserving, and disseminating impartial information on the Commonwealth's geology, geologic resources, and topography in order to contribute to the understanding, wise use, and conservation of its land and included resources."

At the end of this reporting year, the bureau's staff complement is thirty-two: twenty-four geologists plus two vacant geologist positions, one geospatial specialist, four clerical staff, and one librarian. Thirty-two percent of the bureau is eligible to retire. Three vacancies were filled during the reporting period.

GEOLOGIC MAPPING

Bedrock Mapping

PaGS is conducting field mapping over parts of three 7.5-minute quadrangles in Bucks County (southeastern Pennsylvania) including a former military site that is experiencing PFAS contamination. Mapping is focused on the detailed lithologies and stratigraphy of the Triassic Stockton Formation. Progress thus far has made a successful correlation to adjacent mapping and supports evidence of a three-member system within the Stockton Formation. Detailed orientations of joints and fractures, including the discovery of several mappable small-scale faults, will help refine numerical models of contamination and transport. Evidence of diabase intrusions not previously mapped was noted; however, locations could not be confirmed in this highly developed area.

Surficial Mapping

A surficial map of the Corry 7.5-minute quadrangle in northwestern Pennsylvania was delivered as part of the STATEMAP 2020 deliverables. The map covered the City of Corry area in Erie County, headwaters of the south branch of French Creek, and tributaries to Brokenstraw Creek. This mapping advances the study of the glacial lithofacies and bedrock valley configuration in an area with critical water supply issues. Top of bedrock was located using Multichannel Analysis of Surface Waves (MASW) for both 2-D profiles and 1-D sounding. An isopach map of glacial deposits was developed by calculating the sediment thickness across the Corry area using a topographic contour map overlaid on top of the bedrock structure map, providing a hydrologic

framework for the unconsolidated materials of the buried valley. This framework can be used to further understand the unconsolidated materials that impede efforts to locate reliable municipal water supply wells.

3D Mapping

PaGS created a 3D model of the coal-bearing rocks in the central and eastern subsurface of the Broad Top Coalfield in south-central Pennsylvania, demonstrating that a geologic framework model can be built entirely within an ArcGIS environment using elevation data derived from a combination of surface and subsurface sources. Development of the first PaGS 3D subsurface model serves as "proof of concept" in the construction of practical and efficient 3D models by combining disparate datasets such as borehole logs, mine maps, structure contours, water-well data, and geophysical methods. The initial 3D product has advanced our knowledge of modeling practices, and by visualizing structural complexity, improved our understanding of the geology of the coalfield.

PaGS generated an integer digital raster representing the bedrock elevation below Quaternary glacial deposits of northwestern Pennsylvania. The geospatial dataset is a single seamless TIF raster image of the study area with a 30 meter cell size. Using water-well records and results from investigations over the past ten years, PaGS developed a regional, large-scale bedrock elevation raster that will serve as a baseline for future quadrangle projects and as a resource for geologic and ground-water studies. The methodology developed as part of the modeling effort will inform future PaGS work towards completing a statewide raster digital elevation model of the bedrock topography beneath Quaternary sediments.

Methods developed in these projects will directly contribute to Pennsylvania's overall move toward 3D geologic mapping and to the goals of the U.S. GeoFramework Initiative.

OTHER PROGRAM HIGHLIGHTS

Earth Mapping Resources Initiative (Earth MRI)

PaGS continued studies of cobalt-bearing magnetite skarns in Mesozoic rift basins in south-central Pennsylvania associated with diabase intrusions. Bedrock mapping is nearly completed. Additional studies will focus on geochemical and mineralogical studies.

PaGS is part of a multi-state aeromagnetic and radio-metric survey extending across the borders of south-central Pennsylvania and adjacent Maryland, Virginia, and West Virginia and including a swath extending northward along the Allegheny Mountains. The survey will provide high quality detailed magnetic anomaly maps of the Mesozoic magnetite

skarns and diabase, help locate hidden fault zones, and provide insights into the distribution and relative enrichment of U, Th, K, and critical minerals in sedimentary strata.

Laboratory

PaGS upgraded its laboratory and analytical facilities with a new Hitachi SU3900 scanning electron microscope with Oxford energy dispersive spectroscopy (EDS) and a SciAps handheld laser induced breakdown spectroscopy (LIBS) analyzer which will aid in studies of critical minerals, carbon storage, mapping, and public education and outreach.

Carbon Storage

PaGS leads Pennsylvania's Inter-Agency Carbon Capture, Utilization, and Storage (CCUS) Work Group, established in 2019 by Governor Wolf to develop a concerted technical, regulatory and economic approach to facilitate and support the deployment of CCUS in Pennsylvania. Within the past year, the Work Group began to engage external stakeholders considering commercial deployment of CCUS and hydrogen energy projects in the Mid-Atlantic region. This group has come to be known as the Pennsylvania Energy Horizons Cross-Sector Collaborative, and with support from the Team Pennsylvania Foundation, has recently submitted a concept paper to the U.S. Department of Energy for federal funding to support a regional clean hydrogen hub project in the Appalachian region led by Shell, Equinor, and U.S. Steel.

Mid-Appalachian Carbon Ore, Rare Earth, and Critical Minerals (MAPP-CORE) Project

PaGS is working with the West Virginia University Research Corporation, state surveys and other interested parties in the central Appalachian coal basin to provide volumetric estimates of selected rare earth elements and critical minerals contained in multiple potential sources from this area, including unmined Pittsburgh, Upper Freeport, and Lower Kittanning coals; coal preparation wastes from mining operations where these seams are being mined or have been mined; power plant wastes; acid mine drainage; and organic-rich shale wastes associated with development of the Marcellus shale gas play. Coal resource assessments are underway, as are waste stream identification and characterization, economic evaluations, and identification of emerging data gaps. The project will continue through September 2023.

SOUTH CAROLINA

SOUTH CAROLINA GEOLOGICAL SURVEY

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INTRODUCTION

The South Carolina Geological Survey (SCGS) is the second-oldest geological survey in the United States (1825). Its mission is to provide reliable geologic information to decision makers. Current staff consists of eight geologists and three GIS analysts who work in cartography and data management. The SCGS operates a drilling program in support of Coastal Plain mapping with a full-time driller and drill crew. Mapping initiatives cover all physiographic provinces within the state (Blue Ridge, Piedmont, Coastal Plain), as well as offshore. The SCGS is in the South Carolina Department of Natural Resources—Land, Water, and Conservation Division (SCDNR-LWC), and its main office is in Columbia, South Carolina, with a field office in Charleston, South Carolina.

GEOLOGIC MAPPING

Bedrock Mapping

STATEMAP-supported bedrock mapping continues southwest of Columbia and is delineating relations between Neoproterozoic–Cambrian metamorphic terranes juxtaposed within the late Paleozoic dextral Eastern Piedmont fault system (EPFS). A 2021–2022 swarm of 86 earthquakes in nearby Kershaw County highlights the importance of this work—EPFS reactivation is a likely cause of the seismicity. A U.S. Geological Survey (USGS) Earth Mapping Resources Initiative (Earth MRI)-supported project starting fiscal year 2023 will bring our bedrock mapping efforts northeast of Columbia (Figure 1). This mapping will help identify rocks containing critical minerals associated with porphyry Cu-Mo-Au deposits and support earthquake hazard investigations in the area of the recent swarm.

Surficial Mapping

STATEMAP-supported Coastal Plain mapping projects are focused on the transition inland from the lower- to middle-Coastal Plain provinces (Pleistocene to Pliocene sediments at the surface) in Dillon, Horry, and Marion Counties along the North Carolina state line. Five new maps have been completed. The South Carolina Department of Transportation has requested this work to support engineering projects related to the future Interstate 73 corridor. The mapping also provides insight into the evolution of the late Pliocene and early Pleistocene highstand coastal barrier systems and the related Great Pee Dee, Little Pee Dee, and Waccamaw river systems.

Earth MRI projects in the Coastal Plain are mapping Eocene and post-Cretaceous sediments of the upper Coastal Plain province between Columbia and Orangeburg, South Carolina. The projects are supported by airborne geophysical surveys and geochemical sampling to identify potential heavy-mineral placer deposits between the Fall Line and the

Orangeburg Scarp. The mapping provides insights into the Piedmont–Coastal Plain transition, weathering, and sedimentary transportation. Samples for geochronological analysis were collected in the project area and will be used to identify source areas of heavy minerals.

To further goals related to offshore mapping, SCGS partnered with the College of Charleston at Botany Bay Wildlife Management Area in 2021 to collect nearshore geophysical data (chirp sub-bottom profiler and high-resolution sidescan sonar) over former subaerial barrier island deposits. This research investigated the preservation potential of a Native American shell ring (approximately 4300 years old) in the nearshore zone seaward of a rapidly transgressing shoreline.

SCGS has several ongoing projects investigating shoreline-change rates and associated physical processes in modern estuarine systems at two SCDNR-managed coastal Wildlife Management Areas (WMAs). These two areas consist of late Pleistocene to modern barrier island systems and associated estuarine marshes. The long-term (1851–2022) erosion rate at Botany Bay WMA, near Edisto Beach, South Carolina, is high enough (average of -4.8 m/yr and has increased to -9.10 m/yr in the past 10 years) to have completely eroded the 1850s barrier strand (Botany Bay Island). The current retreating barrier island (Pockoy Island) at the property is late Pleistocene in age. Yawkey WMA, on Cat Island near Georgetown, South Carolina, is on the south side of Winyah Bay and has been altered by the creation of the Atlantic Intracoastal Waterway on its landward side and by a jetty built in 1904 on its seaward side. Shoreline change at both properties has been quantified using ten time steps ranging from 1939 to 2022.

OTHER PROGRAM HIGHLIGHTS

An Open-File Report detailing the methods used for a long-term Surface Elevation Table (SET) project in South Carolina salt marshes was written and released by SCGS in June, 2022. SCGS is working with Coastal Carolina University on a project to monitor shallow subsidence in Horry County, South Carolina, through the deployment of five extensometers.

SCGS staff are working with a group of geophysicists and students at University of South Carolina, College of Charleston, and Georgia Tech to identify the fault (or faults) responsible for the Kershaw County earthquakes. The group installed 86 portable seismometers in the vicinity of the swarm.

The GIS and Cartography staff are continuously cataloguing, organizing, and upgrading quadrangle geodatabases into the USGS Geologic Map Schema (GeMS). This includes creating new GeMS databases for older data that may be still located in older file formats or coordinate systems which need to be projected or corrected. Staff developed a comprehensive database for SCGS symbology to keep cartography

consistent between map products. One key development has been the creation of KML databases for the geologic maps of the ACE Basin, the Interstate 73 corridor, and the Charleston peninsula. The KML format allows for greater data dissemination and public use while we are converting older map products to GeMS.

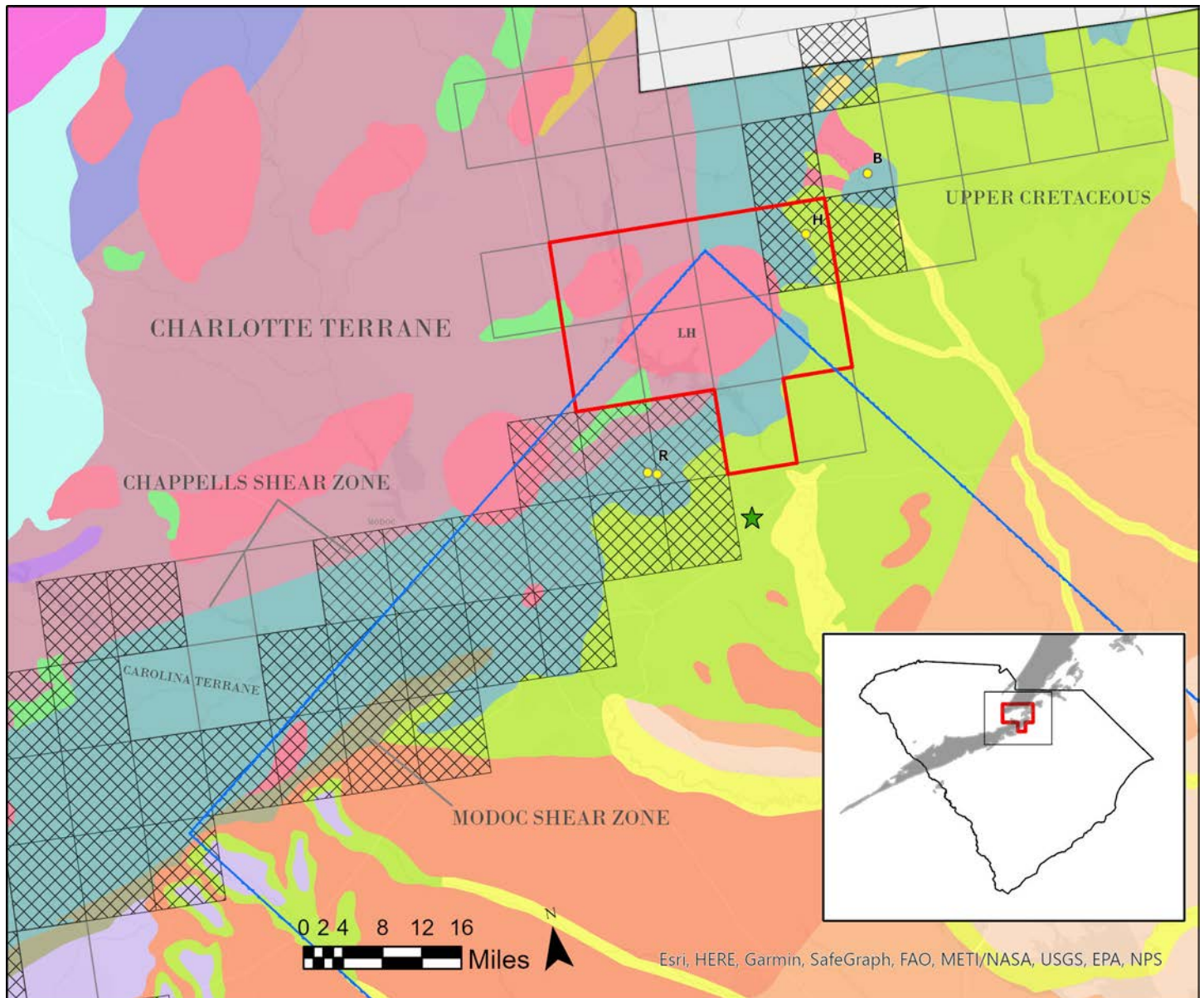


Figure 1. Generalized geologic map showing the proposed fiscal year 2022 Earth MRI quadrangles northeast of Columbia, South Carolina (red). Published 1:24,000-scale geologic quadrangles are represented by the hatched pattern. The blue line denotes the boundary of the fiscal year 2019 Earth MRI geophysical survey footprint. A portion of the Liberty Hill granite (LH) is located within the footprint and fieldwork will utilize aeroradiometric data in mapping its extent. The locations of the Haile (H), Ridgeway (R), and Brewer (B) gold mines are denoted by the yellow circles, and the location of the 2021–2022 Elgin-Lugoff earthquake swarm is denoted by the green star.

SOUTH DAKOTA

SOUTH DAKOTA GEOLOGICAL SURVEY

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INTRODUCTION

The South Dakota Geological Survey (SDGS) is a program in the South Dakota Department of Agriculture and Natural Resources. The SDGS performs surface and subsurface geologic mapping throughout the state. Aquifer mapping and modeling is also a significant part of the activities at SDGS. With two drill rigs that are owned by the agency, the SDGS collects a wealth of new subsurface geologic and hydrogeologic information each year that is used to produce maps and reports used by both the public and private sectors. The SDGS also maintains a statewide ground water quality monitoring network that is sampled regularly to monitor the water quality characteristics of the state's major surface aquifers.

The SDGS has 22 full-time employees including geologists, hydrogeologists, technicians, drillers, and other support staff. In addition, the SDGS hires several geology interns each year to assist with drilling test holes, installing observation wells, ground water sampling, and GIS-based aquifer mapping.

GEOLOGIC MAPPING

The SDGS is producing 1:24,000-scale geologic maps of the Black Hills region. South Dakota's flagship state park, Custer State Park in the heart of the Black Hills, is currently one of the areas SDGS is mapping. The primary use of these maps is to:

- Address concerns regarding quantity and quality of water in the aquifers in the Black Hills region.
- Properly address issues related to geologic hazards, floodway analysis, and mining.
- Understand the development of caves in the Black Hills and to protect the cave resources, such as Wind Cave National Park and Jewel Cave National Monument.
- Allow sound development practices to be implemented and wise land management decisions to be made.

Three geologic quadrangle maps were published in fiscal year 2022. A status graphic of geologic mapping in the Black Hills and links to the published maps are available at bit.ly/3Abdvpd. The SDGS is also publishing 1:250,000-scale geologic maps of western South Dakota. Each map covers a large area and can be used for regional and statewide planning. These maps are beneficial in making land use decisions such as determining the suitability of an area for development, planning major construction projects, identifying shallow sources of ground water, and identifying potential mineral resource deposits. One map of this series was published in fiscal year 2022. A status graphic of this series, along with links to the published map is available at bit.ly/3iOrRFV.

OTHER PROGRAM HIGHLIGHTS

Ground Water Modeling

The SDGS is developing ground water models for several areas to help understand the relationship between ground water and surface water resources used for water supply in the state. These models are used to help determine the amount of surface water induced into public water supply wellfields as well as water quality impacts to these wellfields. A recent publication by the SDGS contains the results of a modeling effort that was used to determine the quantity of Missouri River water induced into the wellfield of a major regional water system serving three states. The results of these modeling efforts are used by regulators and developers to maximize the use of the state's ground water resources. The report can be accessed at www.sdgs.usd.edu/pubs/pdf/UR-97.pdf.

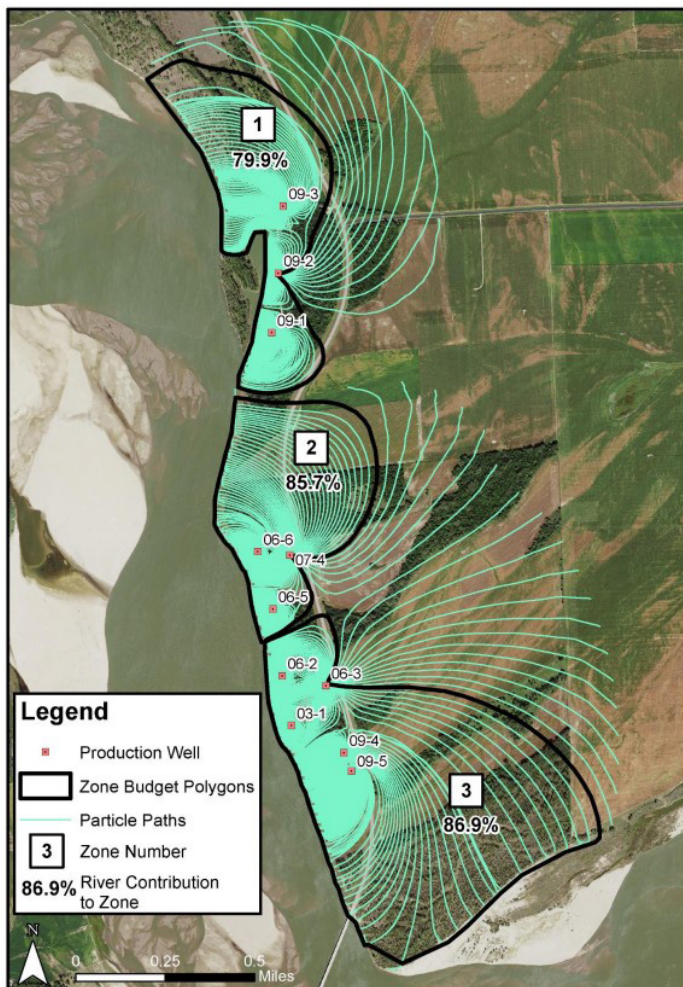


Figure 1. Example from a Ground Water Modeling Application.

Big Sioux Water Quality Impact Study

The SDGS is currently studying the impact of water quality changes in the Big Sioux River on water quality in the Big Sioux aquifer. This project is looking at the potential for increased levels of chemicals such as nitrates in the river to impact public water supply wellfields in the aquifer. Specific objectives of the project are to:

- Quantify contribution of the river to wellfields in the Big Sioux River watershed.
- Determine potential path of chemical constituents from the river to wellfields.
- Determine chemical constituent concentration gradients between the river and the wellfield.

This multi-year study involves monitoring-well installation, water quality sampling and analysis, aquifer testing, and ground water modeling.

Mapping Ground Water Resources

Work related to understanding and documenting ground-water resources in the previously glaciated part of South Dakota continues to be a primary focus for the SDGS. Drilling resources were used to drill test holes and install observation wells in multiple aquifers this past year. New data generated from this drilling program, as well as review of historical data, are used in the interpretation of aquifer occurrence. Products that come from this effort are:

- Aquifer extent maps
- Depth to aquifer maps
- Revised bedrock geology maps
- Revised surface geologic maps

TENNESSEE

TENNESSEE GEOLOGICAL SURVEY

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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. TGS is part of the Bureau of Environment. The state geologist reports directly to the director of the Division of Mineral and Geologic Resources. Established in 1831, TGS advises state agencies and federal and local organizations on matters relating to Tennessee’s geology, energy, and mineral resources. The survey maintains a well-cuttings and core-sample library, seismic station, and maps and publications sales office. Survey staff includes five geologists, a GIS coordinator, and an administrative services assistant, with expenditures of \$925,600 during fiscal year 2021–2022, of which \$291,100 came from state appropriations. The remaining \$634,500 came from federal cooperative projects, interdepartmental funds, and the sales of maps and publications.

GEOLOGIC MAPPING

Geologic mapping is the survey’s primary legislative mandate, and TGS is the only Tennessee state agency that produces and distributes geologic maps. Survey staff perform basic geologic mapping using on-the-ground field traverses and geographic positioning system technology. Survey staff then input geologic field data into a geographic information system (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.

Since 1960, TGS has engaged in detailed geologic mapping at the 7.5-minute quadrangle scale (1 inch=2,000 feet), completing 542 maps 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 fiscal year 2021–2022, TGS was approved for funding under a \$139,110 cooperative agreement from the U.S. Geological Survey (USGS) under the State Geological Mapping Program element (STATEMAP) of the National Cooperative Geologic Mapping Program (NCGMP). Since 1994, the survey has received more than \$1.1 million, completing 64 new geologic maps and converting 24 previously completed geologic maps to digital coverages under this program. The TGS web site has a NCGMP fact sheet updated through September of 2019 under the STATEMAP Fact Sheet Link on the Geology Programs page (direct link to PDF).

Bedrock Mapping

The purpose of the fiscal year 2021–2022 project was to map the geology of the southeast half of the Bean Station (quadrangle ID: 162-SE), all of the Riverton (334-NE), and the southeast half of the Shady Grove (164-NW) 7.5-minute quadrangles. Chief Geologist Dr. Peter Lemiszki and staff geologist Barry Miller from the survey’s Knoxville office worked on the Bean Station and Shady Grove quadrangles. Staff geologists Vince Antonacci, Ron Clendening, and Assistant State Geologist Albert Horton from the survey’s Nashville office were responsible for the Riverton quadrangle.

Surficial Mapping

The purpose of the fiscal year 2021–2022 project was geologic mapping of the Newbern (420-SE), drilling on the Newbern, and pre-mapping drilling on the Dyersburg (420-SW) 7.5-minute quadrangles. Staff geologists Vince Antonacci, Ron Clendening, and Assistant State Geologist Albert Horton from the survey’s Nashville office were responsible for the Dyersburg and Newbern quadrangles.

Derivative Maps

The purpose of the fiscal year 2021–2022 project was to produce mineral resource derivative maps for the prior STATEMAP supported Honey Creek (128A-NW), Oneida South (128A-NE), and Stockton (115-NE) geologic maps. Ron Clendening was responsible for these.

Table: Geologic maps released in fiscal year 2021–2022.

<i>Quadrangle (Quadrangle ID)</i>	<i>Counties</i>	<i>Authors</i>
Bradford (436-SE)	Gibson, Weakley	Vince Antonacci
Church Hill (188-SW)	Hawkins and Sullivan	Walter L. Helton
Eagan (144-SW)	Campbell and Claiborne	Robert C. Price, III and Andrew L. Wunderlich
Herbert Domain (109-SW)	Bledsoe, Cumberland, and White	James L. Moore
Tracy City (99-SW)	Grundy and Marion	Michael L. Jones

OTHER ACTIVITIES

Data Preservation

TGS worked under a \$49,427.98 cooperative agreement for fiscal year 2021–2022 from the USGS under the National Geological and Geophysical Data Preservation Program (NGGDPP). NGGDPP is a federal grant program designed to preserve state geological survey data collections and provide a means for potential users of that data to determine what is available. Since 2007, the survey has received nearly \$277,000 under this program. In January 2022, the survey completed a proposal for nearly \$98,000 for work to be completed during fiscal year 2022–2023. The holdings of each collection will be accessible through an Internet-based catalog, the Registry of Scientific Collections (ReSciColl).

Work completed in fiscal year 2021–2022 consisted of five projects:

- 1. Creating the metadata records and converting 420 documents in the Chattanooga Shale Collection to a digital format.
- 2. Preparing 2616 digital documents in the Mineral Resources (Nashville Office) Collection, Tennessee Valley Authority (TVA) Coal Reports Collection, Coal Geology Maps Collection, and TVA Reports Collection for public access through the TGS Search for Geology Documents webpage.
- 3. Compiling the unpublished geologic maps of the Tracy City and Church Hill 7.5-minute quadrangles to Level 3 GeMS format and uploading them to the NCGMP GeMS portal.
- 4. Converting the Pattie Gap, Philadelphia, and Sweetwater born-digital 7.5-minute quadrangle geologic maps to Level 3 GeMS format and uploading them to the NCGMP GeMS portal.
- 5. Compiling 460 mineral exploration boreholes in the Sweetwater District in ScienceBase using the National Index of Borehole Information template.

Seismic Station

Since April of 1997 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.

Subsurface Geologic Repository

TGS manages a 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 upon request and has been used for a wide range of geologic investigations. TGS considers it a high priority to acquire rock core when it becomes available because of the time, effort and expense companies have undertaken to collect it. Storing and managing our expanding inventory is an ongoing task that requires foresight and flexibility.

Table 2: Uploads to FileNet.

Collection Name	Number of Documents
Mineral Resources (Nashville Office)	235
TVA Coal Reports	244
Coal Geology Maps	508
TVA Reports	576
Total Uploads to FileNet	1563

Table 3: Records compiled.

Worksheet Name	Number of Records (Excel Rows)
LocationData_Sweetwater	460
TF_Sweetwater_Strat	4492
TF_Sweetwater_Mineralization	2455

TEXAS

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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 (UT) at Austin. The Bureau is one of three units in the 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 Texas well logs, having nearly 2 million records on file.

The Bureau owns and operates an airborne lidar system, a high-resolution offshore 3D seismic imaging system, an array of ground-based and borehole geophysical tools, and 20 major laboratories. Research projects are well supported with appropriate hardware and software for data analysis and modeling, and the Bureau's scientists apply relevant technologies, including GIS, GPS, and remote sensing.

GEOLOGIC MAPPING

Increases in available National Cooperative Geologic Mapping Program (NCGMP) funds continue to expand coastal-, groundwater-, geohazards-, and minerals-related geologic mapping in Texas. These funds have supported the hiring of geologists for the mapping program, mapping in a new, critical minerals-focused project area, and preparing maps in the U.S. Geological Survey (USGS) and Association of American State Geologists Geologic Map Schema (GeMS) that will enable the creation of seamless geologic maps. New National Geologic Map Database (NGMDB) funds support a nationwide survey of state-held borehole geophysical log collections to facilitate the creation of 3D geologic models as part of the U.S. GeoFramework Initiative. STATEMAP funds also support corrections and additions to Texas NGMDB entries. Recent additions include maps from the Environmental Geologic Atlas of the Texas Coastal Zone and Submerged Lands of Texas Atlas. A cooperative Earth Mapping Resources Initiative (Earth MRI) project among the USGS, the New Mexico Bureau of Geology & Mineral Resources, and the Bureau focuses on critical minerals hosted in igneous rocks in the Trans-Pecos region and features new geologic mapping in an airborne geophysical survey area flown by the USGS in 2021.

Between June 2021 and June 2022, Bureau researchers completed five new quadrangle-scale Open-File Maps (OFM) and two multi-quadrangle compilation maps as part of the STATEMAP and state-funded State of Texas Advanced Resource Recovery (STARR) programs.

Map Citations

- Caudle, T. L., and Paine, J. G., 2021, Geologic map of the Frozen Point and Caplen quadrangles, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 249, map scale 1:24,000.
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- Hunt, B. B., Woodruff, C. M., Jr., and Barnes, V. E., 2021, Geologic map of the Pedernales Falls, Johnson City, Howell Mountain, and Round Mountain quadrangles, Blanco County, Texas: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 255, map scale 1:50,000, 2 sheets.
- Paine, J. G., and Costard, L., 2021a, Geologic map of the Turtle Bay quadrangle, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 251, map scale 1:24,000, 2 sheets.
- Paine, J. G., and Costard, L., 2021b, Geologic map of the Palacios and part of the Palacios Point quadrangle, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 250, map scale 1:24,000, 2 sheets.
- Paine, J. G., Collins, E. W., and Costard, L., 2021, Digital geologic map of the Bayside, Mission Bay, Rincon Bend, and Woodsboro quadrangles, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 254 (GeMS database only), map scale 1:50,000.
- Woodruff, C. M., Jr., and Costard, L., 2021, Geologic map of the Lytton Springs quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map No. 253, map scale 1:24,000, 2 sheets.

OTHER PROGRAM HIGHLIGHTS

In October 2021, the Bureau of Economic Geology and the Austin Geological Society (AGS) hosted GeoGulf2021, the 71st Annual Gulf Coast Geoscience Convention. AGS and the Gulf Coast Association of Geological Societies (GCAGS) honored Senior Researcher Robert G. (Bob) Loucks by dedicating the 2021 GCAGS Transactions Volume to him.

The Bureau's TexNet seismic monitoring program and its Center for Integrated Seismicity Research (CISR) were recently recognized for their extensive work toward earthquake mitigation in the Permian Basin with the presentation of the Bruno Hanson Environmental Excellence Award. The award

was presented to the Bureau and its co-recipient, the Texas Railroad Commission (RRC), by Midland College at its annual Permian Basin Environmental Regulatory Seminar hosted by the Permian Basin Petroleum Association.

The current energy transition will require a significant expansion of the global supply chain for critical materials needed for electrification of the economy, and deployment of new energy infrastructure. The Bureau's new Comparing Electricity Options (CEO) research consortium is studying the life-cycle environmental impacts of the supply chain and construction of electricity generating technologies.

Carbon storage in deep subsurface geologic environments as part of carbon capture and storage has been of increasing interest at local, state, and federal levels. The Gulf Coast Carbon Center (GCCC) has responded to these needs via a commitment to targeted research with a focus on large scale commercial deployment both offshore and onshore.

GeoH2 is a new research consortium that conducts geoscience and economic research to facilitate and advance the development of a hydrogen economy at scale. GeoH2 connects industry professionals in the energy and power sector with researchers in energy geoscience, subsurface engineering, and energy economics to conduct subsurface hydrogen-storage research and technology development, perform market feasibility analyses, and explore novel subsurface concepts related to hydrogen.

In geothermal research, recent and continuing advances are changing the status quo and positioning Texas to add a major new power source to its grid and to develop a major new industry—new-paradigm geothermal. The new HotRock research consortium focuses on advances in technology that are breaking the old geographic constraint on where geothermal power can be developed and are introducing “geothermal anywhere.”

The Bureau's State of Texas Advanced Oil and Gas Resource Recovery (STARR) has expanded their research into the understanding of how Texas subsurface resources can be positioned to play a role in the ongoing energy transition, aiming at increasing the diversification and resilience of Texas's energy industries and its economy.

EarthDate is a vibrant, entertaining, and educational weekly radio program now reaching thousands of listeners on 429 radio stations in all 50 states and Canada. Bureau Director Scott Tinker hosts each two-minute episode. EarthDate's educational podcasts are also available for download and playback from the Bureau's website.

In May of 2021, a Texas GeoSign created by the Bureau of Economic Geology in cooperation with the city of Austin was installed at Mount Bonnell in Austin, Texas. The mission of the Texas GeoSign program is to enhance the public understanding and appreciation for the geoheritage of Texas.

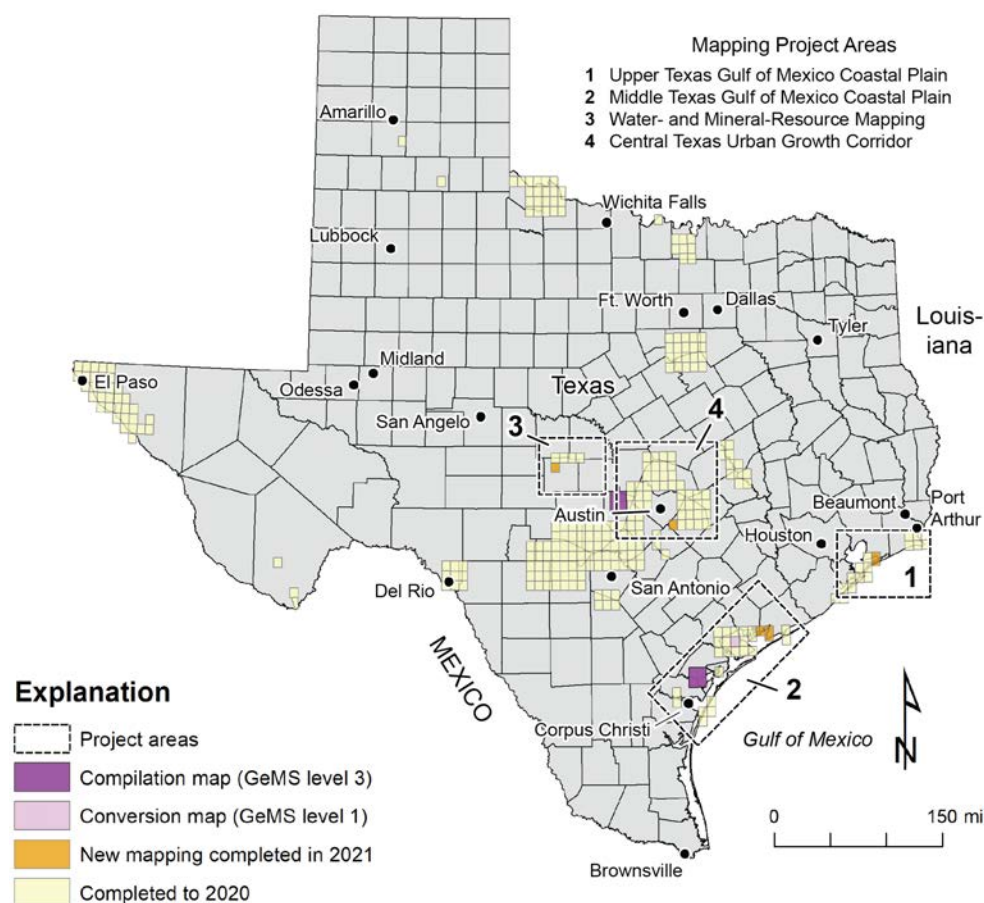


Figure 1. Mapping Project Areas

UTAH

UTAH GEOLOGICAL SURVEY

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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 (DNR). Our mission is to provide timely scientific information about Utah's geologic environment, resources, and hazards. The UGS comprises six technical programs: Data Management, Energy & Minerals, Geologic Hazards, Geologic Information & Outreach, Geologic Mapping & Paleontology, and Groundwater & Wetlands. Additionally, we operate the Utah Core Research Center and our Natural Resources Map & Bookstore retail outlet. Most of our approximately 85 employees work out of our main office in Salt Lake City, and three geologists work out of our satellite office in Cedar City.

GEOLOGIC MAPPING

Our geologic mapping team produces digital GIS and print-on-demand geologic maps at intermediate and detailed scales (30' x 60' quadrangles at 1:62,500–1:100,000 and 7.5' quadrangles at 1:24,000). Two decades ago, the Utah State Mapping Advisory Committee (SMAC) set goals to complete geologic 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, industrial mineral, and water issues associated with Utah's large population centers, high-growth areas, major transportation corridors, and areas of high recreation use. Thanks to recently increased National Cooperative Geologic Mapping Program (NCGMP) funding, our current geologic mapping projects have significantly expanded and now include work focused on U.S. Geological Survey (USGS) Geologic Map



Figure 1. UGS Senior Geologist Eugene Szymanski is leading research into the suitability of the Jurassic Navajo Sandstone as a reservoir for large-scale CO₂ sequestration in southwestern Utah. The work involves rigorous site characterization including subsurface geological CO₂ storage viability and capacity, environmental risk assessment, and economic feasibility options.

Schema (GeMS) GIS conversions of published maps, regional stratigraphic studies, and compilation of various 3D geologic data.

Current projects include detailed mapping of 7.5' quadrangles in the Wasatch Urban Growth area and in southwestern Utah, regional mapping of several parts of 30' x 60' quadrangles scattered across the state, improvement of the state 1:500,000-scale geologic map, border matching with neighboring states, and contributions to national databases. We continue to conduct projects on various older maps to temporarily fill holes in our 30' x 60' series GIS database coverage pending future new mapping projects. Currently, about 80% of the state now has at least preliminary geologic map coverage and about 70% has intermediate-scale GIS coverage. We are currently working on all or parts of six 30' x 60' quadrangles across the state.

We are now in the ninth 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 mapping standards; of these, 28 were mapped or improved in this effort. In the past year we completed geologic maps of six quadrangles in this area and one quadrangle in southwestern Utah's high-growth urban development area as STATEMAP projects. We continue to actively encourage and support EDMAP projects; Utah currently has four new EDMAP projects and a total of eleven active EDMAP projects. Many of these are related to ongoing research on the Sevier gravity slides in southwestern Utah.

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 ([link](#)). Recent improvements to the map interface on the UGS website include an attribute text search and select tool. This tool allows users to select vector data based on any text string and export the selection as a GIS layer. We are also working toward finalizing changes to the Utah geologic map schema to make it fully GeMS compliant.

OTHER PROGRAM HIGHLIGHTS

Our Energy & Minerals Program has been responding to increased interest in projects relating to geothermal; Carbon Capture, Utilization, and Sequestration (CCUS); and critical minerals. We completed the first phase of the INGENIOUS project (INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems), a Department of Energy funded geothermal play fairway analysis of the Great Basin, with collaborators that include the University of Nevada-Reno, Idaho Geological Survey, USGS, and many others. This work involved creation of various regional datasets relevant to geothermal resources followed by selection of sites for geothermal test well drilling of previously undefined resources. At the FORGE (Frontier Observatory for Research in Geothermal Energy) enhanced geothermal system (EGS)

site, work included ongoing research and monitoring of gravity, ground deformation, and groundwater conditions at the site. We began work on a project in the Iron Mountain area west of Cedar City that aims to understand possible reservoirs suitable for CO₂ sequestration; this project is a partnership with New Mexico Tech, Energy & Geoscience Institute (University of Utah), Los Alamos National Laboratory, and the Oklahoma Geological Survey. We also began work on an evaluation of rare earth elements (REE) and critical minerals in coal and coal-adjacent strata, in partnership with the University of Utah, and an evaluation of REE potential of the Permian Phosphoria Formation, in partnership with the Idaho, Montana, and Wyoming geological surveys. Finally, work continued with geologic mapping and critical minerals assessment in the Gold Hill mining district.

The persistence of historical drought in the West keeps water issues a primary focus of UGS work. In addition to ongoing studies related to historical low levels of Great Salt Lake, our Groundwater & Wetlands Program researched salt crust dynamics at the Bonneville Salt Flats, assessed wetland condition and function at two significant wetland preserves, monitored watershed restoration efforts statewide, and installed eddy covariance flux towers for evapotranspiration measurements to calibrate remote sensing data.

Other significant projects included an expanded fossil inventory of the White Rim and Maze districts of Canyonlands National Park, conducted by our Paleontology Section, as well as ongoing efforts to modernize our database of fossil resources across Utah. In addition to ongoing Quaternary fault mapping and monitoring of active landslides, our Geologic Hazards Program provided data and support in efforts to create new legislation addressing radon and earthquake hazards and risk.

In the realm of Equity, Diversity, Inclusion and Accessibility (EDIA), we have experienced a robust, staff-led effort to expand EDIA information and initiatives at the UGS. Working with the DNR Human Resources office, our UGS EDIA committee functions as a staff resource and liaison with UGS management and has served as a template for the creation of a department-level EDIA committee.

VERMONT

VERMONT GEOLOGICAL SURVEY

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INTRODUCTION

The Vermont Geological Survey (VGS), a Division within the Department of Environmental Conservation (DEC) in the Agency of Natural Resources, is guided by a mission to protect the environment and human health and safety and our statutory duty to provide geologic information, expertise, and advice to assist towns, regulatory agencies, and other “clients” in making complex environmental, natural resource, and hazard mitigation decisions. It has been an active year for our small survey of three on a variety of projects, with some highlights provided below.

GEOLOGIC MAPPING

Surficial Mapping

The VGS and our mapping partners have been focused on completing 1:24,000-scale surficial geologic mapping in the Montpelier 1-degree sheet for the past 7+ years in coordination with our STATEMAP Advisory Committee. We

are pleased to announce that our current agreement with STATEMAP will see the completion and seamless compilation of all associated mapping. As part of that important effort, five 7.5-minute quadrangles were published in the last year that allowed for reassessment of many aspects of the area’s glacial and deglacial history and provided the essential geological framework for assessing landslide hazards, groundwater quantity, quality, and flow patterns, stream processes, and potential sources of industrial aggregate and minerals.

Bedrock Mapping

The VGS engaged in large-scale, high-resolution bedrock structural mapping and borehole geophysical logging around the municipal water supplies of Franklin and East Berkshire, Vermont, in support of new source identification. We also mapped high-resolution features near the Rutland Airport for a PFAS fate-and-transport investigation. Finally, we completed a study focused on the impact of groundwater from the fractured bedrock and surficial aquifers on nutrient levels on a lake that is heavily impaired by phosphorous and seasonal eutrophication.



Figure 1. Oblique view of the 12+ acre Cotton Brook landslide that was triggered in 2019. A portion of the toe deposit is shown across the river in the bottom of the view; the dead standing trees in the lower right were submerged under water for several weeks when the Little River was dammed by the toe deposit.

OTHER PROGRAM HIGHLIGHTS

Geologic Hazards

The VGS assisted with a number of landslide evaluations for private residents and supported Vermont Emergency Management with FEMA buyout evaluations for both landslide-prone and flood-prone parcels. We also completed a third year of monitoring of a >200,000 cubic meter landslide at Cotton Brook in Waterbury, Vermont using drone-based photogrammetry and field mapping of surficial and bedrock geology with several state and academic partners. The creation of 3-dimensional point clouds and digital models enabled us to measure the dimensions and orientations of features, calculate volume change, and quantify change over time for better predictions of future hazards. We also performed traditional field mapping of bedrock structures and drone-based photogrammetry to identify blocks of rock that are prone to failure along the spillway of a flood control dam upstream of Montpelier, the state capital, to assist in a rock removal project there for spillway optimization.

Groundwater

Groundwater is protected as a public trust in Vermont, and our Groundwater Coordinating Committee, a broad-based group of government agencies, non-profit organizations, and consultants, recognizes in their Groundwater Management Plan the importance of geologic data to inform local decisions surrounding groundwater and public health concerns (arsenic, radioactivity, nitrates, and other contaminants of concern, such as PFAS). This has guided the VGS in four source water investigations performed in coordination with the Drinking Water and Groundwater Protection Division, a sister division within the Vermont DEC. Our process includes desktop evaluation of the surficial and bedrock geologic framework from existing well logs around municipalities, GIS-based statistical evaluation of yields within ~1-mile of water systems, and localized on-the-ground mapping and borehole geophysical logging for 3-dimensional aquifer characterization and determination of favorable areas for water supply.

Data Preservation

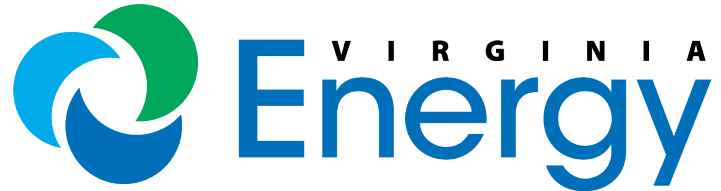
The VGS received funding from the National Geologic and Geophysical Data Preservation Program grant to collate borehole geophysical logging data and videos from 48 wells that were logged over the last decade, to produce useful graphics from those data, and to host the data in an ArcGIS Online WebMap. The goal is to make all associated data and information available online for use by local, state, federal, and private sector scientists engaged in water quantity and quality planning decisions in Vermont.

VIRGINIA

GEOLOGY AND MINERAL RESOURCES PROGRAM

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INTRODUCTION

The Geology and Mineral Resources Program (GMR) is part of the Department of Energy (DE), a Commonwealth of Virginia agency whose mission is to “lead the Commonwealth to a reliable and responsible energy future.” The GMR serves as Virginia’s geological survey. Located in Charlottesville, the GMR 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. Program staff include sixteen full-time geoscientists, one full-time support staff, five part-time support staff, and several external contractors. In fiscal year 2021, funding for the GMR came from state-appropriated recurring general funds (46%) and federal grants (54%).

GEOLOGIC MAPPING

Most of the GMR’s geologic mapping is conducted under the STATEMAP program, funded by the U.S. Geological Survey’s (USGS’s) National Cooperative Geologic Mapping Program. Projects are prioritized pursuant to the Program’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 along the Interstate 81 corridor and in the Richmond Metropolitan Statistical Area (MSA). In the past year, the GMR performed geologic mapping in the Max Meadows and Wytheville quadrangles in the Interstate 81 corridor. In the Richmond MSA, geologic mapping was performed in the Fine Creek Mills, Hopewell, and Hylas quadrangles. All mapping was at 1:24,000 scale and compiled in ArcGIS using the Geologic Map Schema (GeMS) geodatabase data model. Major map compilation efforts during the year were updating the State Geologic Map at 1:250,000-scale and compiling the Virginia portions of six 30- x 60-minute quadrangles at 1:100,000-scale: Bluefield, Bristol, Middlesboro, Pikeville, Roanoke, and Williamsburg. Lidar data were used to improve bedrock geology and to map surficial deposits and landslides.

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, GMR 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.

OTHER PROGRAM HIGHLIGHTS

The USGS Earth Mapping Resources Initiative (Earth MRI) provides continuing support for several activities conducted by the Economic Geology Section. Open File Report 2022-01 ([link](#)) documents the results of a two-year geologic map compilation and a geochemical investigation of heavy mineral paleo-placer occurrences in the Fall Zone of Virginia. A second phase of this study is presently underway that leverages newly available high resolution airborne geophysical data collected in 2021. Mapping and sampling are focused in five 7.5-minute quadrangles in the Fall Zone, assessing potential source rocks for heavy minerals and heavy mineral sands containing critical minerals in the adjacent Coastal Plain sediments.

Virginia Energy is partnering with the U.S. Bureau of Ocean Energy Management (BOEM) to assess the feasibility of extracting economic minerals from sand deposits located on the outer continental shelf (OCS) offshore of Virginia. Our study is evaluating alternative methods for the separation and recovery of heavy minerals containing critical elements, ideally as an integral part of coastal remediation projects. In March 2022, Virginia Energy hosted the Mid-Atlantic Marine Heavy Mineral Sands Forum to gather information about Federal, State, and local regulations and permitting, environmental standards, best practices, and current extraction technologies.

With funding from the USGS through the National Geological and Geophysical Data Preservation Program (NGGDPP), our economic geologists continue to update web content devoted to critical mineral commodities ([link](#)). These web pages provide comprehensive summaries of mapped occurrences, physical characteristics, present day uses, and exploration and mining histories for critical mineral commodities that have been identified in Virginia.

A report published in late 2021 documented the chemical characteristics of produced waters recovered in the Oakwood coalbed methane gas field in southwest Virginia: Publication 191—Economic, Radiochemical, and Stable Isotope Constituents in Formation Waters Produced From Coalbed Methane Wells in Buchanan County, Virginia ([link](#)).

WASHINGTON

WASHINGTON GEOLOGICAL SURVEY

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WASHINGTON STATE DEPT OF
**NATURAL
RESOURCES**
WASHINGTON
GEOLOGICAL SURVEY

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. WGS is Washington's primary state science agency for earthquake, tsunami, 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 July 2021 to June 2022, WGS employed 45–55 full-time staff. The Survey consists of the Geologic Hazards Group, the Landslide Hazard Program, the Geologic Mapping Program, the Surface Mine Reclamation Program, the Washington Geology Library, the Washington Lidar Program, the Publications Group, and the new Earth Resource Program.

GEOLOGIC MAPPING

The Survey's Geologic Mapping Program consists of three full-time mappers, four seasonal field assistants, and a mapping supervisor/mapper. In 2021–2022, the group continued its participation in the STATEMAP program and mapped four-and-a-half 1:24,000-scale quadrangles in the southeast Puget Lowland, in Kittitas Valley near Ellensburg, and along Interstate 90 east of Seattle. Geophysical data collected in these areas enabled the interpretation of geologic cross sections.

The Survey released two new 1:24,000-scale maps of quadrangles in the southeast Puget Lowland and Kittitas Valley as part of the STATEMAP program. The Survey also published three geologic maps prepared by external authors, two 1:12,000-scale maps of Badger Mountain and Candy Mountain in the Tri-Cities area, and a 1:10,000-scale geologic map covering the Sadie Creek fault system in the northern Olympic Peninsula.

The Survey also released new and updated geologic mapping GIS datasets, including 1:500,000- and 1:250,000-scale



Figure 1. A new poster about Mount St. Helens produced in cooperation with the USGS Cascade Volcano Observatory (CVO).

statewide geologic mapping updated from our own internal schema into the U.S. Geological Survey (USGS) GeMS (Geologic Map Schema) format. We also released new GIS data for intermediate-scale geologic mapping (1:25,000–1:99,000-scale), encompassing more than ten newly digitized legacy geologic maps.

OTHER PROGRAM HIGHLIGHTS

Funding from the 2021–2023 legislative session allowed the Survey to establish several new positions, including a dedicated scientist tasked with identifying, characterizing, and mapping aggregate resources in Washington. Additionally, to better engage with our stakeholders in providing them the best available science they can rely on for decision-making, WGS established and filled a new Geologic Planning Liaison position. The position engages with local governments early on in project planning, ensuring full understanding of how to best use our products once projects are completed, and gathering critical feedback to inform how we present our science.

With funding gained from the 2021–2023 Legislative session, WGS was able to form a new program aimed at climate resilience in the Columbia Basin—the Earth Resource Program. This new team is focused on geothermal resources, carbon sequestration, and hydrogeology.

Significant funding was also placed toward the Survey's Lidar Program, enabling completion of the entire state's lidar coverage, funding a 10-year statewide refresh cycle, and ensuring that the large volume of lidar data can be stored and disseminated effectively.

The Landslide Hazard Program released eight Wildfire-Associated Landslide Emergency Response Team (WALERT) reports documenting potential landslide hazards in areas recently burned by wildfires. The Geologic Hazards Group released several tsunami hazard publications, which completes deterministic modeling for Washington's entire coastline, including Puget Sound.

The Publications Group released three new fact sheets: one on geologic planning, another describing the new aggregate resource mapping program, and a third explaining landslide hazards for planners. We also released a new poster about Mount St. Helens (Figure 1), as well as expanded our collection of lidar images, which you can browse online (www.flickr.com/photos/wastatednr/albums).

As part of our data preservation activities, we released a StoryMap presenting archived geologic field notebooks that we scanned and georeferenced as part of a USGS National Geological and Geophysical Data Preservation Program (NGGDPP) grant.

WEST VIRGINIA

WEST VIRGINIA GEOLOGICAL AND ECONOMIC SURVEY

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INTRODUCTION

The West Virginia Geological and Economic Survey (WVGES) was founded in 1897 and celebrates its 125th anniversary in 2022. WVGES is a standalone agency within the state's Department of Commerce with a staff of 33 full-time employees and 6 temporary employees distributed across four programs (Coal, Oil and Gas, General Geosciences, and Information Services). The agency's operations are supported by General Revenue funds with a substantial portion appropriated through the line-item Mineral Mapping Program. Current research is also supported through grants from the U.S. Department of Energy and the U.S. Geological Survey (USGS).

GEOLOGIC MAPPING

Bedrock Mapping

WVGES currently conducts 1:24,000-scale (24k) bedrock mapping in cooperation with the USGS STATEMAP program. For several years WVGES has been working to address areas containing karst terrain in West Virginia. The need for mapping of areas containing karst potential in West Virginia was bolstered with legislation requiring WVGES to determine if proposed oil and gas exploration was located in karst terrain. Therefore, WVGES elevated the mapping and differentiation of the Mississippian Greenbrier Group where it outcrops in West Virginia as the highest mapping priority. The Greenbrier Group is a limestone-dominant geologic interval that contains caves, sinkholes, and other karst related features. This mapping is contiguous with previously mapped quadrangles and addressed other factors that included, but were not limited to, geologic hazards, areas and organisms of biological importance (primarily relating to caves), natural resources, and critical infrastructure.

WVGES previously attempted to concentrate mapping in the fall and spring each year and submit deliverable maps in the late spring. Due to COVID-related impacts, the period of performance has shifted the deliverable date. WVGES began a 1-year period of performance in August 2020 and delivered three 24k bedrock quadrangles (Anthony, Droop, and Trout) at the end of July, 2021. The mapping was concentrated in Greenbrier and Pocahontas counties. Additionally, WVGES delivered the first "supplemental" projects that included a Geologic Map Schema (GeMS) compliant database of the 1968 1:250,000 scale statewide geologic map, GeMS Level 1 database of the Harman 24k quadrangle, edge-matching work with previously mapped quadrangles, training and workflow of the WVGES efforts to produce GeMS compliant maps, and updates to the National Geologic Map Database (NGMDB) catalog.

WVGES had proposed the next period of performance begin the day after the July 2021 products were delivered,

but delays in the USGS processing of awards delayed the start date to early September. The projects that began in September 2021 included the mapping of four full (Asbury, Cornstalk, Lewisburg, and Williamsburg) and one partial 24k (Ronceverte) quadrangles in Greenbrier County, West Virginia. This mapping was contiguous with that of 2020–2021 and adjacent to USGS FEDMAP mapping in Monroe County. Additionally, in the U.S. Geoframework Initiative (USGFI), WVGES is working on the completion of the following tasks: Developing the West Virginia portion of the Hagerstown 100k sheet as a fully GeMS compliant database; creating a Level 2 database of the Harman 24k quadrangle; continuing the development of a workflow for edge-matching geology across map boundaries; and updates to the NGMDB catalog.

WVGES submitted a proposal in December 2021 for new bedrock mapping and several USGFI projects. The agency was awarded funds for a two-year project that will begin September 2022. This project will include: mapping of five full and seven partial 24k quadrangles; compilation of two 1:100,000-scale sheets at 1:24,000 scale; multiple GeMS databases; GIS training; development of a surficial mapping framework in conjunction with other state geological surveys; inventory of completed publications; and updates to the NGMDB Catalog.

WVGES has been steadily expanding the scope of our bedrock mapping due to increased staffing capabilities funding, which enables deployment of mappers to multiple parts of the state.

OTHER PROGRAM HIGHLIGHTS

One of the most critical and long-standing issues for the WVGES is the agency's lack of a modern core repository. The current facility, a corrugated metal building constructed in the 1950s, is filled to maximum capacity and showing its age. Fortunately, this critical need is being addressed via support from the USGS National Geological and Geophysical Data Preservation Program, which awarded WVGES approximately \$50,000 to construct a metal pole building for auxiliary storage. In addition, the agency was encouraged by the state Department of Commerce to submit a Congressionally Delegated Spending (CDS) request to the offices of Senator Joe Manchin and Senator Shelley Moore Capito for the construction of a modern storage facility. If awarded, the requested funding level of \$2 million would be equally matched by the State, and the building would be constructed at WVGES headquarters in Morgantown. This is a very exciting prospect that we hope will come to fruition.

WISCONSIN

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

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**Wisconsin Geological
and Natural History Survey**

DIVISION OF EXTENSION
UNIVERSITY OF WISCONSIN-MADISON

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. For July 2021 to June 2022, the staff of the WGNHS consisted of 27 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.

June 2022 marked the retirement of Dr. Kenneth Bradbury as Director and State Geologist for the WGNHS. Ken served in this role for 7 years, and as a Hydrogeologist with the WGNHS for 33 years prior.

GEOLOGIC MAPPING

Bedrock Mapping

The Survey is progressing on new 1:100,000-scale bedrock geologic mapping in Jefferson County. In this part of south-eastern 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.

WGNHS bedrock geologists are also continuing 1:100,000-scale mapping in Grant, Iowa, and Lafayette Counties in southwestern-most Wisconsin. This area comprises the historic Lead-Zinc Mining District in Wisconsin. Targeted mapping is being conducted at 1:24,000 scale to assess small-scale bedrock structures and mineralization associated with the Lead-Zinc District. This detailed mapping will be combined with similar mapping conducted by the U.S. Geological Survey (USGS) in the mid-20th century to produce complete 1:100,000 scale maps of these counties.

- 1:24,000-scale Geologic map of the Castle Rock and Long Hollow 7.5-minute quadrangles, Grant County, Wisconsin, WGNHS Open-File Report 2022-01
- 1:24,000-scale Geologic map of the Bloomington and part of the Brodsville 7.5-minute quadrangles, Grant County, Wisconsin, WGNHS Open-File Report 2022-03

Surficial Mapping

WGNHS Quaternary geologists continued a long-term, holistic mapping project in the never-glaciated Driftless Area of southwestern Wisconsin. Mapping at a scale of 1:100,000 was completed in Monroe and Grant Counties, bringing the

total of recently mapped, contiguous counties in the area to six, with the long-term goal of mapping all ~14 counties in the Driftless Area at 1:100,000 scale. In support of new mapping in the Driftless Area, WGNHS staff collected two long rotosonic cores—one in lake sediment deposited as part of the late Pleistocene glacial Lake Wisconsin and the other in a slackwater setting along the lower Wisconsin River valley. The two cores provided new accelerator mass spectrometry radiocarbon chronologic control on advance and retreat of the Green Bay Lobe of the Laurentide Ice Sheet and associated sedimentation.

Surficial geologic mapping continues in Bayfield County on the south shore of Lake Superior. The U.S. Forest Service is funding this work as part of a goal of mapping all of the Chequamegon-Nicolet National Forest at 1:100,000 scale.

The Survey is also progressing on the compilation of a 1:500,000-scale surficial map of Wisconsin. This will be an entirely new product in our mapping inventory, with entirely new line work tuned to the scale.

- 1:100,000-scale Quaternary Geology of Fond du Lac County, Wisconsin, WGNHS Bulletin 116
- 1:100,000-scale Quaternary Geology of Jefferson County, Wisconsin, WGNHS Bulletin 118

OTHER PROGRAM HIGHLIGHTS

Agriculture and Groundwater Contamination

In 2021 the WGNHS initiated a multi-year project to monitor and assess the effectiveness of regulations imposed to mitigate groundwater contamination in targeted agricultural areas of the state. Areas underlain by the Silurian dolomite aquifer in northeastern Wisconsin are extremely vulnerable to groundwater contamination from land-use activities, especially the disposal of human wastewater and dairy manure. In the summer of 2018, the Wisconsin Department of Natural Resources adopted the NR151 Silurian targeted performance standard with the goal of reducing the transport of pathogens from land spreading of manure. The targeted performance standard applies to areas in Wisconsin where the surficial sediments that overlie the aquifer are less than 20 feet thick. The WGNHS is conducting long-term monitoring to test the effectiveness of the NR151 rule changes in northeast Wisconsin.

AEM Surveys

The WGNHS has partnered with the USGS and other state and national agencies to collect and interpret Airborne Electromagnetic (AEM) data over eastern, southwestern, and southeastern Wisconsin. In eastern Wisconsin, these data are being used to develop depth to bedrock maps over Silurian dolomite, a region susceptible to groundwater contamination.

tion. These maps will be used to limit manure spreading in areas of shallow bedrock. We will use the AEM data to map aquitard extents and thicknesses, including the Maquoketa shale in eastern and southeastern Wisconsin, and the Glenwood shales in southwestern Wisconsin. Other geologic insights such as the thickness of fluvial sediment in the Mississippi and Wisconsin River valleys will be forthcoming.

Artesian Well Study

In 2022, the WGNHS began an effort to identify and describe flowing artesian wells in Bayfield County on the south shore of Lake Superior. Artesian wells occur in abundance

along the south shore of the lake due to the presence of a regional confining layer of late Pleistocene lake clay. Staff identified 167 flowing wells in the county and completed field surveys and collected water samples at 49 sites. Flowing artesian wells provide a reliable source of water that both community members and tourists value. However, the extent of the artesian aquifer and its amount of use have not been well documented. This study will produce a database of flowing wells and historic artesian conditions, plus well use, modern flow rate, and water chemistry. Our results will help to better understand the sources and quality of the water that feeds artesian wells in the region, and help evaluate how such conditions may be change over time.

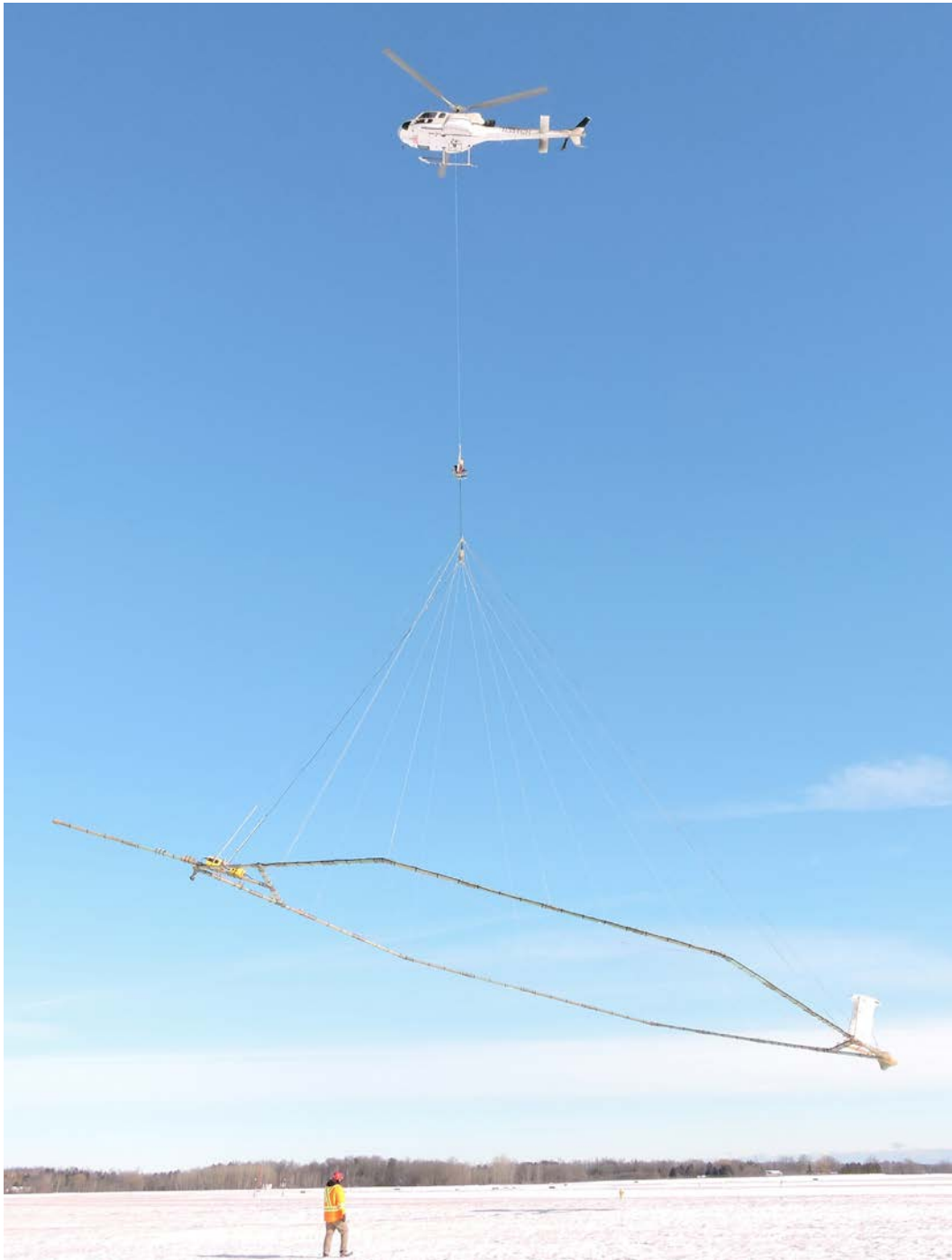


Figure 1. Airborne Electro-magnetic (AEM) array carried by helicopter at completion of a survey in northeastern Wisconsin, 2021.

WYOMING

WYOMING STATE GEOLOGICAL SURVEY

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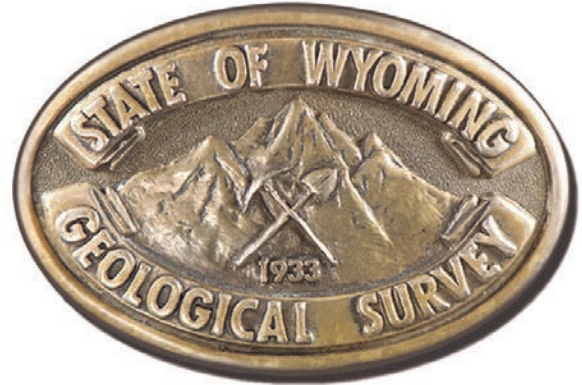
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INTRODUCTION

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 19 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

Five bedrock maps were completed at the 1:24,000 scale in an effort to expand knowledge of energy and mineral resources:

- 1:24,000-scale bedrock geologic map of the Poe Mountain quadrangle, Albany and Platte Counties, Wyoming
- 1:24,000-scale bedrock geologic map of the Guide Rock quadrangle, Albany County, Wyoming
- 1:24,000-scale bedrock geologic map of the Oil Mountain quadrangle, Natrona County, Wyoming
- 1:24,000-scale bedrock geologic map of King Mountain quadrangle, Albany County, Wyoming
- 1:24,000-scale bedrock geologic map of Ragged Top Mountain Quadrangle, Albany and Laramie Counties, Wyoming

Surficial Mapping

The east half of the 1:100,000-scale Jackson Lake quadrangle in Teton County was completed as part of an effort to better understand landslide and seismic risk.

3D Mapping

Precambrian Basement Map of Wyoming: Structural Configuration is a 1:500,000-scale map contoured at a 1,000 foot interval depicting the surface of Precambrian basement rocks in Wyoming.

OTHER PROGRAM HIGHLIGHTS

AASG Award

2021 Association of American State Geologists Charles J. Mankin Award for "Upper Cretaceous Strata in the Powder River Basin: Formation Tops Database, Structure and Thickness Contour Maps, and Associated Well Data"

Other Selected Publications

Heavy-Mineral Sandstone in the Upper Cretaceous Rock Springs Formation, Richards Gap, Wyoming

The WSGS published a new study examining the mineralogy and geochemistry of a heavy-mineral sandstone deposit in southwestern Wyoming.

Trace Element Geochemistry of Coal Deposits in the Adaville and Frontier Formations, Kemmerer Coal Field, Wyoming

This study presents geochemical data for coals and associated strata from the Adaville and Frontier formations, the two major coal-bearing geologic units in the Kemmerer area. The study adds to historic data by including samples of a wide range of rock types associated with coal deposits.

Groundwater Level Recovery in the Sandstones of the Lower Tertiary Aquifer System of the Powder River Basin, Wyoming

This report examines and analyzes three decades of BLM groundwater data from coalbed natural gas production to interpret long-term groundwater changes in nearly 100 coal seam and sandstone wells on 39 monitoring sites in the Powder River Basin.

Online Map: Roadside Geology on Route to Yellowstone National Park

In celebration of the 150th anniversary of Yellowstone National Park, the WSGS developed an interactive web map showcasing roadside geology along different routes through the state on the way to Yellowstone.

Groundwater Salinity in the Wind River and Bighorn Basins, Wyoming

This report is the final study in a series examining groundwater quality in Wyoming energy-producing basins.

Geothermal Data Online Map

This interactive map spatially presents Wyoming's hot springs and wells, geothermal systems, and borehole bottom temperatures. Modeled estimates of geothermal potential and groundwater temperatures are included as well.

Annual Summary Reports

The WSGS published its annual summary report about the state's oil and natural gas industry, which outlines significant events that occurred in the industry during 2021. An additional report on the state of critical minerals in Wyoming was also released.

AWARDS

FRYE 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 (1912–1982) joined the U.S. Geological Survey (USGS) in 1938. He went to the Kansas Geological Survey in 1942 and was its Director from 1945 to 1954. He was Chief of the Illinois State Geological Survey until 1974 and GSA Executive Director until his retirement in 1982, shortly before he passed away. John was active in 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 2022 award was presented to Anna Fehling and David Hart of the Wisconsin Geological and Natural History Survey for the report Potential effects of climate change on stream temperature in the Marengo River head-waters (Wisconsin Geological and Natural History Survey Bulletin 115).

MANKIN 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 2022 Charles J. Mankin Memorial Award are Susan E. Pool, Ray M. Boswell, John T. Saucer, and B.J. Carney of the West Virginia Geological and Economic Survey for their publication Estimates of Natural Gas Resources and Recovery Efficiencies Associated with Marcellus Development in Northern West Virginia (2021, WBGES Reports of Investigations—36).

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 2022 Pick and Gavel Award is presented to Senator John Barrasso, for his support of earth sciences and understanding of its importance and inclusion in public policy. In his role on the Committee of Energy and Natural Resources, he has shown support for programs to address critical mineral and supply chain issues, as well as the preservation of geologic data. His leadership on the Infrastructure Investment and Jobs Act provided much-needed funding for state geological surveys. Senator Barrasso's involvement in geologic topics and his support of public policy to support geologic research is greatly appreciated by AASG.

DISTINGUISHED SERVICE AWARD

The AASG Distinguished Service Award is presented to particularly deserving living retired or retiring State Geolo-

gists, Associates, and Honorary Members other than current officers who deserve to be recognized for the excellence of their efforts over the long term, in particular through AASG, and their pride in advancing our science and its application, in improving the work of state geological surveys, in improving dissemination of the knowledge we produce, in achieving effective coordination with partner agencies, and in promoting camaraderie among the membership of AASG. Four retired State Geologists were honored in 2022.

Jon Arthur is currently Executive Director of the American Geosciences Institute (AGI). He was State Geologist of Florida, 2010–2021; AASG Past President, 2015–2016; President, 2014–2015; President Elect, 2013–2014; Vice President, 2012–2013; and Treasurer, 2010–2012.

Vicki McConnell has been GSA Executive Director since 2015. She was State Geologist of Oregon, 2003–2015; AASG Past President, 2012–2013; President, 2011–2012; President Elect, 2010–2011; Vice President, 2009–2010; and Secretary, 2007–2009.

Robert G. Marvinney was State Geologist of Maine, 1995–2021; Annual Meeting Host, 1998; Secretary, 2001–2003; President Elect, 2003–2004; President, 2004–2005; Past President, 2005–2006; Honoraries Chair, 2016–2021; Education Chair, 2015–2021; and Water Chair, 2010–2012.

Charles G. Groat was State Geologist of Louisiana from 1978–1990, in 1992, and from 2017–2021; Director, U.S. Geological Survey, 1998–2005; Ian Campbell Medalist, 1998; AASG Honorary Member, 1993–present; AASG Past President, 1988–89; AASG President, 1987–88; and AASG President Elect, 1986–1987.

PRESIDENTIAL AWARD

The AASG Presidential Award is presented by the AASG President to particularly helpful, constructive, and worthy members or friends of AASG for extraordinary service to the objectives of AASG. In 2022, AASG President Erin Campbell presented the AASG Presidential Award to Harvey Thorleifson, State Geologist of Minnesota. Harvey has been an incredible asset to AASG through serving as interim secretary, taking co-lead on the Liaison Committee, assisting in monitoring many federal matters including the Bipartisan Infrastructure Law, sharing of institutional knowledge, and willingness to step in whenever needed. The list of Presidential Awards can be found at www.stategeologists.org/award/presidential.

ADDITIONAL AWARDS

The Ian Campbell Medal is presented each year to a nationally recognized, living statesperson with a distinguished record of significant achievements in science, education, and administration, in support of the profession of geology and its role in society. The 2022 Ian Campbell Medal was awarded to Jean M. Bahr.

The Heroy Award is in recognition of exceptional and beneficial long-term service to the American Geosciences Institute. The Institute gave the 2022 Heroy Award to Sharon Mosher.