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Association of American State Geologists

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PRESIDENTS' PAGES



Steven S. Masterman

It has been an honor and privilege to serve as AASG President this past year. Our organization has a rich history of service to the states and the nation and it is a history of which we can be proud. It has been my honor and privilege to serve as the President of this esteemed Association for the year ending June 30, 2018.

Much was accomplished during the 110th year of the Association, and it is a true testament to the dedicated membership and Executive Committee with whom I have had the pleasure to work: Past-President David Spears (VI); President-Elect Karen Berry (CO); Vice President Richard Ortt (MD); Secretary John Metesh (MT); Treasurer Harvey Thorleifson (MN); and Honorary Members Representative Robert Marvinney (ME). As many of my predecessors have noted, there is never enough time to accomplish all the initiatives and plans envisioned at the beginning of the Presidential term of office. However, I feel we made progress in the past year, and am confident the incoming executive team will lead us forward in the spirit of the association.

The Executive Committee met formally during the 2017 Fall Liaison Meeting, the 2018 Spring Liaison Meeting, and, prior to the 2018 Annual Meeting. Additionally, the Executive Committee met monthly by phone during the business year to plan, discuss, and report on meetings and initiatives associated with the liaison, the mid-year, the annual meeting, and legislative and funding initiatives. These meetings were informal but very important in allowing AASG leadership the opportunity to have a dialogue on business matters and strategic planning.

In September 2017, AASG conducted its Fall Liaison in Washington, visiting 28 agencies and hill offices over the course of three days. In a change from the recent Liaison model, emphasis was placed on legislative issues and securing funding for a new mapping initiative. Primary topics of discussion centered on NCGMP reauthorization, Critical and Strategic Minerals (3DEEP) funding, and natural hazards (NVEWS, Landslides, and NEHRP). This strategy was partially successful with the NCGMP being introduced for re-authorization in both the House and Senate, and movement in committee on several of these bills.

The March 2018 Spring Liaison in Washington was a success, with 54 meetings being held. As with the fall Liaison, the focus this spring was to advocate for the benefits of reauthorization of the National Cooperative Geologic Mapping Act, and for funding for the Critical Minerals Initiative (3DEEP). The annual AASG Pick and Gavel Awards Banquet was well attended with Senator Cantwell of Washington being recognized as a most deserving recipient. Senator Cantwell was unable to attend, but her staff was presented with a beautiful specimen of petrified wood from

her home state of Washington. We welcomed three new state geologists and bid farewell to those retiring.

At our mid-year meeting, AASG recognized the recipient of the Charles J. Mankin Memorial Award: Hussey, A. M., II; Bothner, W. A.; Thompson, P. J., 2018, Bedrock geology of the Kittery 1:100,000 quadrangle, southwestern Maine and southeastern New Hampshire: Maine Geological Survey Bulletin 45, 99 p.

At our mid-year meeting, AASG recognized the recipient of the John C. Frye Memorial Award: White, J. L.; Morgan, M. L.; Berry, K. A., 2018, The west Salt Creek landslide: A catastrophic rockslide and rock/debris avalanche in Mesa County, Colorado: Colorado Geological Survey Bulletin 55, 57 p.

During the year, the Association increased dues and entered into contracts for administrative assistance through the AIPG, and a contract for professional services in Washington DC to provide guidance and advice in our advocacy efforts. Both have proved valuable, but the professional services in DC were especially so, facilitating many meetings on the Hill that were instrumental in garnering support for the 3DEEP initiative.

As an Association we have accomplished a considerable amount during this and previous years, yet there will be a variety of issues we must continue to address and successfully navigate if we are to remain a viable and relevant organization. In many ways we are very much the same spirited organization that was founded in 1908. In many other ways we have changed and adapted to new environments, politics, paradigms, and cultural shifts.

I encourage new members to get involved with the Association. It has helped me build relationships with many of the decision makers in the federal agencies we work with and build friendships with other state geologists who are a wealth of knowledge and a great resource. The benefits far outweigh the associated responsibilities.

Finally, I would like to thank all of the members of AASG who made this year a success: those on the Executive Committee tackle the enormous jobs of preparing Liaisons, organize advocacy efforts for funding and legislative initiatives; arrange the Mid-Year and Annual Meetings, keep our finances in order, identify candidates for various awards, and coordinate with our agency partners; those who work to raise money for AASG initiatives; the Committee Chairs and members; and the membership at large for your unwavering support of this organization. You are the Association of American State Geologists and it has been a great honor to serve as your President.

Respectfully yours,

A handwritten signature in blue ink that reads "S. Masterman". The signature is fluid and cursive.

Steven S. Masterman, Alaska, AASG President 2017-2018



Group Photo. Participants in the 2018 AASG Annual Meeting, held in Rehoboth Beach, Delaware. Only State Geologists present at the meeting are shown. *Left to Right:* Thomas Serenko (OH), John Parrish (CA), John Metesh (MT), Jonathan Arthur (FL), John Yellich (MI), Richard Berg (IL), Ronald Zurawski (TN), Harvey Thorleifson (MN), Nelia Dunbar (NM), Jeffrey Hoffman (NJ), David Dockery (MS), Karen Berry (CO), Rick Allis (UT), Scott Tinker (TX), Michael Ratchford (ID), David Wunsch (DE), Ken Bradbury (WI), Steve Masterman (AK), Richard Ortt (MD), Gail Blackmer (PA), Keith Schilling (IA), Margaret Thomas (CT), Steve Mabey (MA), Todd Thompson (IN), Robert Marvinney (ME), James Faulds (NV), Marjorie Gale (VT), Nick Tew (AL), Dave Norman (WA), David Spears (VA), Phil Pearthree (AZ), and Jeremy Boak (OK).



David Spears

Editor's Note: *The AASG journal was not published in 2017, so the 2016–2017 AASG President's page is included in the 2018 journal.*

"Let's do *something*, even if it's wrong. We can fix it later." I was working with my electrical engineer father-in-law, Dick Paxton, on a construction project in my backyard. We'd worked for several days on the foundation for a small building, and were now done with that part. What should we do

next? We were both analytical thinkers and could envision about a dozen different paths forward. We weighed our options, considered our tools and materials, and generally dithered. Finally, having heard enough talk, he said those two sentences. Sometimes, even when you're not absolutely sure, you just have to do something. Maybe you'll make mistakes, but you can fix them later. Even though Dick has been gone many years, his philosophy of action in the face of uncertainty has stuck with me.

Being President of AASG provides one with many opportunities to make mistakes. As I've said before, when you get onto the AASG executive track, you do each job for only one year, which is just long enough to do it badly. Fortunately, for FY16–17, I had an excellent Executive Committee to help keep me out of trouble: Past President Joe Gillman of Missouri, who also served as host for our Annual Meeting; President-elect Steve Masterman (AK);

Vice President Karen Berry (CO); Secretary John Metesh (MT); Treasurer Derric Iles (SD); and Honorary Representative Bob Marvinney (ME). I extend a heartfelt "Thank you!" to all of them.

Attendance at Fall Liaison had been shrinking for several years, so instead of fighting the trend and begging people to come, we decided to bring just the Executive Committee to Washington DC in September 2016. Normally we spend the first morning with USGS senior leadership at the Main Interior Building downtown, but since there were more of them than there were of us, we decided to travel out to USGS headquarters and spend the whole day there. We rode the Metro out to Reston and Darcy McPhee, STATEMAP coordinator, picked us up in a van at the station. We had a productive day meeting with all the usual Associate Directors, and in the afternoon had an entire hour with Director Suzette Kimball.

Less than a month later, we held the AASG Mid-year Meeting in Denver. Several important items were on the agenda for the business meeting, including a report from an ad hoc committee formed to make recommendations about getting professional assistance to organize liaison meetings, administer the day-to-day business of AASG, and help direct our efforts in Washington. The fundamental conclusion of the report was that we needed help and would probably need to raise our dues to pay for it. Also on the agenda was reauthorization of the National Cooperative Geologic Mapping Act (NCGMA). As the home for STATEMAP, the Act is extremely important to AASG, and the time had come to push for reauthorization. On a motion from Karen Berry (CO),

we voted to dedicate \$25,000 of our cash reserve to providing assistance to the Executive Committee in its efforts to get the Act reauthorized and funding to the program increased. Exactly how that money would be spent was left up to ExComm.

One of the greatest responsibilities of AASG President is to organize the Pick and Gavel Banquet, including selection of the P&G Award recipient. The award is intended to recognize someone who has contributed to the advancement of public good through action at the intersection of geoscience and public policy. I once had the pleasure of sitting at the witness table before a hearing of the Energy and Mineral Resources subcommittee of the House Natural Resources Committee. The hearing was about the management of our national forests, specifically the drafting of language for the leasing of fossil fuels and minerals in forest management plans. The chair of the subcommittee at that time was Representative Doug Lamborn (R-CO) and the ranking member was Rush Holt (D-NJ), a past recipient of the Pick and Gavel Award. I was impressed by the way they worked together to run the hearing, so when the time came for me to pick a Pick and Gavel recipient, I considered Rep. Lamborn. My online research turned up some interesting facts. He was one of the most conservative members of Congress. He had proposed eliminating funding for the Corporation for Public Broadcasting. As an enthusiastic consumer of both NPR and PBS content, I found this disturbing. He had, however, a respectable record of votes regarding the management of public lands, and had more than once made public remarks critical of the direction the USGS was taking, expressing opinions that were remarkably aligned with those of AASG leadership at the time. After discussion with the Executive Committee, we decided to invite Rep. Lamborn to receive the award. He accepted the invitation, and agreed to appear in person to receive it (an important consideration!) He turned out to be an appreciative and charming guest at our banquet, even attempting to stump the AASG President with a rock sample that he had in his pocket (thank you, Vicki, for the hint that saved me from great embarrassment). Many months later, when it came time to find a Republican sponsor for our National Cooperative Geologic Mapping Act reauthorization bill, he agreed. Thank you, Representative Lamborn.

The 2017 Annual Meeting was hosted by the Missouri Geological Survey in Branson, MO. Joe Gillman and his team put on an excellent meeting in a beautiful venue with great field trips, food, beverages, and camaraderie. At the business meeting, we once again struggled with the idea of professional assistance. In the recent past, we couldn't seem to decide what we needed most, administrative assistance or an advocate in Washington. On conference calls of the Executive Committee leading up to the meeting in Branson, we decided we needed both. Of course, to do this we would need to raise our dues again. We voted to go with a tiered dues structure, with smaller surveys remaining at \$600 annually, medium-sized surveys paying \$1,200, and the largest surveys paying \$2,400. Any Survey finding the new structure onerous could petition the Executive Committee for relief. The resulting increased revenue eliminated the need for AASG to dip into its reserves to pay for the NCGMA reauthorization effort. We then voted to hire both an administrative assistant through a cooperative agreement with the American Institute

for Professional Geologists at their Colorado headquarters, and a Washington-based advisor and advocate familiar with geoscience issues. For this, on the recommendation of several of our colleagues in Washington, we selected Elizabeth Duffy, who represents the Seismological Society of America and who serves on the organizing committee of the USGS Coalition. Branson was a milestone meeting for AASG, and we owe great thanks to the Missouri Geological Survey for providing the environment and the refreshments to make it all happen.

Serving AASG as President was a great honor and privilege. I thank all the members, associates, honoraries, and emeriti for their confidence and support. Finally, I encourage the newer members of AASG to consider serving as an officer of the Executive Committee. If asked, just say "Yes!"

David Spears, Virginia, AASG President 2016–2017

ALABAMA

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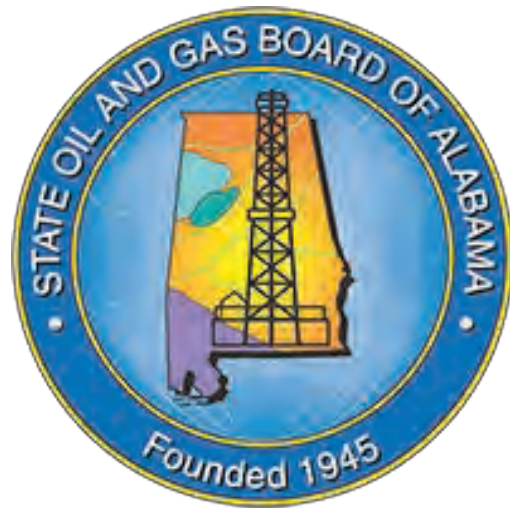
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INTRODUCTION

The Geological Survey of Alabama (GSA) is an independent state agency that reports to the Alabama Legislature and 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.

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

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

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

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

ENERGY INVESTIGATIONS PROGRAM

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

Resource Assessments

Coal research includes characterization of coal resources under the auspices of the U.S. Geological Survey's National Coal Resources Data System (NCRDS). Work under NCRDS includes the compilation of basic coal resource data from more than 7,000 coalbed methane wells and exploratory cores, which have been drilled in the eastern part of the Black Warrior Basin. In addition, program scientists are developing an integrated database and Geographic Information System of underground coal mines in the Black Warrior Basin with the support of the U.S. Department of the Interior's Office of Surface Mining.

Work continues on the Alabama Oil Sands Program (AOSP), established in 2014. The AOSP is charged with providing a roadmap to facilitate prudent commercial development; assisting in realization of economic and societal benefits from prudent, orderly, and environmentally sound development; providing focus for oil sands activities and initiatives; and evaluating and developing appropriate legal and regulatory frameworks. As part of the AOSP, the Energy Investigations Program continues a systematic, scientific assessment of Alabama's oil sands. A geophysical survey utilizing ground-penetrating radar in conjunction with electrical resistivity tomography has been conducted. Coring is set to begin in fall of 2018. Core analyses, petrologic studies, and evaluation of extraction technologies will be integrated with the ground penetrating radar work to provide a comprehensive updated assessment of the resource.

The Southeastern Offshore Storage Resource Assessment project, which is assessing prospective geologic storage resources for carbon dioxide in state and federal waters of the Mid-Atlantic, South Atlantic, and the eastern Gulf of Mexico, is in its final stages. The EIP's work has focused on the Tertiary section of the eastern Gulf of Mexico, building on previous offshore and onshore resource assessments related to geologic carbon sequestration. Building on these efforts, the EIP is just beginning work as part of a new partnership, SECARB Offshore, further investigating the potential for geologic carbon sequestration in the Gulf of Mexico.

The EIP has also been involved with seismic reflection data interpretation in support of Project ECO2S in Kemper County, Mississippi. Our role was to assist in risk reduction by determining the potential for faults cutting the confining units for a proposed geologic carbon sequestration target. The results of this

work have been presented at national conferences, including the American Association of Petroleum Geologists annual meeting.

Modeling and Data Management

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

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

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

GEOLOGIC INVESTIGATIONS PROGRAM

The Geologic Investigations Program conducts research, mapping, and data collection of geology, geologic hazards, mineral resources, and paleontology.

Geologic Mapping and Hazards Section

The Geologic Mapping Group participates in the STATEMAP component of the National Cooperative Geologic Mapping Program, which is administered by the U.S. Geological Survey. Supported through the program, geologic mapping of the Weisner Mountain and Piedmont Northwest 7.5-minute quadrangles was completed, and mapping of the Ballplay, Ellisville, and Piedmont quadrangles was initiated. The section also assisted Auburn University, University of South Alabama, and Florida State University with proposals to the EDMAP component of the National Cooperative Geologic Mapping Program. In addition, the Geologic Mapping group, along with Auburn University, recently completed mapping of the Little River Canyon National Park in the northeastern part of the State, for the National Park Service, .

Hazard-related activities include researching geologic hazards of the state (sinkholes, landslides, and earthquakes); creating and analyzing hazards maps and GIS map data; and answering information requests from the public. Staff also cooperate with planners and emergency managers, contributing, interpreting, and reviewing state and county Hazard Mitigation Plans. Staff are also involved in geologic hazards research and planning

on a larger scale, including regional earthquake disaster response planning with the Central U.S. Earthquake Consortium.

Geologic Resources and Information Section

Minerals resources activities in the GIP focus on nonfuel minerals, and for this year, staff completed a nonfuel mineral resources publication: *Minerals in the Economy of Alabama*, 2008–2013, published in January 2018. The staff also began collecting data for the next publication in this minerals Information Series and also started an aggregate project focusing on the availability of limestone and granite resources. Compilation of rock and mineral kits for use in classroom settings was an additional activity for this year, as was maintaining the historic mineral reference collection for comparative purposes in research.

The curator of the GSA paleontology collection prepares specimen metadata describing fossils in the collection for submission to the National Catalog maintained by the National Geologic and Geophysical Data Preservation Program (NGGDPP). The fossil collection data has been used by geologic mappers, paleontology researchers, and by oil and gas companies proposing to build or expand pipelines with the need to include a paleontological resources assessment as part of the Environmental Impact Statement section of the required application to the Federal Energy Regulatory Commission.

The Program's director and the State Geologist continue to be involved with state GIS planning and coordination by serving on the Alabama GIS Advisory Board and Executive GIS Council as Governor-appointed members. GIS is part of many of the Geologic Investigations Program's mapping and research projects. Additional GIS activities for this year included coordinated efforts with other state agencies to build and maintain the agency's lidar, aerial imagery, and other GIS data resource holdings.

GROUNDWATER ASSESSMENT PROGRAM

The Groundwater Assessment Program (GAP) is involved in a wide variety of hydrogeologic and geochemical assessments throughout Alabama to develop additional sources of public, industrial, domestic, and agricultural water supply, to protect current sources, and to develop basic scientific understanding of Alabama's groundwater resources for water policy development. The scope of the GAP ranges from local and regional to statewide projects. Local and regional groundwater research is performed in cooperation with local governments and water supply systems to address stratigraphic and geochemical considerations related to the occurrence and development of potential water sources. The GAP also performs surface-water assessments to evaluate water quality and sedimentation impacts and to assess groundwater/surface-water interaction related to runoff and recharge. The GAP is organized into four sections reflecting the diverse work this program accomplishes.

Groundwater Assessments Section

The Groundwater Assessments Section is tasked with developing a broad array of groundwater resource products for the public including water table and potentiometric maps, geologic cross sections, geologic structure maps, and groundwater productivity maps, all with the goal to assist groundwater development activities and management of groundwater resources. The GAP recently completed a general statewide assessment of groundwater resources summarizing existing data and collecting new data from over 2,500 wells. The Groundwater Assessment Section is currently collecting samples from wells to update groundwater quality knowledge in Alabama's Cretaceous strata, recently updated a publication of springs in Alabama, and will be developing water budgets for targeted areas in Alabama.

Groundwater Monitoring Section

The Groundwater Monitoring Section maintains a groundwater level monitoring program that currently includes over 400 wells and springs measured semiannually and a real-time monitoring system of 28 wells and two springs. The groundwater level monitoring program is currently expanding to include more wells and springs monitored annually through field work associated with the statewide groundwater assessment. The real-time monitoring system will be expanded in the future to include additional wells to assess impacts such as water use and drought conditions. Data from the groundwater monitoring program, including wells and springs measured annually, and the real-time monitoring system are continuously updated on the GSA GAP website and are available to the public. Data from the monitored wells are used to determine impacts of climate and water production on all major aquifers in the state. The Groundwater Monitoring Section also receives and digitally catalogs drillers' reports on newly drilled wells, in addition to collecting and filing all related groundwater records for GSA research projects. The GSA well file is an extensive collection of water well records in the State. It is being developed with a goal of creating consistent, compatible databases, archiving legacy water data, enhancing capabilities for digital acquisition of field data, and furthering the use of the web for data and information dissemination.

Coastal Resources Section

The Coastal Resources Section conducts land- and marine-based research within Alabama's coastal counties to increase our understanding of beach and shoreline change, environmental quality, and terrain- and marine-based use, and to facilitate the acquisition and development of supporting digital themes and datasets.

Because of the importance of tourism along Alabama's beaches to the State's economy, the Gulf-fronting Shoreline Monitoring Program is conducted by GSA in cooperation with the Engineer-For-Record for the Alabama Department of Conservation and Natural Resources (ADCNR) and the municipalities of the cities of Orange Beach and Gulf Shores. This program includes the acquisition of beach topology profiles and nearshore bathymetry, and archives both historical and recent orthophotography.

Working through the Mobile Bay National Estuary Program and ADCNR, the Coastal Resources Section finalized a multi-phase effort to develop an inventory of geospatial themes to support planning activities within Alabama's coastal counties and within state and federal water bottoms. Planned work this year involves the development of the geospatial data—separated into current and legacy data—into subject distinct web-based interactive maps. A coastal GIS users group has been established to help facilitate cross-discipline collaboration with GIS users and maintain the awareness of updated data. With increasing interests in the replacement of hard shorelines (for example, bulkheads, riprap) with living shorelines, the GSA is working through the Gulf of Mexico Alliance and the Virginia Institute of Marine Science to finalize GIS and spatial modeling work to support hard shoreline restorations. The modeling effort has generated upland and shoreline best management practices for living shorelines and upland modifications. It should be noted that within the Gulf of Mexico Alliance, personnel also serve as the state lead for Resilience and Data and Monitoring Priority Issue Teams.

Geochemical Laboratory Section

The Geochemical Laboratory continued in its support role for GSA research and regulatory analytical needs, and in its acquisition of baseline geochemistry of Alabama waters, soils, rocks, and streambed sediments.

ECOSYSTEMS INVESTIGATIONS PROGRAM

Aquatic biodiversity studies are important not only from the standpoint of faunal inventory but also due to the fact that organisms and communities of organisms are very useful tools for monitoring stream water quality. The Ecosystems Investigation Program (EIP) has conducted scores of studies in this area, including basin surveys of fishes, mussels, crayfishes, and other aquatic invertebrates, status surveys of federally listed threatened and endangered species, and investigations of fish movements in large rivers.

The EIP biologists have recently completed several projects, are continuing other studies, and are negotiating several new studies. Mussel surveys in the Black Warrior River system were completed in 2013 and a comprehensive report including this mussel data and records of freshwater snails collected concurrently by ADCNR Division of Wildlife and Freshwater Fisheries staff is in preparation as a GSA bulletin. A comparison of historic fish faunal assessments in the Locust Fork of the Black Warrior River is in review for publication as a GSA bulletin. Annual monitoring of the endangered Alabama Cave Shrimp and the Tuscumbia Darter on Redstone Arsenal continued for the 25th and 18th years, respectively. A status survey of the Tuscumbia Darter across its range was also completed recently and is in preparation for publication, and a 20+ year retrospective of the Alabama Cave Shrimp project is in the works. Cooperative studies with the Alabama Department of Environmental Management and the Wildlife and Freshwater Fisheries Division of the ADCNR

to develop a boat electrofishing sampling protocol for use in assessing fish communities in deep, nonwadeable rivers, lakes, and streams are ongoing.

The EIP initiated a cooperative effort in 2008 with ADCNR and the U.S. Fish and Wildlife Service, which ends next year, to address the conservation needs of aquatic species through the collection, acquisition, and presentation of integrated aquatic resources data. These data are used in strategic habitat management units (SHUs) and provide information to local landowners, watershed organizations, and local governments to enhance conservation opportunities for species recovery and restoration.

This year a third iteration of a map of the SHUs in Alabama and surrounding states was published. Habitat assessment and biological monitoring studies were recently completed for several other SHUs, including the Big Canoe Creek and Terrapin Creek watersheds in the Coosa River system, Murder Creek in the Conecuh River system, Bear Creek in the Tennessee River system, Sipsey River in the Tombigbee River system, and the Choctawhatchee/Pea River system. Summary reports for most of those projects have been initiated and the Murder Creek fish report and Big Canoe and Terrapin Creek summary reports have been completed.

The Big Canoe Creek project was published as a GSA Bulletin and the Terrapin Creek report has been submitted for publication as a GSA Bulletin. The Murder Creek report is being modified for submission as a GSA Circular. A report on the fish fauna of the Choctawhatchee/Pea River system is in preparation. Members of EIP staff are also assisting with publication of an assessment of the fish fauna of the Cypress Creek system in the Tennessee River drainage, a SHU, in cooperation with faculty and students at the University of North Alabama, which will be published as a GSA Bulletin, and the distributions of crayfish species and geology of the Inland Low Plateaus in cooperation with faculty at the University of Alabama-Huntsville (outlet to be determined).

A four-year State Wildlife Grant project aimed at updating our knowledge of crayfishes statewide started in 2013 and was recently completed, with a summary report delivered to ADCNR. Objectives of that project included filling collection coverage gaps in under-sampled watersheds, ecoregions, and habitats based on the findings of earlier studies. Information from that report and earlier research by GSA, in cooperation with Dr. Guenter A. Schuster, retired professor emeritus from Eastern Kentucky University, and Dr. Christopher A. Taylor of the Illinois Natural History Survey and University of Illinois, is being assimilated into a comprehensive book on the crayfishes of Alabama, to be published by the University of Alabama Press. Another product from that effort will be a poster displaying the crayfish species richness at the Hydrologic Unit Code-10 level in Alabama.

A project to assess various aspects of the burrowing crayfish fauna in the Bogue Chitto Creek watershed in the Alabama River drainage, a SHU, continues, and we expect several publications to come out of that effort. A survey of a critically imperiled crayfish species restricted to a few small tributaries of the Tennessee River drainage was recently completed and delivered to the U.S. Fish and Wildlife Service as part of their Status Survey Assess-

ment for petitioned species. That report is being edited and will soon be submitted for publication in a national journal. The EIP once maintained voucher fish and freshwater invertebrate collections containing approximately 450,000 and 3,000 specimens, respectively. The invertebrate specimens were donated to Auburn University a few years ago, a move that will provide more long-term and secure curation of the specimens. Most of the fish collection has been transferred to the University of Alabama Ichthyological Collection for permanent curation as well.

EIP staff are in the process of negotiating projects with several entities to continue monitoring Alabama Cave Shrimp and Tuscumbia Darters on Redstone Arsenal, assess the threats to vulnerable species and habitat quality in the Locust Fork, assist with determination of host fishes for a rare mussel species found only in the Big Canoe Creek system, assist in delineating the range and status of a rare snail in the Cahaba River system, and evaluate the effectiveness of recent modifications to the habitat of a federally listed species of darter in a spring complex in the Locust Fork system.

The EIP staff also works with cooperating agencies to identify impediments to stream flow and fish passage, such as low-head dams, that are eligible to be removed to restore habitat quality, and to assist with monitoring fish, mussel, snail, and crayfish faunas before and after removal.

ALASKA

ALASKA DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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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 six program sections: Energy Resources, Mineral Resources, Engineering Geology, Volcanology, Geologic Communications, and the Alaska Geologic Materials Center. The division currently has 36 full-time permanent positions, one part-time position, and 10 non-permanent positions. The total FY18 expense budget for the division was \$8.32 million, consisting of \$3.76 million state general fund receipts, \$2.1 million federal receipts, \$2.13 million capital improvement projects and interagency receipts, and \$329 thousand designated general fund and publication sales. DGGs maintains a website at dggs.alaska.gov, which provides access to its publications and digital data as well as to all pre-digital USGS publications on Alaska geology. DGGs also administers websites for the Alaska Volcano Observatory (avo.alaska.edu), the Alaska Seismic Hazards Safety Commission (seismic.alaska.gov), and the Association of American State Geologists (stategeologists.org).

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 17 percent of the state, but our field programs are increasing this coverage gradually every 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. We are committed to delivering the results of our extensive field mapping programs to the public in a timely manner. The total area of published mapping in FY18 was 606 mi² with an annual average area of 2,876 mi² of published, peer-reviewed geologic mapping over the last 10 years.

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 30 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 FY17, DGGs contracted for a new federally-funded airborne geophysical survey covering about 5,382 mi² in the Porcupine River area in northeastern Alaska. DGGs also partnered with the University of Alaska Fairbanks and the USGS to fly four additional surveys for geologic hazard assessments, covering a total of 185 mi². These datasets are scheduled for public release in FY19, with an anticipated release of 5,566 mi² of geophysical surveys.

The state-funded Strategic and Critical Minerals (SCM) project (FY13–15) allowed DGGs to annually publish more than twice the amount of airborne geophysical data published in prior years under the State's Airborne Geophysical/Geological Mineral Inventory (AGGMI) program. Budget cuts in FY16 eliminated both the SCM project and AGGMI program, and the lack of identified future funding means that no further state-funded airborne geophysical surveys of mineral districts are planned.

SECTION HIGHLIGHTS

Energy Resources

Alaska's Statewide Energy Resource Assessment program generates new geologic information about the State's oil, natural gas, coal, and geothermal resources and presents this information to the industry, public, and state and federal agencies through formal reports and presentations. DGGs collaborates with the Alaska Division of Oil & Gas (DOG) to incorporate subsurface data in interpretations of complex depositional systems, tectonic provinces, and hydrocarbon systems analysis. In FY18, the Energy Resources Section has:

1. Completed a two-week field program in the foothills belt north of the Brooks Range focused on Brookian reservoir potential.
2. Completed two-week bedrock geology mapping program in the Red Glacier–Texedni Bay area in lower Cook Inlet.
3. Submitted bedrock geological map of the Red Glacier–Texedni Bay area, lower Cook Inlet, to the U.S. Geological Survey (deliverable to STATEMAP funding agency).
4. Collaborated with Boise State University researchers to develop geochronologic approaches that yield precise and accurate age constraints for use in detailed stratigraphic correlations of potential oil and gas reservoir and source rocks in Alaska's sedimentary basins.

5. Sampled coal seams from several cores from the Susitna and Cook Inlet basins for petroleum source rock evaluation.
6. Delivered seven presentations on oil and gas related geology of Cook Inlet and the North Slope at the Arctic Energy and Environmental Alliance meeting in Houston, TX, Alaska Geological Society, University of Alaska Fairbanks Geology Seminar, University of Alaska Fairbanks Petroleum Engineering Seminar, and University of Alaska Anchorage Geology Seminar.
7. Published two reports in a high-profile journal that address the basin-bounding Bruin Bay fault system and fractures in Mesozoic strata exposed along the west side of Cook Inlet.

DGGS has accumulated a vast amount of relevant petroleum-related geologic data over the past few decades and continues to gather new data. Progress is being made on a division-wide energy resources geodatabase and, once finished, will allow industry and the public to search for relevant geologic data throughout the North Slope, Cook Inlet, and other Alaska frontier basins. This year, the Energy Resources Section finalized a database schema and began the initial phase of loading Cook Inlet reservoir quality data.

Mineral Resources

To attract mineral exploration interest and to support responsible development of Alaska's mineral endowment, DGGS conducts geological mapping and geochemical and geophysical surveys of the most prospective Alaska lands open for resource development. Since 1993 the data products of the Airborne Geophysical/Geological Mineral Inventory (AGGMI) program have been an important component of successful resource exploration programs; products have contributed to the private-sector discovery of more than 22 million oz of gold in the Salcha River-Pogo and Livengood areas since 2004.

DGGS completed fieldwork for the second phase of a 520 mi² geologic mapping and geochemical sampling project in the northeastern Tanacross quadrangle adjacent to Yukon, Canada, in summer 2018. The purpose of this project is to evaluate the area's mineral-resource potential and to create a geologic map to help guide industry exploration efforts. The area contains known porphyry gold-copper-molybdenum systems, which are newly recognized to be spatially associated with high-angle fault systems, many of which can be identified in DGGS airborne geophysical surveys of the area. Ongoing work in FY19 includes synthesis and interpretation of field data, and publishing the geologic map and supporting analytical data.

DGGS completed analysis of the Yukon Crossing airborne electromagnetic data for Alaska DOT&PF, and provided guidance on how to incorporate the geophysics into their next phase of the Yukon Crossing project; this guidance included suggested drill hole locations. DGGS continued to provide geophysical support for the UAF-DGGS Goldstream Watershed Project, and prepared the Goldstream, Yukon Crossing, Yukon Crossing to

Fox, and Western Yukon flats surveys for publication. A portion of the DGGS AGGMI program's VHS-format flight videos, collected as part of historical geophysical surveys, were converted into mp4 files to enable digital archiving, and will be published with their associated surveys. DGGS improved the efficiency of its online data-publication process. DGGS geophysics staff member Abraham Emond co-led a geophysics short course at the Alaska Miners Annual meeting in Anchorage and presented four talks.

DGGS initiated detailed field-geologic mapping and geochemical sampling in the Tok River area, covering 480 mi² of the eastern Alaska Range just south of Tok in summer 2015, and continued field work in 2016. The purpose of this project is to evaluate the Tok River area's mineral-resource potential, which is expected to be high based on that of adjacent lands; they host known occurrences of VMS-type base metals, copper-gold skarns, structurally controlled gold-bearing veins, intrusion-related copper-gold mineralization, placer gold, and other prospects of uncertain origin. Ongoing DGGS work in FY17 includes interpreting our field and geochemical data, creating the final geologic map, writing reports on the area's geochemistry, geology, and mineral-resource potential, and publishing these products on the DGGS website.

Naturally occurring radon gas is the second leading cause of lung cancer after smoking and an under-recognized health risk in the state. DGGS is beginning the final year of an EPA-funded, three-year project to (1) create an Alaska radon database and compile radon test results from across the state; (2) collaboratively develop an enterprise database model for standardized geologic map data; and (3) create an online radon potential map to help the public visualize the risk from radon in Alaska. In the second year of the project, DGGS conducted public outreach with the University of Alaska Fairbanks Cooperative Extension Service, engaging more than 1,000 Alaska residents in free radon testing. DGGS continued to lead geologists and GIS professionals from about 10 state geological surveys, USGS, and Geological Survey of Canada in the development of a national geologic database model.

Finally, DGGS published Alaska's Mineral Industry 2016, an annual summary of activity in the mining sector during calendar year 2017 (<http://doi.org/10.14509/29748>). The report provides a consistent, factual snapshot of exploration, development, and production of Alaska's mineral resources and serves as the authoritative, historical record of mining in the state.

Engineering Geology

In many areas, Alaska lacks the fundamental geologic data needed to guide the proper development and implementation of building codes, land-use zoning, right-of-way siting, and contingency planning for natural hazards events. Maps and reports produced by the Engineering Geology Section are the front-line source of information about where damage is likely to be greatest and where mitigation efforts should be concentrated. Engineering-geologic maps depicting construction materials resources are useful for building infrastructure to support resource exploration and development, and for locating valuable placer-mineral deposits. Groundwater analysis and aquifer modeling

and mapping in oil and gas basins and other areas of high development potential are essential to ensuring an adequate and safe supply of water for development and resource access.

DGGS continues to provide other state and federal agencies with necessary information on geologic hazards for the purpose of land-use planning and decision making. We completed agency reviews regarding potential geologic hazards and engineering-geologic considerations for multiple DNR land disposals, area plans, resource development, and subdivision projects, Environmental Impact Statements, Resource Management Plans, and the State Hazard Mitigation Plan. As a result of work supporting the Alaska Department of Transportation and Public Facilities (DOT&PF), we published a report on a landslide impacting the Alaska Highway near Northway.

DGGS was a major contributing state agency and participant in the State Hazard Mitigation Plan (SHMP) update, directing the portion of the update relating to geologic hazards. We coordinated with the Plan Update Working Group, consisting of the State Hazard Mitigation Advisory Committee (SHMAC), the Division of Homeland Security and Emergency Management (DHS&EM) State Hazard Mitigation Officer (SHMO), and a DHS&EM planning contractor to revise hazard descriptions and update histories for floods, snow avalanches, volcanoes, earthquakes, tsunamis, seiches, ground failure, erosion, sea ice, permafrost, and climate change. The Alaska SHMP serves as the strategy document for Alaska's hazard mitigation program and is required to meet FEMA requirements for a five-year State Hazard Mitigation Plan update under the Stafford Act to qualify the state for disaster relief funding.

The DGGS Coastal Hazards Program continues to establish new flooding/erosion monitoring stations and collect new data to measure the impacts of storms on Alaska's western coast. We played a key role in advocating, securing, and providing contract specifications for NOAA investment in coastal mapping to collect orthorectified aerial imagery and elevation data in Bristol Bay, imagery over North Slope communities to leverage USGS and North Slope Borough investments in lidar, and the collection of short-term water level data at three Alaska communities to support flood mapping and products. Our program also organized and led the 2018 Alaska Water Level Meeting in which approximately 30 participants from state and federal agencies, non-profits, Native corporations, and private industry participated in determining technological options and priority locations and uses for Alaska's tiered coastal water level network.

In support of the Arctic Strategic Transportation and Resources (ASTAR) project, DGGS began work to identify potential sources of construction materials for transportation infrastructure and resource development in the northern National Petroleum Reserve-Alaska (NPPRA). DGGS leads the effort to combine existing data with new targeted fieldwork to generate digital maps of prospective construction materials resources in the mapped priority areas.

DGGS continues to manage the DNR portion of the federally funded Tsunami Hazard Mitigation Program, increasing earthquake and tsunami hazard awareness across the state. Inunda-

tion maps showing areas that could be affected by future potential tsunamis were published for Kodiak, Juneau, Skagway, and Haines, and coseismic permanent flooding maps were published for Valdez, Chenega, Chignik, and Chignik Lagoon. Results of these investigations have been disseminated to local emergency planners. We constantly work with the Division of Homeland Security and Emergency Management (DHS&EM) to communicate these hazards to at-risk communities, both in person and through published reports.

DGGS worked with University of Alaska collaborators on a federally funded project to drill a new groundwater observation well in Goldstream Valley, Fairbanks. The well will be used to monitor groundwater in permafrost for this area, and the data will feed into the National Ground-Water Monitoring Network. This is the third well drilled for this project and brings the number of Alaska wells reporting to the network to four.

The DGGS Climate & Cryosphere Hazards Program successfully secured funding for a multi-year NASA citizen science project that uses crowdsourcing to obtain measurements of snow depth in order to validate remote sensing products and improve snow distribution and hydrological models in Alaska. These models are critical for assessing avalanche hazards to communities, infrastructure, and backcountry travelers.

Volcanology

The Volcanology program of DGGS is part of the Alaska Volcano Observatory (AVO), an interagency consortium which mitigates hazards from Alaska volcanoes. AVO was formed by Memorandum of Understanding in 1988. Its partners are DGGS, the U.S. Geological Survey (USGS), and the University of Alaska Fairbanks Geophysical Institute (UAF/GI). The Director of DGGS established Volcanology as a separate section in early 2007. Funds for DGGS participation in AVO come from cooperative agreements with the USGS through the USGS Volcano Hazards Program.

AVO studies volcanoes to increase understanding of hazards at particular volcanoes and how volcanoes work in general; monitors volcanoes using seismology, geodesy, satellite remote sensing, field studies, and local observers; and provides timely and accurate warning of increasing unrest and eruptions to emergency management agencies, other government entities, the private sector, and the public. The majority of Alaska's 54 historically active volcanoes are remote from human settlements, but all underlie the heavily traveled north Pacific passenger and cargo air routes between North America and Asia; thus, the aviation sector is an important recipient of AVO monitoring reports.

DGGS-AVO staff managed helicopter procurement and fuel logistics for over 100 days of helicopter-based fieldwork in remote Alaska from the Cook Inlet to the western Aleutians. Field operations included geophysical monitoring station maintenance, geologic field investigations, and eruption response.

As part of the ongoing effort to assess volcanic ashfall hazards in the State, DGGS-AVO staff compiled and digitized volcanic ashfall records for more than 4,500 ashfall locations and have created a digital geospatial database of ashfall extents and ash-

fall occurrences. Information in the database includes number of ashfall events at a site, ashfall extent, ash deposit thickness, age of ashfall, source volcano, deposit descriptions, and associated literature references. This report is available to the public and emergency managers in GIS format, suitable for implementation in advanced hazard analyses and risk assessments.

DGGS-AVO staff authored or were co-authors on peer-reviewed journal articles that focused on our eruption response efforts at Bogoslof volcano as well as in-depth discussions of AVO's alert and forecasting methods and achievements.

Volcanology section staff continue to play a lead role in AVO communication and operations by maintaining a robust database of Alaska volcanoes, with several database modules available to the public through the DGGS-managed Alaska Volcano Observatory website (avo.alaska.edu). Users can find the latest information on volcanic unrest and eruption; search, view, and download thousands of well-captioned images of Alaska volcanoes; or learn about past eruptive history and current hazards. Outreach to the community included a trip to Sitka to participate in the "Scientists in the School" program, attendance at the Alaska Teacher's Conference in Fairbanks, answering emails and inquiries received through social media platforms, and posting content to the AVO Facebook and Twitter accounts. These accounts are especially active during times of volcanic unrest such as this past year with elevated activity at Cleveland, Shishaldin, Pavlof, and Bogoslof volcanoes.

Geologic Information Center

Basic geologic information about Alaska's resources helps to inform land-management decisions and encourage investment, exploration, and development of the state's resources, resulting in billions of dollars of impact to Alaska's economy. Availability of information specific to the State's volcanoes, earthquakes, landslides, tsunamis, coastal erosion, climate change, and other natural hazards helps mitigate these hazards, helping to save lives and reduce damage to property and critical infrastructure. The staff within the Geologic Information Center (GIC) design, edit, publish, and deliver division-generated geologic information as authoritative, peer-reviewed maps, manuscripts, geospatial datasets, and easy-to-use online applications. In 2017, the division celebrated the release of its 5,000th publication: *Potential maximum permanent flooding maps for the communities of Chignik and Chignik Lagoon, Alaska*. With the report's publication, DGGS achieved an average rate of releasing one publication every four business days since statehood in 1959.

The GIC's publication, GIS, cartographic, and programming services helped foster 2,018,193 downloads of digital datasets and reports, totaling 104.5 TB of information in FY18. The team helped generate 56 new publications, while the DGGS website saw 25.1 million page-views in FY18. The section continued to add a multitude of data to our public online applications, including lidar, IfSAR, and Structure from Motion (SfM) elevation data (elevation.alaska.gov). In the last year, GIC staff installed 896 TB of additional storage capacity and replaced existing, antiquated storage. These new systems currently store 887 TB of digital geologic data maintained at DGGS and use fault-tolerant

distributed file systems that vastly increase expandability. These open-source file systems replicate data over multiple servers in a storage cluster, maintaining data integrity and availability while duplicating the functionality of expensive, vendor-maintained storage systems for free.

DGGS released more than 6,500 free public-use photographs taken during geologic field projects via an interactive application on its website (maps.dggs.alaska.gov/photodb). The photographs document scenery, landforms, rock outcrops, geologic observations, vegetation, wildlife, and fieldwork activities conducted throughout Alaska, usually in remote locations that are often impossible or prohibitively expensive to revisit. Many of the photographs currently available were taken by former DGGS geologists Charles G. (Gil) Mull and Rocky R. Reifensstuhl from 1970 through 2010 in the Brooks Range and northern Alaska during energy-resources-related geologic mapping projects. Additional photographs, from legacy collections and other geologic projects in Alaska, will become available through the application as time and funding allow.

The GIC released a complete redesign of its geochemistry web application available at maps.dggs.alaska.gov/geochem. The new version allows users to search the database by drawing a box on an interactive map or typing in a Google-like search box. The results include analytical methods, sample types, and specific chemical elements for more than 70,000 samples from all over the state. The database will be continually updated as new DGGS geochemical analyses are released. With this major application upgrade, users can now download the geochemical data in two different formats: one optimized for GIS software and the other for analytical and database software. A linked help file contains useful examples on how to use the lightning-quick search bar to narrow your queries on geochemical analyses.

DGGS is leading the creation of a multi-map, multi-user "enterprise" database model based on the single-map Geologic Map Schema (GeMS) developed by the USGS and state geological surveys (<https://ngmdb.usgs.gov/Info/standards/GeMS/>). The enterprise database model is intended for use by state and federal geological survey programs, as is a pilot data-sharing protocol to be developed with the model. Currently, most GIS databases are designed to facilitate the creation of a paper- or PDF-based map, while for this project, the database is the goal. The project is currently in its second year of a three-year grant awarded by the U.S. Environmental Protection Agency (EPA) Environment Information Exchange Network.

In 2018, the GIC added ArcGIS Enterprise (ArcServer, Portal, Data Store) to DGGS' infrastructure; Portal will help facilitate discoverability of and access to DGGS' GIS assets and allow offline digital field data collection with the Esri Collector application. The custom-built, field geology support system (A.K.A. "Babe the Big Blue Box") is based on a portable, wireless, high availability, failover cluster to connect field devices to a server where no internet connection is available. The wireless connection to Portal & ArcGIS Server replaces the internet connection for syncing data in and out of Portal or ArcGIS Online via the Esri Collector field data collection application. Geologists are able to work collaboratively in the field, seeing each other's data once they sync at

the end of the field day. At the end of the field season, new and edited data are incorporated back into the office infrastructure.

Alaska Geologic Materials Center

The Alaska Geologic Materials Center (GMC), operated by DGGs, archives 75 years' worth of geologic data and more than 700,000 energy, mineral, and geologic samples with an estimated replacement value of \$15–30 billion. The facility provides a wide range of users (industry, government, academia, and public) access to samples for identifying new resource prospects and increasing our geologic knowledge of the State. In the past, this has been done under a very limited budget in a thoroughly inadequate and outdated facility with partial availability of samples due to cold storage in winter. The new Anchorage repository opened on July 1, 2015. Users now have comfortable access to eight viewing bays with roller display tables that provides efficient staging of samples and allows for new technological analyses to be performed on a year-round basis. Other significant changes in FY16 included a bill, Ch27 SLA2016 (SB 170), signed by the Governor in June 2016 that allowed DGGs to “charge and collect fees for facilities, equipment, products and services.” After incorporating feedback from the general public, the GMC began collecting fees in November 2017, and is now a revenue-generating facility for the state. Tax credit distributions of 118 seismic datasets have generated more than \$1M in fees.

There were 1,358 visits to the facility in FY18 (the 10-year average is 450) and the fiscal year saw several major successes for clients of the GMC. Several major exploration successes over the last several years by Repsol USA and ConocoPhillips Alaska had their roots in the GMC sample archives. Both companies utilized North Slope drill samples stored at the GMC to support petroleum exploration that resulted in the subsequent recent discoveries of multiple reservoirs that may reach 220,000 barrels of oil production per day.

Geologists from independent and major energy companies visited the GMC to sample and examine hundreds of feet of well core and cuttings. As production declines within the mature Prudhoe Bay oil field, it is essential to diversify the oil industry in Alaska. The GMC hosted visits by major and independent oil companies and government researchers operating in both the North Slope and Cook Inlet regions, including ConocoPhillips, Hillcorp, Glacier Oil & Gas, Alaska Gasline Development Corporation, U.S. Geological Survey, U.S. Department of Energy, and the U.S. Bureau of Ocean Energy Management.

Professional development and outreach at the GMC were highlighted by the fifth annual core study and public workshop organized by UAA Associate Professor of Geology Dr. Jennifer Aschoff and through nationwide participation in the Nanushuk Topsets Core Workshop for the American Association of Petroleum Geologists' Anchorage conference. In FY18, the GMC also lead a total of 32 tours, including those for education, representing more than 240 visitors from 17 school and public groups.

Significant improvements to GMC inventory were accomplished through matching funds from the USGS National Geological and Geophysical Data Preservation Program grant. More

than 20,000 outcrop samples were inventoried and greater than 48,000 outcrop samples were attached to metadata including geolocations. Major core donations in FY18 were received from Doyon with the Reef Ridge Deposit (carbonate-zinc oxide) and from PacRim with materials from the upper Cook Inlet Chuitna Coal Project.

ARIZONA

ARIZONA GEOLOGICAL SURVEY

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INTRODUCTION

The Arizona Geological Survey (AZGS) conducted geologic mapping across the state, investigated geologic hazard and geologic resource issues in several areas, monitored geologic hazards, engaged in public outreach, and continued to advance geoinformatics in the past year. We began our third year as part of the University of Arizona, and our second year with dedicated state funding as part of the University budget. Our core mission remains the same: we continued to integrate our geologic, GIS, and geoinformatics expertise to produce digital products that are useful to the State of Arizona.

GEOLOGIC MAPPING

The AZGS completed geologic mapping projects in northwestern, southwestern, and southeastern Arizona, and completed draft map products in these areas and northern Arizona as part of the STATEMAP program. We work closely with our 12-member Geologic Mapping Advisory Committee to identify priority areas for new detailed geologic mapping. The GMAC is a diverse group including experts in metallic minerals, industrial minerals, environmental geology, hydrogeology, and representatives of major land and resources management agencies, academia, and an Arizona-based USGS geologist. Most of our mapping projects

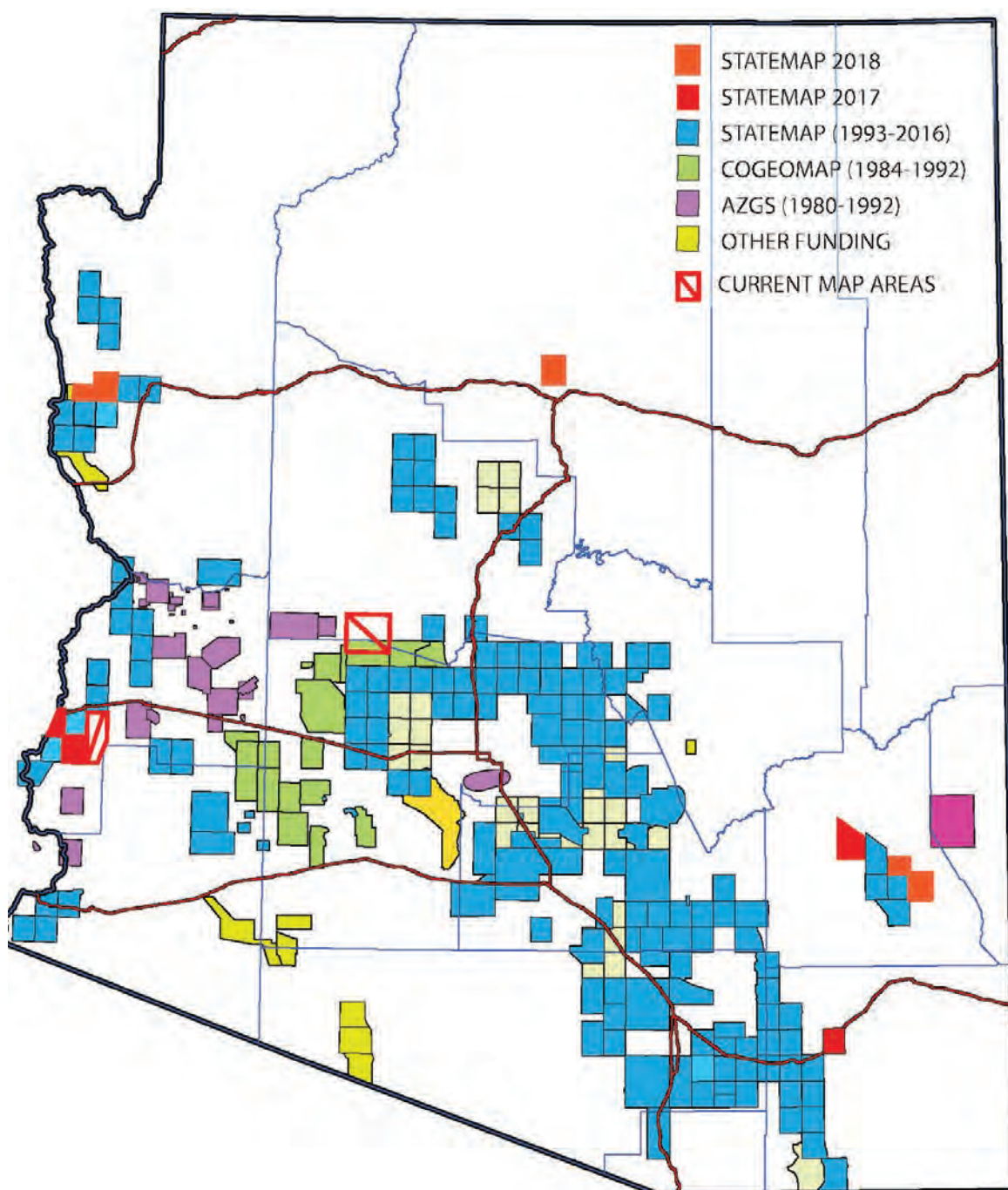


Figure 1. Map showing the status of detailed geologic mapping in Arizona as of September 2018.

integrate bedrock and surficial geology, although some focus on surficial and basin deposits.

Bedrock and Surficial Mapping (combined)

At the end of 2017 we released combined bedrock and surficial geologic maps of the Oatman quadrangle in northwestern Arizona, and the Middle Camp Mountain and Moon Mountain SE quadrangles in western Arizona. We completed draft maps of the North Trigo Peaks and Dragoon quadrangles, in western and southeastern Arizona, respectively. These will be released by the end of 2018. In 2018, we completed draft maps of the Union Pass and Secret Pass quadrangles in northwestern Arizona.

Surficial and Basin Deposit Mapping

At the end of 2017 we released a surficial geologic map of the Pima and Markham quadrangles in southeastern Arizona. We completed draft maps of the Fort Thomas area in southeastern Arizona, and the Blythe quadrangle straddling the AZ–CA border in cooperation with the Flagstaff USGS office. These will be released by the end of 2018. In 2018, we completed draft maps of the northwestern Flagstaff area in northern Arizona, and the San Jose area in southeastern Arizona.

DATA PRESERVATION

We completed a year-long effort to bring 20 of our early digital geologic maps into the modern era. Databases were brought into conformity with NCGMP09 standards, relatively minor updates and revisions to the maps were completed, and new versions of the maps were released in a variety of user-friendly data formats. We are also establishing an archive of all of our publications with the University of Arizona Science Library repository. We have begun a second round of map updating.

GEOLOGIC HAZARDS

Landslides

In late 2017 the AZGS released the first comprehensive compilation of mapped landslides and landslide features in Arizona. The compilation is based primarily on published geologic mapping, supplemented in some areas with new landslide mapping based on aerial photo interpretation. Landslide categories include earth slide, rock slide, debris flow, and rock fall. No attempt was made to classify these features by age, although we hope to pursue this in the future. The features are displayed as a layer in our Natural Hazards Viewer accessible via our main webpage.

Post-Wildfire Hazards

Ann Youberg of AZGS collaborated with hydrologists and geomorphologists of JE Fuller Hydrology & Geomorphology to conduct an innovative assessment of potential post-fire flood-

ing and debris flow hazards in the Flagstaff and Williams areas of Coconino County, northern Arizona. Forested watersheds above developed or developing areas on the margins of Flagstaff and Williams are at risk of wildfire. This study used reasonable burn scenarios to model the potential post-fire hydrology and assessed areas that could be at risk of debris flows. Results were released as an Open File Report.

Earth Fissures and Subsidence

Joe Cook of AZGS continued to monitor and map earth fissures that have formed and continue to develop as a result of land subsidence in central and southern Arizona. Maps of several fissure areas were updated because of new fissure development or extension. The updated maps are displayed as a layer in our Natural Hazards Viewer accessible via our main webpage. In addition, we employed drone capabilities to acquire low-altitude aerial imagery and video of fissures.

Seismic Hazards

Jeri Young Ben-Horin oversaw the completion of an expansion of the Arizona Broadband Seismic Network, with the installation of five new instruments. Data from our stations is generally available through IRIS, although technical issues do result in some lulls in the data flow. We have also begun a detailed investigation of the Mead Slope fault zone in northwestern Arizona as part of the USGS Earthquake Hazards Reduction Program.

WATER RESOURCES

Brian Gootee led a detailed analysis of the subsurface geology in the southeastern part of the Phoenix metropolitan area, funded by the Salt River Project, the major water and power provider for that region. In cooperation with SRP and seismologists in the University of Arizona Department of Geosciences, we developed a much more detailed and realistic portrayal of the basin deposits and the bedrock boundaries of the basin, which will allow for a more accurate assessment of groundwater resources.

EDUCATION OUTREACH

To shore up and improve communications with AZGS stakeholders—mining industry, government, conservation & environmental firms, and the public—we continue to explore social media and Esri StoryMap technology to inform and advise our constituents of the geologic products and services provided by AZGS.

The interactive Natural Hazards in Arizona viewer, in partnership with the Arizona Department of Military Affairs, was relaunched with the addition of the Arizona Statewide Landslide Inventory theme showing the distribution of more than 6,000 mass wasting deposits in Arizona.

We are also exploring a role in the geotourism industry by showcasing geoheritage sites across Arizona. The first such prod-

uct, Geoheritage Tour of Southern Arizona, was released earlier this year. A brief description, location map, and online resource accompanies each geoheritage site.

In October 2017, AZGS and our partners, Arizona Department of Emergency & Military Affairs, enrolled 110,000 Arizonans in the Great Arizona ShakeOut—the largest voluntary emergency preparedness event in Arizona. In 2018, we hope to increase enrollment substantially.

GEOINFORMATICS

The AZGS Geoinformatics Division has completed several major upgrades to its data sharing systems this past year. The most noticeable and visually pleasing change is the significant modernization of our website (now at <http://azgs.arizona.edu>) as part of our ongoing integration with the University of Arizona. In another notable partnership with the UA, we have successfully copied our entire document repository over to the University of Arizona Library system. This is part of our broader efforts to increase the number of access points to our data, and we expect to see significant progress in this area over the coming year as we finish adding our data to USGS, AGI, Rockd, and Flyover Country data services.

We've also completed this year's National Geological and Geophysical Preservation Program project to restore the GIS data of twenty older digital map products. You can look forward to viewing these revitalized maps in NCGMP09 format through our online document repository, our new node at the UA library, or through our new map browsing and download tool over the coming months.

The National Geothermal Data System, originally funded by DOE, has been undergoing renovations (<http://search.geothermaldata.org>) and added numerous datasets, as current DOE research and exploration projects are published through the OpenEI Geothermal Data Repository (<http://gdr.openei.org>) and harvested into the NGDS search engine.

AZGS continues to participate in several NSF-funded EarthCube projects. EarthCube provides advanced cyberinfrastructure to improve access, sharing, visualization, and analysis of geosciences data. Numerous AASG member datasets have been made available and accessible through the EarthCube infrastructure as part of continued efforts with AASG Geothermal Repository, NGDS, Cinergi Data Discovery Studio, the Flyover Country Mobile App, and the U.S. Geoscience Information Network.

ARKANSAS

ARKANSAS GEOLOGICAL SURVEY

Arkansas Geological Survey
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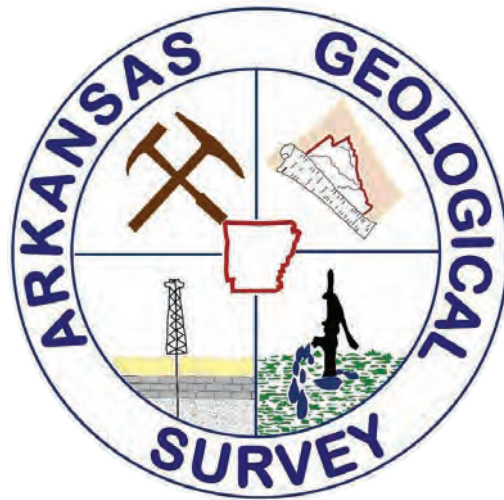
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INTRODUCTION

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 for the public, private industry, academia, and government agencies as well as local, municipal, county, state, and federal officials, regulators, and decision makers for over 160 years. The AGS's mission is to educate the public about the importance of geology and how it affects their everyday lives. The AGS serves the citizens of Arkansas by providing accurate geological information by cost-effective methods to promote the development and effective management of the State's rock, mineral, fossil fuel, and water resources while protecting the environment—all in a transparent manner.

ECONOMIC MINERALS SECTION

There are two geologists in the economic minerals section. This section provides information on the State's minerals and encourages their orderly development. The agency serves as a point of contact for industry personnel gathering information on the mineral resources we have available in the State. The agency website has a searchable database on the mine locations, commodities and status, and the agency's core and well-cutting repository. Descriptions of the industrial minerals and metallic mineral and USGS annual reports on non-fuel resources can also be located on our website.

In 2011, Arkansas non-fuel raw mineral production was valued at \$789 million, based upon annual U.S. Geological Survey (USGS) data. This was a \$153 million (19 %) increase from the State's total value of \$636 million in 2009, which followed a \$74 million (10 %) decrease from the State's total value of \$710 million in 2008, which followed a \$66 million (8.5 %) decrease from a total of \$776 million in 2007. The State was 27th in rank among the 50 states in total non-fuel mineral production value in 2011 and accounted for slightly more than one percent of the U.S. total. Per capita, the State remained 15th in rank in the Nation for its total nonfuel mineral production value; with a population of 2.89 million, the per capita production value was \$220 in 2009, \$26 less than the total of \$246 in 2008. In 2008, Arkansas's per capita production value was five percent greater than the national average per capita production value of \$234. In 2009, this increased by 15 percent, owing to the 18 percent decline in the national per capita average to \$192.

This section has an on-going project to collect, characterize, and interpret geologic data pertaining to rare earth element (REE) concentrations in phosphate deposits in north-central Arkansas.

EDUCATION/OUTREACH SECTION

There are two geologists in the education section. The education section provided speakers to various industries, universities, public schools, clubs, and scouts. From kindergarten through senior high school, this program has been well received at all levels. Some of the services provided were workshops for teachers to experience hands-on geology while earning professional development hours. Two Educational Workshops included a field trip workshop to Mt. Nebo State Park and a workshop on identifying minerals and rocks for local teachers. AGS participates in training the public in geology and provides education through AR Master Naturalists throughout the state. This section also provided and proctored a test on rocks and minerals for the Science Olympiad of Arkansas, held at the University of Arkansas at Little Rock. We participated in a State Park celebration at Devils Den State Park by leading field trips and giving presentations about the geology of the park. The AGS also participated in the Arkansas Curriculum Conference by setting up a booth and giving out rock and mineral samples, posters, and other written materials to Arkansas teachers.

FOSSIL FUELS SECTION

The AGS has two geologists assigned to fossil fuel research. The Fossil Fuels section is responsible for the identification and geologic assessment of the state's fossil fuel resources including oil, condensates, natural gas, coal, and lignite. The totality of these resources directly impacts the existing and future economies of the State of Arkansas. The Fossil Fuels Section has recently conducted the following research projects:

The Mississippi Embayment hydrocarbon potential project is a collaborative research project between the AGS and Cimarex Energy, Denver, Colorado. Cores and cuttings of wells in the study area are sampled in the AGS Well Sample Library and sent to laboratories conducting multiple geological and geochemical analyses. The research findings of the project can facilitate determining the source rock quality in the Mississippi Embayment, northeast Arkansas. The results will be published by the AGS.

The Smackover Formation project is a five-year (FY16–20) research project that is funded by the NCRDS program of the USGS (funding withheld in 2017–2018). The electric/driller logs and files of every oil and gas well that penetrates Smackover Formation in southern Arkansas have been thoroughly examined and utilized in identifying stratigraphic tops for Smackover and other key formations. Selected well logs have been digitized for making cross sections. Base map and structural/isopach contour maps have been constructed for each productive county and the whole southern Arkansas region. Existing geological and producing information has been evaluated for a typical producing oilfield case study and regional reservoir characteristics analysis. Geochemical analyses have been conducted on Lower Smackover cores in assessing the source rock characterization.

The cores of Upper Smackover have been examined for reservoir properties analysis.

AGS conducted five core and cutting sampling projects with clients from industry (for example, Chesapeake Exploration LLC and Standard Lithium Ltd.) and academia (for example, Auburn University, University of Kansas, and Oregon State University) in FY17–18. The objectives of the projects include: 1) identifying the provenance of the Cretaceous sandstones of the Gulf Coastal Plain; 2) documenting the sediment source terrains and sediment routing for the pre-salt earlier Jurassic and Triassic stratigraphic record in south Arkansas; 3) identifying the deeper potential quality reservoirs in south Arkansas; 4) acquiring basic rock-quality parameters of the Upper Smackover grainstones for Lithium extraction development in south Arkansas; and 5) confirming the tuff beds in Stanley Formation in the Ouachita Mountains of Arkansas. AGS will publish the results from these projects after the confidentiality agreements are expired.

The Mississippian Moorefield Shale has recently seen more unconventional exploration activities in Cleburne and White Counties, east Arkoma Basin. AGS has compiled the well data and constructed the base map.

GEOHAZARDS SECTION

The AGS has three geologists assigned to identify/study, monitor, and advise the public and officials about active or potentially active hazardous geologic processes (earthquakes, landslides, and ground subsidence) in Arkansas. Geohazard study findings may be used to support analysis, decision making, and risk reduction including: 1) improve understanding of geohazard/seismic risk in Arkansas (New Madrid Seismic Zone and other areas); 2) promote geohazard risk awareness and mitigation of high-risk communities; 3) support awareness of seismic building code provisions; and 4) support disaster response and recovery planning.

The AGS owns and operates the Arkansas Seismic Network (ASN) in cooperation with the Center for Earthquake Research and Information (CERI) and Arkansas State Parks system. The ASN consists of nine state-of-the-art permanent broadband seismic stations strategically placed across Arkansas. This network provides real-time earthquake monitoring 24/7/365 and seismic data and information to the public and officials via the AGS website, publications, and maps.

GEOLOGIC MAPPING SECTION

Arkansas recognizes the importance of geological mapping as a tool for decision makers who have a need to understand the nature, composition, and distribution of earth materials. The AGS Commissioners and representatives from universities and other state agencies serve as the STATEMAP Mapping Advisory Committee (SMAC) for the state. The AGS participated in the STATEMAP component of the National Cooperative Geological

Mapping Program, having participated since 1995. The AGS understands the importance and usefulness of creating and maintaining maps in digital format. In 2017, the AGS received \$59,943 from the U.S. Geological Survey National Cooperative Geologic Mapping Program to map the Japton and Witter 7.5-minute quadrangles in northwest Arkansas.

The AGS has recently started a new series of publications directed to “geology-based tourism”—the Geologic Road Guide Series of reports featuring Scenic Highways of the State (as designated by the Arkansas State Highway Department). The AGS is also currently working on Hobbs State Park as part of the State Park Series publications. The War Eagle 7.5-minute geologic map was completed to assist with creating the Hobbs State Park Series.

HYDROGEOLOGY SECTION

There is one AGS geologist assigned to this section. Arkansas has abundant water resources due to its geographic location. Arkansas receives an average of 49 in. of rainfall a year or approximately 124 bgd. Streams and rivers flowing into the State add an additional 37 bgd as surface water. However only about four percent or two in. out of the 49 in. of rain that falls on Arkansas finds its way into the ground to become what is referred to as groundwater. The average resident of Arkansas uses about 160 gallons of water per day with the state as a whole using close to 11.5 bgd. Because some regions in the state are having difficulty finding adequate supplies of groundwater, regional water systems are being constructed to supply water for multiple counties. These systems are relying on the major man-made lakes within the state.

The AGS is currently in the process of synthesizing the collected water well completion reports into a database with nearly 900 reports for two counties to create county water well maps to be used as a groundwater depth and yield screening tool by the citizens of Arkansas. The AGS also participated in three projects with the USGS Arkansas Water Science Center. These projects cover the monitoring of groundwater levels and groundwater quality along with stream gaging. Following an investigation of a site of a fatal accident on the Spring River in Fulton County involving a sinkhole in the river, it was determined with surface inspection and a dye test that the sinkhole was not formed in the local carbonate bedrock but formed in a river deposit rim-stone structure made of tufa. Aerial images of the river revealed that there could be dozens of these tufa structures along the length of the river. Further study plans to understand why the Spring River is producing so many of these unique features.

PROFESSIONAL AND EDUCATIONAL FIELD TRIPS

The AGS helps lead many field trips in order to benefit the state of Arkansas through education, bringing visitors from around

the world, to further research in Arkansas geology, and to aid with partnerships between the state and private industry. Many field trips are conducted in the State of Arkansas by energy companies and other groups, as a part of professional development. Arkansas and only a few places in the world have rocks deposited in a deep water environment (over 5,000 ft) exposed at the surface, where they can be studied in detail. The AGS also leads field trips and geologic floats for many geology clubs, K-12 school students, and college students throughout the state.

NEW PUBLICATIONS

The AGS has released several new publications over the past year. The Fossil Fuels Section has recently published three Open File Reports, which are free for downloading on the AGS website (<https://www.geology.arkansas.gov/home/index.htm>):

- Li, P., 2018a, Arkansas fossil fuels activity update for 2017: Arkansas Geological Survey Open File Report 2018-3000, 9 p.
- Li, P.; Mills, C., 2018b Scanning electron microscope analysis of the lower Smackover Formation, Anadarko Talley #1-22, Columbia County, Arkansas: Arkansas Geological Survey Open File Report 2018-2000, 58 p.
- Li, P.; Mills, C., 2018c, X-ray CT imaging of continuous core from the lower Smackover Formation in selected wells, southwest Arkansas: Arkansas Geological Survey Open File Report 2018-1000, 186 p.

CALIFORNIA

CALIFORNIA GEOLOGICAL SURVEY

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INTRODUCTION

CGS Vision

The California Geological Survey (CGS) is the primary source of geological and seismological products and services for decision making by California's government agencies, its businesses, and the public.

CGS Mission

The mission of CGS is to provide scientific products and services related to 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 California Geological Survey (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 118 geologists, engineers, seismologists, GIS cartographers, field instrument technicians, and clerical staff. The CGS has four separate funding sources. At any given time, the CGS manages projects under about 50 individual contracts. Today, the CGS operates six separate programs authorized by five legislative acts.

GEOLOGICAL MAPPING PROGRAM

Geologic Mapping is a core program within CGS. Each year CGS completes new geologic mapping, compiles geologic maps into regional maps, and works to publish geologic maps of California. Geologic maps are prepared with support from the USGS Nation-



Figure 2: Fault map of the greater Los Angeles area.

al Cooperative Geologic Mapping Program, with state funding, and through contracts with state agencies. These maps provide the geological basis for many of the other CGS programs. The CGS plan for geologic mapping has been developed in consultation with the California Geologic Mapping Advisory Committee (CGMAC). This plan has established priorities for geologic mapping based on the following factors:

- Geologic threats to life and safety, including seismic shaking, liquefaction, slope stability, surface faulting, flooding, naturally occurring asbestos, and sources of radon gas.
- Population density and projected development, including transportation corridors and utility infrastructure.
- Potential threats to water quality or habitats from erosion, landslides, and flooding.
- Regional identification of natural resources, particularly in areas targeted for urban development.
- The adequacy and availability of existing geologic mapping to addressing these needs.
- Areas of scientific need to help address broader, regional geologic framework questions.

Regional geologic maps prepared by CGS provide a foundation upon which CGS builds a variety of derivative maps, including maps of geologic hazard regulatory zones. Because geologic map unit boundaries may become boundaries of regulatory zones, new large-scale mapping must show the distribution of both bedrock and surficial deposits with consistent methods and standards. Local mapping experience is also important for the diverse geology, climate, and morphology of California. For these reasons geologic maps that may become the basis for regulatory zones are prepared by geologists from regional CGS offices having local experience in mapping landslides and other surficial deposits, as well as bedrock.



Figure 1: CGS headquarters building, Sacramento.



Figure 3: Open pit mine.

MINERAL RESOURCES PROGRAM

The oldest of CGS's programs, Mineral Resources provides unbiased, technical information about non-fuel mineral resources in California to federal, state and local government agencies, industry, and the public. This information enables them to make informed land-use and long-term planning decisions that will impact the economic and environmental future of their communities, regions, and the State.

Mineral resource lands are classified by the State Geologist as to their economic value, based upon criteria adopted by the State Mining and Geology Board. The program also produces an annual report summarizing the State's non-fuel mineral production. Additionally, Mineral Resources provides technical assistance on issues related to mineral hazards, such as radon, heavy metals, and naturally occurring asbestos in the environment. Current projects include the production of radon potential maps for the Department of Health Services and mineral hazard maps for the Department of Transportation.

FOREST AND WATERSHED GEOLOGY PROGRAM

This program performs mapping and analysis of the geology of the State's forests and watershed basins. Specifically, the program deals with landslide potential and stream load sedimentation. Under contracts with the Department of Forestry and Fire Protection, this program annually reviews about 350 Timber



Figure 4: Aftermath of mudflow in Montecito—note boulder lodged in tree.

Harvest Plans for their potential geological impact to the harvest areas. The Forest and Watershed Geology unit maintains three regional offices in northern California in addition to the Sacramento headquarters. The program also is involved with the State Parks and Recreation Department, providing mapping of various features of the State's parklands.

Forest and Watershed engineering geologists also provide immediate post-fire geological hazard mapping and assessments for the Governor's Office of Emergency Services and the California Division of Forest and Fire Protection (CalFire). In the last year, CGS field teams completed assessments on nearly 500,000 acres of burned lands and evaluated the disastrous results of debris and mud flows in the Montecito area near Santa Barbara.

SEISMIC HAZARDS PROGRAM

Seismic Hazards Zonation

Under this program are three major projects. The first is authorized by the Alquist-Priolo Earthquake Fault Zoning Act, in which active faults (as defined by the State Mining and Geology Board as having movement in the Holocene—approximately the last 11,700 years) are zoned where they express surface rupture. Construction of structures for human habitation within these



Figure 5: Laguna Beach landslide.

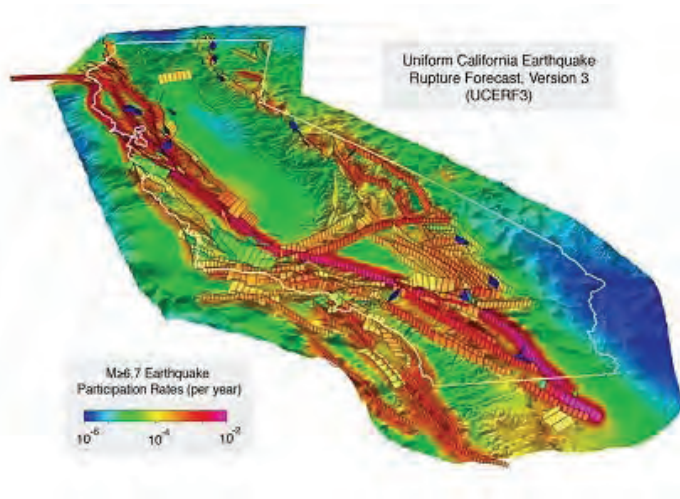


Figure 6: Uniform California earthquake rupture forecast 3.



Figure 7: Diablo Canyon nuclear power plant.

regulatory zones generally is prohibited. CGS has zoned more than 5,000 mi of active surface faults in the State, publishing 589 quadrangles displaying those zoned faults. Approximately 2,000 additional mi of active surface faults remain to be zoned.

Seismic Hazards Mapping is a major project, authorized by the Seismic Hazards Mapping Act. This project zones the extent and likelihood of secondary hazards after an earthquake, such as ground liquefaction and triggered landslides in urbanized areas. Under this project, 120 maps have been produced covering more than 7,000 mi². These maps are regulatory in nature and enforced by local permitting agencies.

Work continued on the joint CGS–California Emergency Management Agency Tsunami Hazard Mitigation and Preparedness Program. Preliminary probabilistic inundation maps for portions of the California coastline were evaluated and shared with representatives of two pilot study communities, Crescent City and Huntington Beach. Partnerships exist with the University of Alaska and Humboldt State University to assist in tsunami inundation modeling and development of a tsunami deposit database. Meetings are frequently held with local emergency managers throughout California’s coastal communities in support of tsunami preparedness and eventual certification as “Tsunami Ready” as part of California’s partnership in the National Tsunami Hazard Mitigation Program (NTHMP). A CGS tsunami field-response team has been formed, with support from NTHMP, to enable collection of valuable information before and during tsunami events that can help assess damage, facilitate response operations, and be used to validate tsunami inundation models. Future products under construction include tsunami hazard maps for land-use planning and construction in all coastal communities and tsunami map products for the maritime community to help improve the resiliency of infrastructure and to provide guidance for evacuation to designated safety areas during tsunami events.

Seismic Hazard Assessments

The construction of new schools, or structural modifications to existing schools, requires a permit from the Division of the State Architect. Before the issuance of a school construction permit, CGS reviews consulting reports describing the school site’s geology and seismic hazards to ensure that those hazards, if any, are taken into consideration in the construction of the school. Failure to thoroughly and adequately evaluate existing seismic hazards will prevent the school from receiving a construction permit. CGS reviews reports from more than 500 school sites each year and makes field checks of sites where fault trenches are exposed.

Also, under this program, the CGS evaluates the seismic hazards site conditions for hospital construction for the Office of Statewide Health Planning and Development Safety Board (OSHPD). Hospitals must be constructed in strict accordance with OSHPD building standards. The CGS reviews consulting reports from approximately 60 hospital sites each year. Earthquake risk and loss assessments also are conducted for “critical structures” under this program, wherein local and regional damages to the

infrastructure are calculated and analyzed for various earthquake scenarios along major fault systems.

Strong Motion Instrument Program (SMIP)

This earthquake engineering program commenced in 1971 and has evolved into the largest state-operated Strong Motion Network in the nation, with more than 1,300 stations and more than 8,900 instruments installed in hundreds of structures and ground-response sites throughout the State. Strong motion information gathered by this network is provided to the earthquake engineering and structural design communities to

improve the earthquake resiliency of California's structures. Ultimately, this information is incorporated into the building code. The CGS SMIP network comprises the largest part of the California Integrated Seismic Network (CISN), which is a partnership with the California Office of Emergency Services (CalOES) and the networks of the USGS, Caltech, and UC Berkeley.

Development and expansion continues, in partnership with the USGS, of the Center for Engineering Strong Motion Data (CESMD). Strong motion data from throughout the U.S. and from around the world are sent to the Center for processing, display, and archiving. Data arriving from the CISN system are automatically processed and offered on the Internet within minutes

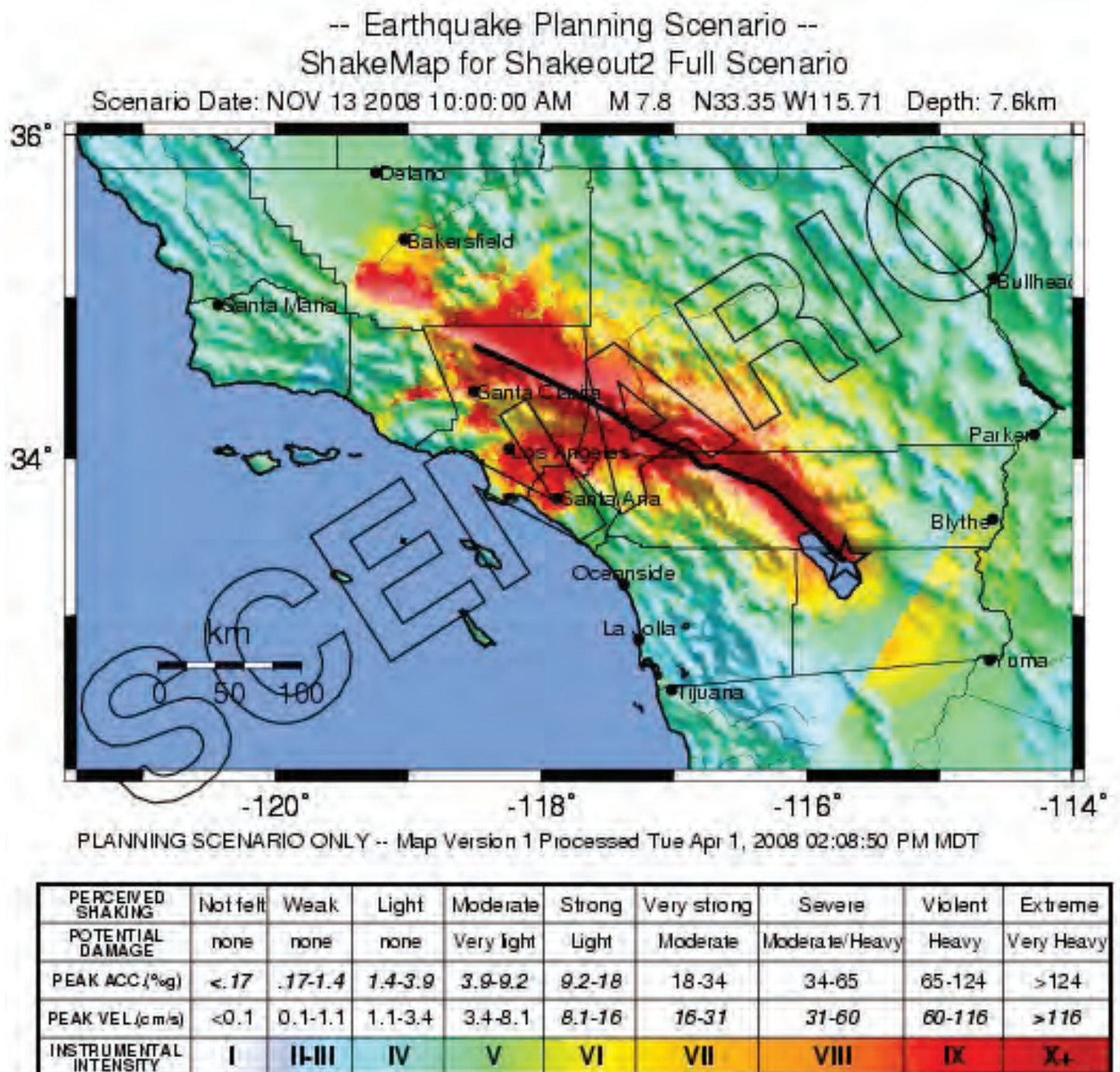


Figure 8: Earthquake scenario ShakeMap.



Figure 9: Seismically instrumented Rincon Tower building, San Francisco.

of an earthquake. Earthquake data from distinct parts of the world may take several days to post because of some countries' data-holding policies. The Center's archives may be accessed at <http://strongmotioncenter.org/>.

Library/Publications and Outreach Program

By statute, since 1880 the CGS maintains a geological research library for its staff and conducts public outreach and education activities that include a publications unit and website.

The library contains about 100,000 documents, including rare maps and publications on a host of geological topics. The library is open during regular business hours to all government and education researchers and to the public four days a week.



Figure 10: CGS library, Sacramento HQ.

COLORADO

COLORADO GEOLOGICAL SURVEY

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MISSION OF THE COLORADO GEOLOGICAL SURVEY

Building vibrant economies and sustainable communities safe from geologic hazards, for people to live, work, and play through good science, collaboration, and sound management of mineral, energy, and water resources.

The Colorado Geological Survey (CGS) is part of the Colorado School of Mines. Founded in 1874, the Colorado School of Mines is a public research university devoted to engineering and applied science. The Survey employs 22 geologists and other professionals. The programs and priorities of CGS are largely set in statute and are geared towards protecting public safety and promoting economic development of the State's natural resources.

CGS DIGS MARS

A CGS scientist developed key components of a heat probe onboard the Mars InSight Lander. The probe (landing on November 26, 2018) will explore what's inside the Red Planet to better grasp the history of our Solar System. The Heat Flow and Physical Properties Probe will dig down into Mars's surface about 16 ft. Readings from Mars's interior will reveal how much heat is flowing out of the body of the planet, and what the source of the heat is. NASA hopes to discover if Mars formed from the same stuff as Earth and the Moon, and get a sneak peek into how the Red Planet evolved. The probe was tested in various locations in Colorado.

COLORADO ABANDONED MINED LAND DATABASE

Mining has been a significant part of Colorado's history since the 1850s. As such, the State has an unknown number of adits, shafts, waste piles, and other abandoned mined land features (AML). These legacy sites can pose hazards to the public and environment. One study estimates that Colorado has more than 17,000 AML features that may pose a threat to public health and safety.

A statewide inventory of AML features is needed to address legacy sites. However, Colorado AML data is not easily assessable. The data is incomplete, resides in numerous databases, in diverse forms with varying degrees of accuracy, and across a multitude of local, state, and federal agencies. In 2017, to help solve this problem, CGS created a single data hub to bring together and share existing AML databases.

CGS researched electronic sources of AML information, formed a multi-agency AML Steering Committee, and compiled general information associated with existing electronic AML databases. Using an interactive web-based GIS platform, Colo-

rado's known AML features can be viewed in conjunction with other spatial information (for example, base maps or overlays). Two levels of information are available: general information about AML features is available to the public, and more detailed information is available to participating agencies and non-profits that work to reclaim historic mines and (or) improve watershed health (<https://erams.com/map>)

LAND USE REVIEW PROGRAM

For over four decades, CGS has assisted local governments with geologic hazard problems and other geologic concerns related to proposed land-use changes. CGS reviews proposed developments for geologic hazards and constraints and makes recommendations on hazard avoidance and mitigation to local officials. In 2017–18, CGS reviewed over 2,500 proposed building sites and offered recommendations to avoid or mitigate potential hazards.

GEOLOGIC MAPPING

CGS published geologic maps of nine 7.5-minute quadrangles and three county-wide compilations, which are used to identify groundwater resources, mineral and mineral fuels, geologic hazards, and construction materials. Mapping included areas of projected high population growth, major transportation corridors, and areas with suspected or known geologic hazards.

GROUNDWATER PROGRAM

Colorado faces significant and immediate water supply challenges. The State is experiencing rapid population growth, and Colorado's population is expected to nearly double within the next 40 years. Due to population pressure, the use of non-renewable groundwater is increasing, particularly for municipal use, creating reliability and sustainability concerns.

The CGS groundwater program primarily focuses on counties where development pressures, in combination with prolonged drought, are straining limited groundwater resources. CGS completed a comprehensive assessment of all aquifer types for three counties, including near-surface unconsolidated aquifers, bedrock aquifers, and fractured crystalline aquifers in rugged mountainous areas. Data is made available to the public in a web-based interactive viewer.

GEOHERMAL PROGRAM

Colorado has numerous direct-use geothermal applications that range from an alligator farm, mountain resorts with hot springs, a town's heating system, and greenhouses, to geothermal heat pumps in public and private buildings. However, there are high

temperatures below most of Colorado's mountains and valleys, and power generation is possible if sufficiently high temperature resources are available at reasonable depths.

CGS has identified promising deep drilling targets east-south-east of Mount Princeton and north of Poncha Hot Springs in Chaffee County. A widespread, but deeper (~8,000 ft) electricity-grade geothermal resource has been identified and mapped in the Raton Basin, west of Trinidad, in Las Animas County.

Many enterprises in Colorado use geothermal energy as direct heat for heating, domestic, commercial, greenhouses, and aquaculture, for spas and other bathing, and indirectly for geothermal heat pumps. A large, hot springs spa recently opened in Glenwood Springs, Garfield County: Iron Mountain Hot Springs, catering primarily to family recreation. CGS continues to assist in economic and technical studies of using direct heat for a variety of potential commercial and industrial businesses, primarily in small rural communities.

GEOLOGIC HAZARDS PROGRAM

Coloradans are familiar with the threats and impacts of disasters. Colorado experienced a nearly \$4 billion flood (including landslides and debris flows) in 2013. Since 2010, wildfires and the resulting debris flows have destroyed nearly 1,250 homes. There is a growing consciousness that Colorado must systematically adapt to and prepare for natural hazards and changing climate.

In recognition of this reality, and a desire to make Colorado the most resilient state in the nation, Colorado is making significant investment in identifying natural hazards. CGS is a key partner in this statewide effort, investing in high-resolution lidar and creating landslide and debris flow susceptibility maps across the State. Mapping for four counties was completed in 2017–18. CGS continues to participate in the creation of hazards planning tools for local communities. Tools include Colorado-specific information about how to assess a community's risk of hazards and how to implement land-use planning tools and strategies for reducing a community's risk.

In addition, CGS provides emergency response to local communities impacted by landslide and rockfall events. Working with state and local emergency managers, CGS provides rapid assessment of risks, ways to protect public safety, and potential ways to reduce risks.

MINERAL AND MINERAL FUELS PROGRAM

Annual Reports

CGS published an annual mineral and energy industry report for 2016. Nonfuel mineral resources include metals, industrial minerals, and construction materials (for example, cement, crushed rock, lime, sand, and gravel). In 2016, Colorado produced an

estimated \$1.5 billion, or approximately two percent of the estimated total U.S. production value.

Metals mined in Colorado include gold, molybdenum, and silver. CGS estimates that the 2016 production value of these metals was about \$673 million. This is approximately a 22 percent increase compared to the 2015 production value of \$551 million. This increase in value was due to the increase in gold production at Newmont's Cripple Creek and Victor (CC&V) mine located in Teller County.

Coal mining in Colorado dates to 1864. Colorado's clean, high-quality coal reserves help utilities meet air quality regulations. Data provided by the Colorado Mining Association indicate that in 2014 the industry accounted for \$900 million in sales. With reduced production and lower prices, sales fell to an estimated \$510 million in 2016 but are expected to increase in 2017 and 2018 based on forecast increases in production. Per the National Mining Association, the industry contributed \$1.9 billion to Colorado's economy, and directly employed 3,723 workers, with 12,977 indirect and induced jobs.

Mineral Resource Derivative Maps

CGS creates mineral resource derivative maps from geologic maps and historical mine locations to provide information on the general distribution of select potential mineral resources. Derivative maps are generated for three general resource types: construction aggregate materials, industrial minerals, and placer gold. The results are available in an interactive web-based viewer (<https://cologeosurvey.maps.arcgis.com/apps/webappviewer/index.html?id=853e8c4cd294482eaa296d82486a9910>).

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- Barkmann, P. E.; Curtiss, W.; Carroll, C. J.; Hosler, D. R.; Rogers, N. T.; Logan, Z. D.; Zawaski, M. J., 2017a, Geologic map of the Castor Gulch quadrangle, Moffat County, Colorado: Colorado Geological Survey Open File Report OF-15-02, scale 1:24,000.
- Barkmann, P. E.; Houck, K. J.; Dechesne, M.; Lovekin, J. R.; Johnson, E. P., 2017b, Geologic map of the Hartsel quadrangle, Park County, Colorado: Colorado Geological Survey Open File Report OF-17-04, scale 1:24,000.
- Barkmann, P. E.; Johnson, E. P.; Curtiss, W., 2017c, Geologic map of the Ralph White Lake quadrangle, Moffat and Routt Counties, Colorado: Colorado Geological Survey Open File Report OF-16-07, scale 1:24,000.
- Barkmann, P. E.; Johnson, E. P.; Sebol, L. A.; Fitzgerald, F. S., 2017d, Geology and groundwater resources of Chaffee County, Colorado: Colorado Geological Survey Open File Report OF-16-04, 114 p.
- Barkmann, P. E.; Sebol, L. A.; Johnson, E. P.; Fitzgerald, F. S.; Curtiss, W., 2017e, Geology and groundwater resources of

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CONNECTICUT

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INTRODUCTION

The Connecticut Geological and Natural History 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 Survey is defined in the Connecticut State Statutes (Ch 462, Sec 24-1 to 24-4). In the Department of Energy and Environmental Protection, the Geological Survey is within the Office of Information Management (OIM) and the Natural History Survey is within the Bureau of Natural Resources (BNR) Wildlife Division.

Program Trends

The Survey's principal effort continues to involve statewide geologic and biologic inventory mapping, database enhancements, and development of derivative products for use in environmental policy and management decisions. The Survey continues to conduct resource mapping in State Parks and Forests, and make significant contributions in DEEP program areas related to water resources, aquifer protection, land use and conservation, and endangered species. During the last 20 years, the Natural History Survey has operated the CT Natural Diversity Database, which manages information on state-listed species and significant natural communities. Survey staff participated in the development of the CT Aquatic Nuisance Species Management Plan. The Survey has also developed basic resource datasets for Long Island Sound in cooperation with the University of Connecticut. Survey publications continue to update the selection at our DEEP Store with more than 1,000 titles available, covering the natural resources of Connecticut.

The Geological Survey is focusing on greater involvement of students and academic partners in Survey work. The State Survey office at the University of Connecticut furthers student engagement in applied geoscience and environmental projects. These educational collaborations not only provide valuable work experiences for students, but also contribute to the State's environmental protection efforts, and further the Survey mission toward improved geoscience information for natural resources conservation, environmental quality, and outdoor recreation.

Geographic Information System (GIS)

The central GIS operation for the Department of Energy and Environmental Protection resides in the Office of Information Management (OIM). OIM manages the DEEP/GIS database, which is accessible to all DEEP staff. DEEP utilizes a suite of Esri GIS products including ArcGIS, ArcSDE, and ArcGIS Online (AGOL). The primary long-term goal of the GIS Program is the development of an integrated spatial information system that incorporates and regularly updates all of the basic data layers necessary to support the Department's research, planning, and management activities. Surficial materials, Quaternary geology, bedrock

geology, and soils are available for use in GIS. DEEP's GIS data is downloadable through the agency's website (www.ct.gov/deep/gisdata).

A web-based GIS tool, CT Environmental Conditions Online (CTECO) is available through a partnership between the DEEP and the University of Connecticut. This application provides users direct access to geography-based natural resource and environmental information such as aquifer protection areas, watersheds, flood zones, geology, soils, water supply wells, open space, and imagery. With CTECO, basic environmental conditions can be assessed anywhere in Connecticut by mapping online, without GIS experience or software. A map catalog is available to view or print PDF maps of environmental themes by town, 7.5-minute quadrangle, or statewide. A variety of orthophotography (1990–2010) is also available. CTECO also provides a direct connection to desktop GIS or CAD software or ArcGIS and WMS map services as an alternative to downloading GIS data files (<http://www.cteco.uconn.edu>).

Aerial Photography

All historic low-altitude statewide flights (1:12) are available through the CT State Library or the University of Connecticut. This includes some four-band color, infrared. Detailed oblique photography is also available for agency use. Statewide lidar (2016) and the 2014 NAIP imagery are available online through the DEEP/UConn CTECO cooperative (<http://www.cteco.uconn.edu/data/lidar/index.htm>).

Topographic Mapping

OIM maintains statewide published topographic maps at scales of 1:24,000, 1:50,000, and 1:125,000. In cooperation with the USGS, Digital Line Graph (DLG) 7.5-minute quadrangle information and Digital Raster Graphics (DRGs) were produced for the State before the year 2000. A joint funding agreement between DEEP and USGS has provided high-resolution National Hydrography Data (NHD) for Connecticut. The NHD data has been updated for most of Connecticut, and is available through www.ct.gov/deep/gisdata.

GEOLOGY PROGRAM

The Survey is continuing to develop cooperative partnerships toward the goal of improved geoscience information for DEEP programs and the citizens of Connecticut. Bedrock and surficial geologic mapping, topical research projects, and educational initiatives are pursued through a combination of federal, state, academic, and non-profit collaborations.

MAPPING

Bedrock Mapping

The 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 and supported as contributions toward the overall effort. Within the National Cooperative Geologic Mapping Program, STATEMAP component, the Connecticut Survey is actively pursuing modern bedrock mapping and working with federal and academic partners to update the Connecticut bedrock map. The mapping includes traditional fieldwork, petrography, and geochemical analyses to support geologic correlations and tectonic interpretations. Completed map products and geologic reports are available online (www.ct.gov/deep/geology and <https://ngmdb.usgs.gov>).

Surficial Mapping

1:24,000-scale surficial and Quaternary geologic mapping is available statewide, both onshore and within Long Island Sound, and was published as USGS Scientific Investigations Map 2784, by Stone and others in 2005. The digital geologic data is one of the primary resources layers used in environmental analysis by the CT Department of Energy and Environmental Protection, and is available for download at www.ct.gov/deep/gisdata.

Soils Mapping

1:12,000-scale soils mapping for CT, authored by the USDA Natural Resources Conservation Service, was digitally compiled through cooperative efforts of DEEP and NRCS. These data and interpretations for wetlands, farmland, and other applications are available as the Soil Survey Geographic database (SSURGO) for Connecticut: www.ct.gov/deep/gisdata and <https://websoilsurvey.sc.egov.usda.gov>.

GEOLOGIC INVESTIGATIONS

Environmental Quality

Arsenic and uranium in private drinking water has become an increasing environmental issue in Connecticut. The State Geologist has convened an arsenic and uranium work group, bringing together academic researchers, DEEP, USGS, and the CT Health Department to review research findings and discuss the issue on a regular basis. This forum provides an opportunity to collaborate and share research ideas, as well as devise funding strategies. New bedrock mapping contributes to collaborative research initiatives.

Hazards

Seismic

An unusual seismic swarm occurred in the town of Plainfield, eastern Connecticut, in early 2015. These minor seismic events ranged in magnitude from 0.9-3.1M, with the recognized swarm from January 8 to February 24. The State Geologist briefed the Governor's office with information received from the USGS Advanced National Seismic System and regional experts at Weston Observatory of Boston College. A portable seismic array deployed by Weston Observatory recorded an additional 180 confirmed microquakes (less than 1.0M) continuing through July. In partnership with Weston Observatory, the State Survey coordinated seismometer data transfer and supported the geophysical investigation. Event locations were mapped beneath an abandoned shallow rock quarry at depths ranging from 1.6 km, to just below the surface. The largest event (MLg 3.1) was determined to originate from fault planes oriented 020 and 200, with 45 degree dips. Swarm events suggest the potential intersection of a shallow westward dipping fault with a deeper eastward-dipping fault. These events occurred in a region near the mylonitic Lake Char fault zone, a major terrane boundary. Surveillance with local seismometers provides a unique opportunity to investigate and map these previously undetected events, and contribute to our understanding of earthquakes in Connecticut. Collaborative geologic studies to investigate the relationship between seismicity, brittle fractures, geologic structures, and the quarry are planned.

Concrete Degradation

Chemical weathering of concrete home foundations in eastern and central Connecticut is a growing issue affecting hundreds to thousands of homeowners. The State Geologist briefed Lt. Gov. Nancy Wyman, providing geologic expertise on weathering of iron sulfide (especially pyrrhotite) minerals in concrete. She presented mapping on the distribution of active mines and geologic resources containing iron sulfides and pyrrhotite and responded to inquiries from elected officials, the media, and the U.S. Army Corp of Engineers. The State Geologist continues to serve in an advisory role for resource assessments, conducts technical review of reports, and provides geoscience information.

DATABASE DEVELOPMENT

Resource Inventory and GPS Mapping

Field mapping services are provided to units within the Department of Energy and Environmental Protection's Conservation Branch. These units include Land Acquisition, Boating, Parks, Forestry, Fisheries, Greenways, and Natural Areas. Mapping activities include trail mapping in parks and forests, facility mapping of State Parks, public boat launches, biologic and geologic features of significance, and establishment of survey benchmarks. Hard copy and digital map products are available through the DEEP store and online.

The CT Geologic Sites Database

The CT Geologic Sites Database is an ongoing program of documenting institutional knowledge. Database verification and enhancements are the focus of ongoing Geological Survey fieldwork. Recent components related to mining activities and mineral collecting locations have contributed data to the CT Office of Legislative Research, the USGS Eastern Region Minerals Yearbook, and routine technical assistance to DEEP programs, consultants, and citizens. The geologic sites database is also a central resource for Geological Survey land acquisition reviews within the DEEP.

COLLECTIONS

Collections/Data Preservation

As a participant in the National Geological and Geophysical Data Preservation Program, the Geological Survey is making collections information available to academic researchers and the public. Geoscience data preservation efforts are ongoing for the library collection of books, manuscripts, maps, scientific specimens, and unpublished Survey files. Pipeline companies and other infrastructure projects in Connecticut produce new rock core, providing opportunities to enhance the Survey collection with scientifically important core. Information on the Connecticut Rock Core Collection, Educational Hand Sample Collection, dinosaur track catalog, Survey historic Biennial Reports, and unpublished map files are available through the Survey website (www.ct.gov/deep/geology) and the USGS Digital Catalog (<http://ndc.sciencebase.gov>).

Access to the Connecticut Survey library and collections facility is by appointment.

OUTREACH AND EDUCATION

The Connecticut Survey is an active participant in Earth Science Week and CT Trails Day educational initiatives. Survey publications, support of teacher training on the geology of Connecticut, online geologic descriptions of CT State Parks, and Earthcache sites (www.earthcache.org) all contribute to the agency environmental education effort. The Educational Mineral Collecting Permit Program supports the educational mission of schools, museums, and mineral clubs. An online Connecticut Garnet Trail highlights locations of Connecticut's state mineral on public land, and provides additional outdoor recreational opportunities (<http://bit.ly/1L3bcmW>). An online geologic guide to the Appalachian Trail in Connecticut is in development.

Student Engagement

In 2017 the State Geological Survey opened an office at the University of Connecticut in Storrs. The goal of the Connecticut Survey office is to engage students in collaborative research

initiatives in applied geologic and environmental research in Connecticut. University students are able to work with the State Geological Survey through student internships, part-time employment, approved independent studies, and volunteer opportunities on a variety of projects involving bedrock, glacial materials, soil, groundwater, and publications. These educational collaborations not only provide valuable work experiences for students, but also contribute to the State's environmental protection efforts furthering the work of DEEP in the areas of natural resources conservation, environmental quality, and outdoor recreation. Student projects have included geophysical data processing to identify microseismic events, well logging to investigate the geologic terrane boundary underlying Hammonasset State Park, and assessing Long Island Sound coastal erosion hazard vulnerabilities.

BIOLOGY PROGRAM

In addition to conducting basic inventories of the state's biota, the Natural History Survey maintains the Natural Diversity Database (NDDDB), which is an inventory of historic and current information about state and federally listed plants, animals, and significant natural communities. The Natural History Survey is a member of NatureServe's National Heritage Network and uses Biotics, a nationally accepted GIS and database application designed by NatureServe, to manage this information. The Natural History Survey coordinates regular updates to Connecticut's list of endangered, threatened and special concern species. Biologists provide technical assistance through the environmental review process, and are involved in identifying and protecting significant ecological areas.

Forestland Habitat Impact Screening Tool

In response to Public Act 17-218, the NDDDB worked cooperatively with the DEEP Divisions of Fisheries, Wildlife, Forestry, Water Monitoring, and Energy to complete a screening tool to help large-scale solar developers avoid impact to core forest. This spatial screening tool identified prime contiguous core forestland blocks. The screening layer was derived from a variety of resource layers representing areas which would experience a disruption of core forestland processes with the development of large solar installations.

PUBLICATIONS

www.ct.gov/deep/geology

Publications list: www.ct.gov/deep/lib/deep/geology/ct_survey_publications_list.pdf

On-line publication sales: <http://www.ctdeepstore.com>

(860) 424-3555 or 424-3692 or email deep.store@ct.gov

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DELAWARE GEOLOGICAL SURVEY

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INTRODUCTION

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

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. The DGS budget is funded by an annual direct appropriation from the State of Delaware with related reporting responsibilities to both the Office of the Governor and the Delaware General Assembly. The DGS provides objective, factual information that affects public policy decisions, and aids in solutions for individuals, business, and industry. In addition, we contribute to the educational mission of the University through collaboration with faculty and students, and by providing students and interns hands-on experience working with DGS researchers, and exposure to our scientific and field equipment. The DGS became formally affiliated with the University's growing College of Earth, Ocean, and Environment (CEOE) in July, 2008. Most DGS scientists have secondary faculty appointments in the College's Department of Geological Sciences.

Our research and service activities are focused on five areas: (1) geology; (2) hydrology; (3) natural hazards; (4) the state geospatial framework; and (5) information dissemination. DGS activities in these areas impact a wide variety of issues, including water resources, agriculture, environmental protection, energy and mineral resources, economic development, land-use planning, emergency management, public health, coastal issues, sea-level rise, and recreation. Our responsibilities have continued to grow over the years and our program priorities continue to evolve to ensure that we are aligned with the highest priority needs of Delaware's citizens. For example, the high rate of population growth and associated development throughout Delaware necessitates evolution of our work plans to anticipate areas of strategic future importance, including increased emphasis on determining the occurrence, availability, quantity, and quality of groundwater resources from our aquifer systems; increased emphasis on land-based wastewater disposal, coastal flooding, and natural hazards; and efficient and effective dissemination of information and spatial data via electronic means such as the internet.

DGS ADMINISTRATION

David R. Wunsch is the State Geologist and director of DGS. Previously, Wunsch served as the State Geologist and Director of the New Hampshire Geological Survey from 2000 to 2010, and also served as the Director of Science & Technology at the National Ground Water Association in 2010/11. Denise Heldorfer is the ex-

ecutive assistant to the Director, and chief financial officer. Laura Wisk is our administrative assistant.

GEOLOGIC INVESTIGATIONS AND SERVICES

The DGS geology program includes surficial geologic mapping, subsurface geology, and coastal geology. Many areas of the State have shown significant growth and development over the last decade. 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/agriculture, geotechnical engineering, coastal protection, and beach nourishment.

Surficial geological mapping is a major element of the DGS geology program. In 2018, DGS published one map: No. 24, Geologic Map of the Millington, Clayton, and Smyrna Quadrangles, Delaware.

DGS maps will significantly advance understanding of the near-surface geology of the State through integration of geomorphology derived from high-resolution topographical data (lidar).

DGS manages and has submitted statewide map services of 1:100,000-scale surficial geologic units and 1:100,000-scale surficial geologic contacts. These services support both WMS and WFS protocols with data attributes supporting the GeoSciML-portrayal schema. Currently, DGS maintains a four star web service accreditation rating. DGS is one of only five states in the U.S. that participates in OneGeology and is working with the developers on documentation and testing for an open-source implementation.

The DGS maintains the Atlantic Outer Continental Shelf Core and Sample Repository. This repository includes nearly all remaining sample materials related to geologic investigations conducted offshore of the eastern coast of the U.S., and has been recently utilized by parties anticipating possible future interest in potential offshore East Coast energy resources such as wind. Issues related to the impact of recent and future sea-level rise on Delaware's coast also are of growing interest. DGS has been funded by the federal Bureau of Ocean and Energy Management (BOEM) since 2015 to explore additional sand resources in federal waters offshore of Delaware. DGS is currently working with BOEM to expand our project to examine a regional context. The proposed project will increase understanding of sedimentation processes and the geologic framework of the sediments in OCS waters adjacent to Delaware, Maryland, Virginia, and New Jersey. This goal will be accomplished by a cooperative effort between the states to 1) collect new data from analyses from existing cores, and 2) synthesize the new data with existing data to produce a regional, rather than a state-based framework.

DGS entered into the Midwest Regional Carbon Sequestration Partnership (MRCSP) in 2015. Dr. Peter McLaughlin will be the DGS lead, and Dr. David Wunsch will be co-PI for our participa-

tion in this effort. DGS partnered with Battelle National Lab and the neighboring states of New Jersey and Maryland to better understand both onshore and offshore reservoir potential for carbon capture and storage (CCS). Recently DGS revised its policies for loaning OCS samples to researchers and private entities.

The DGS continues numerous activities and responsibilities involving interaction with other government agencies on geology-related issues. These include service as a permanent professional member of the Delaware Board of Geologists; acting as the State's interface and primary cooperators with the U.S. Geological Survey and the U.S. Bureau of Ocean Energy Management, Regulation, and Enforcement; service as Delaware's representative on U.S. Department of the Interior's Outer Continental Shelf Policy Committee; cooperation with the Minerals Information Team of the USGS in compiling sand and gravel production data for the state; service on the Association of State Boards of Geology (including a term as President); serving on the Delaware Geographic Data Committee Executive Council; and generally advising state and local government organizations on coastal geology issues ranging from shoreline migration to sand characterization. State Geologist David Wunsch is statutorily assigned as the Delaware principal to the Delaware River Master Decree Party, and also represents the Association of American State Geologists on the federal Advisory Committee on Water Information (ACWI) and the ACWI Subcommittee on Ground Water. Wunsch was also recently named as the federal co-chair of the NGWMN Program Board, which will serve as the peer review panel for the new USGS cooperative program to enlist data providers interested in serving as a node in the national groundwater monitoring network (NGWMN). Wunsch also serves as a trustee of the AASG Foundation, a 501(c)(3) organization that supports the public service and education activities of AASG.

HYDROLOGIC INVESTIGATIONS AND SERVICES

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, and water-resource issues associated with land-based wastewater disposal.

The DGS released two Report of Investigations in 2018: *No. 81, Characterization of tidal wetland inundation in the Murderkill Estuary*, and *No. 82, Southern New Castle–Northern Kent Counties groundwater monitoring project: Results of subsurface exploration and hydrogeological studies*.

We also released two Open File Reports: *No. 51, Groundwater monitoring procedures part 1: Equipment and procedures for manual and automated field measurement of groundwater levels in dedicated monitoring wells*, and *No. 52, Results of groundwater flow simulation in the East Dover Area, Delaware*. DGS researchers

have also been active in the development of thermal imaging applications as they relate to hydrology. One project uses thermal imaging to map the spatial and temporal distribution of tidal inundation on a salt-marsh platform. The other project uses ground-based multi-spectral thermal imagery to map spatiotemporal topographic variability and help characterize hydrologic and sedimentary processes and properties in tidal wetlands and sand/mud flats.

As an ongoing responsibility, the DGS is the lead agency for collection and analysis of data on groundwater levels and stream discharges in Delaware. In 2017, DGS was awarded funds to enhance the State's groundwater monitoring network in Kent County. Well installation is complete; currently groundwater levels are monitored in 34 monitoring wells with automated data loggers mainly located along the coastal region to monitor potential saltwater intrusion. More than 510,000 observations have been collected to date. Data are reviewed by DGS for quality control and then are available from DGS online sources. DGS is also a participant in the USGS National Ground Water Monitoring Network (NGWMN) by receiving several funding agreements with the USGS. Delaware wells in the national network are available through the NGWMN portal.

We will also continue to track surface-water conditions using 16 stream-gage and nine tide-gage stations that are maintained around the State in cooperation with the USGS. 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, and through participation on committees such as the Governor's Drought Advisory Committee, Delaware Water Supply Coordinating Council, and the Northern New Castle County Groundwater Availability Technical Advisory Committee (TAC). We also continue our role in interfacing with federal, interstate, state, county, municipal, and local agencies on a variety of other water-related issues via: Delaware River Master Advisory Committee, the Decree Party Workgroup and Regulated Flow Advisory committees of the Delaware River Basin Commission, New Castle County Resource Protection Area TAC, Inland Bays Scientific TAC, and the Delaware TMDL TAC. The DGS co-chairs the Data Management and Data Standards Workgroup, which is part of the ACWI Subcommittee on Groundwater. The DGS has statutory responsibility for dealing with its federal counterpart agencies, such as the USGS, in matters related to hydrology.

GEOLOGIC HAZARD INVESTIGATIONS AND SERVICES

The DGS has ongoing responsibilities for understanding natural hazards in Delaware and advising appropriate emergency management agencies on these hazards and related mitigation and response. Flooding hazards, including stream flooding and coastal flooding, and seismic hazards are the main focus of our efforts.

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

The DGS is a regular participant in assessing flooding risks due to storm events throughout the year. Staff participate in statewide interagency emergency management coordination conference calls convened for major storm events and provide real-time evaluation of stream-flow and tide-gage data and meteorological information. We cooperate with the Office of the State Climatologist and the Delaware Emergency Management Agency (DEMA) in the maintenance of the Delaware Environmental Observing System (DEOS), a real-time system for monitoring environmental conditions. In our effort to assist emergency managers, the DGS, in cooperation with the Delaware Environmental Observing System, placed new data loggers and cell phone modems at seven coastal tide gages in Delaware. Minutes count during a tidal flooding event, and this system will provide an advantage to emergency managers and scientists by having access to six-minute updated gage height information prior to and during coastal storms. These high-quality data loggers and cell modems will provide significantly higher resolution tidal information to evaluate and mitigate emergency situations resulting from coastal storms. The data are currently available over a web interface for near real-time access. In 2017 DGS led a state effort to update the State's response and projections for sea-level rise, which resulted in the report *Determination of future sea-level rise planning scenarios for Delaware*.

GEOSPATIAL INVESTIGATIONS AND SERVICES

DGS activities related to geospatial investigations and services continue rapid growth. DGS has been refining a new web-based tool for delivery of geologic and geospatial information. The Delaware Geologic Information Resource (DGIR), is a new web service that combines a multitude of databases and map services to offer a geoscience information tool specifically for professional users. Most DGS digital products are migrating to DGIR.

The DGS led a multi-agency state and federal effort to secure \$1.1M in funding from the Hurricane Sandy Relief program to collect new, high-quality lidar for the entire state of Delaware. As part of this effort, DGS is currently developing updated one-ft elevation contours for the entire state that will be used for predicting the impacts of storm surge and sea level rise, improve our geologic and land use mapping, measure changes in marshes and wetlands, and much more. DGS will store and maintain the new dataset as well as provide expertise for the State. We recently hired a GIS analyst/lidar specialist to perform watershed

analyses, develop quality control of the contour data, and develop new derivative products.

INFORMATION DISSEMINATION

The DGS ensures the results of our work are of use to our stakeholders through our programs of publication and outreach. Publication has traditionally been the main focus of our information dissemination program and the last year has seen a continued growth into the digital realm. The Delaware Geological Survey unveiled a new version of its public website (www.dgs.udel.edu) in 2010. Although many of the technologies employed are consistent with modern web standards, giving the user a familiar feel and comfort level, this version pays particular attention to the retrieval of information. The DGS also conducts education and public outreach on issues related to Earth science through presentations, workshops, and building tours. We regularly participate in the University's annual Coast Day, an open house and festival at the College of Earth, Ocean, and Environment bayside campus in Lewes, Delaware. Director David Wunsch was invited to serve on the University of Delaware's Public Engagement Committee, which is focused on enhancing interaction and beneficial services to communities in the State. Outreach related to geospatial issues has included GIS-related teacher-development activities and service as key topics for next year's state GIS conference. DGS also convenes our Delaware Geology Symposium, which is held every two years, and typically draws over 100 geoscientists from state agencies, academia, and the private sector.

AASG 100th Annual Meeting

The DGS hosted the 110th Annual Meeting of the Association of American State Geologists (AASG) at the Atlantic Sands Hotel & Conference Center in Rehoboth Beach, Delaware, from June 3–7, 2018. The AASG convenes its annual meeting in a different state each year, and the Delaware Geological Survey last hosted the annual meeting in 1978.

The meeting was a four-day event with technical sessions, field trips, and a closing banquet designed to foster ideas and promote exchange and communication among state, federal, and non-profit partners. The theme of this year's meeting was "Applied Geoscience for a Changing Planet". The meeting also included keynote addresses by invited speakers from across the realm of science, energy, environment, and policy. Opening remarks were given by Dr. Tim Petty, the Assistant Secretary of the Department of Interior for Water & Science, and the recently confirmed director of the U.S. Geological Survey, Dr. James Reilly.

The Delaware AASG Meeting included several field trips. A mid-meeting trip was a half-day event for all attendees, and included stops at the historic Indian River Life-Saving Station Museum at Delaware Seashore State Park, Indian Bay inlet bridge to view coastal engineering projects, and Camp Henlopen State Park and historic Camp Miles. Field trips were led by DGS staff with expertise in coastal geology and near-shore hydrology.



Figure 1. Group photo of the attendees at the 110th AASG Annual Meeting held in Rehoboth Beach, Delaware, June 3–7, 2018.

In addition, several staff are hobbyist historians, and offered interesting historical notes related to the sites along with other anecdotes related to Delaware's rich maritime and colonial history. A post-meeting field trip was held mainly in the Piedmont region of northern Delaware and included stops at the historic Hagley Museum of early industry along the Brandywine Valley, and ended with geology by train, with stops at rock outcrops and sites of interest visible along the tracks of the Wilmington & Western railway.

This year there were state geologists and representatives from 41 state surveys, as well as representatives from many federal departments and agencies. The guest speaker for the event banquet was UD professor Dr. Art Trembanis, who spoke on the development and use of autonomous vehicles for data collection and discovery. The meeting was a memorable and successful event that provided a forum for national leaders in geoscience and policy to convene in a beautiful location along coastal Delaware.

FLORIDA

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INTRODUCTION

The Florida Geological Survey (FGS) can trace its origin to the Office of State Engineer and Geologist established in 1853; however, it was not until 1907 that an autonomous Florida Geological Survey was established by the Florida Legislature. In February 2015, the FGS moved from the Gunter Building on the campus of Florida State University (FSU) to an upgraded FSU facility a few doors down from the FGS Geologic Sample Repository and the Florida Department of Environmental Protection (DEP) headquarters. The FGS Geologic Sample Repository also maintains office space, laboratories, a core and well-cutting sample repository, and publications storage at an annex in Tallahassee. The Geologic Data Acquisition and Management Program employees are housed at the annex. The FGS is a division within the Florida Department of Environmental Protection (DEP). The Director of the FGS serves as the State Geologist and oversees the administration, geological and hydrogeological research, and other activities of the Survey.

FGS is strategically positioned within the Regulatory Programs branch of DEP. Here it can provide the objective geologic research and support required to address many of the State's environmental issues. Florida's geologic framework comprises the "bucket" that holds five major freshwater aquifer systems and comprises the foundation of our diverse ecosystems. In 2017–18, the Florida Geological Survey was engaged in several research projects designed to better understand our State's geology, the environment, and the hydrogeological issues facing our continually-growing state. These include continued development of statewide potentiometric surface mapping, detailed geologic and geomorphologic mapping, springshed delineation studies, hydrogeological modeling assistance, and assessing the favorability of the State's geology to sinkhole formation for the Florida Division of Emergency Management. Many projects are grant funded, employing full and part-time workers and engaging the skills of interns, leveraging the best science for the least state dollars.

ORGANIZATION

FGS is organized into five sections: Administration, Geological Investigations, Applied Geoscience Services, Geoscience Information and Data Management, and Geological Sample Acquisition and Management. The Survey's Administration Section consists of Operations, IT Coordination, Human Resource Management, Budget Management, Communications and Outreach, and Special Projects. This section is responsible for administration (budget, department, and interagency liaison, among others), contract and grant tracking, personnel management (travel, leave, benefits, among others), IT administration and infrastructure support, and building maintenance and repair.

The Geological Investigations Section collects and interprets statewide surface and subsurface geological data. It conducts geologic and geomorphic mapping and maintains, updates, and

disseminates information on Florida's lithostratigraphic nomenclature. It sustains the core statutory mandate to investigate and report on Florida's stratigraphy, mineralogy, sedimentology, and paleontology. The section provides expertise to state and federal agencies and the public, and provides outreach and educational opportunities for citizens highlighting the importance of geoscience. The Geological Investigations Section also maintains the Walter Schmidt Museum of Florida Geology.

The Applied Geoscience Services Section conducts studies related to delineation of springshed boundaries and assessment of related water quality issues as well as sinkhole favorability. The section is also responsible for creating potentiometric surface maps, conducting surface and groundwater interaction studies, springs inventory surveys, ground penetrating radar (GPR) surveys, surface water, groundwater, and contaminant fate and transport modeling, and geologic site characterizations. Additionally, the section conducts aquifer vulnerability, aquifer storage and recovery, and arsenic/trace metal assessments. It also helps maintain the subsidence incident reports database and responds to requests for sinkhole and other geologic hazard assessments. Much of the work produced by this section provides geoscience support for DEP and other state agency regulatory needs, such as minimum flows and levels of surface water bodies.

The Geoscience Information and Data Management Section facilitates access to, organizes, and determines the accuracy of FGS geologic information. The section organizes GIS data, which includes managing databases of well records, outcrop descriptions, STATEMAP products, potentiometric surface maps, sinkholes, and digitally-converted paper documents with geologic information (for example, geophysical and lithologic logs). The section also provides data visualization using various dashboards when needed, and maintains and provides access to FGS publications and other scientific publications through the Herman Gunter Geological Research Library.

The Geological Sample Acquisition and Management Section maintains the FGS Geological Sample Repository and provides access to it for research by the academic, scientific, regulatory, and private sector communities. It obtains rock and sediment cores and cuttings and maintains these acquisitions within the FGS Geological Sample Repository. The section installs moni-



toring wells in support of projects involving groundwater quality monitoring, potentiometric surface mapping, and development of minimum flows and levels. The section also maintains the FGS drill rigs and associated equipment required for collecting geological samples and geophysical log data. It also maintains the R/V GeoExplorer, other FGS research vessels, and associated data-acquisition equipment to conduct offshore geophysical data and geological sample acquisition.

STAFF, EQUIPMENT, AND FACILITIES

The FGS staff includes 31 full-time positions, nine research assistants, and six interns. Geoscience staff have the support of numerous assets including laboratories for micropaleontology, sedimentology, hydrogeochemistry, microscopy, and scanning electron microscopy. Other assets include a geologic research library; a sample repository with over 19,800 sets of well cuttings, cores, and outcrop samples; discharge measurement instruments; water quality and level sondes; ground-penetrating radar; and geophysical borehole logging tools. The FGS also has a Mobile Drill B-31 core and auger rig, a Schramm T450MIIA drilling rig capable of a total coring depth of 3,000 ft, a CME 75 drilling rig with associated support vehicles, seven four-wheel drive field vehicles, and four research vessels (boats) with data-acquisition equipment (for example, side-scan sonar).

GEOLOGICAL INVESTIGATIONS

Section staff continued conducting fieldwork necessary to produce a geomorphic map of Florida in 2017–18. The new map builds on much earlier map data and incorporates extensive field investigation, use of newly acquired lidar imagery, and the utilization of GIS software. Anticipated publication is during the 2019 calendar year.

Geological Investigations Section staff continued to aid the Geological Sample Acquisition and Management Section in preparing the FGS's 50-ft research vessel, the RV GeoQuest, to collect side-scan sonar data over selected areas of interest. Areas that show abrupt changes in bottom topography and reflectance may be places where rock exposures provide protective habitat for many species of marine animals. Identifying areas where rock is exposed on the seafloor also illuminates the geology. The side-scan data is processed into mosaic images. Coupled with video, photographs, and seafloor samples, this data will foster production of offshore geologic maps—an understudied part of the State.

STATEMAP

The Geological Investigations Section's STATEMAP team completed and submitted the 2017–18 grant deliverable, which includes a surficial geologic map, cross sections, geomorphology, and written report for the Kissimmee 30 x 60-minute quadrangle.

The USGS awarded \$154,219, to the FGS's STATEMAP program for 2017 to 2018. The mapping effort is the culmination of a year-long effort which includes fieldwork, data compilation, data analysis, and generation of map products and a written report. The maps and report will be finalized and available to the public for digital download by December of 2018. The study focused on detailed geologic quadrangle mapping with benefits in identification of water and mineral resources, environmental protection and improved quality of life, and improved quality and credibility of land-use planning.

To date, the STATEMAP program has mapped 53.4 percent of the state, collected over 1,400 outcrop samples, produced 120 new geologic cross sections, and collected formation data on thousands of boreholes. The program has generated new geologic maps for over 28,000 mi² of Florida at an average cost of \$207.60 per mi², making it one of the most cost-effective programs in the agency. It has also produced 33 new publications in the form of Open File Map Series and Open-File Reports. All of these publications are available online.

During 2017–18, the FGS focused more staff and resources on surficial and three-dimensional geologic mapping with the goal of accelerating completion of the statewide surficial geologic map of Florida. The STATEMAP program will continue to map the State, contingent upon future funding, and newly-dedicated staff will work independently but with the common goal of revising and publishing a revised statewide surficial geologic map by 2024. FGS will utilize innovative techniques to ensure geologic data are accessible in all formats for end users by collecting and consolidating geologic data from previous STATEMAP projects, converting those data and other legacy geologic data to more usable digital formats, and mapping more area than can be funded by STATEMAP alone. This will also allow the FGS to utilize the newly-compiled legacy geologic data and construct derivative products such as top-of-rock, aquifer thickness, aquifer vulnerability, confinement, and other three-dimensional geologic maps.

APPLIED GEOSCIENCE SERVICES

Applied Geoscience Services Section staff successfully executed important hydrogeology projects in collaboration with local and state agencies. The Leon County Public Works Department requested that the FGS conduct a ground-penetrating radar (GPR) survey in Lake Munson and collect, describe, and sample 37 vibracores. The goal of the GPR survey and the vibracore descriptions are to generate detailed maps of the sediment types, their distribution, and their thicknesses. The results from this project will assist the County in hydrologic restoration efforts. It will also support the development of a Lake Munson Management Plan allowing Leon County to examine projects that would result in nutrient reductions to meet the watershed's Total Maximum Daily Load goals.

The Florida Fish and Wildlife Conservation Commission (FWC) requested the FGS provide springs characterization of the Big Bend Wildlife Management Area (WMA). Through geospatial

analysis and drone-assisted field mapping, the FGS located and verified 27 previously uncatalogued springs, most of which contain multiple vents. GPS location data, site descriptions, photographs, estimated discharge, and water quality samples were collected.

The section was also actively engaged in the production of statewide potentiometric surface maps of the upper Floridan aquifer system in 2017–18. The mapping is being conducted in cooperation with the State's five water management districts. The districts provide water-level measurements obtained from monitor wells twice a year in May and September. The data are converted using geo-statistical methods to 10-foot contour lines on the map representing the water-level surface of the aquifer. Maps are anticipated to be updated in December and July of each year.

Potentiometric surface maps can be compared with historic maps to determine regional water level changes over time. Such changes may also be correlated to natural influences, such as seasonal rainfall or drought as well as anthropogenic influences.

As part of its efforts to assist the DEP, modeling staff provided review of and consultation on several hydrogeological models that were designed to assess groundwater response to proposed housing development and underground contaminant flow characterization at existing contamination sites statewide. These contributions provided testimony used in a legal ruling as well as guidance in site remediation efforts.

GEOLOGIC INFORMATION AND DATA MANAGEMENT

The Geologic Information and Data Management Section continued its efforts to digitize legacy hard copy geologic data from the FGS's 108-year history. In 2017–18, the section secured a National Geological and Geophysical Data Preservation Program (NGGDPP) grant of \$45,000. The FGS used the funds to inventory its collection of samples. The FGS sample repository has records of cuttings and core for over 19,800 borehole locations. Of that, it was determined that over 3,400 sample sets have been lost or discarded over time. The inventory will provide more efficient, cost-effective access to information by making the actual holdings information discoverable to professional and public entities. Staff also worked closely with project managers and other DEP programs to ensure the proper long-term management of data. This included work for Florida's five water management districts.

Through the FGS internship program, 14 student volunteers from Florida State University and Tallahassee Community College contributed over 1,000 hours towards the Survey's efforts to preserve and rescue at-risk data during 2017–18. This included inputting and updating data found in the FGS collection of paper records, card catalogs, and inventory sheets into a searchable and discoverable database. Almost 7,000 records were either input or modified.

Section staff also worked closely with DEP's Office of Technology and Information Services/GIS Section to build a Geologic Enterprise Database (GEODES). Employees worked for months documenting our current database issues and received help from the State's technology office to complete the project. The work has not yet been completed, and is continuing during 2018/19.

The State Geologist and Section staff also helped lead efforts to acquire a needs assessment of statewide lidar. The Florida Legislature appropriated funds for the study, which was awarded after a competitive process to Dewberry Consultants, LLC. The final report, Florida Statewide Lidar Assessment, was completed and served to inform the FY17–18 Florida Legislature regarding lidar applications and return on investment. As a result, alongside advocacy by multiple parties, the Legislature appropriated \$15M for lidar data collection, which is presently being administered through the Florida Division of Emergency Management. These efforts have been enhanced by the U.S. Geological Survey, which contributed Storm Supplemental funds in the amount of \$7.6M.

GEOLOGICAL SAMPLE ACQUISITION AND MANAGEMENT

In addition to ongoing core and cutting curation duties at the FGS sample repository, the Geological Sample Acquisition and Management Section completed cored boreholes for the 2017–18 STATEMAP Kissimmee mapping project. Data from these wells were utilized in cross sections through low-density data regions of the field area. The section also drilled a new 855-ft core and installed a monitor well at FGS headquarters. This core is the deepest core in Leon County, and represents significant new data at the margin of the Gulf Trough, a feature which played a significant role in the deposition of sediment in Florida's geologic history. The section also acquired a pontoon boat through the Federal Surplus Property program. After welding in tubular aluminum supports for the center of the deck and replacing the transom, section staff can now collect vibracores in lakes and shallow coastal areas, representing a significant new tool for geologic sample acquisition which will support FGS and DEP projects. The system has already proven itself safer and more efficient than the previous method, while supporting an ongoing FGS-Leon County cooperative project.

EDUCATION AND OUTREACH

Outreach and education is a cost-efficient public service that realizes incalculable positive return on investment. During the past fiscal year, FGS staff provided geoscience talks to classroom and civic groups, hosted class tours of our facilities, conducted field trips for a variety of audiences, and engaged in media interviews ranging from local newspapers and TV reporters to national and international documentary film crews. FGS staff also participated in the annual FGS Earth Science Week Open House, which in-

cluded interactive talks and geoscience displays, building tours, and demonstrations of recent FGS geoscience projects.

FGS geologists are often consulted as state, if not national or international, experts. As one example, FGS Director and State Geologist Dr. Jon Arthur continued to participate on the National Academy of Sciences (NAS) Committee to Review the Edwards Aquifer Habitat Conservation Plan. The Edwards Aquifer is a karstic aquifer serving more than two million people in the San Antonio region of south-central Texas. Because of its karstic nature the Edwards Aquifer has similarities with the Floridan Aquifer system, the principal source of drinking water for most of Florida. Characterizing complex and diverse types of groundwater flow using hydrologic models presents a challenge, especially at sub-regional and local scales. Accurate models are important to provide optimum protection of water resources. Dr. Arthur also gave invited lectures in Nanjing and Kunming, China on the nexus of karst geology and environmental policy.

Of particular interest to Florida geoscientists, the NAS report presents discussion of the value of a singular model in a regional karst terrain and stresses the importance of documenting quantified model uncertainty including well-defined sensitivity analyses and validation. The authors also note that including worst-case scenarios regarding water availability (for example, drought conditions, pumping) and other factors is important toward implementation of the HCP. For more information, a report summary and a pre-publication copy are available.

CONTINUING EDUCATION

FGS employees attended the annual Digital Mapping Techniques Workshop, which supports awareness of the latest technologies and approaches in digital mapping. It was a hands-on workshop providing advanced knowledge of GIS and geodatabase applications to foster geologic data dissemination. Rick Green, P.G., the FGS STATEMAP program manager, attended to gain skills to increase efficiency in this award-winning program. Seth Bassett, a highly skilled GIS analyst with experience in lidar and other digital mapping at the FGS, also attended in support of many priority FGS projects.

FGS staff also took part in multiple workshops throughout the year covering topics such as GIS, geochemical modeling, aquifer storage and recovery, well drilling, marine geophysical and geological data collection, and other geoscience topics. In addition, the FGS participated in an on-going DEP-wide employee development plan, with funds allotted for staff to pursue advanced education or technical training in their job-related specialties.

SELECTED PUBLICATIONS

(**bold** identifies FGS staff in multi-collaborator publications)

Arthur, J. D.; Baker, A. E.; Cichon, J. R.; Wood, A. R., 2017, Florida aquifer vulnerability assessment: contamination potential

models of Florida's principal aquifer systems: Florida Geological Survey Bulletin 67, 148 p.

Bryan, J. R.; **Means, G. H.**, 2018, Quaternary geology of the Gulf Intracoastal Waterway, Walton and Bay counties, northwest Florida [abstract]: Geological Society of America, Southeast Section, 67th Annual Meeting.

Cichon, J. R., 2017, Potentiometric surface of the Upper Floridan Aquifer, September 2012: Florida Geological Survey Map Series 151, scale 1:900,000, 1 map sheet.

Cichon, J. R., 2018, Potentiometric surface of the Upper Floridan Aquifer, May 2013: Florida Geological Survey Map Series 152, scale 1:900,000, 1 map sheet.

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Cotton, L. J.; Bryan, J. R.; Eder, W.; **Means, G. H.**; Monechi, S., 2017, Larger benthic foraminifera of Florida and the Eocene Oligocene transition [abstract]: Geological Society of America Annual Meeting, Abstracts with Program, vol. 49, no. 6. [<https://doi.org/10.1130/abs/2017AM-306177>]

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Kusnerik, K. M.; **Means, G. H.**; Portell, R. W.; Kowalewski, M., 2017, Tracking changes in the historical ecology of Florida's rivers using recent and fossil freshwater mollusks [abstract]: Geological Society of America Annual Meeting, Abstracts with Program, vol. 49, no. 6. [<https://doi.org/10.1130/abs/2017AM-301269>]

Locatelli, E. R.; Briggs, D. E. G.; Stemmann, T. A.; Portell, R. W.; Means, G. H.; James-Williamson, S.; Donovan, S. K., 2017, Leaves in marine turbidites illuminate the depositional set-

ting of the Pliocene Bowden shell beds, Jamaica: *Geology*, vol. 46, no. 2, p. 131–134. [<https://doi.org/10.1130/G39780.1>]

Means, G. H., 2018, Review of *Water from Stone: Archaeology and Conservation at Florida's springs*, O'Donoghue, J., 2017, University of Florida Press. *In* *The Florida Historical Quarterly*, Winter 2018, vol. 96, no. 3, p. 372–374.

IDAHO

IDAHO GEOLOGICAL SURVEY

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MISSION OF THE IDAHO GEOLOGICAL SURVEY

The Idaho Geological Survey (IGS) is the lead state agency for the collection, interpretation, and dissemination of geologic, mineral, fossil fuel, and geothermal resource information, and assessment of groundwater resources and characterization of geologic hazards that pose a threat to the State's infrastructure, such as roads, dams, and bridges and personal property and life.

BACKGROUND AND OVERVIEW

IGS was created by the Idaho legislature in 1919 and prior to 1984 was named the Idaho Bureau of Mines and Geology. The IGS is a non-regulatory state agency that is currently administered as a Special Program of the University of Idaho. In addition to the main office on University of Idaho's Moscow campus, the Survey has a branch office in Boise at the Idaho Water Center. The agency is staffed by approximately 12 state-funded employees and 17 externally-funded temporary and part-time employees. Staff geologists conduct applied research with a strong emphasis on providing technical and relevant information about Idaho's geologic setting, mineral and earth resources, and geologic hazards. Externally funded projects enhance this research.

Members of IGS staff acquire geologic information through field and laboratory investigations of sponsored and cooperative programs with other governmental agencies and the private sector. Other major research programs include geologic hazards, hydrogeology, geothermal research, oil and gas assessments, mineral and aggregate research, mining record compilations, and Earth science educational outreach. As Idaho grows, demand is increasing for geologic and geospatial information related to population growth; energy-, mineral-, and water-resource development; geologic hazards; and earthquake monitoring.

GEOLOGICAL MAPPING AND DIGITAL MAPPING LAB

Since 1993, IGS has been awarded over \$3.7 million in federal funds and matched an equal amount of "in kind" salaried employees' participation to complete geologic mapping projects in Idaho. Over two hundred geologic maps have been published from this program and are available for download from the agency website.

During the last two decades IGS has conducted geologic field investigations in selective areas of the state to address development impacts in urban settings, for assessment of possible new energy and mineral resources, and monitoring of geologic hazards such as earthquakes, seismicity, and devastating landslides. Examples of how IGS's geologic map products have been used are: to designate landslide hazards; to define mineralization potential; to delineate rock units that form boundaries

of aquifers; to show geologic materials for engineering needs; to better predict groundwater resources; to identify petroleum resource areas, to assist in highway design and construction; and to define geologic resources on public lands, including U.S. Forest Service and BLM lands, Idaho's parks, recreation areas, and endowment lands.

Funding of Idaho's geologic mapping program is shared by the STATEMAP component of the National Cooperative Geologic Mapping Program and the U.S. Geological Survey. IGS also conducts geologic mapping through external sponsorships such as the Survey's recent surface mapping efforts in the Stibnite Mining District with external funding provided by Midas Gold Corporation.

The IGS Digital Mapping Laboratory provides services that include digital cartography and map creation, spatial data management, database management and design, network system administration, graphic design, desktop publishing, and website support. All digital geologic maps and reports are available as printed products or can be viewed free on the IGS website.

Databases continue to be an important way of managing and distributing information to Survey customers via the agency website. Database updates of active faults, mines and prospects, oil and gas wells, geothermal wells, and publications are an ongoing effort. Recent database activities include: new oil and gas wells and regulatory field boundaries in the western Snake River Plain; an updated design of the IGS Oil and Gas database; improved accuracy and content in the Idaho Mines and Prospects database; development of an aggregate material sources database; and continued migration of geologic map data into the NCGMP09, a new national and voluntary standard for geologic map data.

MINING AND MINERALS

Since its inception in 1919, IGS has been providing information, research, and documentation of the mineral resources of Idaho. IGS collaborates with the U.S. Geological Survey in production of the Idaho chapter of the Minerals Yearbook, a widely used global compilation of developments and statistics in mining and minerals information. There has been a contraction in minerals exploration activity in Idaho and other western states due to wide fluctuations in metal commodity prices for precious and base metals coupled with new federal land restrictions particularly those regulations that set aside large regions for wildlife security and habitat enhancement.

Hecla Mining Company's Lucky Friday Mine is a deep underground silver, lead, and zinc mine located in the Coeur d'Alene Mining District of northern Idaho. In 2017, the mine produced 838,658 oz of silver. Twenty to thirty years of mine life have been added to the Lucky Friday mine thanks to Hecla's \$225 million investment of a new internal shaft that reaches to a depth of 8,600 ft. The union members at Lucky Friday have been on strike since March 2017; in 2018 limited silver and lead production was reported using salaried staff. Another major mine, the Thomp-

son Creek molybdenum mine, has been on a “care and maintenance” status since the end of 2014, a casualty of the global downturn in molybdenum concentrate prices.

In contrast to Idaho’s metal mines, the phosphate markets and mines and other industrial mineral operations in the State have done well in recent years. For example, Idaho’s phosphate mining district in the southeastern part of the State is a solid and consistent performer employing approximately 2,000 employees at mines and processing plants from three notable companies: Monsanto, J.R. Simplot, and Agrium Resources. Phosphate resources are mined at the Idaho facilities and converted into commercial products such as fertilizers for food production, agrichemicals, elemental phosphate for food products and toothpaste, herbicides, and many other products.

On the exploration front, a major minerals-related research project currently underway is a field and laboratory-based investigation of the mineral resources within the Stibnite Mining District, Valley County, Idaho. The IGS work is funded by and in collaboration with Midas Gold Corporation, which has been exploring the district, known for its structurally-controlled gold-antimony-tungsten mineralization. IGS work in recent years has included regional geologic mapping of the mine district, identification of stratigraphic and structural controls, and a focused study of mineral paragenesis and hydrothermal alteration associated with ore emplacement.

OIL AND GAS

Idaho became a hydrocarbon-producing state in 2015 owing to recent exploration and drilling activities and completion of successful gas, oil, and liquid condensate wells in the Payette County region of southwestern Idaho. These efforts have been focused on the western Snake River Plain and areas to the north toward Midvale, Idaho and to the west toward Vale, Oregon. Drilling from 2010 to the present has resulted in over 23 new well completions, eight of which are currently in production from the Willow field north of New Plymouth. In 2017, two successful step-out wells (Barlow 1-14 and Fallon 1-10) were drilled and completed four mi west of the Willow field near the community of Fruitland. Production from these wells is pending completion of a new pipeline and related infrastructure. IGS is monitoring activity in the field including the exploration and drilling of new wells, emplacement of pipeline and gas plant infrastructure, acquisition of 3D seismic surveys, and mineral lease acquisition.

Over \$180 million in expenditures has been reported by Alta Mesa Energy for pipeline and gas plant infrastructure for the extraction and separation of natural gas, light oil, and liquid condensates and for 3D seismic surveys and mineral lease acquisition. Collaboration and research agreements between public and private entities (Idaho Department of Lands and Alta Mesa Resources) have permitted the Survey to acquire subsurface data and begin the process of petroleum system assessments for the region. The IGS was awarded a grant from the U.S. Geological Survey to conduct reservoir characterization and petroleum assessment of this newly discovered resource in the southwestern

part of the state. The digital map: *Southwestern Idaho Natural Gas Play* was published for this area and is available for download on the IGS website.

Drill core and well cuttings analysis, subsurface mapping, well log correlations, microfossil designations, source rock evaluation, chemical and isotopic analysis of natural gas and liquid condensates, and petroleum system modeling are included within the scope of research for the petroleum resources in southwestern Idaho. In 2017, gas and condensate samples were collected and analyzed from seven of the producing wells. Work is currently underway to understand the origin of the hydrocarbons and how they may be related to potential source rocks in the area.

In conjunction with this scope of work, new geologic surface mapping projects are underway in the Weiser-Payette area with the objective of tying the surface geological units to reservoir rocks in the producing basin at depth. Since 2012, field-based mapping of Miocene and Pliocene sediments (Payette, Chalk Hills, and Glens Ferry Formations) and associated volcanics has been conducted in twelve quadrangles (1:24,000 scale) with maps available for download and viewing from the IGS website. Work on unmapped quadrangles is expected to continue in the 2018/2019 calendar year.

IGS has also identified areas of south-central and south-eastern Idaho as perspective for oil and gas exploration and have near-term and long-term plans to conduct petroleum assessments in these regions of the state. Although the areas are sparsely drilled and elements that make up a working petroleum system poorly understood, the extension of hydrocarbon producing units related to the Basin and Range province of Nevada and the Fold and Thrust Belt of Wyoming are present and hydrocarbons shows have been observed. As new drilling and completion technologies have advanced in recent years, both of these areas should be re-evaluated for oil and gas resources, particularly from unconventional reservoirs.

IGS maintains files on over two hundred historical oil and gas exploration wells in the state. These files include well reports and downhole logs provided by companies to the Idaho Oil and Gas Commission from 1903 to 1988. The files were transferred to IGS in 2009 from the Idaho Department of Lands and consist of drilling correspondences, permits and applications, industry reports, maps, and geophysical logs. Many are unique historic documents and in fragile condition. Recent geothermal and oil and gas exploration activities in Idaho have greatly increased the number of requests for these records. The Survey has now scanned all of the reports and logs and made them available for download from the IGS website, and 25 of the historic logs have been digitized and incorporated into the Weiser-Payette area subsurface petroleum system model. As other historic and contemporary reports become available, IGS will continue to enhance and expand the oil and gas archive geodatabase.

GEOTHERMAL ENERGY

The Raft River geothermal plant is Idaho's only commercial geothermal plant in the state and is located in Cassia County along the southern border region with Nevada, approximately 200 mi southeast of Boise. The Raft River region is by far the most studied region for geothermal resources in the State. The Department of Energy (DOE) began construction at this site for the world's first commercial-scale binary geothermal power plant in the early 1980s and the facility was subsequently idled and later purchased by a private sector company for commercial operation. The plant produces about 11-13 MWe generated from hot brines within Precambrian metamorphic rocks. Maximum bottom hole temperatures of geothermal waters range from 271°F to 300°F at an approximate depth of 5,000 ft. The plant was previously owned and operated by U.S. Geothermal Inc. but has recently been acquired by Ormat.

A comprehensive technical report of a new high-temperature geothermal system in the Idaho Thrust Belt is currently under peer review and was initiated from IGS's participation with the Department of Energy's National Geothermal Data System (NGDS) data compilation. The report focuses on integration and synthesis of all data in southeast Idaho compiled for the NGDS project and presents a conceptual model of the hydrothermal system based on its volcanic heat source, subsurface structure, reservoir architecture, and geohydrologic characteristics. The final report will be published at IGS as part of a Technical Report series as well as a hyperlinked document referencing online appendices and data files.

The economic potential of the resource, both from a geothermal and brine-mineral perspective, was also evaluated. The electric power-generating potential of this large, strata-bound geothermal resource, based on available subsurface data in the best-characterized portion of the system, is on the order of one GW, whether produced via conventional flashed-steam or binary-cycle power-conversion technologies.

Results of the Survey's work on geothermal energy illustrates that heat transfer from the Eastern Snake River Plain (ESRP) basement rocks occurs via both conductive heat transport and advective transport of thermal fluids and corroborates observations of open fractures associated with thermal fluid flow in a deep core hole drilled beneath the Idaho National Laboratory (INL) facility. The existence of localized poro-permeability that is sufficient to support fluid flow has implications for how these rocks can be hydraulically stimulated and flow paths between injection and production wells can be enhanced.

HYDROGEOLOGY

The IGS's hydrogeological work comprises various areas of applied research, with elements of outreach and education. Research activities cover a wide range of topics, including aquifer hydrogeology; water levels and geochemical indicators of flow system processes; groundwater contaminant sources;

and water-supply potential of aquifers. Recent activities involve collaboration with state and federal agencies (regulatory and non-regulatory) related to groundwater supply and quality issues in Idaho.

IGS activities also include regular participation with the Ground Water Monitoring Technical Committee (GWMTC), which routinely holds its meetings in Boise. The GWMTC is led by the Idaho Department of Environmental Quality and meets twice each year to discuss water quality issues. IGS also provides hydrogeology input for the Treasure Valley Modeling Technical Advisory Committee (TVMTAC) meetings held in Boise and the Wood River Valley Modeling Technical Advisory Committee (MTAC) meetings held in Hailey. The purpose of these meetings is for IGS to assist with technical input during the construction of numerical groundwater flow models. IGS also provided representation recently at a water conference hosted by Boise State University's Andrus Center for Public Policy to address issues related to southern Idaho's future outlook for water supply and water quality in an era of rapid population expansion and climate change.

GEOLOGIC HAZARDS

Idaho is prone to damaging earthquakes, volcanic eruptions, landslides, and alluvial fan flooding. The Survey assists with mitigation of these hazards in several ways. Survey staff are informed about regional earthquakes through seismic monitoring performed by the U.S. Geological Survey, Montana Bureau of Mines and Geology, the University of Utah, the Idaho National Laboratory, and the Pacific Northwest Seismic Network. When an earthquake occurs, location, magnitude, and shaking intensity data are posted within minutes to the internet by the USGS. IGS staff members receive automated emails and cell phone texts for Idaho-area earthquakes and check the USGS website for major regional activity on a regular basis. A significant earthquake sequence occurred near Soda Springs early in September 2017 with a magnitude 5.3 earthquake, followed by over 2,000 aftershocks. The sequence included 33 earthquakes with magnitude 4 to magnitude 5. Several of the larger earthquakes were felt in and across southeast Idaho and northern Utah, but no damage from any of these earthquakes was reported. Also, approximately 50 earthquakes as large as magnitude 2.7 were recorded in the Challis area during FY18. These earthquakes are part of a continuing earthquake swarm that has been occurring for several years. No damage from any of these earthquakes was reported.

The Survey collaborates with monitoring of regional volcanic activity as a member of the Yellowstone Volcano Observatory Consortium (YVO). YVO members consist of the USGS, Yellowstone National Park, University of Utah, and the geological surveys of Idaho, Wyoming, and Montana. In the event of volcanic ash eruptions from Cascade volcanoes, the Survey will collaborate with the USGS Cascade Volcano Observatory.

Seismicity related to Yellowstone volcanic activity occurred throughout this past year, with earthquakes as large as magnitude 3.6 recorded northeast of West Yellowstone, Montana.

Landslides, debris flows, and alluvial fan floods occur frequently in Idaho's mountainous landscapes. Transportation networks such as highways and railroads are particularly vulnerable to these hazards.

In FY18, no significant landslide events were reported. However, landslide damage to several homes in the Boise foothills continued from FY16 and FY17 and many of these homes were condemned and removed for safety reasons.

In FY18, the Survey initiated a pilot project to map landslides along transportation corridors in the Panhandle region of the state in response to landslide activity in FY17. The Survey also secured a grant proposal to develop an updated digital landslide database for the State. The bullet points listed below are an overview of how the IGS approaches landslide hazards in the State and disseminates information.

- Geological hazards mapping provides baseline information on the location, size, and frequency of these hazards. This information may be incorporated into planning documents and serves as the basis for more detailed studies.
- Expert opinion and advice are provided to state and federal agencies involved with Idaho hazard mitigation. This includes the Idaho Office of Emergency Management (IOEM), and the U.S. Federal Emergency Management Agency (FEMA).
- Public education and outreach through publications, press releases, media interviews, social media, and occasional public lectures.
- Participation in the Western States Seismic Policy Council (WSSPC). The WSSPC mission is to develop seismic policies and share information to promote programs that reduce earthquake and landslide-related losses.

EARTH SCIENCE EDUCATION

The American Geosciences Institute sponsors Earth Science Education Week in cooperation with its member societies on behalf of the geoscience community. IGS participates annually with the Idaho Science Teachers Association meetings held throughout the state by supplying Earth Science Teacher Kits. These kits are also delivered and distributed to school districts throughout the state by Survey staff and affiliates. IGS also participated in Earth Science Week by highlighting recent geologic mapping by the Survey through the agency website, through a University of Idaho press release, and via Twitter.

ILLINOIS

ILLINOIS STATE GEOLOGICAL SURVEY

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INTRODUCTION

During the past year, the Illinois State Geological Survey (ISGS) continued to provide innovative research, as well as supportive service initiatives, that had a significant impact on the State's economic development, energy and water issues, environmental protection, and overall scientific understanding of the geology of Illinois. The following are highlights:

- Quaternary glaciation of the Great Lakes region: Process, landforms, sediments, and chronology—Three papers written by ISGS Quaternary geologists were published by the Geological Society of America in its Special Paper 530. The compendium includes papers ranging in topic from hydrogeology, historical and environmental geology, geomorphology, and shallow geophysical methods.
- Preliminary delineation of areas for a critical minerals mapping initiative in Illinois and surroundings—The effort is in response to a December 2017 Presidential Executive Order that calls for increased lidar, geological mapping, and geophysical investigations as part of a new exploration program for critical minerals. This pre-assessment map is a first step to assess Illinois's critical mineral resource potential.
- Geothermal research for heating and cooling at the University of Illinois at Urbana-Champaign—This project evaluates tapping of geothermal energy for heating and cooling on the University of Illinois's Urbana-Champaign campus, and will determine the potential for cost-effective, renewable thermal energy from the low-temperature sedimentary basins that underlie large portions of the U.S.
- Wabash CarbonSAFE: Geological storage of industrially sourced CO₂—This project will evaluate the feasibility for commercial-scale CO₂ geological storage at a gasification combined cycle plant in Vigo County, IN by drilling a test well, performing tests, analyzing core/water samples, and conducting a 2D seismic survey. It will also evaluate options for using CO₂ for enhanced oil recovery in the Illinois Basin.
- Natural gas in Illinois: A Need for Safe and Effective Storage—To meet the demands for natural gas, Illinois has 24 underground storage sites. Gas leakage has occurred at multiple sites, including a major incident in 2016 into a designated sole source aquifer. In response, a Natural Gas Working Group (including the ISGS) was convened to address the issue.

ISGS, together with the Illinois Natural History Survey, Illinois State Water Survey, Illinois State Archeological Survey, and Illinois Sustainable Technology Center, form the Prairie Research Institute at the University of Illinois at Urbana-Champaign.

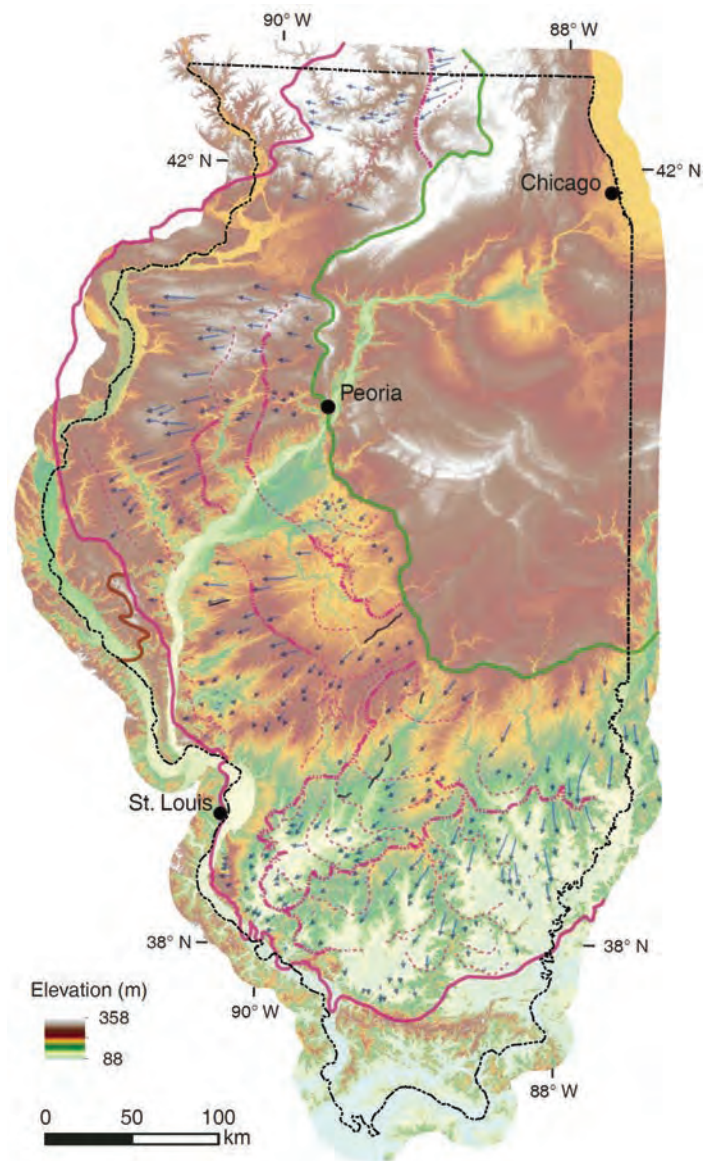


Figure 1. Summary figure of marine isotope stage (MIS) 6 glacial flow directions (blue arrows) and sublobes in Illinois. Surface digital elevation map of Illinois shows radiating flow from Lake Michigan Basin during the Illinois Episode. Arrows, showing interpreted direction of Illinois Episode glacial flow, are based on megalineations, flutings, sloss lee features, striations, and moraines. The maximal Illinois Episode margin (solid) and estimated recessional ice-margin positions (dashed) are shown as pink lines. The maximum last glacial (Wisconsin Episode) ice margin is shown as a green line.

PROGRAM HIGHLIGHTS

Quaternary Glaciation of the Great Lakes Region: Process, Landforms, Sediments, and Chronology

In celebration of the 100th anniversary of the classic publication by Frank Leverett and F. Taylor (1915) entitled *The Pleistocene of Indiana and Michigan and the history of the Great Lakes* (U.S. Geological Survey Monograph 53), the Geological Society of America published a compendium of 13 papers in Special Paper 530. Edited by Al Kehew (Western Michigan University) and Brandon Curry

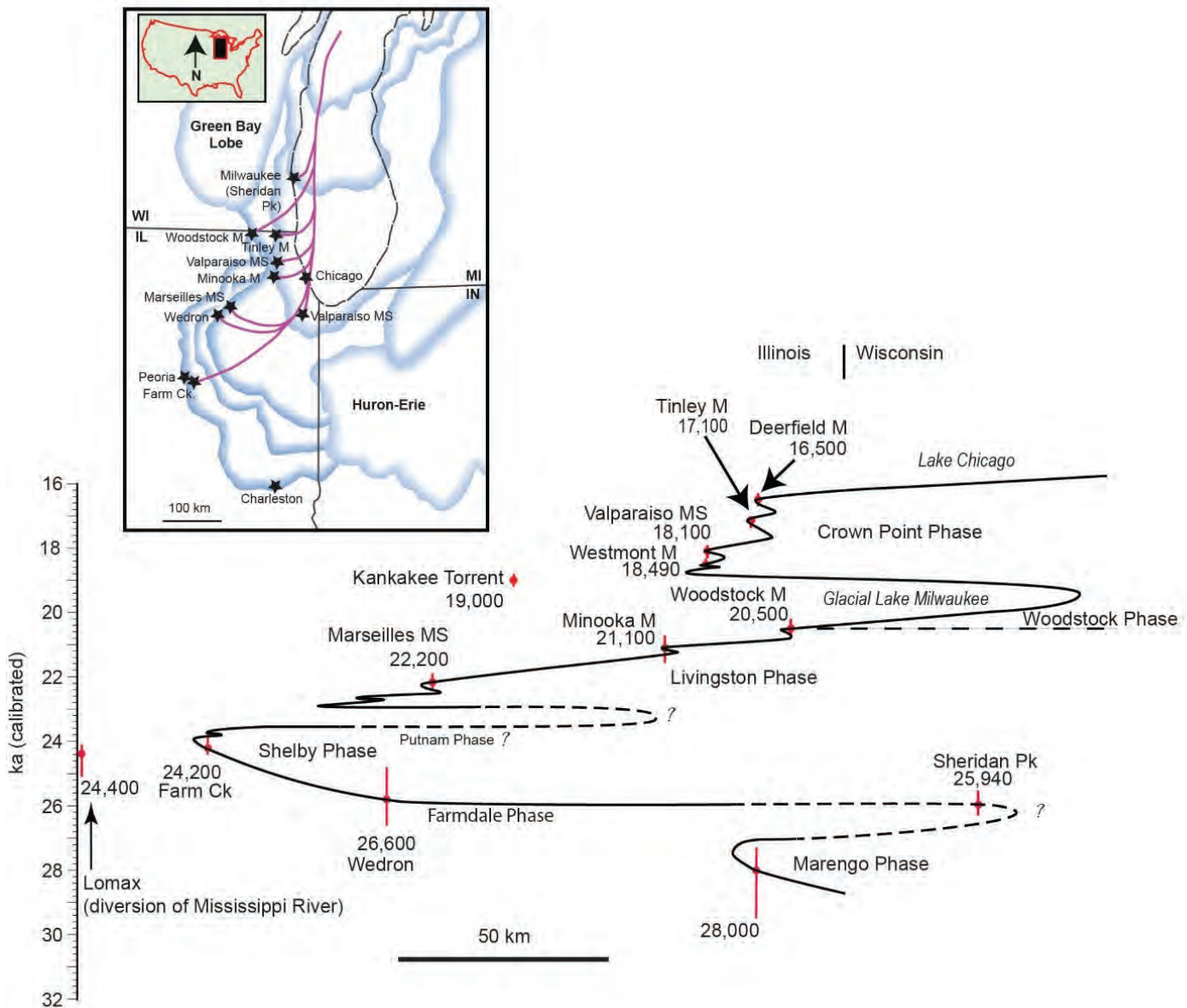


Figure 2. Time-space diagram of the Lake Michigan Lobe during the last glaciation.

(ISGS), the breadth of topics highlights recent progress in technologies that have advanced surficial mapping, interpretation of glacial landforms, and the unravelling of the region's Quaternary history. In addition to papers on paleosol dating, hydrogeology, and interpretation of glacial drainage and landform systems, ISGS contributed three papers.

The special paper leads off with an interpretation of the fascinating and subtle (and in some cases, not-so-subtle) landforms of the Illinois Till Plain that was formed during the penultimate glaciation (Fig. 1). Entitled *Geomorphic expression of the Illinois Episode glaciation (marine isotope stage 6) in Illinois: Moraines, sublobes, subglacial lineations, and possible ice streaming* and authored by David Grimley, Andrew Phillips, Don McKay III (ISGS), and Alison Anders (UIUC), the paper presents geomorphological and sedimentological evidence of newly discovered sublobes of the Laurentide Ice Sheet as it flowed into central Illinois. The authors posit that some landforms, especially long lineations, are

indicative of rapid ("streaming") ice flow. The paper highlights recent contributions to the understanding of the surficial geology of the region based on careful surficial geologic mapping at 1:24,000 scale, as well as the profound influence of lidar imagery.

Another chapter led by ISGS geologists regards the long history of radiocarbon dating at the Illinois State Geological Survey. By amassing a database of 893 radiocarbon ages, most of them determined at the ISGS Radiocarbon Laboratory, the authors reveal their basis for a new time-space diagram of the Lake Michigan lobe during the last glaciation (Fig. 2). Their database, available from the GSA data repository, lists the location, stratigraphic context, calibration data, and other information of finite ages greater than 10,000 radiocarbon years old. A probability density curve of these data reveals intriguing peaks and valleys likely related to sediment accumulation rates of paleosols, lacustrine sediment, and loess. Exploration of one "valley" revealed a previously unknown low level of Lake Michigan between the

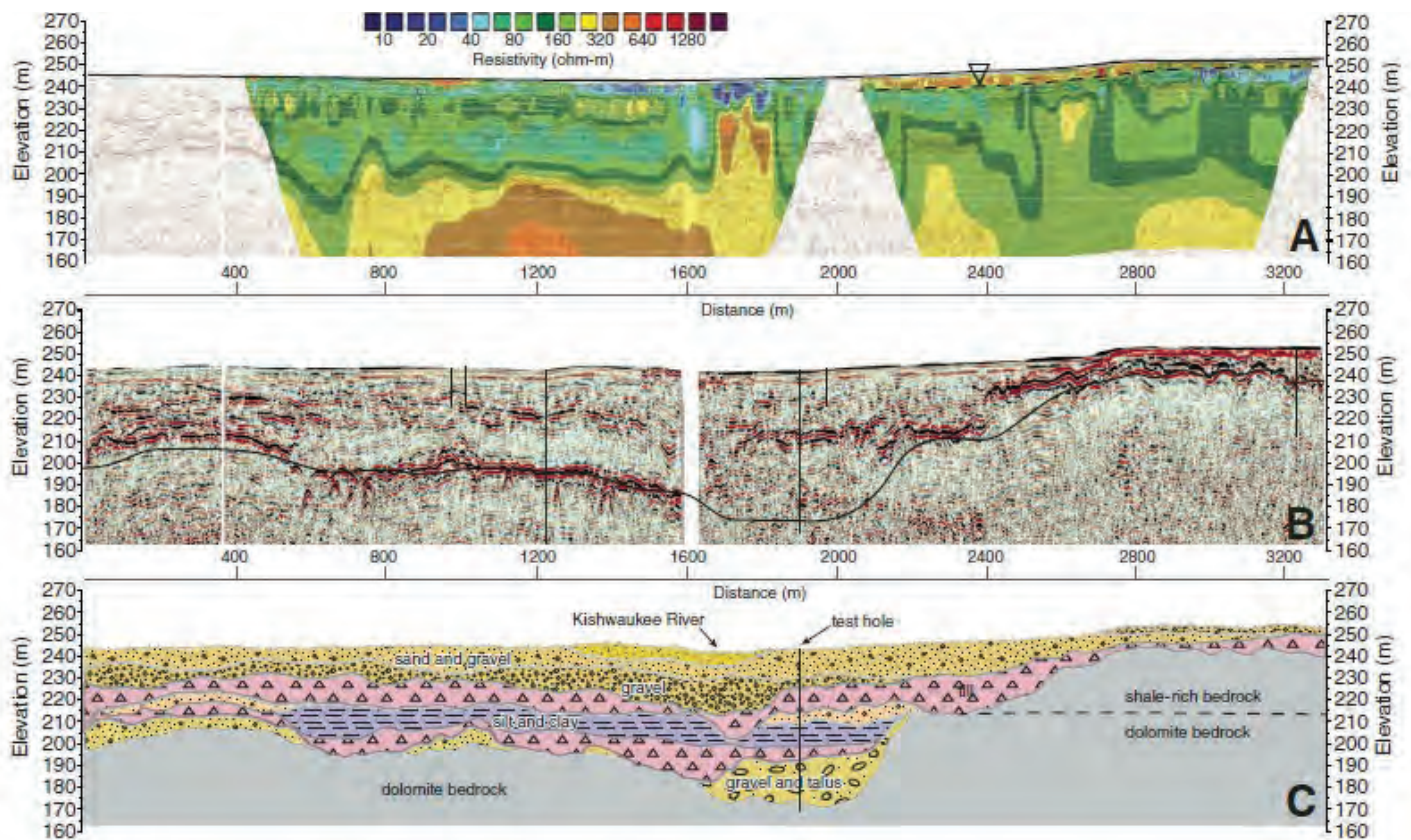


Figure 3. Depth-corrected geophysical profiles and interpretation at site 1, Kishwaukee bedrock valley. (A) Electrical resistivity profile with transparent seismic profile for reference. Interpreted water table is indicated with dashed black line and arrow. (B) Seismic profile with traces of interpreted bedrock reflector and water-well record locations. (C) Interpreted geologic profile.

Glenwood and Calumet phases of glacial Lake Chicago between about 15 and 14 thousand years ago. The low-levels reflect the complex deglacial history of the Lake Michigan lobe, which in this case, was the result of eastward flow of meltwater across the Straits of Mackinaw, and eventually down the St. Lawrence Seaway.

The last chapter in GSA Special Paper 530 is by ISGS geologists Jason Thomason, Tim Larson, Steve Sargent, and Ahmed Ismail (now with Oklahoma State University). Entitled *Characterizing glacial sediments and features in northeast Illinois using electrical resistivity and seismic-reflection profiling*, the paper shows how these methods elucidate sedimentological interpretations of sorted glaciogenic sediments in alluvial fans and channels, and second, their relative hydrological significance (Fig. 3). Concentrating on the complex glacial geology of McHenry County, located in the north-central part of the state, the paper's conclusions are vetted through several decades of ISGS investigations including descriptions and analyses of sediment cores and downhole geophysics (for example, natural gamma-ray logs). Long recognized as an area of sensitive hydrogeology (in an area where groundwater resources provide most of the potable water for its 300,000 residents), this paper highlights the importance of including shallow geophysical work to provide a resonant and robust 3D framework for informed groundwater use, both now and in the future.

Preliminary Delineation of Areas for a Critical Minerals Mapping Initiative in Illinois and Surroundings

On December 20, 2017 a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals was officially initiated by a Presidential Executive Order, followed the next day with a Secretarial Order from the Department of Interior. The primary focus was to address a national security issue because of our heavy dependence on critical minerals imports and to ensure that our Armed Forces, who are the most significant consumers of critical minerals, have a reliable supply. There was immediate recognition that considerably increased exploration was needed to identify sources within U.S. borders, and subsequent topographic, geologic, and geophysical mapping of the U.S. would be required. The Midcontinent, including Illinois, has been recognized as a region that “should” contain significant quantities of these critical minerals based on its buried geology when compared to other regions of similar geology to the north (northern Minnesota, northern Wisconsin, and southwestern Ontario) and south (southeastern Missouri) within North America, as well as compared to other regions of similar geology in other parts of the globe.

Most of the context of critical mineral exploration in the Midcontinent will be focused on the Precambrian crystalline basement. However, it's also well known in Illinois that considerable mineralization is found in the Paleozoic strata as well.

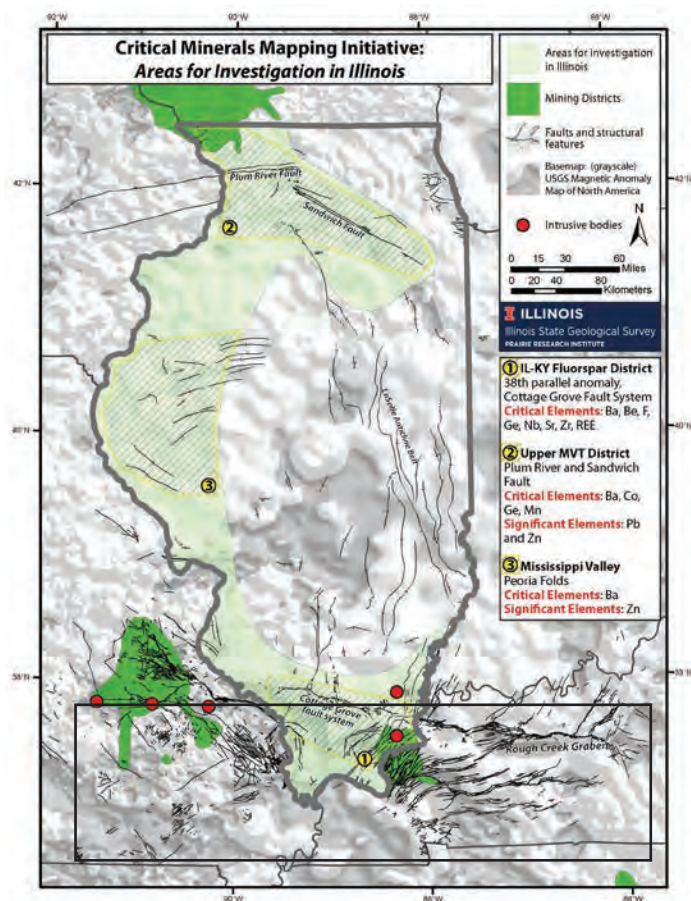


Figure 4. Critical minerals pre-assessment mapping in Illinois and surroundings. Black box indicates targeted area based on the likelihood of critical mineral occurrence.

Therefore, ISGS proactively developed a pre-assessment map of the State and its surroundings as a first step to assess critical mineral resource potential.

The Illinois map (Fig. 4) for the Critical Minerals Mapping Initiative was constructed in a hierarchical manner. Candidate regions were identified based on knowledge of existing deposits, basinal processes, and ranked priority areas with a likelihood for the occurrence of critical minerals. First, known mineral and mining districts, established geologic trends, lineaments, and geologic features such as intrusive complexes, fault systems and other geologic features potentially conducive to originating and transmitting mineralizing fluid flow were identified and overlain on the existing USGS magnetic anomaly map of Illinois and surrounding regions. Second, mining districts, regional fluid flow pathways such as large fault systems or basinal flow pathways, intrusive complexes, and depths shallower than 1,000 m, were used to delineate an investigative region (“Areas for Investigation”) with mineralization potential in Illinois. Third, the investigative region was subdivided into targeted areas using a qualitative ranking for priority based on the likelihood of critical mineral occurrence (Fig. 4). For example, an area in close proximity to known mining districts, intrusive bodies and major fault zones would rank high. Lastly, critical and significant elements likely to be found within the ranked areas were listed in order to communicate the potential for undiscovered mineralization.

This map was developed to help guide and prioritize exploration, particularly use of modern aeromagnetics, which is a geophysical procedure that can identify “hot spots” containing a higher likelihood of critical mineral occurrence. Our methodology used 1970s USGS magnetic data as an information source for our pre-assessment, and while this was quite useful, newly enhanced procedures will provide considerably more detailed results. Once hot spots are identified, then other geophysical procedures, and possibly test drilling, can be used to provide an even more detailed assessment to additionally target potential critical mineral occurrences.

Geothermal Research for Heating and Cooling at the University of Illinois at Urbana-Champaign

The Illinois State Geological Survey (ISGS) received a \$730,000 grant from the U.S. Department of Energy to determine the feasibility of tapping geothermal energy for heating and cooling on the University of Illinois’s Urbana-Champaign campus located in east-central Illinois. The project will determine the potential to provide cost-effective, renewable thermal energy from the low-temperature sedimentary basins that underlie large portions of the U.S. ISGS scientists will evaluate harnessing the natural heat from two geological formations (the St. Peter and Mt. Simon Sandstones) in the Illinois Basin, a region previously unexplored for geothermal energy.

The ISGS team will test Deep Direct-Use (DDU) technology to tap heat from low-temperature subsurface reservoirs below 90°C (~195°F). The goal is to use the geothermal system to offset the current heating and cooling loads supplied by non-renewable resources. The system will also be designed to meet the future demand of the expanding “ACES Legacy Corridor”—the 320-acre “living laboratory” managed by the College of Agricultural, Consumer and Environmental Sciences (ACES) where U of I researchers work on agricultural projects—and other campus buildings (Fig. 5). Results of the feasibility study could be applicable to oth-



Figure 5. View of the Beef and Sheep Research Field Laboratory looking south along the ACES Legacy Corridor at the University of Illinois at Urbana-Champaign.

er educational campuses and multi-building industrial, military, and medical facilities overlying the Illinois Basin.

The ISGS will evaluate DDU technology that extracts heat from deep reservoirs of water. Using a paired set of wells (referred to as a doublet), brine will be pumped to the surface from deep bedrock aquifers, circulated through a thermal exchange system, and returned to the aquifer at a lower temperature. Geothermal systems using DDU technologies are typically used for space heating and air conditioning, water heating, and refrigeration.

The low-temperature DDU systems differ from conventional geothermal energy systems, which consist of either: (1) several deep wellbores capturing high-temperature fluid or steam that generates electricity with turbines; (2) very shallow wellbores that act as heat exchangers, tapping the constant temperatures near the land surface using ground source heat pumps to supplement existing heating and cooling systems in homes and commercial buildings; or (3) direct-use geothermal systems that provide heat directly (without converting the resource to electricity) in areas with high-quality hydrothermal resources, such as in the western U.S.

The ISGS project will include the evaluation of geologic, engineering, and economic aspects of a large-scale geothermal system applicable to campus and other large energy users. Complex models will simulate the geothermal reservoir, wellbore extraction and injection of brine, above ground distribution systems, and cascading usage to reuse the heated water over and over.

The University of Illinois was one of six institutions to receive funding from the DOE's \$4 million DDU program. The grant will

support studies done by the ISGS and Department of Civil and Environmental Engineering at the Urbana-Champaign campus and its partners, including the U.S. Army Construction Engineering Research Laboratory in Champaign, IL and the University of Wisconsin-Madison. Engineering partners in the project are Loudon Technical Services LLC, MEP Associates LLC, and Trimeric Corporation.

Wabash CarbonSAFE—Geological Storage of Industrially Sourced CO₂

Geological storage of CO₂ is one of the major strategies in the portfolio of technologies to mitigate greenhouse gas emissions to the atmosphere. The Illinois State Geological Survey (ISGS) successfully led one of the first successful demonstrations of this technology via the Illinois Basin–Decatur Project (IBDP) that injected one million tonnes (MT) of CO₂ into the Cambrian Mt. Simon Sandstone for permanent storage. The IBDP demonstration was closely followed by an industrial-scale project (IL-ICCS) that is currently injecting about 1MT of CO₂ per year into the Mt. Simon with a target of about 5 MT. The U.S. DOE CarbonSAFE initiative is designed to advance commercial-scale carbon storage at sites with >50 MT capacity and the ISGS is leading two Phase II CarbonSAFE projects. One of these, CarbonSAFE Wabash, has the objectives to establish the feasibility of developing a commercial-scale geological storage complex at Wabash Valley Resource's Integrated Gasification Combined Cycle (IGCC) plant in Vigo County, Indiana. The facility will produce up to 1.57 MT per year of pure CO₂ associated with the production of ammonia from the repurposed IGCC plant. The ISGS and our research colleagues including the Indiana Geological & Water Survey will examine the feasibility of geologic storage within the Mt. Simon

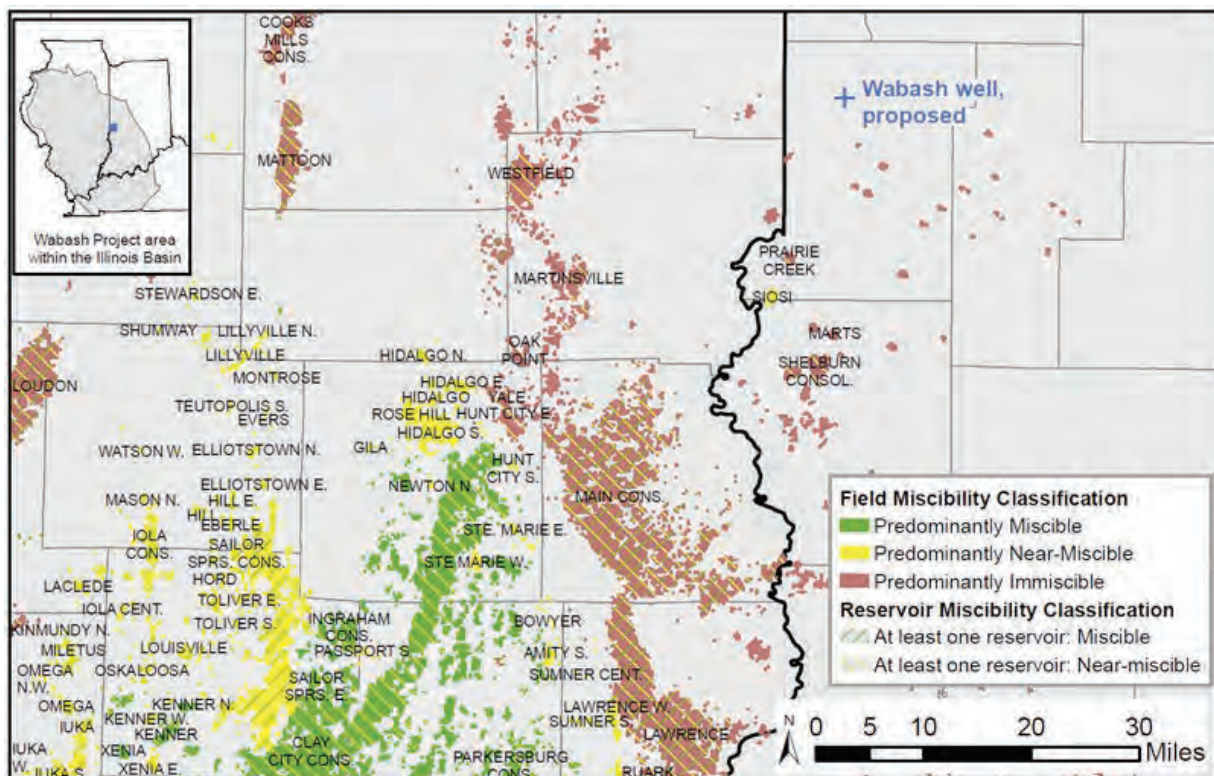


Figure 6. Location of project area and stratigraphic test well in relation to oil field miscibility classification for CO₂ EOR.

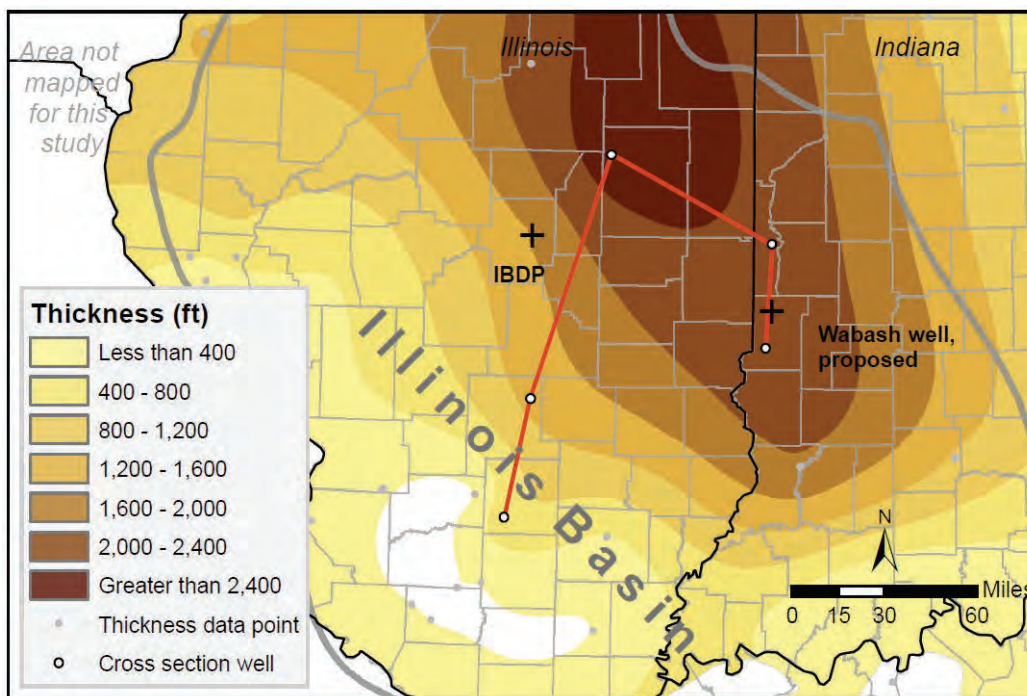


Figure 7. Isopach (thickness) map of the Mt. Simon Sandstone in the Illinois Basin showing the depocenter (dark brown), location of the Illinois Basin–Decatur Project (IBDP) project, and proposed well at the Wabash plant. The red line indicates the location of the wells used in a cross section.

Storage Complex of the Illinois Basin at the Wabash site. To accomplish this we will drill a stratigraphic test well, perform well tests, analyze core and water samples, and conduct a 2D seismic survey over the study area. The resulting datasets will be analyzed to determine the reservoir (storage) and seal parameters for evaluating the suitability of the Wabash site. Objectives of this evaluation are to determine the expected performance of the site for long-term security, storage capacity, and ability to receive CO₂ at the required rate. These evaluations will be accomplished in part through static and dynamic modeling, which will also be applied to address improvements in storage capacity estimations.

The project will further evaluate options for utilization of CO₂ for enhanced oil recovery (EOR) in the Illinois Basin (Fig. 7). Options for transporting CO₂ to oil fields include repurposing an existing propane pipeline directly from the site to the heart of the oil fields associated with two additional pipeline rights-of-way. The Wabash CarbonSAFE team will develop a detailed characterization plan with requirements to reduce subsurface uncertainty, and for continued work toward commercialization of storage complexes. The permitting requirements, legal and contractual issues, and assessment of social attitudes toward the project will be documented.

The thickest, deepest and most widespread saline reservoir in the Illinois Basin is the Cambrian-age Mt. Simon Sandstone (Fig. 8), considered to be the most significant CO₂ storage reservoir in the Midwestern U.S. (Finley, 2014). The Mt. Simon has excellent properties for large-scale carbon storage: it is deeply buried with pressures and temperatures maintaining CO₂ as supercritical; contains highly saline formation fluids and has a tremendous storage capacity (12 to 172 GT; U.S. DOE-NETL, 2015); is overlain by numerous laterally extensive sealing formations; and has suitable petrophysical characteristics for injection. The Mt. Simon Sandstone reservoir with the overlying Eau Claire

Formation shale member as the primary seal comprise the Mt. Simon Storage Complex, which has been extensively evaluated for carbon storage by the ISGS and Midwest Geological Sequestration Consortium (MGSC) of the Regional Carbon Sequestration Partnership (RCSP) program (Finley, 2014).

The Mt. Simon Sandstone can be divided into Lower, Middle, and Upper sections based on petrophysical, depositional, and diagenetic attributes (Freiburg and others, 2016). The Lower Mt. Simon is considered the best reservoir for carbon storage and at the IBDP and IL-ICCS project areas, it exhibits high quality reservoir rock throughout, with the exception of a few tight baffles. The best quality reservoir in the Lower Mt. Simon is within a highly arkosic zone that thickens into the Mt. Simon Sandstone depocenter (Fig. 8). The Mt. Simon at the Wabash site is southeast of the depocenter, and is expected to exceed 2,000 ft in thickness with the top at 6,100 ft measured depth (about -5,600 ft subsea depth).

Additional storage targets at the Wabash IGCC site include shallower units in the Knox Group, particularly the Potosi Dolomite and the St. Peter Sandstone. These units were the focus of a DOE regional study that assessed the potential storage capacity of these units (Leetaru, 2014). Numeric simulation determined that each Knox reservoir has capacity to store almost 90 million tonnes of CO₂ at a single site, indicating the Knox Group is a viable secondary target for storage at the project site.

Finley, R. J., 2014, An overview of the Illinois Basin–Decatur project. *Greenhouse Gases: Science and Technology*, vol. 4, no. 5, p. 571-579.

Freiburg, J. T.; Ritzi, R. W.; Kehoe, K. S., 2016, Depositional and diagenetic controls on anomalously high porosity within a deeply buried CO₂ storage reservoir—The Cambrian Mt.

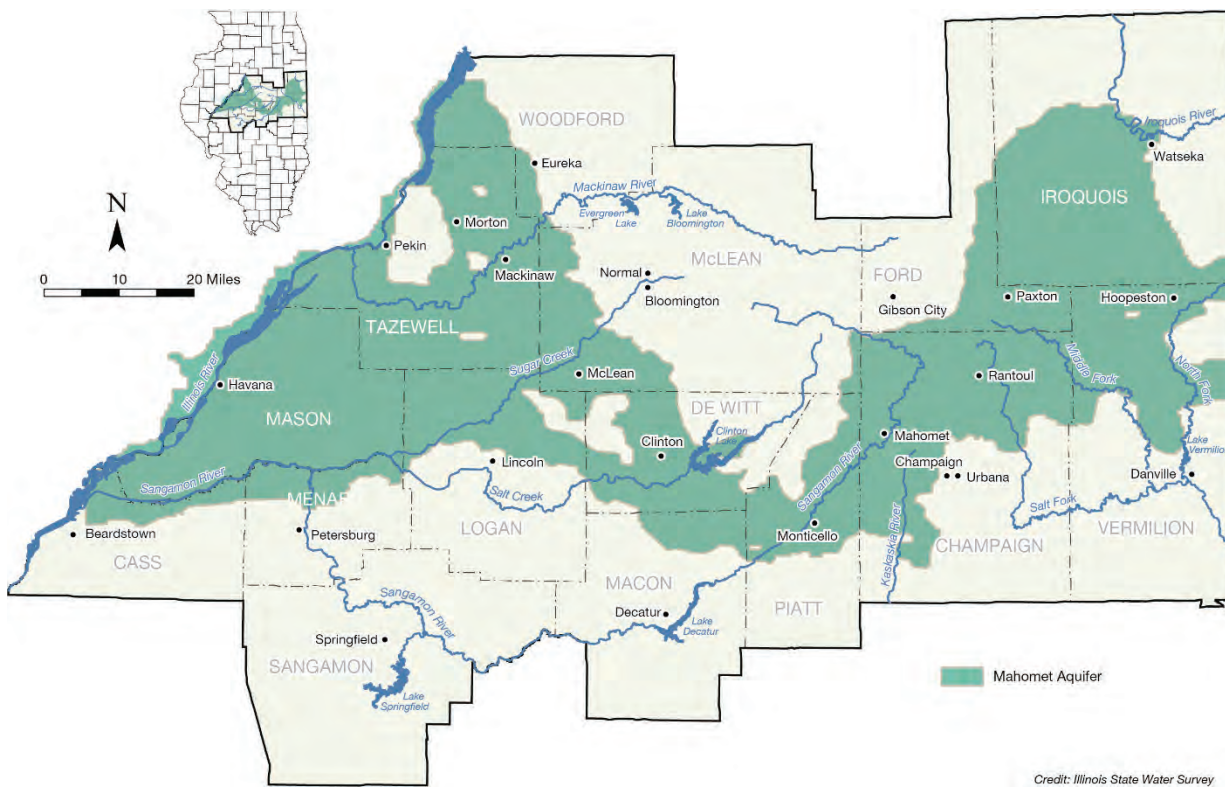


Figure 8. East-central Illinois regional water supply planning area and the boundaries of the Mahomet aquifer (Roadcap and others, 2011).

Simon Sandstone, Illinois Basin, USA: *International Journal of Greenhouse Gas Control*, vol. 55, p. 42-54.

Leetaru, H. E., 2014, An evaluation of the Carbon sequestration potential of the Cambro-Ordovician Strata of the Illinois and Michigan Basins: Illinois State Geological Survey, Prairie Research Institute Final Report.

U. S. Department of Energy, 2015, Carbon Storage Atlas: 5th edition: U.S. Department of Energy, 113 p.

Natural Gas in Illinois: A Need for Safe and Effective Storage

Illinois has no significant sources of natural gas and must rely on other states to supply this important fuel via 18 interstate pipelines. To meet the volume and timing of the demand, Illinois has 24 active underground natural gas storage sites with the largest amount of storage in the nation in saline (i.e., deep geologic) formations, totaling more than 780 billion cubic ft. In Illinois, utilities have been effectively storing natural gas in the subsurface for over 50 years. However, over the past several years, natural gas leakage has occurred at multiple sites. Further, the likelihood of leakage is expected to increase because of aging infrastructure that was often developed in the 1960s to 1970s. This is similar to the national context of natural gas storage safety and efficiency that was described in a 2016 report by the federal Interagency Task Force on Natural Gas Storage Safety.

In December 2016, a natural gas leak was identified at the surface near a withdrawal well in the Manlove Natural Gas Storage Field, near Mahomet, Illinois. The site is located in northern Champaign County (Fig. 8) and is within the U.S. Environmental Protection Agency designated sole source aquifer boundary

for the Mahomet aquifer. The aquifer is a key water resource supporting more than 500,000 people in east-central Illinois across the 15-county, east-central Illinois, regional water supply planning area.

Underground gas storage at the site uses the upper Mt. Simon Sandstone, which occurs at about 4,000 ft below ground surface. The leak occurred in one well through the casing at a depth of about 500 ft below ground surface with one estimate of the leakage being more than 39 million ft³ of natural gas. The natural gas leak affected the water wells of at least five area properties based on field testing conducted by the Illinois Environmental Protection Agency, Illinois Department of Natural Resources, and Illinois Department of Public Health. Natural gas is predominantly composed of methane, CH₄, and affected wells showed a diagnostic presence of thermogenic methane, which has a different isotopic signature than biogenic methane that also occurs in the region. Mitigation activities and litigation are ongoing.

In response to this and previous leaks in Illinois, the Prairie Research Institute (PRI) convened the interdisciplinary Natural Gas Working Group (NGWG; go.illinois.edu/ngwg) with subject matter experts from ISGS and Illinois State Water Survey (ISWS) to:

- Provide relevant data and objective expertise to state agencies and other stakeholders responding to the natural gas leak.
- Consider natural gas storage activities in Illinois as they relate to natural resource characterization, management, and protection issues.

- As appropriate, make recommendations for improving the safe and reliable operation of natural gas storage in Illinois in the context of existing state and federal requirements.

The NGWG has established communication protocols, hosted periodic interagency coordinating calls, produced two timely publications, and compiled a comprehensive set of information (>500 documents) about the hydrogeological and geochemical contexts in which the leakage occurred. The Prairie Research Institute has also assisted the Governor's Mahomet Aquifer Protection Task Force efforts related to aquifer characterization and protection, and bipartisan efforts that resulted in a new law requiring increased inspection and leakage notification requirements.

Interagency Task Force on Natural Gas Storage Safety, 2016, Ensuring safe and reliable underground natural gas storage: Interagency Task Force on Natural Gas Storage Safety final report, 83 p. [<http://energy.gov/downloads/report-ensuring-safe-and-reliable-underground-natural-gas-storage>]

Roadcap, G. S.; Knapp, H. V.; Wehrmann, H. A.; Larson, D. R., 2011, Meeting east-central Illinois water needs to 2050: Potential impacts on the Mahomet aquifer and surface reservoirs: Illinois State Water Survey Contract Report 2011-08, 188 p. [<http://hdl.handle.net/2142/39869>]

INDIANA

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INTRODUCTION

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

After years of declining staff numbers, IGWS has begun to fill out its ranks again. New Assistant Directors for Research, Lee Florea, and Information Services, Gary Motz, were hired in 2017. New staffers also include: Alyssa Bancroft, Research Geologist; Shalom Drummond and Carlie Greven, Administrative Support Team Members; Eric Gamble, Research Geologist; Megan Harris, Don Tripp, and Rachael Amorosa, Water Testing Program Coordinators; Nic Downton, Water Testing Sampler; Jennifer Lanman, Archives and Collections Manager; Clayton McGuire, System Analyst/Programmer/Web Designer; John Hettle, Building Manager; and Brandon Phillips, Internal Projects Coordinator. Longtime geologists Walter Hasenmueller and Charly Zuppann, Assistant Director for Information Services Rick Hill, mineral statistician Kathy Shaffer, and administrative assistant Donna Webb retired. Web developer Michael Daniels also left the organization. In all, about 50 percent of the IGWS staff were replaced in the past five years.

Name Change

The long-standing name of the Indiana Geological Survey has made way for the "Indiana Geological and Water Survey," reflecting the Survey's expanded efforts in the study and dissemination of information about the quality and quantity of Indiana's surface and groundwater.

"I think it's no surprise to anyone that follows the news that water is a growing issue in the 21st century," said Survey Director Todd Thompson. "As a midwestern state, we assume that sufficient water exists for human and livestock consumption, agriculture, and business uses. However, we have a limited inventory of the quantity, and even less knowledge of the quality, of this important resource. At the Indiana Geological and Water Survey, we hope to more accurately define water resources statewide."

The name change was codified in Indiana Senate Bill 416, which took effect on July 1, 2017.

ECONOMIC IMPACT STUDY

A new study conservatively estimates that IGWS has an annual economic impact of \$110.4 million on the state of Indiana. Con-

ducted by the Indiana University's School of Public and Environmental Affairs, the study cites the Survey's online tools such as IndianaMap and the Petroleum Data Management System at nearly \$25 million alone. The value of projects that would never be completed without the IGWS's freely available or low-cost data is listed at more than \$56 million annually.

WATER RESEARCH

Indiana School Lead Sampling Program

The IGWS received a \$2.07 million grant from the Indiana Finance Authority to help sample drinking water in public schools across Indiana. Teams of IGWS Technical Assistance Providers, led by IGWS research hydrologist Sally Letsinger traveled throughout the state collecting samples from drinking fountains, sinks, and other fixtures that provide drinking water across participating school campuses (see Fig. 1). IGWS has completed inventories and collected 57,000 samples from drinking water fixtures in the more than 900 schools that participated in the program. Data synthesis, analysis, and reporting are currently underway.

Spatial Analysis of Significant Water Withdrawal Facilities in Indiana

Legislators and state agencies have taken initial steps to improve databases needed for water resources planning in Indiana. As a part of that effort, the IGWS has implemented a program to provide accurate location information for significant water withdrawal facilities (high-capacity water users) registered with the state. Locations for approximately 19,000 wells and intakes (including ~9,000 active water sources) were reviewed or corrected.

Improving our Understanding of Buried Valley Aquifers

Bedrock elevation data associated with recently completed Indiana bedrock topography and sediment thickness maps were

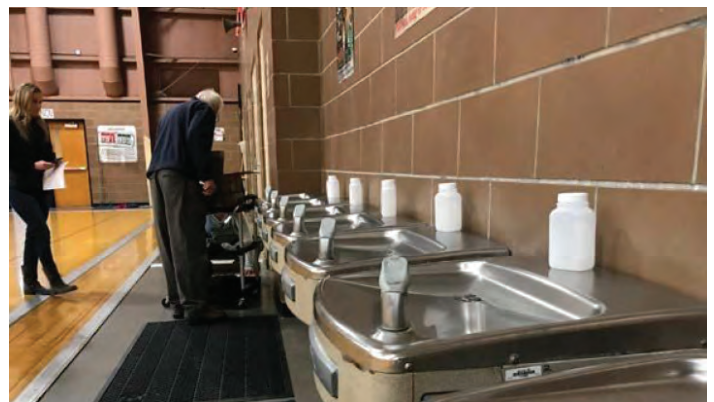


Figure 1. One of the more than 900 schools in Indiana where drinking fountains and other fixtures were tested for lead by the Indiana Geological and Water Survey. This was a voluntary program funded by state government.

combined with the latest bedrock elevation data from other states. Bedrock topography and sediment thickness maps for much of the continentally glaciated portion of the U.S. were developed, including analyses of glacial erosion and deposition patterns that have influenced aquifer characteristics. Currently, the bedrock topography data and reconstructed pre-glacial topography are being used as input for a continental ice sheet numerical model to improve our understanding of erosion and deposition patterns and drainage re-organizations caused by glacial advance and retreat. The resulting insights will enhance conceptual models for sediment-fill sequences in deeply buried valleys in Indiana where there is limited core data to constrain aquifer geometries.

Understanding the Distribution of Arsenic in Groundwater

Arsenic is known to have adverse health effects on humans. Because bedrock lithology can play a role in groundwater chemistry in the dissolved phase, the IGWS is investigating the composition of unconsolidated materials that contain bedrock fragments. These might also yield insights into the distribution of elevated arsenic concentrations in groundwater. This project seeks to investigate the relationship between lithology and groundwater chemistry, as it relates to arsenic in groundwater.

Assessing the Persistence of Chloride from Source Water to Tap and its Implications for Potential Corrosion of Metal Pipes

Chloride is a conservative constituent of surface and groundwater, occurring naturally and anthropogenically from substances applied to the land surface (for example, agricultural fertilizers and road de-icers). Because chloride dissolves completely, it is difficult to remove from the environment, especially water, except by expensive processes such as reverse osmosis. The inquiry into chloride for this study is its potential role in corrosion of metal infrastructure, including water distribution pipelines and solder. The presence of chloride can increase reactivity of metal complexes, initiating corrosion. We tested water collection and analysis methods along the treatment pathway from raw source-water composition through the distribution system and at the destination (drinking water tap) to bolster understanding of the persistence of chloride throughout that journey and document any changes along the way. A companion spatial analysis is underway to provide a statewide assessment of chloride in Indiana waters.

ENERGY RESEARCH

U.S.–China Clean Energy Research

This project supports collaborative research activities of the Advanced Coal Technology Consortium as part of the U.S.–China Clean Energy Research Center, which is the flagship initiative for collaborative R&D by the world's two largest emitters of carbon

dioxide. The goal is to advance the portfolio of technologies necessary to achieve significant reductions in greenhouse gas emissions in the next one to two decades.

Geothermal

IGWS is involved in an NSF-funded project to evaluate geothermal resources and innovative applications of low-temperature geothermal technologies for the Indiana University Bloomington campus and the broader IU campus system. The project will also be applicable to the State of Indiana and the Great Lakes region.

Midwest Regional Carbon Sequestration Partnership

This ongoing project aims to better understand the possibilities of using the deep subsurface environment to sequester large volumes of carbon dioxide over long periods of time. This can potentially reduce the amount of CO₂ introduced into the atmosphere and help mitigate global warming and climate change. The objective of this part of the project is to compile known basic geological attributes of deep oil and gas reservoirs, black shales, coals, and saline aquifers. These attributes will be assessed as to their suitability for storing liquid CO₂. The second phase will test the candidate formations with a drilling and injection program.

GEOLOGIC MAPPING

STATEMAP

Work in Morgan County will continue to map unconsolidated deposits at a 1:24,000 scale. Mapping is complete in the central part of the county, and a new project will map the eastern and western parts. The primary objective is to produce a high-resolution 3D framework of unconsolidated sediments in the entire County. The final unconsolidated map compiled to 1:48,000 scale and associated datasets will provide foundational knowledge to support new highway construction (I-69) and other infrastructure developments as the population of this County expands in the coming years.

A second project focuses on mapping the bedrock geology of the Logansport quadrangle at a scale of 1:100,000, beginning a ten-year effort to map the buried Silurian-Devonian bedrock aquifer.

The unconsolidated deposits of the Elkhart quadrangle will be mapped at 1:100,000 scale—the first part of a multi-year initiative to generate a series of 1:100,000-scale maps across the northern morainal region of Indiana. Related to this direct application to water resources management, the area is unique to the study of glacial geology, as three glacial lobes (Michigan, Huron-Erie, Saginaw) of the Laurentide ice sheet interacted repeatedly during the Quaternary. This multi-lobe record of glacial advance and recession is still under active research and interpretation. Our mapping program will develop the subsurface dataset needed by researchers to understand older glaciation

programs for the general public. From the well-known Quake Cottage Program to partnerships with Indiana State Parks, more than 12,000 Hoosiers participated in IGWS outreach activities in 2017. New additions, including scouting workshops, library programs, quarry tours, and Master Naturalist courses, have reached another 6,300 people by July 2018. Polly Sturgeon, the Survey's outreach coordinator, has also promoted new lesson plans and social media campaigns to increase awareness of Indiana geology around the state.

IGWS will host the 130th meeting of the Geological Society of America in Indianapolis. Staff have been working with the GSA for the past year to organize the event. During the meeting, IGWS will conduct six field trips and present more than 40 posters and talks. IGWS will also host a student and early career professional gathering at the Indiana State Museum.

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INTRODUCTION

The Iowa Geological Survey (IGS) was established by the Iowa legislature in 1855. IGS is a part of IIHR-Hydrosience & Engineering, a research institute within the University of Iowa's College of Engineering. IGS currently reports through the Board of Regents State of Iowa, having been legislatively transferred to the University of Iowa in 2018 from the Iowa Department of Natural Resources.

Currently, 10 professional, and 1 part time support positions 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 Iowa Geological Survey (IGS) includes two sub-projects in vastly different geologic areas of the state. The STATEMAP project added bedrock and surficial geologic maps of Floyd County (1:100,000 scale), providing much-needed geologic maps in the Upper Cedar River watershed. This area has been the subject of water quality projects in the past, but there was a renewed focus on the Cedar River following catastrophic flooding in 2008.

Additionally, the STATEMAP project created bedrock and surficial geologic maps of the Sperry and West Burlington quadrangles (1:24,000 scale) which focused on the Skunk River valley in southeast Iowa. 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.

Interactive maps have been added to the IGS website at <https://www.iihr.uiowa.edu/igs/publications/map/>

GEOPHYSICS

IGS incorporates electrical geophysics into a host of geologic and hydrogeologic research projects. Geophysical surveys provide a continuous model of the shallow subsurface, complementing traditional point data.

Through geophysical surveying and groundwater modeling, possible well locations are identified and electrical resistivity geophysical surveys are completed in each location. These surveys allow water managers to make an informed decision on the best location for a new well. Choosing the proper well location the first time can make financial sense and save undue problems down the road.

DATA PRESERVATION

The IGS is currently inventorying and photographing rock core samples as part of a data preservation effort, supported with funding from USGS. The images are hosted in GeoCore (<https://www.iihr.uiowa.edu/igs/geocore/home>).

WATER RESOURCES

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

The Linn and Johnson County Groundwater Protected Area (LJCPA) was designated by the Iowa legislature in 2014 based on declining water levels in many of the Jordan wells. The IGS investigated and quantified the long-term availability of water in this area for the Jordan aquifer in Linn and Johnson County. A 3D local-scale groundwater flow model for the LJCPA was developed and calibrated, and was used to predict future water availability for both industrial and municipal users in the area. Groundwater modeling results indicated that the Jordan aquifer could remain a long term source of water for users in Linn and Johnson County. However, it is important for users in the LJCPA to identify and develop alternative water sources in order to assure a sustainable future water supply.

A toolbox was developed to provide water systems and operators using alluvial aquifers with a way to compare different solutions and determine what may be best for their wellfield. These wellfields are utilized for many different purposes, including by communities for water supply and by agri-businesses for animal production. Shallow alluvial aquifers can be productive; however, they can also be susceptible to drought and water quality issues.

Funding from the Iowa Nutrient Research Center (INRC) has supported several projects at the Iowa Geological Survey over the past few years. Established by the Iowa Board of Regents in response to legislation passed by the Iowa legislature in 2013, the INRC pursues science-based approaches to evaluate the performance and implementation of current and emerging nutrient reduction practices. IGS has been awarded funding for at least one project during every funding cycle, tackling research projects as diverse as paired watershed monitoring, oxbow restorations, quantifying phosphorus losses from streambank erosion, and assessing the nutrient reduction benefits of roadside ditches.

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KANSAS

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INTRODUCTION

The Kansas Geological Survey (KGS) is a research and service division of the University of Kansas and reports to the Vice Chancellor for Research. The KGS has no regulatory authority and does not take positions on natural resource issues. It has a 12-member advisory council that meets three times a year to provide review and guidance and a geologic mapping advisory committee that meets twice a year. The main headquarters is in KU's West District in Lawrence, and KGS-Wichita houses the Well Sample Library.

Established in 1889, KGS is charged by statute with making a complete geological survey of the state, with special attention to natural products of economic importance. KGS research focuses mainly on groundwater, oil and gas, and other natural resources as well as basic geology. Historically, KGS was known for research in invertebrate paleontology and cycles of deposition. KGS is the repository for water well records, oil and gas records and logs, and drill cuttings submitted to the state of Kansas. It also houses donated historical records, logs, and drill cores.

With a staff of about 110 employees, including approximately 37 student employees, the KGS has an annual state-appropriated budget of approximately \$5.8 million. Another \$5.3 million in grants and contracts were awarded in FY17.

The KGS has four research sections—Energy Research, Exploration Services, Geohydrology, and Stratigraphic Research—and three service sections—GIS and Computing Services, Outreach and Public Service, and Administration.

ENERGY RESEARCH

The Energy Research section provides insight into the subsurface and stratigraphic settings of oil and natural gas resources. In 2017, about 35.8 million barrels of oil and 216 billion ft³ of natural gas were produced in Kansas.

Carbon Capture, Utilization, and Storage

Energy Research is continuing multi-year projects to develop the science behind and investigate the use of anthropogenic CO₂ for both enhanced oil recovery in favorable oilfields and safe storage of CO₂ in closed geologic structures. CO₂ was injected into the Mississippian reservoir in 2016 to recover additional oil in the nearly depleted Wellington Field in south-central Kansas. Water injection, which also aids recovery, is ongoing, and the CO₂ plume continues to be confined and delineated. Monitoring is being carried out to verify the displacement of oil and to identify how CO₂ is stored in the reservoir.

Work started in late 2018 under Phase II of the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) program shares similar objectives of previous project stages but will target new potential geologic CO₂ storage sites in southwest Kansas and Nebraska. These sites were identified during pre-feasibility work in

Phase I (<http://www.kgs.ku.edu/PRS/ICKan/index.html>). Current efforts focus on the potential for a commercial-scale storage hub for a variety of industrial CO₂ sources in the Mid-continent region. Phase II reservoirs included in the investigation are deep saline formations within the Pennsylvanian, Mississippian, and Ordovician-Cambrian systems.

The component of the study pertaining to safe storage of CO₂ in the Arbuckle aquifer is on hold pending permitting of a test injection well. The projects are largely funded by the U.S. Department of Energy and carried out with industry and academic partners, including Berexco, LLC, the operator of Wellington Field. Since 2009, the KGS has received nearly \$21.5 million from DOE to study CO₂ sequestration in southern and central Kansas.

EXPLORATION SERVICES (GEOPHYSICS)

Exploration Services develops and uses near-surface imaging and characterization for applications ranging from engineering to groundwater monitoring to public safety. Its researchers locate underground anomalies, such as voids, tunnels, and abandoned mines; image rock layers to study groundwater flow and map geologic structures; and appraise subsurface hazards.

Earthquake monitoring

KGS staff members maintain and collect data from a multi-station seismic monitoring network. An updated list of Kansas

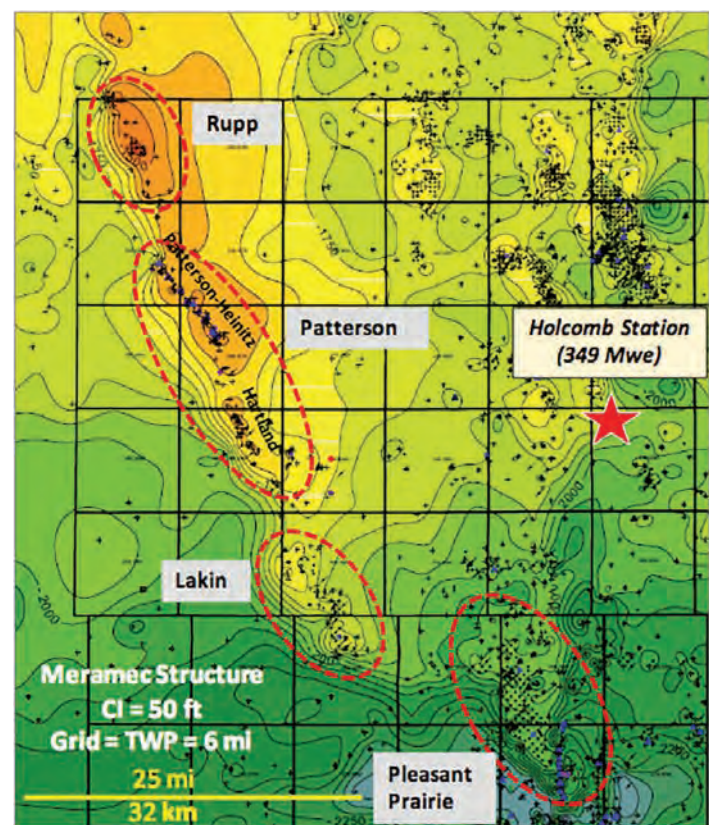


Figure 1. Four potential CO₂ storage sites in southwest Kansas. Shown on the structure on top of the Meramec (Mississippian).

earthquakes, an interactive map showing earthquake locations, and other resources are available on the KGS earthquake webpage (<http://www.kgs.ku.edu/Geophysics/Earthquakes/index.html>).

Other Activities

Exploration Services runs KGS's annual water-well measurement program with the Division of Water Resources of the Kansas Department of Agriculture (see more under Geohydrology) and provides drilling support for water, petroleum, and basic subsurface research.

Equipment used by section staff includes four sampling/coring drills—a RotoSonic drill with aqualock sampler, a Longyear drill NQ with wireline coring, an Acker Soilmax with split-spoon sampling, and a CME with split-spoon and N coring. federal, state, and private sector sponsors fund most of the section's research.

GEOHYDROLOGY

The KGS Geohydrology Section investigates groundwater quantity and quality issues of significance to the State of Kansas, with an emphasis on the High Plains aquifer. KGS has four major activities related to the High Plains aquifer.

Annual Water-Level Program

The KGS and the Division of Water Resources of the Kansas Department of Agriculture (DWR) measure groundwater levels in 1,400 wells in 48 western and central Kansas counties every January. Measurement results are online at www.kgs.ku.edu/Magellan/WaterLevels/index.html. Geohydrology Section research-

ers developed new approaches for using these data to predict the High Plains aquifer's response to climatic and anthropogenic stresses and to assess the prospects for more sustainable conditions in the aquifer.

Index Well Program

This program generates continuously updated water-level information from transducers in a network of wells in western Kansas and provides an interpretation of this information for insight into conditions in the High Plains aquifer. Real-time data from 13 telemetry-equipped wells and periodically downloaded data from an additional 16 transducer-equipped wells are available at www.kgs.ku.edu/HighPlains/index.shtml.

Modeling Program

KGS researchers are developing groundwater flow models for portions of the High Plains aquifer and other significant aquifer systems in Kansas. The KGS is currently working on models of portions of the High Plains aquifer for Groundwater Management Districts #2 and #4 in south-central and northwest Kansas, respectively.

Database Development

The KGS developed the Kansas Master Groundwater Well Inventory, a central repository that imports and links the State's primary groundwater well datasets (hercules.kgs.ku.edu/geohydro/master_well/index.cfm). Continuously updated, the KGS *High Plains Aquifer Atlas* features more than 70 maps related to water levels, irrigation, land cover, water rights and use, and climatic trends (www.kgs.ku.edu/HighPlains/HPA_Atlas/index.html).

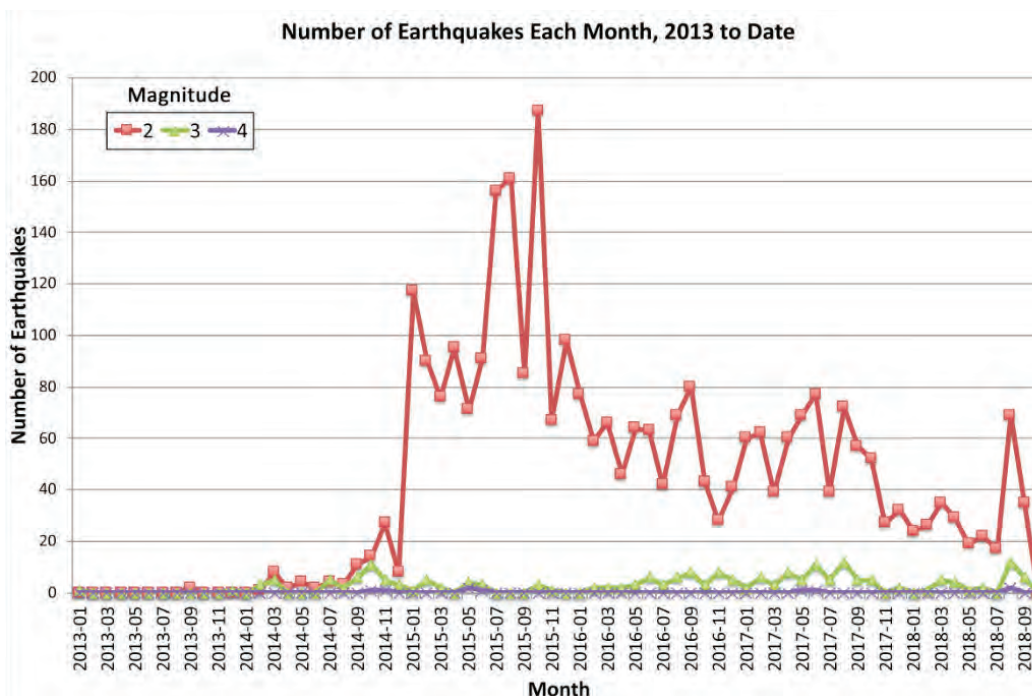


Figure 2. Earthquakes of magnitude 2 and larger in Kansas from January 2013 to mid-October 2018.

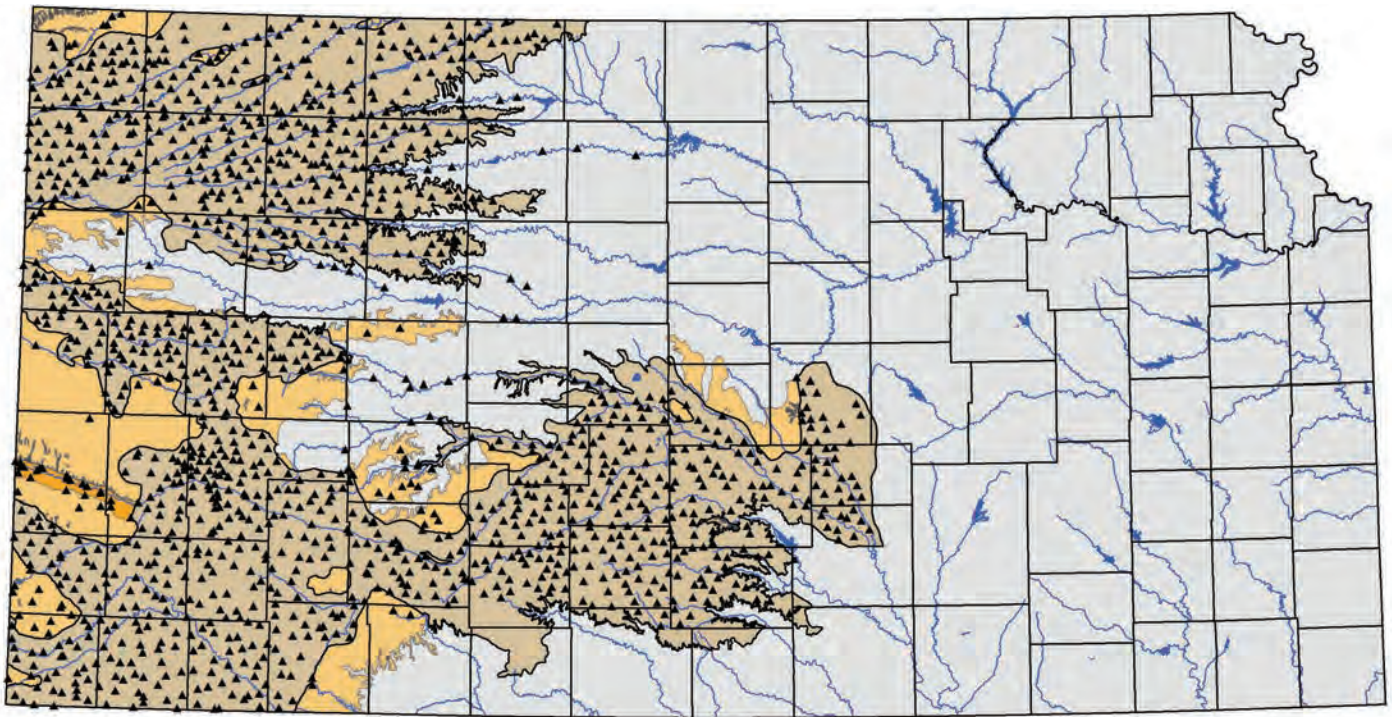


Figure 3. Location of wells in the High Plains aquifer measured annually by KGS and DWR.

Groundwater Quality

Groundwater quality projects include an assessment of crop uptake of uranium from groundwater used for irrigation and the fingerprinting of saline groundwater to determine whether the salinity is natural or from contamination by oil-field brines. Section members receive competitive external funds from a variety of federal entities for development of new methods for applied hydrogeology. Current projects include a USGS-funded project with Stanford University and USGS researchers on the use of nuclear-magnetic resonance (NMR) logging for measuring and mapping hydraulic conductivity in glacial aquifers; a DOE-funded study with Vista Clara on expanding the use of NMR logging for hydrogeologic characterization; a Strategic Environmental Research and Development Program (SERDP) project on the use of direct-push technology for characterization of formations of low hydraulic conductivity; and two National Institute of Food and Agriculture (NIFA-USDA) funded projects with Michigan State University on aquifers supporting irrigated agriculture.

STRATIGRAPHIC RESEARCH

For quantitative characterization and dating of sedimentary deposits, the Stratigraphic Research section uses traditional methods—measuring stratigraphic sections, sedimentologic description, and allied paleontologic research—and advanced technology tools, including digital petrographic imaging/quantification, stable isotope geochemistry, and radiogenic isotope geochemistry. Studies are aimed at improving constraints on the geologic ages of sedimentary deposits. Among other projects, staff members are involved in collaborative efforts to improve

stratigraphic understanding of Cenozoic deposits that comprise the High Plains aquifer.

The section manages the KGS's participation in the STATE-MAP component of the National Cooperative Geologic Mapping Program and the Odyssey Geoarchaeological Research Program at the University of Kansas (www.kgs.ku.edu/Odyssey/about.html). The Odyssey Program is supported by private endowment funds to use geoscientific methods to search for evidence of the earliest human occupation of the central Great Plains. In the 2017 field season, Odyssey crews excavated at the Spring Valley Paleoindian site in southeastern Missouri, and searched for a mammoth recorded in the early 1970s near the town of Meade in southwest Kansas.

The Stratigraphic Research section operates shared lab spaces dedicated to sediment particle size analysis, sample preparation for organic carbon isotope analyses, and digital cathodoluminescence imaging of geological samples. The principle application of stable isotope geochemistry by section researchers is chemostratigraphy. Section members collaborate with the Isotope Geochemistry Laboratory operated by the KU Department of Geology to date sediments of interest using uranium-lead dating techniques and work with laboratories around the U.S. to apply results from optically stimulated luminescence, cosmogenic isotopes, and other dating techniques.

GIS AND COMPUTING SERVICES

The GIS and Computing Services section comprises four primary units—GIS support, the Data Access & Support Center (DASC), cartographic services, and computing services (IT engineer-



Figure 4. Excavation block at the Spring Valley Paleoindian site in southeast Missouri.

ing and support). Eight state-funded and nine grant-funded full-time-equivalent employees are assigned to the section.

Cartographic services collaborates with the mapping geologists on all mapping done for the STATEMAP program. All or part of 17 USGS 7.5-minute quadrangles are being mapped as 2018 STATEMAP deliverables. Map production and printing is done on site.

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

DASC (www.kansasgis.org) serves as the state's GIS data clearinghouse and operates under contract with the Kansas Department of Administration's Office of Information Technology Services (OITS). It is located at the KGS by statute. DASC provides application development, database development, and other services to state agencies, including the Kansas Department of Revenue, Kansas Department of Transportation, Kansas Department of Agriculture, Kansas Water Office, Kansas 911 Coordinating Council, Kansas Division of Emergency Management, Kansas Department of Commerce, and the Kansas State Department of Education.

Computing services deploys and maintains the KGS's primary IT infrastructure. As the primary statewide distribution center for water- and energy-related data, the KGS continually develops and maintains systems to transfer data from partner agencies into the KGS's central data repository. Those partners include the Kansas Corporation Commission, Kansas Department of Health and Environment, and the Kansas Department of Revenue. Several agencies and organizations provide funding for the continued development of software and online methods for delivering information.

OUTREACH AND PUBLIC SERVICE

The Outreach and Public Service section comprises the Data Resources Library; Well Sample Library at KGS-Wichita; Drill Core Library; KGS Library and Archives; public outreach; web design and management; nontechnical writing; editing, design, and publication production; and publications sales.

Well Records, Samples, and Cores

The Data Resources Library—the State of Kansas repository for oil, gas, and water well records—houses geologic and production records for more than 450,000 oil and gas wells and 273,000 water wells. It is open to the public and many records can be accessed online. KGS-Wichita is the State repository for geologic samples of more than 149,000 oil, gas, and exploratory wells. In 2017, the KGS-Wichita office collected, processed, and preserved 660,000 sample-ft (147 mi) of geologic samples from 609 recently drilled wells. Additionally, restoration of existing geologic samples was completed on 2,734 wells. The repository's complete collection of geologic samples is accessible online. The Drill Core Library in Lawrence is the repository for more than 67,000 boxes of core and rock samples from more than 5,000 drill holes. More information about the Data Resources Library, KGS-Wichita, Drill Core Library and accessible records is available at www.kgs.ku.edu/PRS/petroDB.html.

Data Preservation

A grant from the USGS National Geological and Geophysical Data Preservation Program is helping fund the preservation and inventory of at-risk well records at the Data Resources Library, rock cuttings at the Wichita Well Sample Library, and a large collection of aerial photos in the KGS Library and Archives. The aerial photo database is online at <http://www.kgs.ku.edu/Magellan/Aerials/index.html>.



Figure 5. KGS booth at 2018 Kaw Valley Eagles Day in Lawrence.

Outreach

Public outreach and communications staff members provide information and services to technical and nontechnical audiences, increasingly online. The KGS's annual Kansas Field Conference for state legislators and other decision-makers was held in north-central Kansas. Topics addressed include harmful algal blooms, the State's brick industry, biofuels, Republican River water management, subsurface exploration technology, sustainable agriculture, and urban river revitalization. The Kansas Department of Wildlife, Parks and Tourism, Kansas Department of Transportation, and Kansas Water Office were co-sponsors.

FY17/18 PUBLICATIONS

Whittemore, D. O.; Butler, J. J.; Wilson, B. B., 2018, Status of the High Plains Aquifer in Kansas: Kansas Geological Survey Technical Series 22.

Layzell, A. L.; Sawin, R. S.; Mandel, R. D.; Ludvigson, G. A.; Franzen, E. K.; West, R. R.; Watney, W. L., 2017, Quaternary Stratigraphy and Stratigraphic Nomenclature Revisions in Kansas: Kansas Geological Survey Bulletin 263.

Evans, C. S.; Stover, S.; Tollefson, J., 2018, Rocks, Minerals, and Fossils of Kansas: Kansas Geological Survey Educational Series 18.

KENTUCKY

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INTRODUCTION

The Kentucky Geological Survey (KGS) is a state-supported research center and public resource within the University of Kentucky. KGS has investigated the mineral, energy, water resources, and geologic hazards of Kentucky for 180 years. Our mission is to support sustainable prosperity of the commonwealth, the vitality of its flagship university, and the welfare of its people. With 50 staff members, we accomplish our mission by conducting research and providing unbiased information about geologic resources, environmental issues, and natural hazards affecting Kentucky. KGS has offices, laboratory facilities, a Well Sample and Core Library in Lexington, and a Western Kentucky Office in Henderson.

LEGISLATIVE MANDATES

Kentucky Oil and Gas Data Repository

The repository, established in 1960, contains records of drillers' logs, wireline logs, well-location survey plats, plugging affidavits, stratigraphic tops, and well-completion reports. These records are among the most frequently searched information by users of the KGS webpages. The system is accessible at www.uky.edu/KGS/emsweb/data/ogdata.html. It now provides access to more than 797,000 scanned images of records. The database records come from more than 186,500 entries, which also include records from wells drilled before permits were required, permits that were cancelled or expired before work was done, and records for re-entries or deepening of wells.

Kentucky Groundwater Data Repository

The repository was begun in 1990 to archive and disseminate groundwater data collected by state agencies, independent researchers, and other organizations. The Kentucky Groundwater Data Repository contains data for more than 102,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data for more than 5,200 springs and 45,000 sample suites (representing millions of individual analytical results) are available. Access is available at www.uky.edu/KGS/water/research/gwreposit.htm. Data can be searched by county, 7.5-minute quadrangle, or radius from specified latitude and longitude coordinates, and the resulting data can be viewed in tabular form or on an interactive map. Recently, the Kentucky Geological Survey developed the Kentucky Geologic Map Information Service, an online, interactive map service that allows users to enter any address in Kentucky to determine the surface geology for that location. In addition, many layers of geologic information can be turned on or off, including a layer for the repository's water wells and springs. The map's base layer can also be changed from topographic maps to 2016 aerial photography. This service is located at kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp.

Kentucky Interagency Groundwater Monitoring Network

In 1998, the Kentucky General Assembly directed the Survey to establish a long-term groundwater monitoring network. The network collects data, characterizes quality, distributes information, improves coordination between agencies that use these data, and facilitates data sharing. These activities are conducted in coordination with the Interagency Technical Advisory Committee, an oversight group of 15 state and federal agencies and departments at the University of Kentucky.

Network activities are reported on an annual basis to the Governor's Office and Legislative Research Commission. From July 2017 through June 2018, more than 33 investigations and data-collection activities were carried out by ITAC member agencies. Groundwater and related surface-water information was communicated to scientific and regulatory communities and to the public through various publications and presentations, as well as postings on websites. More information about the network, including previous and current annual reports and a map of network sampling sites, can be viewed at www.uky.edu/KGS/water/gnet.

Continuation of New Statewide Groundwater Observation Network

The KGS Water Resources Section monitors groundwater levels at 10 well locations in seven counties in Kentucky as part of an ongoing effort to rebuild a statewide groundwater observation network. Groundwater levels were continuously monitored throughout 2017–18 by automatic logging equipment installed in network wells. Additional potential observations are being sought and evaluated in other locations where groundwater-level data and monitoring of groundwater recharge and availability are considered to be high priorities for water resource users and managers. KGS plans to develop a webpage to display water-level hydrographs for the observation network wells and enable public access to the data.

Well Sample and Core Library

The 48,000-ft² Well Sample and Core Library is Kentucky's only public collection of well samples and rock cores; cuttings from about 18,000 oil and gas wells and core samples from more than 3,000 sites are stored there. The library provides a service to individuals, universities, and companies needing direct access to samples for research or investigations. Twenty-one industry geologists examined 20 cores and seven sets of cuttings during FY17–18. Seven researchers requested 124 samples for geochemical and physical properties testing. The number of geologists visiting the library to examine both cores and cuttings, along with requests for materials for research, was low because of a continuing decline in the price of oil and gas, resulting in decreased drilling in Kentucky.

MAJOR PROGRAMS

Energy and Minerals

Berea Sandstone Petroleum System Consortium

The final report from a consortium formed to study the Upper Devonian Berea Sandstone in northeastern Kentucky was made available to the public in May 2017. The consortium was led by KGS and included the U.S. Geological Survey, Ohio Division of Natural Resources, and R.J. Lee Group as in-kind technical partners, along with several industry partners. The study focused on understanding the origin of the oil and gas, and the stratigraphic controls on reservoir quality of this play. Results from the study were presented at a theme session, “Devonian-Mississippian Petroleum Systems,” at the 2017 annual meeting of the Eastern Section of the American Association of Petroleum Geologists in Morgantown, WV.

Regional Carbon Storage Partnerships

KGS participates in the Midwest Regional Carbon Sequestration Partnership, funded by the U.S. Department of Energy to assess the technical potential, economic viability, and public acceptability of carbon storage in the region. KGS researchers are working on phase III of the project, assessing the potential for carbon storage and enhanced gas recovery in organic-rich Devonian shales in the region, and compiling cross sections.

KGS also participates in enhanced gas recovery research through the MRCSP. Total organic carbon content, density, and maturity data have been compiled and are being analyzed for the Marcellus and Utica Shales in the eastern U.S. KGS researchers are proposing new models for estimating total organic carbon from wireline-log data for the Ordovician Utica Shale, and these models are being used to compile a new series of maps and storage assessments. We are collaborating with researchers from other states to make a series of cross sections that display the subsurface geology of the region relative to carbon-storage potential (showing potential reservoirs and confining intervals), from Precambrian basement to the surface.

Assessing Environmental Impacts of Abandoned Oil and Gas Wells

Because the potential impact of methane leaks from abandoned wells can be both local (groundwater contamination) and global (greenhouse gas contribution), KGS and the University of Kentucky Department of Civil Engineering are interested in research on these impacts. They hope to find funding to: (1) develop a hazard profile for potential leakage from abandoned wells, which can then be transformed into a hazard potential map; (2) measure the methane flux and soil-gas geochemistry at a subset of abandoned wells that fall into different hazard categories; and (3) estimate chemical flux from abandoned wells in different hazard categories using numerical models that describe vapor transport.

Methane emissions associated with oil and gas infrastructure have received national attention as the boom in natural-gas

production from unconventional reservoirs has dramatically changed the energy portfolio in the U.S. The number of abandoned wells nationwide is significant (more than a million), and in Kentucky the number exceeds 14,000.

Rare Earth Elements from Coal and Coal-Combustion Byproducts

KGS is collaborating with researchers from the UK Department of Mining Engineering and the Center for Applied Energy Research to test for economic concentrations of rare earth elements in Kentucky coal, coal-preparation refuse, and coal-fired power-plant byproducts. These projects are part of an aggressive effort to boost domestic production, because nearly all of the rare earth elements used in the U.S. are imported from China. The role of KGS in both of the projects is to identify and collect samples, crush the samples, convert the coal to ash in a muffle furnace, and then dissolve the ash using strong mineral acids and test it for rare earth elements.

So far, the team has evaluated approximately 500 samples from coal preparation plants. The U.S. Department of Energy is funding a second project to evaluate the rare earth element potential of western Kentucky coal beds.

Water Resources

Aquifer Designation Project

In the fall of 2017, KGS began a new collaborative project with the Kentucky Division of Water, funded by the U.S. Geological Survey's Water-Use Data and Research Program, to identify and better characterize aquifers used for public and industrial water supplies. The project will help improve the Division of Water's program to manage Kentucky's groundwater resource and the division's permit processing by creating a new digital hydrogeologic framework of major Kentucky aquifers; the aquifers will be designated by identification codes used in the USGS National Water Information System database. Existing data, including water-well construction logs, oil and gas well records, geophysical logs, and other digital geologic mapping data presently archived by KGS, will be compiled and synthesized.



Figure 1: KGS hydrogeologists regularly wade the streams of Kentucky gathering data.

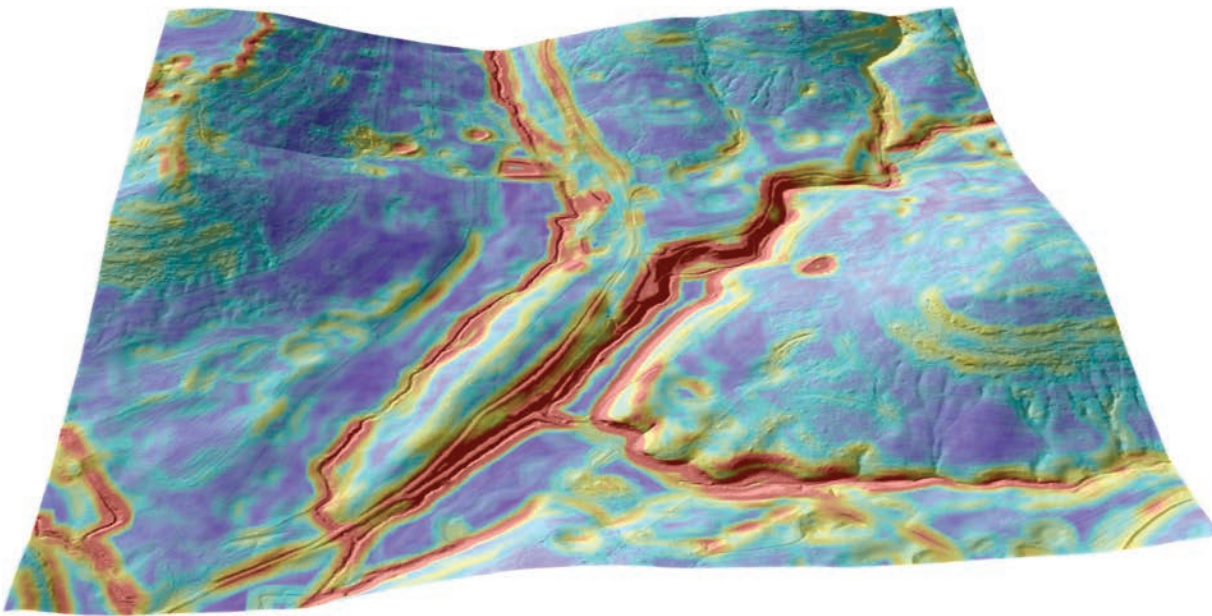


Figure 2: Lidar-derived hillshade image draped with colors representing the degree of topographic roughness, which can be used to identify features such as bedrock outcrops, land-slides, land-use differences, and land disturbances. Blue and green indicate smooth areas; orange and red indicate rough areas.

Sinkhole Mapping Using Lidar Data

An effort to create a digital map of sinkhole locations in Kentucky, which began in 2014, is continuing. It utilizes the now-complete lidar coverage for Kentucky. KGS hydrogeologists mapped three more counties—Bourbon, Hardin, and Madison—which added 17,500 more locations to the sinkhole database during the past year, bringing the total number of counties mapped to 10. The results are available on the KGS internet map service. The sinkhole mapping team is turning to machine-learning techniques to help automate and expedite the process.

Drinking Water Corrosiveness Study

The Water Resources Section worked with the UK Department of Earth and Environmental Sciences to complete a study of the quality of the Lexington-Fayette County public water supply, with an emphasis on the water's corrosiveness. This study was in response to the highly publicized water crisis in Flint, MI, and was supported by the U.S. Geological Survey through the Kentucky Water Resources Research Institute at UK. The project team collected and analyzed 24 tap-water and source-water samples from throughout Lexington in spring and fall 2017. Results indicated that corrosiveness was generally low, but can increase significantly during icy or snowy winters when large amounts of road salt are applied. Correlation analysis suggested that metal concentrations increase with pipe distance and also are influenced by pipe materials. An ArcGIS model was developed to locate potential areas of concern for metals leaching into Lexington's water distribution system. The final report was submitted to the institute in May 2018.

Geologic Mapping

KGS continued surficial mapping of 7.5-minute quadrangles in northern Kentucky, with funding from the USGS STATEMAP program. This completed surficial mapping in northern Kentucky and will allow KGS mappers to start producing compilation maps for three northern Kentucky counties. Mapping was

enhanced by the use of technological tools, including lidar data, grain-size analysis, geochronology, and data gathered from outside sources.

KGS hosted the 2018 Digital Mapping Techniques national conference on the UK campus, attended by more than 70 cartographers, GIS professionals, and other geoscientists from around the country. At a "digital open house" during the conference, KGS staff gave presentations on their use of new mapping technologies, digital field data-collection methods, and the capabilities of the Survey's online map service.

Digital Earth Analysis Laboratory

KGS established the Digital Earth Analysis Laboratory—known as KGS DEAL—in 2017 to help make the Survey a leader in lidar solutions for geologic, engineering, and environmental problems in Kentucky. KGS DEAL has three high-speed computer workstations, specialized software, a dedicated lidar data server that facilitates accessing the 14 terabytes of Kentucky statewide data, and an 80-in. touchscreen monitor for group collaboration. The final installment of statewide airborne lidar coverage was released early in 2018. KGS geologists have been using lidar data for projects around the commonwealth as they have become available.

The data were used to identify sinkhole and landslide locations in Kentucky and to accurately map both modern and ancient floodplain deposits. An effort began in 2018 to determine whether a machine-learning approach can help to locate previously unknown abandoned oil and gas wells, which could pose environmental and safety hazards.

GeoHealth Initiatives

Radon Research

KGS continued its work with the UK College of Nursing's Bridging Research Efforts and Advocacy Toward Healthy Environments

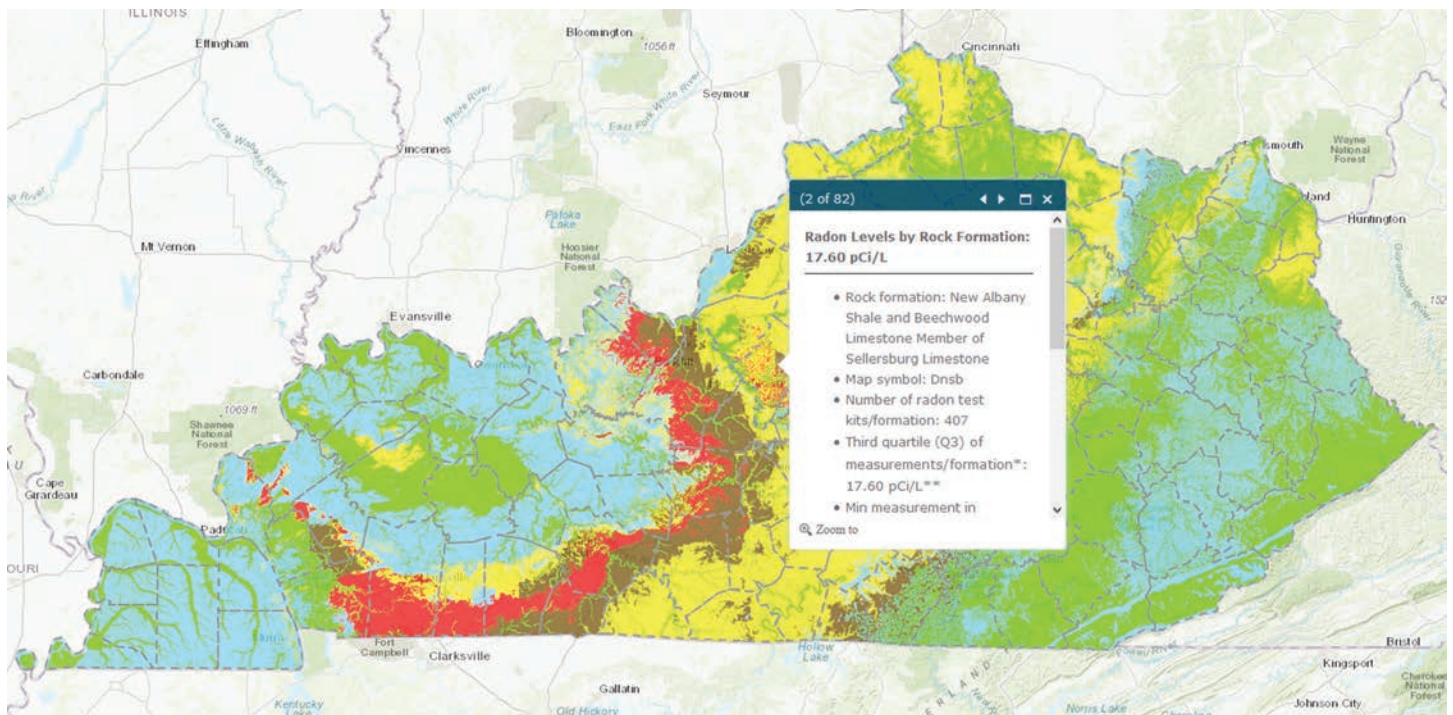


Figure 3: The KGS radon webpage contains an interactive map of statewide radon potential.

(BREATHE) team, completing geologic maps showing radon potential for each of Kentucky's counties. These maps were included on easy-to-read infographic sheets to show indoor radon-gas potential by rock type. Staff researchers also chaired the session "Origin, Transport, and Accumulation of Geogenic Carcinogens" at the American Geophysical Union 2017 fall meeting. A radon information and research page was added to the Geohazards section of the KGS website; it includes a link to an interactive statewide radon-potential map that allows users to look up the radon potential in their neighborhoods.

Two new portable instruments to measure radon, funded in part by the UK Vice President for Research, gave the Survey the ability to monitor radon concentrations in real time. They will allow KGS scientists to validate the information on which the radon-potential maps are based and help expand radon research to include soil and groundwater in addition to indoor radon gas.

Geology and Epidemiology Short Course

KGS worked with several University of Kentucky departments to organize a short course, "Geospatial Approaches to Epidemiology," in January 2018, attended by 32 people. The three-day course covered data sources and challenges and basic GIS operations that support integration of epidemiologic, geologic, and topographic information.

Geologic Hazards

The Kentucky Seismic and Strong-Motion Network

The Kentucky Seismic and Strong-Motion Network monitors seismic events across Kentucky. KGS maintains a real-time data share of network recordings with the neighboring seismic network operated by the University of Memphis and also with the

Data Management Center at Incorporated Research Institutions for Seismology for archiving and global usage. Recordings from networks operating in Kentucky and surrounding states were acquired in tandem with real-time data from the Kentucky Seismic and Strong-Motion Network and used to detect mine blasts and earthquakes in and around Kentucky and larger events around the world. Thirty earthquakes were recorded in the state during the fiscal year, ranging in magnitude from 1.0 to 3.3.

Landslide Hazards

New entries to the KGS landslide database brought the total number of entries to 2,667 by the middle of 2018. The landslide locations come from state agencies, field investigations, published maps, lidar mapping, and reports from the public. Landslides are documented as point data that represent larger landslide deposits such as translational slides, slumps, debris flows, earth flows, and rockfalls. With likely thousands of unknown or unreported landslides, this inventory is a critical step in hazard assessment and mitigation efforts. All landslide data can be viewed and queried in the online KGS Geologic Map Information Service.

The USGS invited KGS, along with a few other state surveys, to help in the initial planning for a national-scale landslide inventory. The planning included discussions about data standardization, quality, and delivery.

KGS researchers set up monitoring stations at shallow colluvial landslides in Kenton, Lewis, and Pulaski Counties, collecting and analyzing data on hillslope moisture conditions, precipitation, landslide movement, and surface electrical resistivity. The data will be the basis of a framework that uses long-term field monitoring techniques to link hydrologic and electrical-resistivity data to geotechnical properties of soil.



Figure 4: Monitoring equipment at a landslide overlooking Lake Cumberland in Pulaski County, KY.

Updating the Geologic Hazard Assessment for State Mitigation Plan

The Kentucky Division of Emergency Management contracted with KGS to update the geologic hazards section of the State's hazard mitigation plan, which is required by FEMA to establish eligibility for federal assistance after major natural disasters. KGS staff worked to update previous assessments of the earthquake, landslide, karst/sinkhole, and mine-subsidence threats in the state, using data such as landslide and sinkhole locations, maps showing the extent of underground coal mines, and FEMA's HAZUS loss assessment tool. They also developed new assessment methods for all four geologic hazards.

Technology Transfer and Public Outreach

Web Services

More than 20,000 files are accessible from the KGS website's homepage, and for the year ending in June 2018, the site attracted close to one million page views. Almost 235,000 users from 207 countries accessed information from the website about KGS, Kentucky's resources, and geoscience education. Approximately 76 percent of the users were from the U.S.; others were from the Philippines, India, the United Kingdom, Canada, and Australia. Since 2001, KGS has provided free online access to oil and gas records and data, water-well and springs data, coal data, publications, images, and other geologic data, now numbering more than 6.6 million records. During the year, KGS developed a new coal information service, a new page of information on upright fossil tree stumps, and a new version of the databases, maps, and publications search website, called "KY Geode."

Earth Science Week Open House

Each October during Earth Science Week, KGS invites students and families to browse Earth science-related displays and demonstrations at the KGS headquarters on the University of Kentucky campus. Rocks, minerals, fossils, gems, and meteorites are on display, and demonstrations of volcanoes, earthquake

recordings, and geologic carbon storage are available to the public. The 2017 open house featured the popular "Quake Cottage." Brought to the event by the Indiana Geological and Water Survey, it simulates how much a building shakes at different earthquake magnitudes.

Distinguished Lectures

KGS invites scientific lecturers to the UK campus several times each year. Scottish geoscientist Iain Stewart, Director of the Sustainable Earth Institute at Plymouth University in England, delivered "Between a Rock and a Hard Place: Communicating Contested Geoscience to the Public." His visit to campus was a stop on his James B. Thompson Jr. Distinguished International Lecture tour sponsored by the Geological Society of America. It was also a part of the KGS Donald C. Haney Lecture Series, named for the former State Geologist and director of KGS from 1978 to 1999, who died in 2014.

Annual Seminar

The 2018 KGS annual seminar focused on geoscience communication and featured speakers from KGS and several other UK and outside organizations. More than 140 people attended the May 18 event at the Well Sample and Core Library. Representatives of the Kentucky Water Resources Research Institute and the UK Colleges of Nursing and Public Health made presentations. Keynote speakers were Lauren Cagle from the UK Department of Writing, Rhetoric and Digital Studies and Aileen Buckley of the mapping and spatial software company Esri.

Major Publications

KGS staff produced eight new publications, all available from the Survey's online publications and maps catalog. Among them were four surficial geologic maps of quadrangles in northern Kentucky, funded by the USGS STATEMAP program.

Several staff members contributed to *Ground Motions Induced by the March 11, 2018, Implosion of the Capital Plaza Tower, Frankfort, Kentucky* (Report of Investigations 2, series 13). KGS seismologists set out four temporary seismic instruments situated 1,300 ft to 2.5 mi from the 28-story tower to record ground motions created by its planned destruction.

To make KGS publications easier to find online, the Survey worked with UK's W.T. Young Library to assign digital object identifiers to hundreds of existing publications. A DOI is a unique string of numbers and letters assigned to a publication, identifying its content and providing a persistent link to its location on the internet. Copies of older KGS publications assigned DOIs will be found at the library's UKnowledge webpage. KGS will assign DOIs to new publications, and the publications will be posted at UKnowledge as well as on the KGS website.

LOUISIANA

LOUISIANA GEOLOGICAL SURVEY

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INTRODUCTION

The Louisiana Geological Survey (LGS) was originally set up in 1869 and was later officially established by the Louisiana legislature in 1934 (Act 131). LGS is presently a research unit affiliated with Louisiana State University, having been legislatively transferred in 1997 from the Louisiana Department of Natural Resources. LGS currently reports through the Executive Director of the Center for Energy Studies to the LSU Vice President of Research and Economic Development.

LGS Mission Statement

The mission and goals of LGS are to perform geological investigations that benefit the state of Louisiana by:

- Encouraging the economic development of the natural energy, mineral, coastal, water, and environmental resources of the State through appropriate research projects.
- Provide unbiased geological information on natural and environmental hazards and other issues as and when

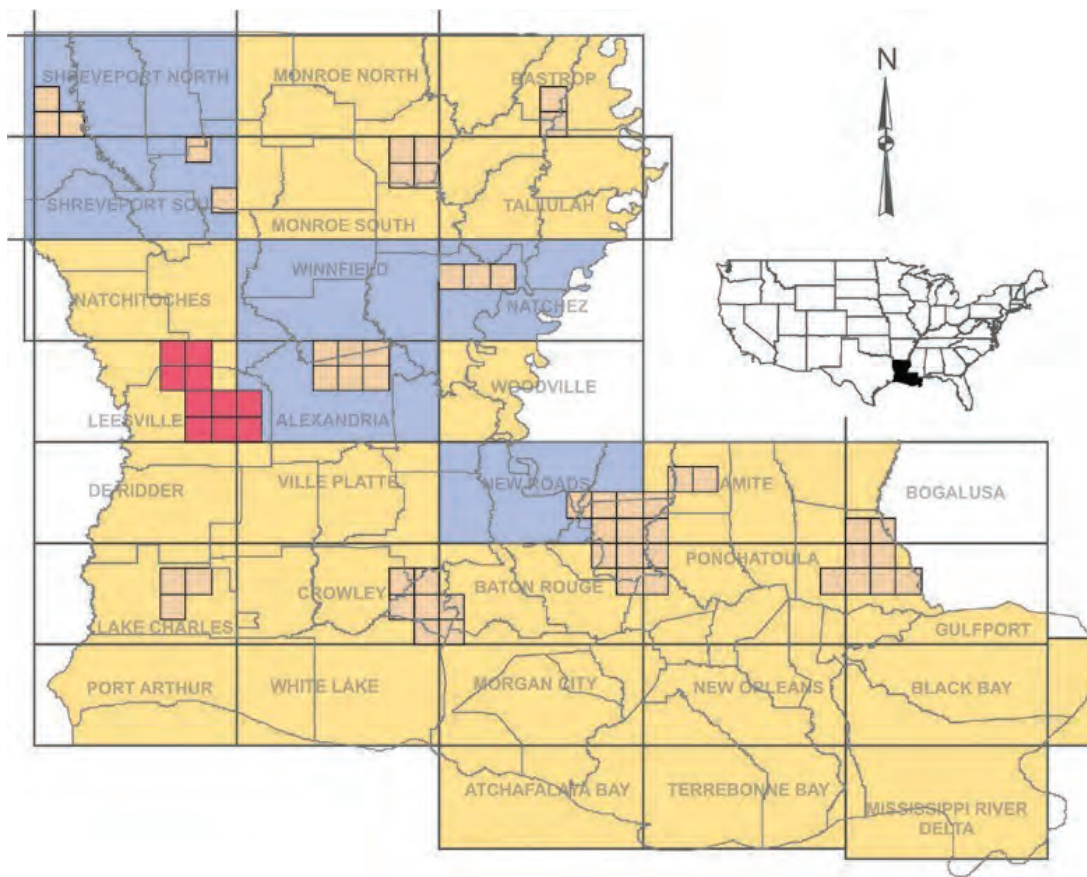


Figure 1. Generalized geology of Louisiana, and geologic map coverage generated at 1:100,000 and 1:24,000 scales since the advent of the STATEMAP program in 1993.

1:24,000-Scale Geologic Quadrangles

- STATEMAP
- NonSTATEMAP

1:100,000-Scale Geologic Quadrangles



GIS Compilation



Printed Lithograph

called upon to do so by state, federal, or other agencies and private companies and citizens.

- Ensure the effective transfer of geologic information through research publications, presentations at professional conferences and other meetings, and production of geologic maps.

Continuing budget cuts for the last five years have resulted in the reduction of the LGS state budget by approximately 58 percent from about five years ago. The state's severe deficit budget situation coupled with the oil and gas industry downturn, matching requirements for contracts, and a lack of sufficient staff with necessary expertise have made successfully getting externally funded research contracts difficult.

LGS currently has 14 full time and two part time staff including all categories of personnel. A summary description of ongoing LGS projects is provided below.

GEOLOGIC MAPPING

Surface geologic mapping projects conducted by LGS during the past 20 years comprise 1:100,000-scale compilations of 30 × 60-minute geologic quadrangles and 1:24,000-scale field-mapped 7.5-minute geologic quadrangles. The vast majority of these mapping efforts were funded under the STATEMAP component of the National Cooperative Geologic Mapping Program (NCGMP), begun in 1993 and administered by the U.S. Geological Survey.

The principal goal of this program of geologic mapping for LGS initially was to prepare statewide surface geology coverage at 1:100,000 scale in 30 × 60 minute quadrangle format. This scale was emphasized because it is at the large end of the range

of intermediate scales, and preserves abundant detail from source mapping done at larger scales (principally 1:62,500 and 1:24,000) while yet covering relatively large areas. By the close of FY13, LGS had completed 30 × 60-minute geologic quadrangle coverage of the entire state (30 sheets total) with a mix of published lithographs and draft open-file compilations.

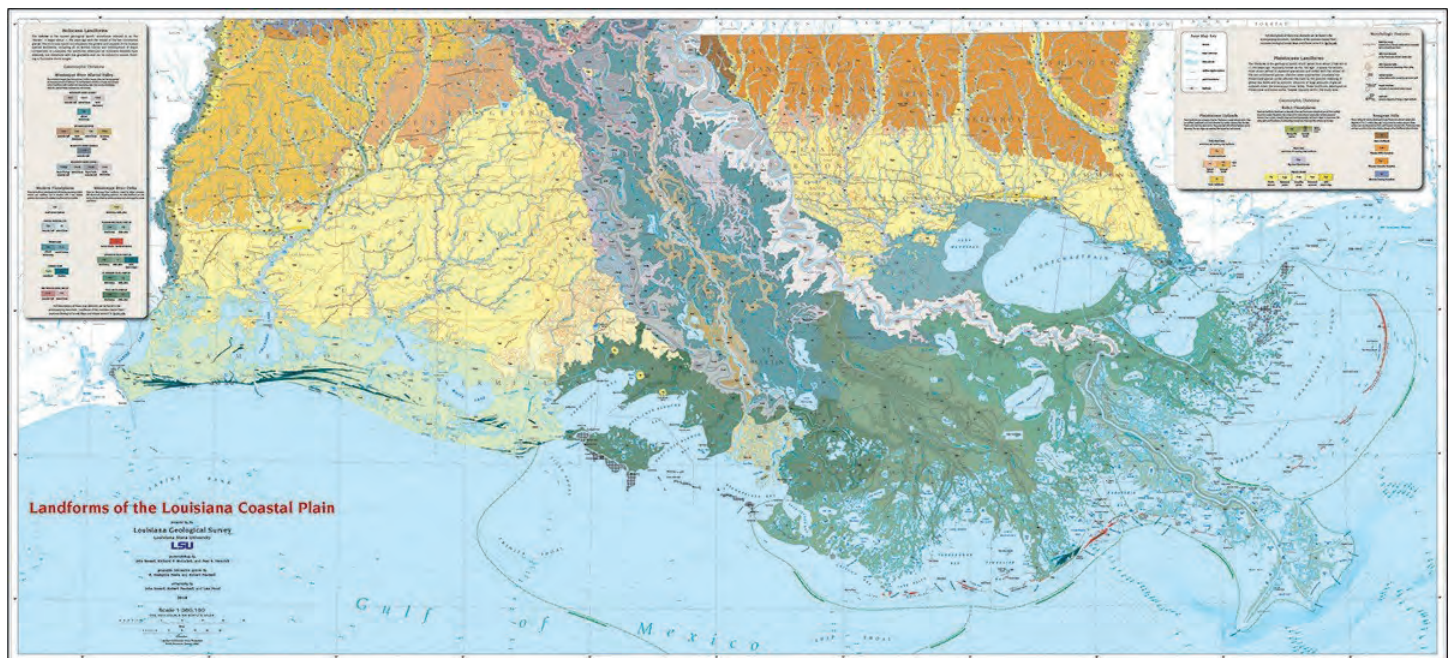
Since the late 1990s LGS also has prepared 7.5-minute geologic quadrangles at 1:24,000 scale totaling 62 sheets. Fifty-two were prepared with STATEMAP support, and the other ten were prepared for the U.S. Army Corps of Engineers within the Fort Polk region, south-central Louisiana.

The STATEMAP 2017–2018 deliverables completed and submitted included geological maps and pamphlets covering five 7.5-minute quadrangles in two study areas (the greater Lafayette area in southwestern Louisiana and the southern Baton Rouge area in southeastern Louisiana).

SURFACE MAPPING

LGS has published several series of surface geologic maps in various scales over the decades that have been of great use to the geologic community. However, it has been recognized that traditional geologic mapping is not always well understood by non-geologists seeking information relevant to their needs. This can be addressed with a “non-traditional” geologic map emphasizing landforms rather than age, stratigraphy, and lithology. Landforms are described by the appearance of their surfaces, their position in the topography, the processes that created and shaped them, and the ecosystems they support.

These landforms are key to understanding natural systems in a state like Louisiana with generally subtle relief, very similar deposits at the surface, and features widely obscured by dense sub-tropical vegetation. Landforms exert tremendous influence



and control on soil development, drainage, natural vegetation patterns, wildlife habitats, and the occupation patterns of indigenous peoples. They affect subsequent human developments such as agriculture, forest management, highway patterns, and the suburban sprawl into wetlands. Landform recognition is essential to the research and engineering efforts that help manage Louisiana's coastline and rivers.

LGS will soon publish Landforms of the Louisiana Coastal Plain in an effort to meet the requirements of coastal scientists that need to better understand how geology relates to their areas of interest. The mapped landforms help define Louisiana's extensive riverine and coastal floodplains, areas that are subject to episodic stream flooding and hurricane storm surges. They also offer insight into the increased flooding potential of very flat upland regions that retain such low gradients that they can still flood during extreme rain events.

The intent is to produce maps that have relevance to a wider target audience, including the general public. Environmental scientists, coastal engineers, planners, and decision-makers working in coastal Louisiana may find that landform awareness is highly relevant to the issues that they are examining, such as subsidence, flooding, erosion, habitat change, natural hazards, and land loss.

WATER RESOURCES

Trends in Hydraulic Fracturing

There is an ongoing investigation of trends with hydraulic fracturing (HF) in the state of Louisiana with a focus on the eight parishes that the Haynesville shale gas play lies in: Bienville, Bossier, Caddo, De Soto, Natchitoches, Red River, Sabine, and Webster. After approximately ten years of Louisiana Department of Natural Resources collection of sources and volumes of water used for hydraulic fracturing, it is possible to determine trends (HF) for Haynesville Formation (shale) as well as other units: Cotton Valley Group (mainly Bossier Formation/shale); Wilcox Groups, and Hesston Formation. There is also nine years for FracFocus data analyzed for trends within the chemistry of reported fracture solutions. FracFocus is a voluntary online data base where contractors report site location, volumes of water used, depth of fracturing and water chemistry of solution for fracturing. Results have been presented at regional and national professional meetings as well as at a variety of conferences in Louisiana.

Mississippi Alluvial Aquifer Study

This regional study of the groundwater within the Mississippi Alluvial Aquifer in a nine parishes region (Catahoula, Concordia, East Carroll, Franklin, Madison, Morehouse, Richland, Tensas, West Carroll) in northeastern Louisiana is funded by the Louisiana Water Institute. This project involved sending letters to owners of private wells and contacting public supply managers requesting permission to sample their wells. At present the first phase of contacting private well owners has been completed,

which has yielded results for 78 wells. Private well sampling was completed between October 2017 and March 2018. The second phase of contacting public supply managers will begin shortly in the fall of 2018 and should be completed in the spring of 2019. Each of the samples was and will be analyzed for 25 analytes: aluminum, arsenic, barium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, phosphorous, potassium, silicon, sodium, strontium, vanadium, and zinc. Preliminary results will be presented this fall at a meeting in Shreveport. The final report will be submitted to the Louisiana Water Institute and for publication as an LGS report and possibly in an appropriate journal.

Denham Springs Historical and Spring Study

This is a study near the Amite River funded by the City of Denham Springs to determine the location of historical sites and examine spring water chemistry. Five springs within Spring Park have been sampled twice and water has been analyzed for over 20 different analytes. Water has also for comparison been collected and analyzed from the city's six water wells. These samples were collected in the summer of 2018. In the fall of 2018 a series of magnetic surveys will be completed to determine the location of where an early water well was dug within Spring Park and the location of two nineteenth century hotels that hosted tourists that came to Denham Springs to receive the believed health benefits from bathing in the spring water.

Louisiana Geological Survey, LSU Agcenter, LA Water Institute Host Louisiana Water Conference

Staff of the Louisiana Geological Survey were involved in hosting the twelfth annual Louisiana Water Conference in the spring of 2018. Attendance for the conference was approximately 100, many of whom earned continuing education credits as required to maintain their status as registered professional geoscientists.

GEOLOGIC STUDIES

The LGS has continued to study a diverse range of topics that are considered important to understanding the geology of Louisiana. For example, joint research with the LSU Department of Geology and Geophysics and the University of Texas, Austin, Department of Geology concerning the age and origin of the Sabine Plate was published in *Geology*. More recently, the results of research conducted with Texas A&M University and Brigham Young University-Hawaii on the age, extent, and stratigraphic significance of a volcanic ash bed exposed in Rapides Parish and known as the "Chalk Hills Member" of the Catahoula Formation, has been accepted for publication in the *Journal of Geology*. A monograph about the Quaternary stratigraphy and geoarchaeology of the southwest Louisiana continental shelf is currently in preparation for publication by the Bureau of Ocean Energy Management. Research is continuing with the LSU Department of Geology and Geophysics on a suspected extraterrestrial impact crater in St. Helena Parish.

ENERGY

Integrated Carbon Capture and Storage in the Louisiana Chemical Corridor

This 26-month project commenced in February 2017 and is funded by the U.S. Department of Energy; LGS researchers are participants in this multidisciplinary project headed by the Center for Energy Studies. Other LSU departments on the project team include the Department of Engineering, Department of Geology & Geophysics, Department of Environmental Science and the Law Institute.

The objectives of this project are: (1) to develop a multidisciplinary team of stakeholders with interest in carbon capture and storage in the Louisiana Chemical Corridor along the Mississippi River; (2) to analyze the technical and economic feasibility of an integrated carbon capture and storage project that captures 50 million tons of CO₂ from one or more industrial sources, transports it via pipeline and stores it in underground saline reservoirs in existing hydrocarbon fields; and (3) to provide a geologic evaluation using publicly available geologic data for the potential for CO₂ storage in saline reservoirs found in oil and gas fields in South Louisiana.

The LGS role in this project is to provide a geological evaluation of selected saline formations with requisite shale seals in Bayou Sorrel (Iberville Parish) and Paradis fields (St. Charles Parish) situated along the Mississippi River industrial corridor. This area has a concentration of petro-chemical industries that generate large volumes of CO₂ emissions which would be the source for CO₂ needed for sequestration. LGS researchers have completed the geologic evaluation of the selected saline reservoirs in the two fields based on publicly available data and literature. The top of the brine sand reservoir evaluated at Bayou Sorrel lies at a depth of 7,300 ft and is approximately 900 ft thick. The prospective saline sand reservoir selected by the project team at the Paradis field is at a depth of 4,300 ft and has a thickness of 350 ft. Both Bayou Sorrel and Paradis currently have hydrocarbon production from other mostly deeper zones.

The LGS researchers have pointed out potential geologic issues that need further investigation. These include: (1) coring shale reservoirs both above and below the target sections to determine their effectiveness as seals; (2) obtaining seismic data to more accurately determine faulting and lateral extent of both the target and sealing reservoirs; (3) evaluating conditions of casing in the numerous well bores in both fields as they are potential leakage pathways; (4) potential chemical reactions between the injected CO₂ and brine in the target reservoirs; (5) where and how far the brine displaced by CO₂ injection would travel; and (6) mode of transport of CO₂ from source to sink.

New Oil & Gas Map of Louisiana

The 2008 Oil & Gas Fields Map has been updated and a new 2018 map has been compiled and is in the process of final editing and review. It is planned to be published before the end of 2018.

Offshore Gulf of Mexico Partnership for Carbon Storage-Resources and Technology Development

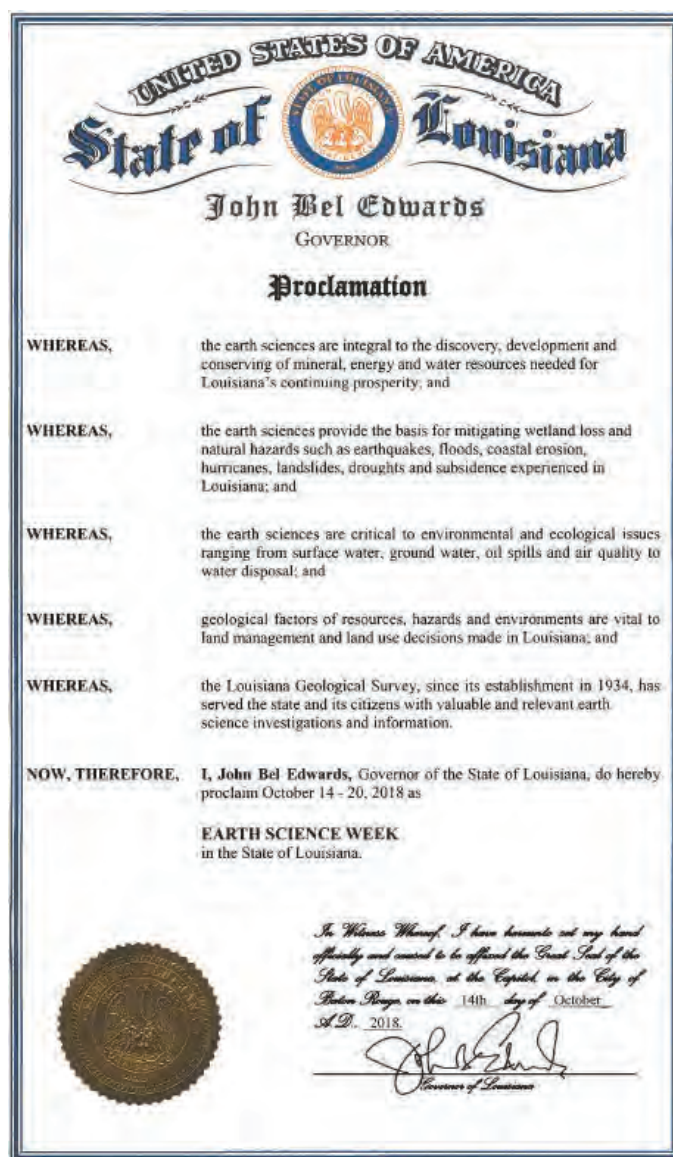
LGS has partnered with the Bureau of Economic Geology (BEG), University of Texas, on this project, which is funded by the U.S. Department of Energy under their carbon sequestration program. This research program has just been initiated and LGS will be providing assistance to BEG for selecting suitable offshore sites for carbon sequestration.

Projects in Planning

- Parish Oil & Gas Atlas
- Potential shale plays in South Louisiana

GEOLOGIC REVIEW

Geologic Review is an ongoing program created by the Louisiana Geological Survey in 1982, which provides regulatory technical



assistance to the Office of Coastal Management (OCM) of the Louisiana Department of Natural Resources and to three districts of the U.S. Army Corps of Engineers (USACE). It has a proven track record of reducing industrial impacts to environmentally sensitive areas and has been extended through 2021.

GEOPHYSICS

LGS (M. Horn) continues development of electrical resistivity and magnetometry geophysical techniques for near subsurface features relevant to geology, archaeology, and civil engineering. The techniques have successfully resolved prehistoric and historic human habitations, human graves, modern buried pipelines, and lithostratigraphic relationships in the shallow subsurface. Archaeological field studies have identified locations of potential significance at a dam site (Fannin County, Texas) and floor plan elements of Antelope Creek (1200–1450 AD) dwellings (Potter County, Texas). Field methods have also been applied to the internal structure of five-thousand-year-old Indian mounds that are widely distributed along the lower Mississippi River fluvial province. Comprehensive geological and geophysical studies in historic Louisiana and Texas cemeteries have identified unmarked 19th century graves, providing custodians with guidance for renovations and future interments. Investigations of geological and civil engineering problems along the Louisiana Gulf Coast have focused on resolution of regionally and locally important faults as well as undocumented pipelines, both of which impact planning of new construction.

Application of these low cost, minimal impact field techniques represents a highly valuable contribution by LGS to the myriad of archaeological, historical, geological, and engineering challenges in the growing Louisiana region.

OUTREACH ACTIVITIES

Sponsored Nationwide by the American Geoscience Institute (AGI), this week was celebrated from October 14 to 20, 2018.



Educational outreach Coordinator Riley Milner, P.G., has been quite busy as of late. On December 19, 2017 after an invitation from the 4th- and 5th-grade teachers at The Laboratory Key Academy in Baton Rouge, he presented a demonstration of the rocks and minerals in Louisiana and other states and countries as well as ocean geologic history and life. The students from the four classes in attendance came prepared with their own questions. Their questions ranged from a discussion of the Rock Cycle to how do you become a geologist and how much money does a geologist make.

On March 10, 2018 the BREC Bluebonnet Swamp Nature Center held their annual event “Rockin’ at the Swamp”. It is an all day event featuring geologic displays from LGS, LSU Geology Club, jewelry vendors, and rock and mineral specimens on display as well as for sale.

The week of May 7–11, 2018 was Louisiana Tourism Week sponsored by the Louisiana Department of Recreation and Tourism. LGS was asked by the Atchafalaya National Heritage Center at the Butte La Rose tourist Center on I-10 to display our Cartographic products (30 x 60-minute geologic maps) at the Heritage Center for the week. Mr. Milner spent the week at the center, providing discussion and information for the local visitors as well as travelers from across the country.

On June 6–11, 2018 Mr. Milner assisted the St. James Parish Library in Litcher and Vacherie kick off their Summer Program “Libraries Rock” with displays at both libraries featuring rocks and minerals of Louisiana, specimens from 3.2 billion-year-old Stromatolites from South Africa, to fossils from the past and present, mineral specimens representing the full range of mineral types, a microscope display with a Scope-on-a-Rope showing a thin section of the Greenwell Springs Chondrite Meteorite (stony not Iron-Nickel) and others from many types of rocks and minerals, and a display of rocks representing the Rock Cycle (sedimentary, igneous and metamorphic). Mr. Milner has also been invited to participate in the St. James Parish’s “Geology of St. James Parish” Dinner and presentation. The activity is to celebrate the geologic history of St. James Parish and its oil and gas and other economic resources.

On September 22, 2018 a presentation was made to the Louisiana Master Naturalists of Greater Baton Rouge workshop Introduction to Plants: Identification and Landscaping with Natives, hosted by the LSU Hilltop Arboretum. In addition, Mr. Rick McCulloh led a workshop with classes and discussion ending in a short nature trail walk to the Waddill Wildlife Refuge Area in East Baton Rouge Parish.

LGS RESOURCE CENTER

The LGS Resource Center consists of a core repository and log library. It is located behind the Graphic Services building on River Road. Most of our cores are from the Smackover and Wilcox Formations. The core facility has more than 30,000 ft of core from wells mostly in Louisiana. The well log library contains over 50,000 well logs from various parishes in the state.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of Shreveport South and North at 1:100,000 Scale.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of Winnfield South and North at 1:100,000 Scale.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of CarenCro at 1:24,000 Scale.

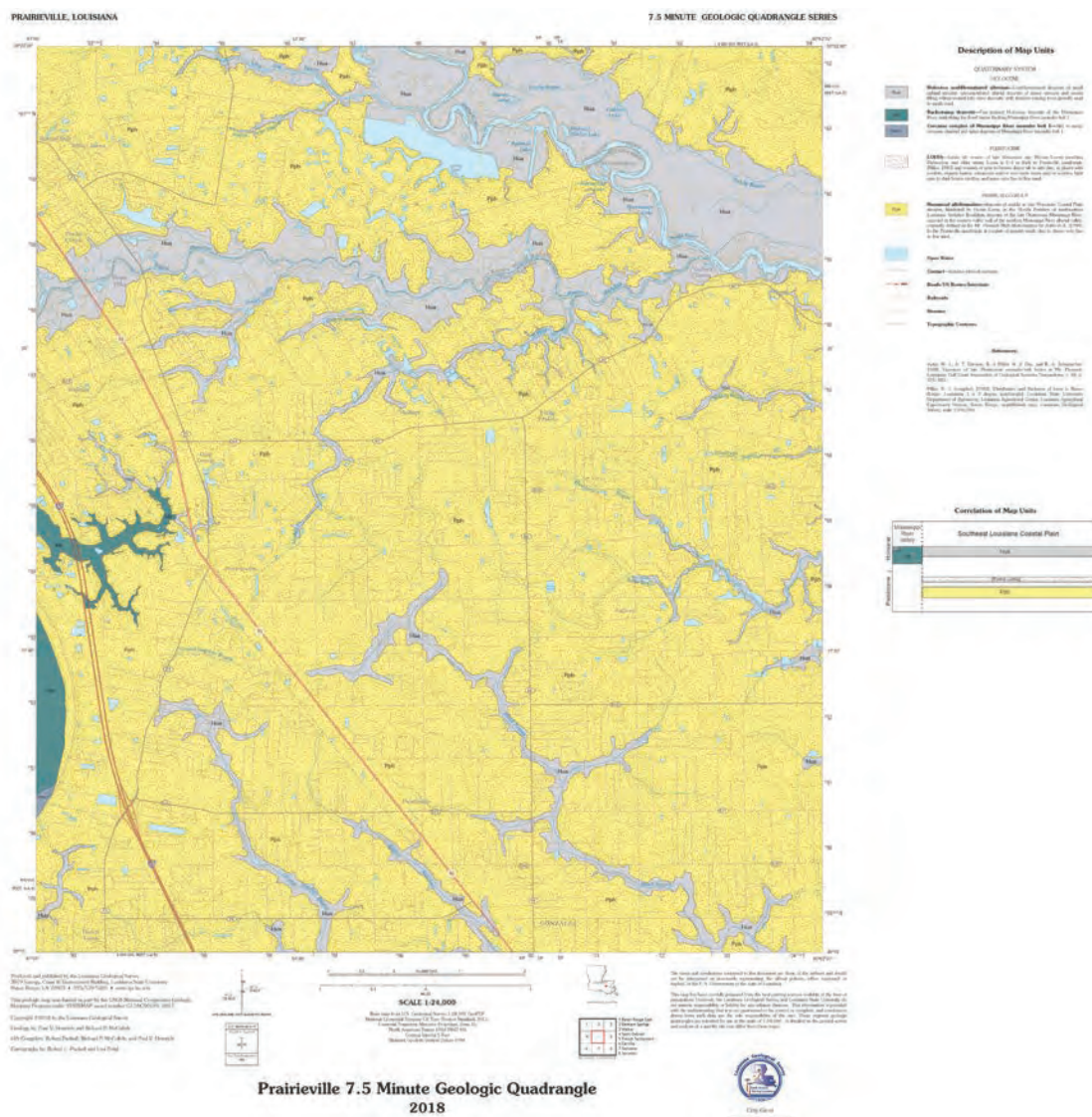
Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of Duson at 1:24,000 Scale.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of Mire at 1:24,000 Scale.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of Prairieville at 1:24,000 Scale.

Heinrich, P. V.; McCulloh, R. P., 2018, Geologic Mapping of St. Gabriel at 1:24,000 Scale.

Schedl, Andrew, 2018, A Study of the Brushy Creek Feature,
St. Helena Parish, Louisiana: Louisiana Geological Survey
Open-File Series 18-01, 7 p.



MAINE

MAINE GEOLOGICAL SURVEY

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INTRODUCTION

Geologic information is fundamental to economic, environmental, and social applications in Maine. Water and mineral resource distribution, their qualities, and consequences of their use and misuse can be better understood with geological information. The Maine Geological Survey (MGS) has active programs that we and our customers believe will provide the greatest benefits to the citizens of Maine. These benefits can be defined as promoting a sound understanding of the State's geological resources and their appropriate use while safeguarding the environment.

Our mission statement reflects the benefits of geological investigations to society: "The mission of the Maine Geological Survey is to provide the people of Maine with quality information to facilitate informed decision-making for natural resource management, economic development, conservation planning, and regulation; to provide public assistance; and to promote education. The MGS maps, inventories, assesses, and interprets Maine's geology and supports its mission by using computerized geographic information systems and databases, and by publishing maps and reports."

Geology has played an important role in the development of the State. In the eighteenth and nineteenth centuries, minerals were extracted along the coast to provide raw materials for manufacturing of all types. Lime was mined and fired in kilns as an agricultural amendment. Granite and slate were quarried to provide the basic building blocks of modern civilization. Early geological surveys of the state by C.T. Jackson in 1837 and C.H. Hitchcock in 1885 emphasized these critical mineral resources and their geologic settings.

Since those early days, the significance of geology to society has broadened. MGS programs reflect this broad application of geology to societal issues:

- The Bedrock and Surficial Geology program provides basic geologic mapping and interpretation of surficial materials and bedrock mapping and interpretation of rock types and structures. Basic geologic mapping is the foundation for the evaluation, appraisal, and inventory of specific physical resources, mineral occurrences, and geologic hazards in the State.
- The Hydrogeology program assesses ground and surface water conditions, emphasizing groundwater quality and quantity, and the protection and wise use of the State's groundwater resources.
- The Marine Geology program conducts research on the geological setting of the coast and near-shore submarine environment and provides technical services to other state agencies involved in the coastal zone. Research and mapping is conducted for shoreline stability, landslides, sea-level rise, beach nourishment sources, and dredge spoil disposal sites.
- The Publications and Outreach program ensures that the geological information generated by the other programs is made available to a variety of users.

GEOLOGIC MAPPING

Slightly more than 700 topographic maps at 1:24,000 scale cover the State. Of this total, MGS has produced surficial geologic maps for about 190. Preliminary surficial maps at a more generalized

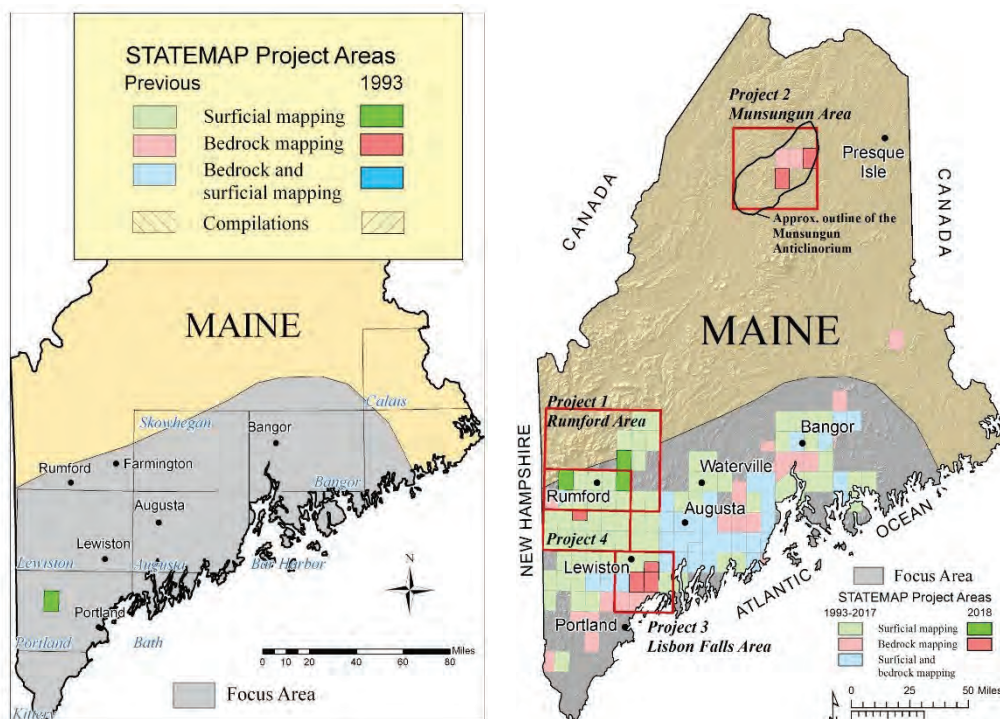


Figure 1. Status of STATEMAP mapping in 1993 (Left). 1:100,000-scale quadrangles named in blue. Status of STATEMAP mapping through 2017 (Right).

scale cover much of the rest of the State. With regard to bedrock maps, there are about 70 completed at the 1:24,000 scale with another 10 in progress. About half of the State is covered with more generalized preliminary bedrock maps. Through STATEMAP, we have made enormous progress in mapping the more populated areas of the State, as captured in Figure 1.

A key emphasis of our STATEMAP program is on areas with important societal issues for which only regional or reconnaissance maps are available. The Rumford region in western Maine is one such area. Forest products and four-season recreation drive the economy in the region for which our only surficial geologic map coverage is at 1:250,000 scale. We continued a project begun in 2016 to complete detailed surficial mapping for a block of eight quadrangles, providing details of glacially-derived surficial units that represent potentially significant aquifers and sources of aggregate. Glacial lake deposits and some till units are also susceptible to landslides. Newly available lidar for the region greatly facilitated mapping.

In 2017 we also began a bedrock mapping project in the Rumford region. The reconnaissance maps currently available show large seemingly uniform granitic intrusions surrounded by meta-sedimentary units. Among the many resources of the region are abundant pegmatite deposits that have produced some world-class specimens of tourmaline, beryl, and other gemstones. Pegmatite deposits like these and salt brines are the only

two geologic settings globally for significant lithium resources. In fact, enormous spodumene crystals have been found in the area, raising the potential for an important lithium resource (Fig. 2). For many decades, the common interpretation for the origin of pegmatites has been that they are the final distillates of large magmatic intrusions, enriched in fluids and incompatible elements (Be, B, Li, Cs) that do not fit into the common rock-forming minerals that crystallized first. Recent work shows that the large tracts mapped as granite are mostly migmatite with which the pegmatites are spatially associated. Additionally, radiometric dating of pegmatites and detailed geochemistry argue against a genetic link with mapped intrusions. Our bedrock mapping in the Rumford area is aimed at further understanding the setting of pegmatite deposits and their association with migmatites.

We continued a bedrock mapping project in northern Maine begun in 2016, focused on Ordovician volcanic rocks. The southwestern portion of the Munsungun Anticlinorium (Fig. 1) was mapped in detail in the 1960s, but the geology of the northeastern part was known only from reconnaissance mapping in advance of the 1985 bedrock geologic map of the state. The justifications for this mapping project are mineral and cultural resources. The volcanic rocks host the State's largest volcanogenic massive sulfide deposit at Bald Mountain (34 million tons). Chert layers in the volcanic rocks were exploited by Native Americans for tool-making, evidenced by numerous quarries. Our mapping will contribute to a better framework for additional discoveries of both resources.

In the Lewiston area (Fig. 1), our bedrock mapping focuses on developing a better understanding of the rock units that are the drinking water source for half the residents of the region.

HYDROGEOLOGY

Groundwater Monitoring Network

We continue work begun in 2016 to improve Maine's groundwater monitoring network. The USGS network in Maine consists of just 24 wells. Through a USGS grant, we are working to enhance the network with existing high quality wells. The Maine Department of Environmental Protection, a sister agency to the Maine Geological Survey, maintains the Environmental and Geographic Analysis Database (EGAD) (<http://www.maine.gov/dep/maps-data/egad/>) which is used to manage all environmental information, including groundwater levels and groundwater quality information, at numerous permitted and remediated sites throughout Maine. This database contains over 59 million records. Geologists at MGS currently use EGAD to extract groundwater level information from select background wells at sites across Maine.

Unlike networks in some other states, data collected for the wells in EGAD are primarily to address environmental needs rather than solely for groundwater level or background quality monitoring. However, the breadth and quality of this statewide database provides an enormous opportunity to contribute groundwater level information to the NGWMN unparalleled by



Figure 2: Huge spodumene crystals unearthed in 2017 at Plumbago Mountain, Rumford region, western Maine. Photo: Gary Freeman

any other database in Maine. Data from more than 23,000 wells are stored in EGAD, a subset of which are background wells intended to capture ambient conditions at each site, unaffected by anthropogenic activities. More than 900 wells from 44 sites with records spanning ten years or more were reviewed by MGS geologists for inclusion in the monitoring network. Among criteria used for selection of wells were geographic distribution and completion in each of Maine's principal aquifers: the New England Crystalline Rock aquifer, the Surficial Aquifer System, and the Carbonate Rock aquifer. The thirty new wells added to the network are shown in Figure 3.

Water Well Database

Digital compilation of bedrock water-well data continued, including well depth, well yield, and overburden thickness/depth to bedrock. Private drillers provide MGS with reports on these factors for each domestic water well they drill. Our database now contains over 100,000 entries and is a critical element in the analysis of groundwater vulnerability. It is accessible through an interactive web mapping app: <http://www.maine.gov/dacf/mgs/pubs/digital/well.htm>

Water Use

MGS received continuing grant funding from the USGS National Water Census Program to improve water use information in Maine. In this second year, we worked to improve agricultural water use information. The methods were based on irrigator surveys and climate-based models. We worked with Maine's Soil and Water Conservation Districts and other agriculture industry bodies to survey water users about their irrigated crop acreage and water sources in crop-dominated counties, and herds of livestock in major dairy producing counties. This was for the 2016 water year, a significant drought year in Maine, which resulted in significant irrigation demand.

The total number of responses to the survey was 319, out of 1447 total farms contacted, for an overall response rate of 22 percent. The survey outreach was successful in targeting water users, with 199 farms (62% of all respondents) reporting that they used water for crops or livestock during 2016. The number of farms reporting an irrigated crop was 114, or 36 percent of all respondents, notably higher than the overall percentage of farms irrigating as reported by the U.S. Department of Agriculture (USDA), National Agricultural Statistics Service for the year 2012. The number of farms in the survey reporting livestock water use was 144, or 45 percent of all respondents.

The number of farms that indicated growing any crop was 238. Those that provided their crop acreage, reported cultivating 56,081 total acres, or 14 percent of the 2012 USDA total in the ten counties surveyed. Farms that provided a value for irrigated acreage reported a total of 3,352 irrigated acres, or 12 percent of the USDA total. In summarizing the responses, we grouped crops into 20 categories, as presented in Figure 4. The data on water demand for each crop category will be used in future years to develop better agricultural water use coefficients statewide.

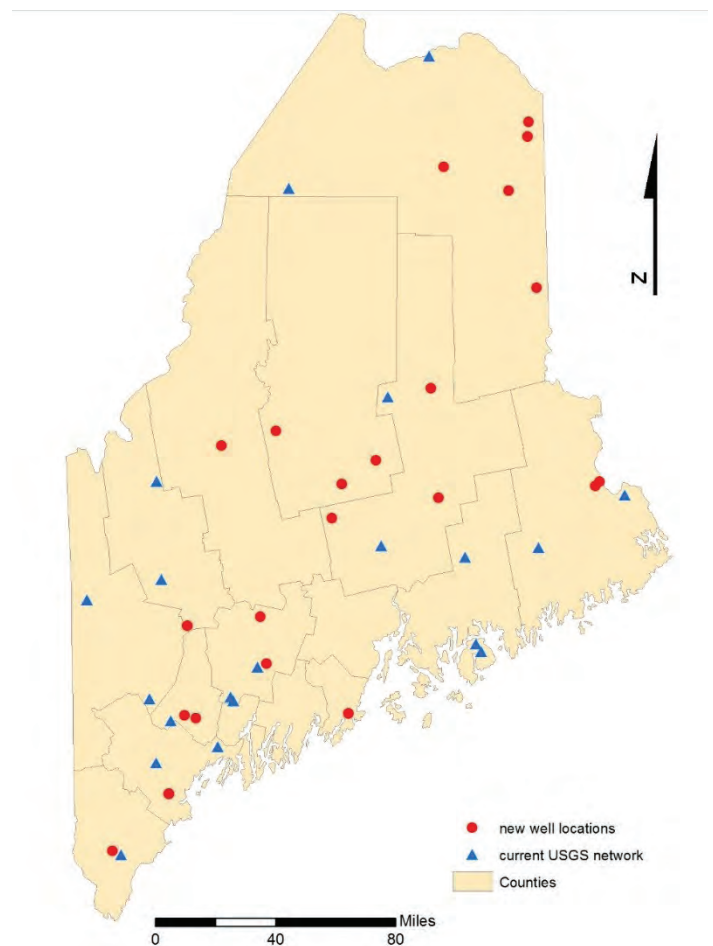


Figure 3. Surficial and bedrock wells, extracted from existing databases and added to the groundwater monitoring network.

Soil-Water-Balance Recharge Project

We continue work with the USGS New England Water Science Center Maine Office on a soil-water-balance model to estimate groundwater recharge statewide. Very limited groundwater recharge (or potential recharge) information exists for the State. There are but a small number of published site-specific recharge estimates, mostly from calibrated groundwater flow models and those cover very limited geographic areas. The Soil-Water-Balance (SWB) method of recharge estimation provides a new opportunity to calculate average annual recharge to groundwater across the entire state, using inputs of precipitation, land cover and soil information, and estimates of potential vs. actual evapotranspiration. The calculations done using this method traditionally have been used in the agricultural sector to estimate crop water demands, but they also can be used to provide estimates of excess soil moisture, which is the source of recharge to groundwater. Recent advancements in digital data availability make the computation of recharge using land use, soil type, daily temperature and precipitation, and topography possible in an unprecedented way. The SWB program uses daily estimates of changes in soil moisture to calculate soil moisture surplus (recharge) for any size spatial area. The model was built in the first year and is currently being calibrated to surface water base flows in select watersheds, with completion expected in early 2019.

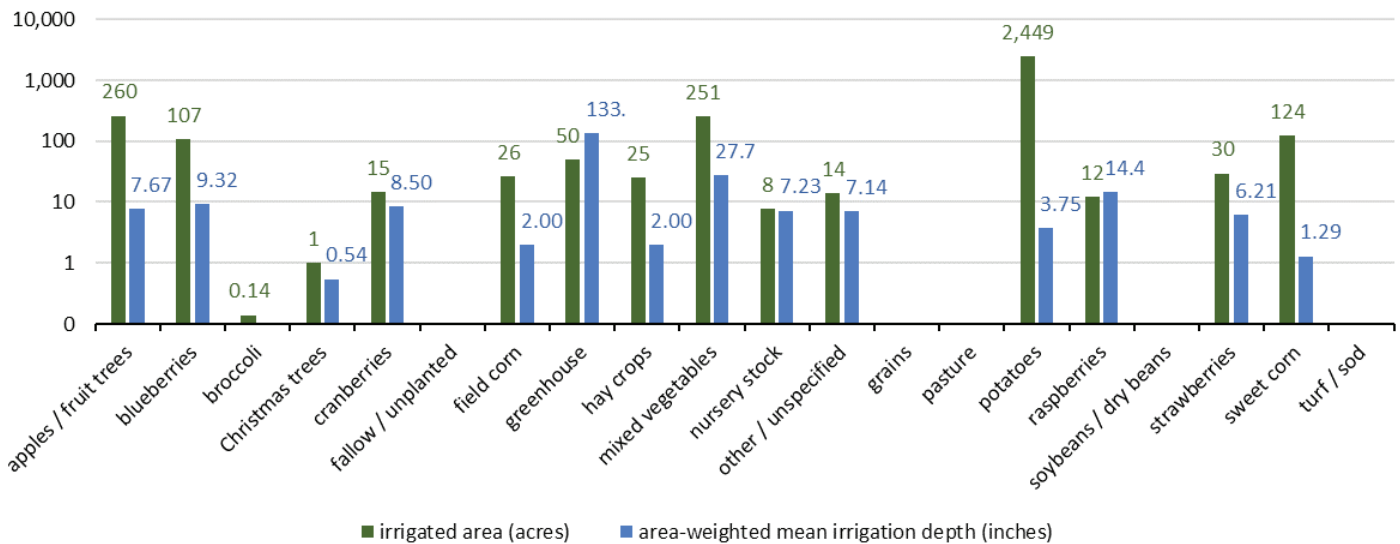


Figure 4. Total irrigated acres of each crop type reported by survey respondents, and area-weighted mean inches of water applied to each type of irrigated crop in all of 2016. Vertical axis scale is logarithmic.

Model components

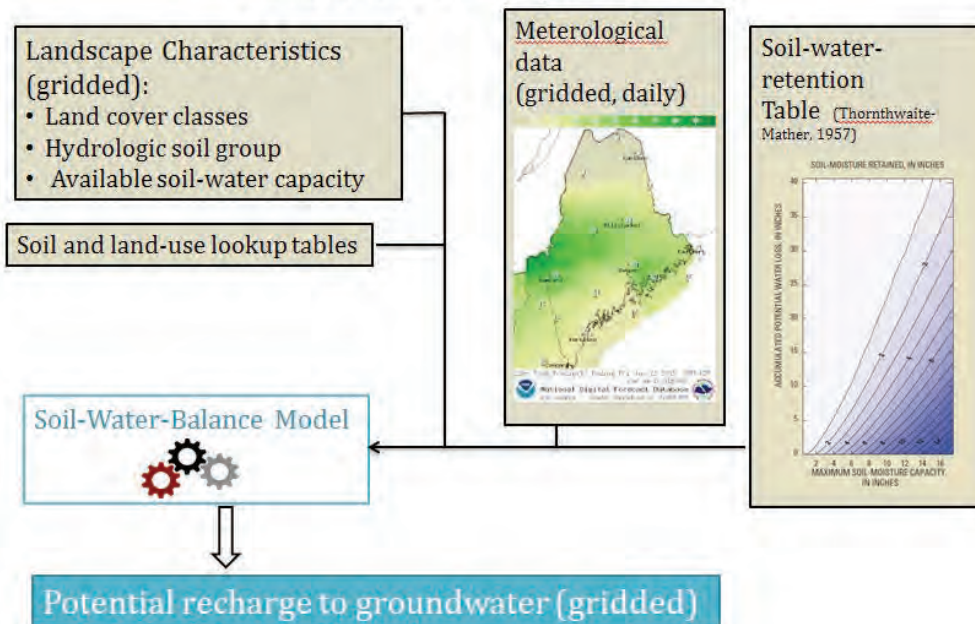


Figure 5. Schematic of primary inputs to the SWB model. When completed, the model will estimate recharge in any user-defined area.

MARINE GEOLOGY

Beach profiling

Since 1998, the MGS has been involved in a beach profiling program that uses local volunteers on about a dozen southern Maine beaches to collect monthly profiles from multiple transects on each beach. This program is funded in cooperation with U Maine and the Maine Sea Grant program. Through this program, MGS and its cooperators are compiling seasonal and long-term information on the health of some of the most economi-

cally important beaches of the state. The results of several years of profiling are posted at <http://www.seagrant.umaine.edu/extension/beach-profile-monitoring/home>. Seasonal changes to the beaches are being documented to understand natural cycles and volumes of erosion and accretion. Results of the profiling are compared to coastal wave and wind data to understand how storms affect various beaches in southern Maine. In 2017, information was compiled in the biennial State of Maine Beaches report (<https://www.maine.gov/dacf/mgs/explore/marine/beaches17/contents.htm>) that assesses the long-term accretion/erosion trends of the beaches and was presented at the biennial Maine Beaches Conference in July 2017.



Figure 6. Sea-level rise/storm surge inundation map for Portland, Maine. The light green areas are those that will flood on a HAT plus 2 ft, and the dark green areas will flood with 3.3 ft of sea-level rise or storm surge.

Sea-Level Rise/Storm Surge/Hurricane Inundation Mapping Portal

This application (https://www.maine.gov/dacf/mgs/hazards/slr_ss/index.shtml) approximates the inland extent of several scenarios (1, 2, 3.3 or 6 ft) of sea-level rise or storm surge along the Maine coastline on top of the 2015 Highest Annual Tide, or HAT. That HAT layer displays the maximum predicted astronomical high tide for 2015. The data were developed using a static (“bathtub”) inundation model that uses lidar topographic data as a base digital elevation model, and then adds scenarios of 1, 2, 3.3, and 6 ft of either storm surge or sea-level rise to that initial starting elevation. The primary purpose of these data is to help inform storm surge and sea-level rise vulnerability assessments. Figure 6 shows an example of a map available through the portal.

land County Soil and Water Conservation District, MGS marine geologists completed the following tasks.

1. Developed and applied a transferable, predictive bluff erosion model using sound, scientifically proven methodologies and existing and newly available Maine datasets.
2. Assessed model efficacy for use locally and bay-wide in Casco Bay.
3. Selected several locations for potential application of “living shoreline” approaches to bluff stabilization, to be done in a later phase of the project.

HAZARDS

Bluff erosion and landslides

Approximately 40 percent (1,400 mi) of Maine’s shoreline is comprised of soft bluffs, with steep slopes of gravel, clay, or sand. In addition to ongoing erosion, the threat of catastrophic landslides, especially in high coastal bluffs made of muddy sediment, is a significant concern. In Casco Bay, MGS previously mapped about 108 mi of bluff, of which 34 were classified as either unstable or highly unstable (for example, Fig. 7). Bluff shorelines are present on year-round populated islands in Casco Bay as well as the Bay’s mainland.

Through a NOAA Project of Special Merit begun in 2016 in collaboration with the Maine Coastal Program and the Cumber-



Figure 7. This landslide occurred in the Casco Bay study area while our project was underway in 2016. The image was collected by a drone operated by the Cumberland Soil and Water Conservation District.

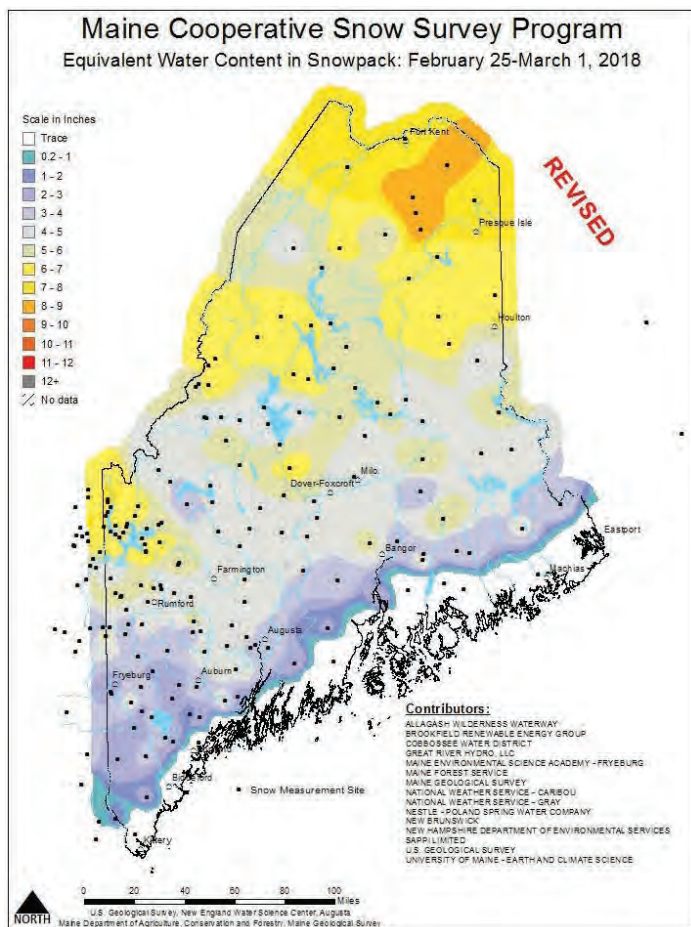


Figure 8. Snow survey map from March 1, 2018 showing water equivalent content of the snowpack (inches of water). This map and others were used by the River Flow Advisory Commission to assess the threat for spring flooding.

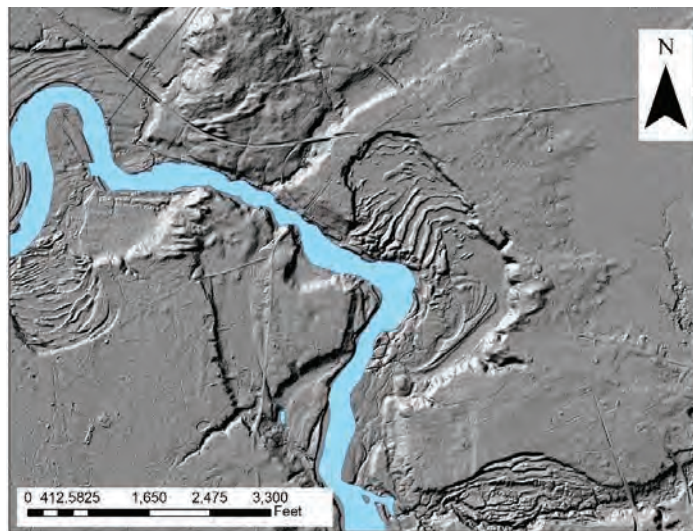


Figure 9. Three landslide features are starkly exposed in this bare-earth shaded relief lidar image along the Saco River near Steep Falls, southern Maine. These features had been erroneously identified previously as old meander scrolls along the river.

Flooding

The Maine Cooperative Snow Survey program, managed by the Maine Geological Survey, provided critical information on water content of the snowpack to emergency responders and forecasters during the winter of 2018 and throughout the snowmelt period (for example, Fig. 8). Our information helped forecasters refine the timing and extent of possible flooding from the snowpack. Cooperators include the Maine Emergency Management Agency, U.S. Geological Survey, National Weather Service, dam operators, the State of New Hampshire, several academic institutions, and other major water users.

Landslide studies

MGS began working with the Maine Emergency Management Agency (MEMA) to increase the focus on landslide hazards through the update of Maine's State Hazard Mitigation Plan, currently under way. MGS reviewed newly available lidar for landslide features, identifying dozens of previously unrecognized landslide features developed in areas underlain with glacial-marine mud (Fig. 9). Our research focuses on establishing the ages of many of these landslides. Working with MEMA, MGS received funding from the Federal Emergency Management Agency to investigate and date these features. Our preliminary analysis shows that landslides have occurred sporadically over time, but with a cluster of events in the 500–700 year range, leading us to conclude that landslide hazard is on-going. Had most of the events occurred immediately post-deglacial, around 10,000–12,000 years ago, they would have had less bearing on current landslide potential.

GIS AND PUBLICATIONS

Web Pages

Through an innovative partnership, all digitally available MGS maps and reports (~2600 items) are hosted, managed, and maintained by the Maine State Library through a cloud-based web interface system called Digital Commons providing stable long-term access and enhanced search capabilities. Since upload to the Digital Commons in April 2017, MGS surficial geology maps have been downloaded 7,492 times and MGS bedrock geology maps have been downloaded 8,454 times. Geologic maps of all scales and types can also be viewed on the popular MGS web mapping application (<http://maine.maps.arcgis.com/apps/webappviewer/index.html?id=f52e6fa4f79b46a48203ad07cd55a9d7>), giving users a seamless preview of all available maps before selecting a particular map for viewing or download. In the last twelve months, the web mapping application has had 2,623 views.

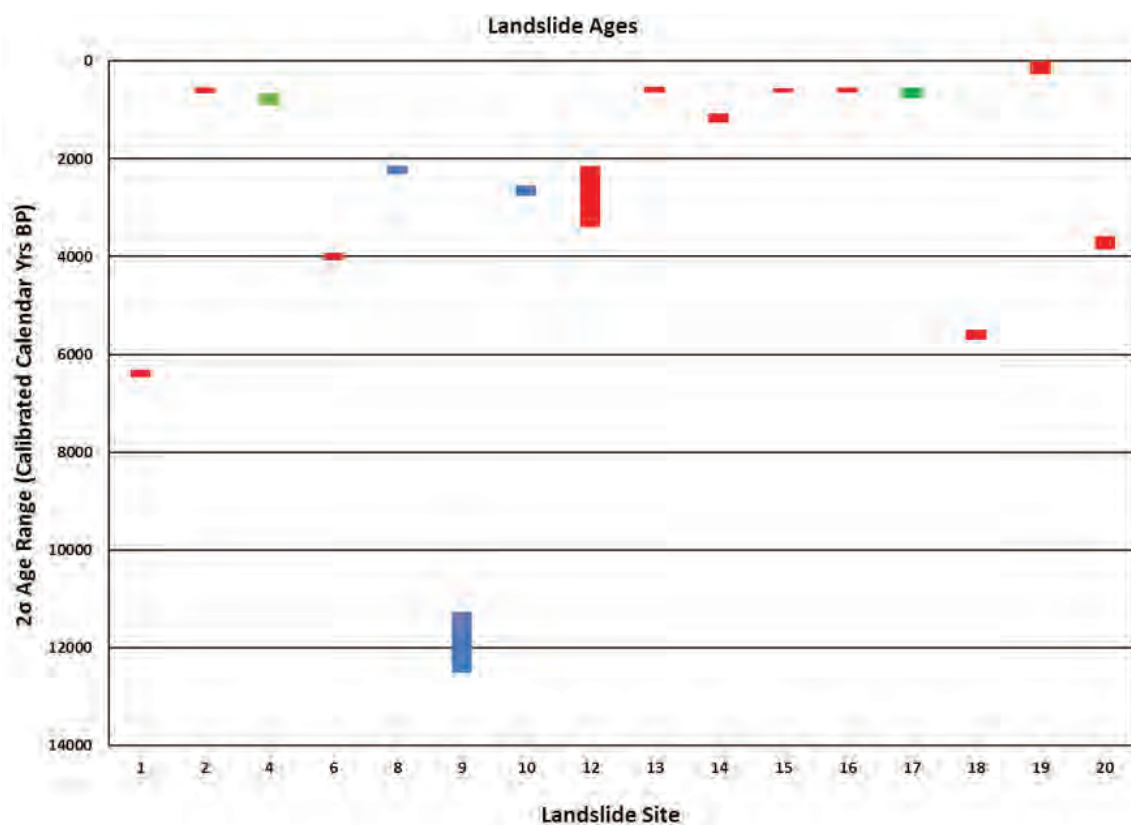


Figure 10. C¹⁴ dates for 20 landslide sites in southern Maine. Based on sample stratigraphy, red bars represent maximum ages, green represent minimum ages, and blue represent ages somewhere between.

PROFESSIONAL, PUBLIC, AND EDUCATIONAL OUTREACH

Earth Science Week

As part of Earth Science Week, we organized “Earth Science Day” at the Maine State Museum. In 2017 about 1,200 middle and high school students attended this popular event, which highlighted special displays on Maine minerals and fossils, water resources, gemstones and gem cutting, Maine granites, soils, and mineral collecting. This event is the anchor for our Earth Science Week activities each year.

MARYLAND

MARYLAND GEOLOGICAL SURVEY

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INTRODUCTION

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

- Conduct topographic, geologic, hydrographic, and geophysical surveys.
- Prepare topographic, geologic, and other types of maps to meet specific needs.
- Prepare reports on the extent and character of the geology, minerals, and water resources of the State.
- Periodically assess the paleontological resources of the State and coordinate the assessment with interested persons and public agencies.

These responsibilities are still incorporated into the Code of Maryland Regulations, although some of the activities such as assessing the State's paleontological resources are functions no longer performed. Since 1969, the Survey has been part of the Department of Natural Resources and many of the activities and functions that the Survey carries out are conducted to support the management activities of the larger Department. In addition, particularly with regard to groundwater studies, the Survey conducts studies in support of the Maryland Department of the Environment's regulatory control over groundwater quality and quantity and for improving understanding of the quality of the State's groundwater resources.

STAFFING

Currently, staffing levels are 18 scientists, one contractual scientist, one full-time support, and one part-time support. In 2016, Ms. Anna Gillmor was hired in the Coastal Geology program as a Geochemist; Ms. Tiffany VanDerwerker was hired as a Hydrogeologist focusing on water quality; and Mr. Christopher Connallon was hired in the Coastal Program as a Geologist. In 2017, Mrs. Jeanne Gary, Administrator, retired, and Mrs. Tina Williams was recruited to lead the Administrative office. In 2018, Mr. David Bolton, chief of the Hydrogeology program, retired, and Mr. David Andreasen, an existing hydrogeologist, was promoted to lead that group. Also, in 2018, Ms. Isabel Glassman was hired as a Conservation Associate, and Mr. William Junkin was hired as a Field Geologic Mapper.

HYDROGEOLOGY

Groundwater-Level Network

MGS personnel are involved in collecting annual water-level data from more than 450 wells in Maryland (mostly in the Coastal Plain). These data provide information on long-term changes in

groundwater levels and are used to identify areas where lowered water levels may indicate the need for alternative water-withdrawal strategies.

Maryland Ground Water Quality Monitoring Network

The Maryland Ground Water Quality Monitoring Network is an ongoing effort to document the chemical quality conditions of Maryland aquifers. In 2017, MGS conducted a study of baseline water quality in drinking-water wells in the Appalachian Plateau province of Maryland, which includes all of Garrett County and the western edge of Allegany County. The study compiled data from local, state, and federal agencies, including the Garrett and Allegany Health Departments, the Maryland Department of the Environment (MDE), the Maryland Geological Survey (MGS), and the U.S. Geological Survey (USGS). This investigation is intended to provide information on concentrations of major ions and field measurements (pH, specific conductance, dissolved oxygen), trace elements, and radionuclides, as well as on regional patterns of well-water quality.

Similar to the work in western Maryland, MGS compiled and assessed data from multiple data sources (local, state, and federal agencies) into a GIS-based dataset in the Coastal Plain Province (Anne Arundel, Wicomico, and Worcester Counties). These data can help identify trends, suggest causative factors, spot data gaps, and examine data in relation to health issues. The data are collected for varying objectives, and samples are analyzed for different water-quality constituents using different collection protocols, analytical techniques, and detection and reporting levels. For example, County health departments test wells for nitrate and bacteria; some also require testing for arsenic, radioactivity, chloride, iron, cadmium, and other constituents before a Certificate of Potability can be issued. Public-supply wells are tested for constituents that have drinking water standards established by the U.S. Environmental Protection Agency. Additional water-quality data have been collected



Figure 1. Johanna Gemperline taking field measurements of groundwater chemistry.

associated with groundwater studies by federal, state, and local agencies to investigate specific research topics.

Land-Subsidence Monitoring

Concern regarding land subsidence from groundwater withdrawals led to the establishment of a long-term project of documenting land subsidence. Elevations at benchmarks located in areas of greatest groundwater withdrawals (and deepest groundwater levels) in the Coastal Plain are determined yearly using high-resolution GPS. Collaboration with the National Geodetic Survey is helping to constrain errors and produce accurate heights (sub-cm scale). The marks will be monitored for at least 18 years to document any vertical changes and will be evaluated against local, regional, and statewide control points.

Spring Assessment—Biological Habitat

In collaboration with the U.S. Fish & Wildlife Service, a geophysical investigation was undertaken to gain insight into the hydrogeology of seepage springs in Washington DC and Montgomery County, Maryland where habitats of threatened and endangered amphipod species have been identified. This project employed a novel use of the direct-current electrical resistivity survey method to collect data from the subsurface without disturbing sensitive amphipod habitat. Processed resistivity data were interpreted, in concert with surficial geological mapping and hand-augered sediment sampling, in order to identify the locations of the water table and solid bedrock, as well as structural anomalies that may be indicative of joints, fractures, or faults. Results of the survey suggest the subsurface around the springs is highly complex. Low-resistivity areas interpreted as saturated zones are often directly beneath surface drainage features that are dry at the land surface, indicating local recharge from surface runs. Interpreted saturated areas are also commonly found in the highly permeable zone of the basal saprolite (weathered bedrock), directly above the crystalline metamorphic bedrock. Resistivity anomalies indicate that there may be fracture zones near all of the springs, which could act as preferential flow conduits.



Figure 2. Well camera image of shallow coastal plain well as it approaches well screen.

Karst Spring Flow—Albert Powell Fish Hatchery

Infrequent and episodic turbidity events within a karst spring feeding the Albert Powell Trout Hatchery in Maryland's eastern Great Valley threatened late winter fry populations. During the winter of 2016-2017, several turbidity events at the spring prompted a study of potential flow paths supplying recharge to the spring. Geologic mapping had indicated several faults in the area that could act as conduits or barriers to flow. Dye tracing was conducted using fluorescein and rhodamine WT injected at two potential input sites near the faults and Beaver Creek, with monitoring stations at the hatchery and other surrounding sites. Fluorescein was never conclusively recovered, but rhodamine WT was detected in low concentrations about a week after injection at the hatchery spring and several other sites, suggesting a possible flow path along a northwest trending cross fault. Resistivity studies were conducted to identify subsurface voids near the hatchery spring. A high resistivity anomaly was found, indicating a possible air-filled void or dry bedrock. This anomaly follows bedrock orientation, and contains a lower resistivity area that may represent fractured bedrock. A review of precipitation and quarry blasting data did not indicate a correlation between those events and the turbidity events. Data from stream flow in Washington County suggests that the turbidity events, as well as other turbidity events in 2004, occur at times of low spring and surface water flow.

National Groundwater Monitoring Network

MGS received a grant from the USGS to include approximately 110 water-level observation wells in the National Groundwater Monitoring Network. Since the wells are already part of the USGS National Water Information System, work under the grant is focused on ensuring that data (location, altitude, well construction, and lithology) are complete and accurate, and that these data meet the standards established by the Advisory Committee on Water Information (2013). Many of the wells used to collect water-level data are valuable long-term data sources (21 wells are over 50 years old), but for this reason they are also vulnerable to deterioration or blockage related to their old age and lack of pumping. It is clear that certain wells need maintenance above ground (mostly to repair and secure well heads). What is less clear is the integrity of the subsurface portions of these wells. To that end, MGS is performing well-integrity tests including well-depth sounding, borehole camera surveys, and slug testing to locate obstructions, identify deterioration, and assess the physical condition of the casings, joints, and screens.

GEOLOGIC MAPPING

Funding from a USGS STATEMAP grant continues to be utilized for geologic mapping in areas of western Maryland underlain by Devonian, gas-bearing strata. The most recent mapping was conducted within the Friendsville and Bittering quadrangles and is a continuation of efforts in earlier funding cycles that encompassed the Accident, McHenry, and Sang Run quadrangles. The mapping traced surface expression of several high-angle faults

that were previously believed to be blind reverse faults at depth. This mapping was meant to codify our understanding of the stratigraphic offset and help in our understanding of potential stray gas movement from deep gas reservoirs to shallow potable groundwater. This information is important to the planning and management of energy and water resources in this growing region.

In 2016, MGS initiated a new STATEMAP project in rapidly developing areas of the central Maryland Piedmont, carrying forward 1:24,000-scale mapping started by the USGS in 1998–2003. Mapping focuses on quadrangles along the I-270, I-70, and I-95 corridors between Frederick, Baltimore, and Washington DC, where housing development is greatest and rapid mass transit lines are proposed. The Maryland Survey also added a third field geologist, William Junkin, whose presence doubles our mapping capabilities within the Piedmont.

CARBON SEQUESTRATION

As increased awareness of climate change continues, a desire to document the potential for carbon dioxide sequestration continues. Through a cooperative with Battelle, surrounding states, the Federal Department of Energy, and Maryland's Power Plant Research program, MGS is documenting the potential for geologic carbon sequestration.

Off-Shore CO₂ Sequestration

MGS is collaborating with a team of geoscientists led by Battelle in a systematic carbon storage resource assessment of the offshore mid-Atlantic region. Key outcomes include the development of input parameters to reduce uncertainty for offshore resource assessment and efficiency estimates, evaluation of risk factors that affect storage resource assessment, and industry and regulatory stakeholder outreach to assist future projects. MGS has served in a supportive role by providing information on the on-shore hydrostratigraphic framework as well as GIS services.

On-Shore CO₂ Sequestration

The Maryland Survey is also completing a two-year geologic mapping project within the Culpeper and Gettysburg Triassic rift basins. Sedimentary facies within these two exposed rift basins are being described and mapped in the hope that that data can be applied to poorly understood rift basins buried beneath the Atlantic Coastal Plain. This effort was partially funded by the Mid-west Region Carbon Sequestration Partnership (MRCSP) through Battelle Memorial Research Corporation and the Department of Energy.

COASTAL GEOLOGY

Sediment management in Maryland's non-tidal surface waters is of increasing interest to local resource managers and communities, especially in light of the regional focus on reducing sediment loading to the Chesapeake Bay. MGS personnel are applying the same techniques developed to study sediment transport and deposition in tidal waters to assist in answering questions related to proposed dam removals, and sediment accumulation in reservoirs and recreational lakes. Acoustic surveying techniques including side-scan sonar, swath bathymetry, and sub-bottom profiling provides critical information for locating and collecting cores of accumulated sediments. Textural and chemical analyses of the collected materials are central to environmental assessments preceding dam removals including potential sediment delivery and associated contaminants.

Offshore Sand Assessment

The Bureau of Ocean and Energy Management and MGS joined in a cooperative to analyze data collected through the Atlantic Sand Assessment Project (ASAP). Cores, grab samples, seismic lines, side-scan sonar, and various other geophysical data are being analyzed and presented in a GIS. Information from this cooperative will expand our ongoing database of offshore sand resources as we continue to seek appropriate sand and mineral resources along our coastlines.

Dam Removal—Mapping Geomorphological Changes

Currently, MGS is studying the impacts of sediment due to the removal of Bloede Dam on the Patapsco River near Ilchester, Maryland. The project is being funded by American Rivers and their partners, including the National Oceanic and Atmospheric Administration (NOAA), with the goal of to open up this section of the river for fish passage. Prior to dam removal, MGS conducted topographic surveys of 30 cross section profiles throughout a stretch of the river above the dam and well down river of the dam. Also included in these surveys were photo monitoring, facies mapping, and sediment sampling for each transect. The dam impoundment, which spans from the dam to a quarter-mile upstream of the dam, was also surveyed to create a detailed digital elevation map and complete facies map of the impoundment. Now that Bloede Dam is being deconstructed (breached September 11, 2018), transect surveys will soon begin and we will continue to monitor the sediment as it moves down river and track riverbed habitats through facies maps and photography for a year post removal. Data collected by MGS will also be used in validation of the sediment flow model used to calculate the movement and deposition of sediments released from the dam removal project.

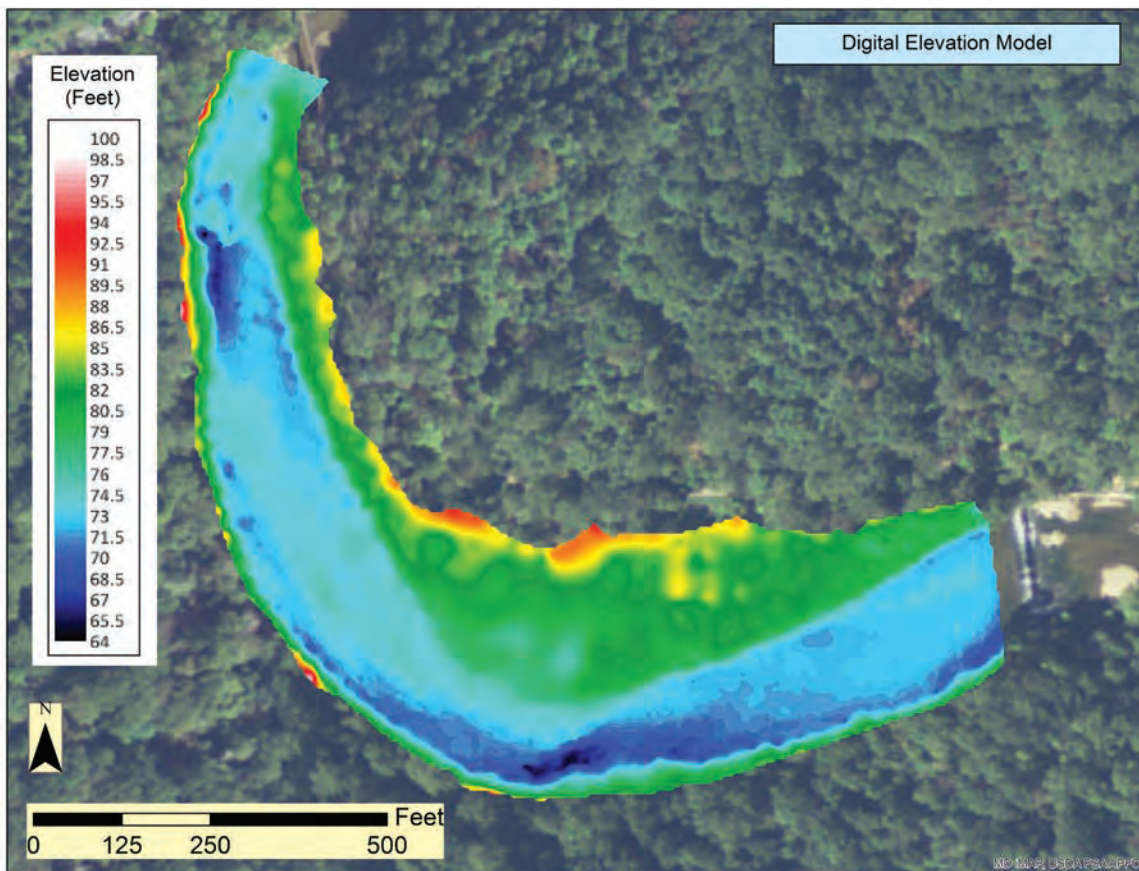


Figure 3. Digital Elevation Model of legacy sediments behind Bloede Dam.

Sediment Management Support to Dredging Operations

Maintaining the shipping channels leading to the Port of Baltimore generates approximately 3.5 million yd³ of dredged sediment every year, for which suitable placement sites are needed. MGS staff provides support to the Port by serving on a number of committees and management groups that are part of the State's ongoing 20 Year Dredged Material Management Plan. This working relationship ensures that the scientific information related to sediment transport and deposition processes is fully incorporated into management decisions regarding locating and developing suitable placement sites. In addition, MGS has ongoing monitoring programs at existing sites including sediment monitoring and groundwater monitoring. The monitoring efforts and studies result in five or more publications per year provided to the Port and other state resource agencies.

SEISMIC STATION

A second broadband seismic station was installed in Western Maryland at Garrett College. This sensor is part of the Lamont-Doherty Cooperative Seismographic Network, which monitors earthquakes in the northeastern U.S. Data is fed into the Advanced National Seismic System operated by USGS. The earthquake stations continue to be one of the most viewed datasets on the MGS website.

DATA PRESERVATION

MGS continues to participate in the U.S. Geological Survey National Geological and Geophysical Data Preservation Program (NGGDPP). Thanks to NGGDPP funding over the last ten years, MGS has made great strides in preserving its geoscience collections—including creating a long-range data preservation plan, digitizing paper collections, creating detailed metadata for collection items, and submitting collection metadata to the National Digital Catalog online database. Recently, MGS finished scanning and inventorying all paper photographs in its Aerial Photograph Collection; ongoing tasks include finalizing internal collection databases, re-housing the photographs in archival-quality boxes and folders, and transferring the photographs to a Maryland State Archives (MSA) facility for permanent storage. MGS also recently completed a detailed inventory of its land-based core collection and started a detailed inventory of its drill-cuttings collection. In addition to data preservation activities tied to NGGDPP grants, MGS has been collaborating with MSA and the Johns Hopkins University (JHU) library to scan collections of MGS-produced historical maps and reports. This collaborative effort grew out of the formation of the MGS Data Preservation Advisory Panel (DPAP). The DPAP consists of geoscience professionals, librarians, and archivists who help MGS set preservation priorities and resolve technical preservation questions.

MASSACHUSETTS

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INTRODUCTION

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

The MGS remains a “soft money” organization hiring post-docs, research fellows, graduate students, undergraduates and contractors as needed to complete project work. The Survey receives no funding from the State. We have no support staff but rely on the Department of Geosciences for administrative help. The State Geologist is the only state-funded position. Currently, we have no benefited staff and our post-doctoral fellow ended his employment in November 2017. However, we have had 9

undergraduate students working with the Survey on various projects over the last year.

The Massachusetts Geological Services cost center is working well. The cost center allows us to do fee-for-service work and interact directly with consulting firms, private citizens, even other state agencies, without having to go through the University grants and contracts office. We have developed approved billing rates and have four product categories: Geologic Reports, Map Suites, Field and Site Services, and Lab Services. We currently have a large contract with the Massachusetts Department of Conservation and Recreation through the cost center. This allows the Survey to respond more rapidly to requests and provides greater flexibility in our operations.

GEOLOGIC MAPPING

Approximately 33 percent of all grant funding secured by MGS to-date is for geologic mapping, most of which comes from the NCGMP. We have been working through STATEMAP to update older

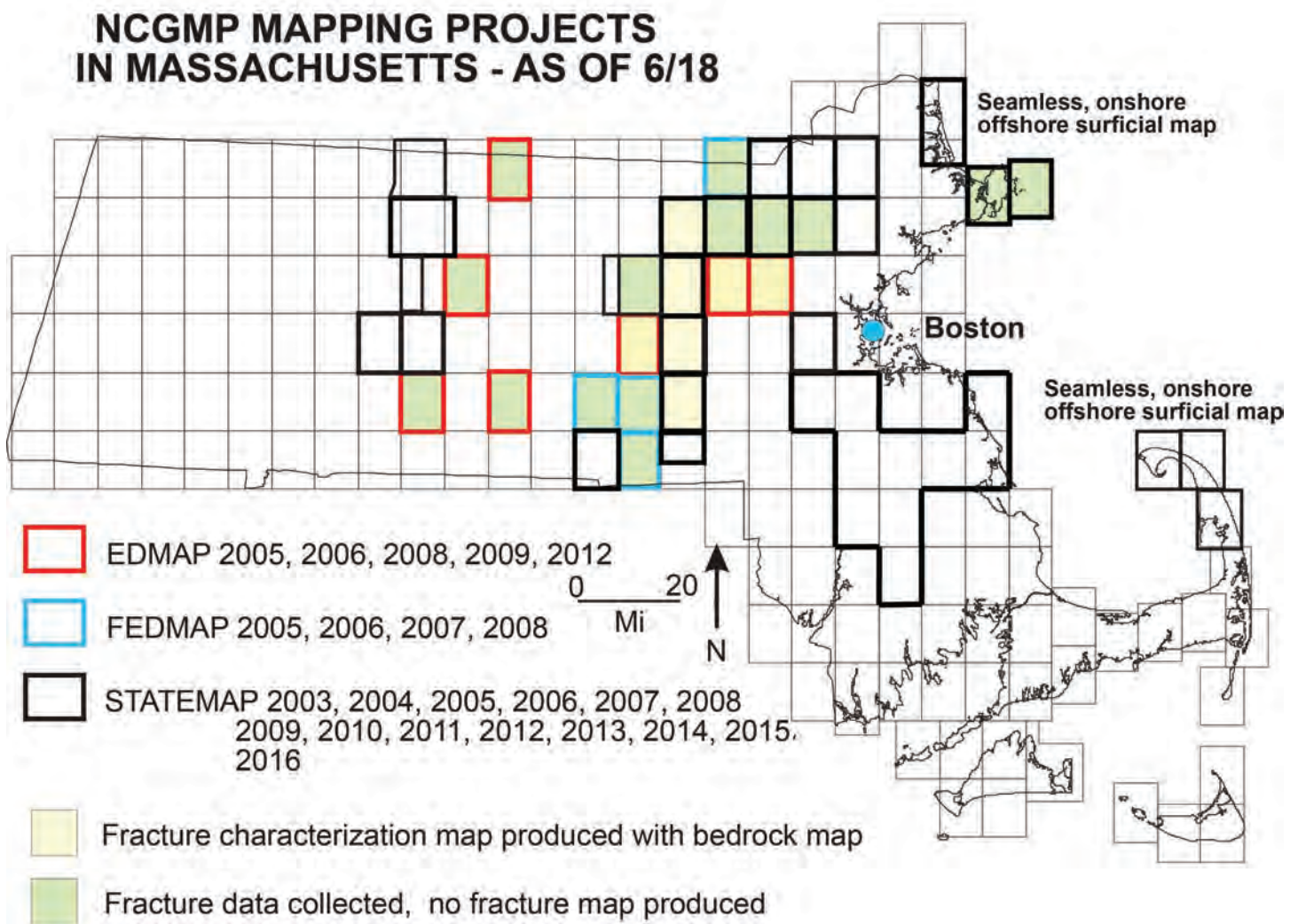


Figure 1. Map showing all NCGMP projects in Massachusetts since the Survey was established at the University in 2002.

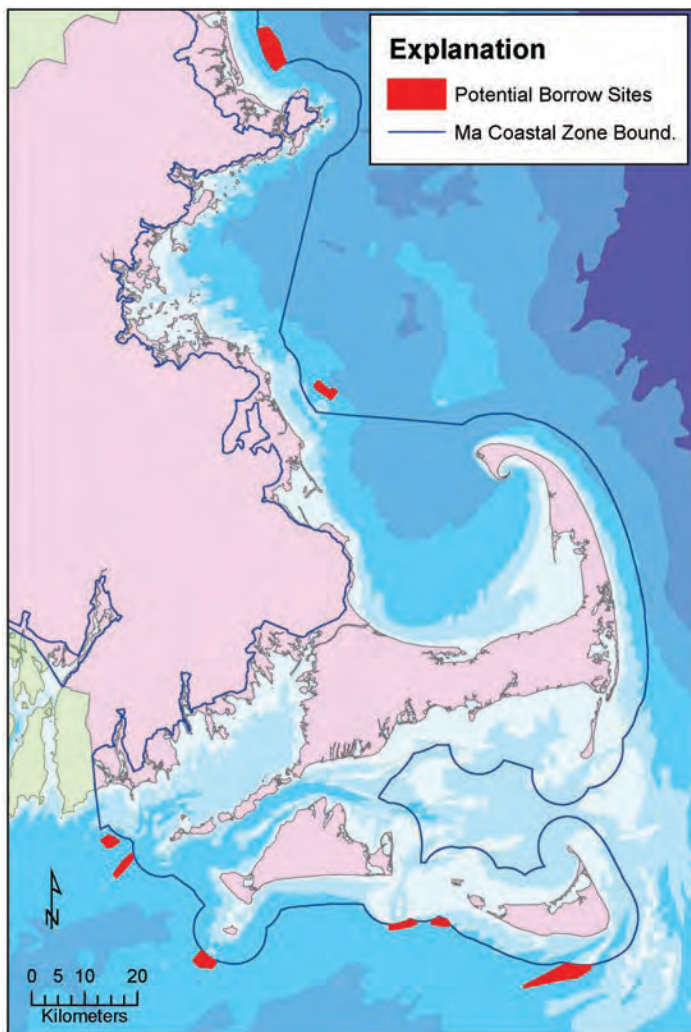


Figure 2. Location of potential offshore borrow areas being evaluated for possible beach nourishment.

and outdated bedrock geologic maps focusing on the eastern portion of the state, where development and stresses on water and other resources are greatest. A total of 46 geologic quadrangle maps have been completed or open-filed since 2002 using all three components of the NCGMP—35 STATEMAP products, four FEDMAP quadrangles and seven EDMAP products (Fig. 1).

Last year the MGS completed one map as part of STATEMAP: *Onshore-Offshore Surficial Geologic Map of the Wellfleet Quadrangle and Portions of Eastern Cape Cod Bay, Barnstable County, Massachusetts*.

MGS is currently taking a break from STATEMAP. The focus now is to work collaboratively with the USGS to complete two major statewide map products: *Surficial Materials of Massachusetts: A 1:24,000-scale Geologic Map Database* and the *Quaternary Geologic Map of Massachusetts*. The surficial materials map is 98 percent complete, having just completed USGS editorial review. A draft of the statewide Quaternary map will be submitted sometime in late 2018. Both map products will be based on 1:24,000-scale mapping. This represents the culmination of nearly 80 years of federal/state cooperative effort.

ENVIRONMENTAL GEOLOGY AND HAZARDS

MGS just completed a project with HMGP funding to improve the estimates of earthquake losses determined in HAZUS-MH by reclassifying the NEHRP soil categories in parts of Massachusetts using new 1:24,000-scale surficial geologic maps combined with the acquisition of shear wave velocity data. The goal of the project was to see if the combination of expert analysis afforded by new statewide surficial geologic mapping and shear wave velocity data produces different earthquake loss estimates when compared with other methods such as Wald and Allen (2007) or assuming all soils as NEHRP category D. Comparison of different soil classification methods using two earthquake scenarios indicates that direct economic losses and casualties are highest when shear wave data is combined with expert analysis and has the greatest contrast with the Wald and Allen method, which consistently underestimates the seismic risk.

The MGS is completing the final year of a project with funding from the Bureau of Ocean Energy Management to characterize sand resources at eight potential offshore sites for possible beach nourishment (Fig. 2). MGS analyzed vibracores, grab samples, bathymetry, side-scan sonar and seismic data at each site to map the extent, character, thickness, and volume, if possible, of any sand resources. The ultimate goal is to match the characteristics of beaches requiring nourishment with those of the



Figure 3. Drilling 70-foot replacement well on Cape Cod and installing 2-in. pvc casing.

offshore resources. Collaborators include the University of Massachusetts Department of Geosciences and the Massachusetts Office of Coastal Zone Management.

The MGS is also just completing a major study with MassDOT to develop a protocol and decision-support tool for assessing, prioritizing, maintaining, and upgrading road-stream crossings across the State. This is a pilot study that focused initially on the Deerfield basin in northwestern Massachusetts, an area that was hit hard by Tropical Storm Irene. The project is unique in that the protocol will examine road-stream crossings for vulnerability not only from a hydraulic standpoint, but also from a structural, ecological services, and geomorphic perspective. In addition, the vulnerability study incorporates climate change in the protocol using output from mid-century and end-of-century climate models. Road-stream crossings are also assessed in terms of their disruption to emergency services. Results have been put into an online data viewer (<http://sce.ecosheds.org/>) that allows users to explore overall vulnerability at a specific culvert or the risk at that culvert due to a single parameter.

This is a multi-disciplinary study involving the University of Massachusetts civil engineering, geosciences, and computer sciences departments, USGS Conte Anadromous Fish Research Laboratory, Trout Unlimited, and private sector consultants. MGS was responsible for the geomorphic assessments.

WATER RESOURCES

The MGS continues to contribute to the Climate Response Network, a network of over 70 wells used to monitor groundwater levels across the state. MGS monitors 19 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 Department of Environmental Protection. Some of these wells have been in service since the 1950s. The dataset 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.

Over the past year, the MGS, through its new Geological Services cost center, has been replacing some of the older wells in the network (Fig. 3). Many of these older wells have steel screens and casings that are failing or have collapsed. As of June 30, 2018, 27 wells in the network have been replaced (Fig. 4).

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

MGS is assisting the Department of Conservation and Recreation to convert its daily rainfall records to digital data. Massachusetts has 132 citizen-run rainfall stations that have paper records that date back to 1966. Students have been hired



Figure 4. Developing the newly installed well in Wakefield, MA.

to help with the digital conversion. So far, 92 stations have been converted.

ENERGY

With funding from the Massachusetts Department of Energy Resources, MGS explored the feasibility of space heating in some of our granites. Results from the DOE Geothermal Technologies grant to the AASG through the Arizona Geological Survey identified five areas in Massachusetts with higher heat production. MGS went back to these five areas and collected 40 more samples for XRF analysis and thermal conductivity measurements and to acquire temperature gradient data from 10 additional deep wells to improve estimates of heat flow. Results will be examined during this next year.

MICHIGAN

MICHIGAN GEOLOGICAL SURVEY

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INTRODUCTION

As of 2018, the Michigan Geological Survey (MGS) has been functioning at Western Michigan University, Geosciences Department for seven years. The base functions of the Survey at this time include geologic investigation of regional areas of the State, the collection and archival of samples, cores, and cuttings, and documentation of geological investigations in the state. 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 selective areas of the Upper Peninsula (UP). The MGS mission is to serve the people of the State and governmental entities, the Client.

MGS had received a \$500,000 legislative grant in 2016 to assess natural resources and received a second \$500,000 grant in October 2018 to further assess resources and conduct additional subsurface and surficial 3D mapping. The MGS has received multiple grants in the last 15 months totaling over \$800,000 to support the assessment of natural resources and both conduct research and compile geologic data in areas of Michigan where a new groundwater contamination issue is emerging—perfluoroalkyl substances (PFAS). MGS is extremely grateful for these two legislative grants, however, without an annual funding mechanism, MGS cannot hire full time staff. As a result, MGS is continuing to operate primarily on soft money, utilizing the expertise of the faculty members within the Geological and Environmental Sciences (GES) Department and local experts.

The MGS and all state surveys want to be recognized as the “go-to” resource for geologic information in the State and marketing our capabilities is number one. To meet this requirement, the MGS has established a more formalized structure of nine Resource Centers, MGRRE Sample and Data Repository, and Surface Mapping, Hydrogeology/Environmental, Energy, Economic Minerals, Geologic Hazards, GIS/Data Management, Outreach, and Remote Sensing sections to provide scientific information to the public and the state legislative body. To initially meet these goals, the MGS is utilizing the support of faculty members and outside resources until funding can provide hiring of permanent staff.

SURFACE MAPPING, GROUNDWATER, AND NATURAL RESOURCES

The USGS National Cooperative Geologic Mapping Program (NCGMP) has been actively funding state geologic mapping for over 25 years, which in all the U.S. states has been focused on critical-need areas. Michigan is now faced with a new groundwater dilemma: emerging contaminants, known as perfluoroalkyl substances (PFAS). Since early 2017, the identification of water resource impacts by this carcinogen has multiplied from 35 to hundreds and perhaps thousands of locations in just over a year, with confirmation analysis. This includes community and individual drinking water supplies. Michigan has little to no compiled geologic knowledge of the many natural resources that may exist

within its borders. Now the impacts of PFAS present the case that most technical experts cannot say where groundwater is flowing, because most of the subsurface geology has not been compiled and mapped in sufficient detail and consistency to predict direction and rate of flow, further evidence of the continuous lack of focus on geology. It would be relatively useless to show a map having PFAS locations, because the number and locations would change the next day.

MGS participates in both the USGS STATEMAP and Great Lakes Geologic Mapping Coalition projects under the direction of Dr. Alan Kehew. Emphasis in the two USGS mapping programs is now concentrated in areas of potential mineral resources in the Upper Peninsula and accurate geologic data to qualify water resources and aquifer characteristics in the Lower Peninsula (LP). This will also provide geologic data on aggregate locations and extent. The LP studies are being done with a refined 3D 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, wireline core and (or) geoprobe drilling program; downhole geophysical logs; and 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 dataset in assessing water-bearing strata and resource availability for high-production users, primarily the agricultural community, identifying glacial units that have a high probability of producing aggregate resources, and determined the groundwater flow direction and projected rate of flow. An expanded mapping program is being proposed to the State in sensitive high water-use areas and areas having need of future aggregate resources so that these areas can be identified and not be excluded from development by changing land use.

CURRENT ACTIVITIES

The Director, John A. Yellich, has continued a road program to introduce the “re-invented” survey to the client, and to meet the critical stakeholders in the State. This includes meetings with the Directors and Chiefs in the Governor’s Quality of Life departments of Environmental Quality (DEQ), Natural Resources (DNR), Agriculture (MDARD) and Great Lakes (OGL) and with local and regional economic development managers, business and municipal associations. The goal is to continue to identify the key geological issues currently facing the State of Michigan in all aspects of agriculture, industry, and rural growth. This includes identification, assessment, protection, and development, and data collection to support management of critical natural resources (i.e. water and aggregate resources in populated areas). Outreach has also included formal presentations and formal and informal meetings and discussions in a number of areas of the State for all stakeholders, general public, legislators and the K–12 science education requirements. Michigan has not been active in geological research for over 30 years.

MGS has had productive discussions during the past three years with the USGS Mineral Resources and Mapping groups

in both Reston, VA. and Denver, CO. These discussions have resulted in offering moral and technical support for an August 2018 completed aeromagnetic survey in the UP of Michigan, the first open file report on geophysical data for Michigan in decades. The second opportunity is a 2018 collaborative program for a FEDMAP project in the Michigan Lowland Basin, which will include the Indiana, Illinois, and Wisconsin geological surveys.

MGRRE—SAMPLE AND DATA REPOSITORY

The Michigan Geological Repository for Research and Education (MGRRE), which has functioned for over 30 years under the direction of Dr. William Harrison III, continues to be the strength of the MGS. Many requests for data review have occurred over the last 30 years at MGRRE and 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 Labs and the 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 seven million barrels of entrained oil, providing millions of dollars in additional revenue for the Michigan economy. MGRRE continues to receive funding for core and data storage from industry donations. MGS and MGRRE are continuing to research and study CO₂ sequestration in Michigan through a DOE grant that has three years remaining.

MGRRE has received grants from the National Geological and Geophysical Data Preservation Program (NGGDPP), which has been functioning for nearly 10 years. For the past few years of grant funding, the project scanned and inventoried 1,178 gas chromatograph analyses. Paper copies of the data were reviewed for clarity and organized for scanning and data entry. These hydrocarbon analyses provide near-immediate access to data, which can now be used to identify prospective wells and zones for secondary oil recovery and for safe underground CO₂ storage. Additionally, a state university was going to send their sample suites and cores to the dump and MGRRE rescued them two years ago. These are samples not seen for over 30 years or more and they are being cataloged and located into the MGRRE public database. There was no inventory of how many wells and core data were rescued, so we are compiling that data right now.

The USGS recognized MGRRE as a national “poster repository” for the USGS National Geologic and Geophysical Data Preservation Program (NGGDPP), 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 MGRRE. NGGDPP funding allowed MGRRE to catalog the core and data, which was then placed on the MGRRE website. This archived data resource was identified on the MGRRE website by a prospective mineral mining company/developer. The developer

came to MGGRE to examine the core and have it analyzed, which resulted in the 2013 re-discovery of the purest quality potash in the U.S., deposited at 7,500 ft beneath the surface, located in Osceola and Mecosta Counties. This natural resource asset has an estimated in-place value of \$65 billion dollars, and is currently in the pre-development and final permitting process. Below is the USGS article/link, January 2017:

<https://www.usgs.gov/center-news/mineral-discovery-could-mean-billions-michigan>

OIL AND GAS

MGS, through the Resource Center at MGRRE, continues to be associated with the Petroleum Technology Transfer Council (PTTC), which conducts day and multi-day workshops on oil and gas production technologies in Michigan and which had one conference in 2018. These workshops and conferences focus on relevant topics in the petroleum industry and are attended by over 150 industry professionals.

GROUNDWATER RESOURCES & ENVIRONMENTAL QUALITY AND ENERGY

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

GIS DATA MANAGEMENT AND MGS STORE

There are many maps and documents that are being input to MGS data management systems. The new functioning role of the MGS has been initiated and it includes preparing documents and maps for distribution and sale through the MGS website. The MGS continues to search for many older Michigan publications and paper resources that can be input to the document archives and made available to the scientific community and general public. MGS has also compiled a publications bibliography on Michigan geology from every library, university, or public resource in the U.S.. There are currently over 7,000 publications, many of which have not been seen for years. Their locations have been noted in the bibliography found on the MGS website.

OUTREACH AND K-12 PROGRAM

The K-12 program at MGS-MGRRE has had increasing interest by the Michigan education community under the direction of Dr. Peter Voice. The emphasis is the importance of Earth science education starting with elementary students, but has greater emphasis on models and demonstrations for our middle and high school students. Many teachers are now turning to the educational resource 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 four and a half years to approximately 81,500 contacts and the response from adults at gem and mineral shows has increase dramatically. The Coordinator and staff have made over 17,000 contacts in the last budget year and current expectations are that we will meet last year's contact numbers in the next year. Teachers are seeing the benefits of this program and the MGS hopes to incorporate this into the state K-12 program going forward.

MINNESOTA

MINNESOTA GEOLOGICAL SURVEY

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Phone: (612) 626-2969



INTRODUCTION

The Minnesota Geological Survey is a department in the N.H. Winchell School of Earth Sciences, College of Science and Engineering, University of Minnesota, charged by its enabling act of 1872 to investigate the geology of Minnesota and provide geological information to the Legislature and the public. The Director of the Geological Survey is, by tradition, a professor in the Department of Earth Sciences.

The Minnesota Geological Survey (MGS) carries out its mission through geological mapping and related studies that either contribute to the mapping effort or derive from it. Sediments deposited by Quaternary glacial processes cover the rock almost everywhere in the State. Because the Quaternary sediments and rock that they cover are both of economic and environmental significance to society, geologic mapping in Minnesota most often entails the production of a surficial geologic map, a bedrock geologic map, and a suite of products that describe the sediment and sedimentary rocks in three dimensions. Most MGS products are County Geologic Atlases that provide a framework for hydrologic analysis, and descriptions of water levels, chemistry, age, and sensitivity to contamination. Those products are created by our colleagues at the Department of Natural Resources (MnDNR).

GEOLOGIC MAPPING

One of our mapping goals is 1:500,000-scale statewide maps of bedrock geology, surficial geology, bedrock topography, and cross sections of Quaternary stratigraphy, all at reasonably up-to-date status. These are supported by geodatabases of outcrops, geophysics, geologically interpreted water well construction records, karst features, springs, shallow Quaternary borings, textures, grain lithologies, geochemistry, and geochronology. We are creating a new statewide surficial geology map that is about 90 percent complete as a result of support from the Great Lakes Geologic Mapping Coalition.

Another goal is a statewide set of county geologic atlases at 1:100,000 scale that include comprehensive geologic mapping (surficial, bedrock, bedrock topography, Quaternary stratigraphy, Quaternary sand distribution models) at planning and management scales. The data derived from these mapping efforts go into the databases described above. The atlases are essential to the operations of county and state agencies that manage water and mineral resources, and are written into the plans for sustainable management of water in Minnesota. We have 15 atlas projects underway including work in northeastern Minnesota that will support economic and environmental considerations regarding proposals for mining in that region.

All of our maps and publications are available digitally, many as GIS files, and map GIS files typically include digital surfaces of significant geologic unit boundaries in three dimensions.

GEOPHYSICS

Minnesota's statewide-high resolution aeromagnetic and gravity data are applied to virtually all mapping projects that include Precambrian rocks. Seismic refraction work, conducted in cooperation with MnDNR, is used to determine depth to bedrock for the County Geologic Atlases, as is a passive seismic technique that is much faster, easier, and less expensive. We continue to develop passive seismic interpretive methods specifically for the geology of Minnesota.

Borehole geophysical logging, including flow meter logging, is also active. That program has logged more than 7,329 holes spanning more than 2.5 million ft of strata. We continue to manage and update the digital infrastructure of these logs using funds awarded from the National Geological and Geophysical Data Preservation Program (NGGDPP). Data from about 878 multi-parameter logs, 761 caliper logs, 207 electromagnetic (EM) flow meter logs, and 210 borehole video logs have now been properly inventoried and archived in digital formats suitable for long-term use and efficient dissemination. Metadata was generated for 7,950 unique geophysical log collection events (including natural gamma logs), which will soon be made available on the USGS Science Base Catalog (Collection of Borehole Geophysical logs from MN) and by request. We are currently finalizing a web-based map of our borehole geophysical database that will allow users to view and download PDF and Log ASCII Standard (LAS) files for available logs in our collections. This web-based map will be made accessible through our website in the coming months.

GEODATABASE DEVELOPMENT

The County Well Index (CWI), a database of water-well records and geologic interpretations of them, now contains more than 535,000 records. The CWI database is widely used by state agencies, local government, contractors and consultants. MGS focuses on the content of the database, providing accurate digital locations of the wells, and stratigraphic interpretations, typically associated with a county geologic atlas project. The Minnesota Department of Health is a partner in operating this database and they recently completed work to rebuild the software and create a new user interface for this heavily used database <http://www.health.state.mn.us/divs/eh/cwi/>.

HYDROGEOLOGY

MGS conducts research to promote understanding of the water-bearing characteristics of the geologic units of Minnesota. A variety of techniques are applied, including geochemistry, geochronology, distributed temperature sensing, and borehole measurements including flow meter logging, pressure and temperature monitoring, and pumping tests. These provide insights into flow characteristics that can then be applied to aquifer

management by utilizing our geologic mapping. Currently we are investigating fracture flow in the Platteville Formation, the effects of geologic setting and groundwater discharge on brook

trout populations, and we are supporting work by the USGS to investigate the hydraulic conductivity of glacial tills.

Status of County Geologic Atlas Part A July 2018

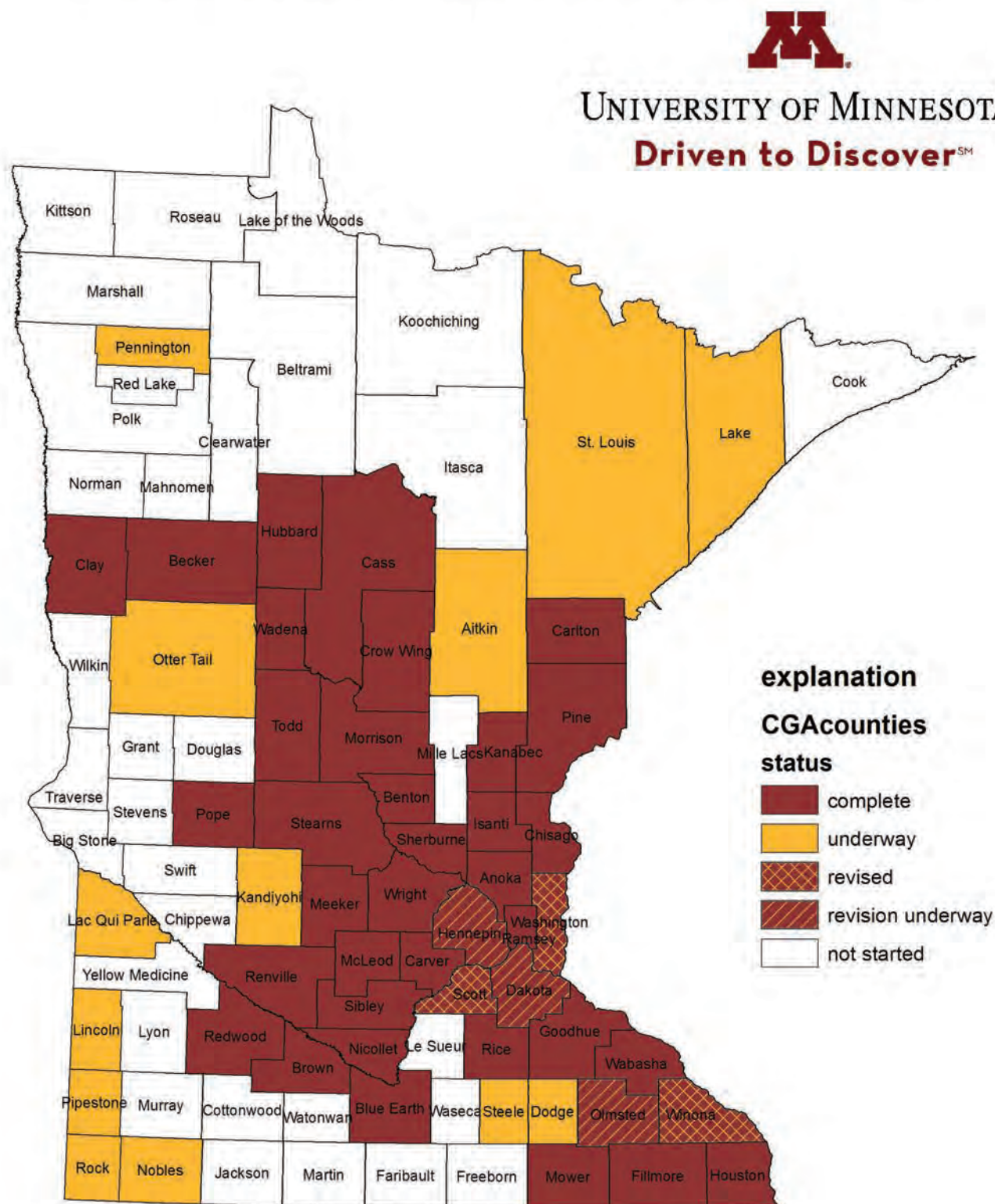


Figure 1. Status of the County Geologic Atlas Program in 2018

MISSISSIPPI

MISSISSIPPI OFFICE OF GEOLOGY

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Mississippi Department of Environmental Quality
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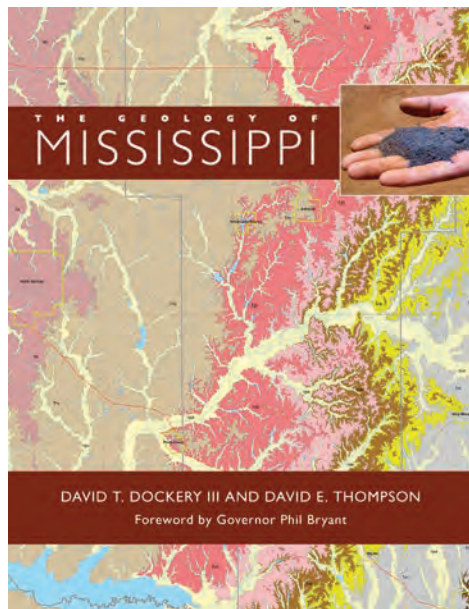


Phone: (601) 961-5544



INTRODUCTION

During FY18 the Mississippi Office of Geology continued research into the surface and subsurface geology, paleontology, and mineral resources of Mississippi; regulatory responsibilities for surface mining and reclamation also continued. The Office of Geology is a component of the Mississippi Department of Environmental Quality, and our staff interacts extensively with personnel of the water management and pollution control offices. The State Geologist is a member of the Environmental Quality Permit Board. Our recent book on *The Geology of Mississippi* (2016) at 751 pages, half a million words, 1,099 figures, and in color and hardbound is a must-read for the State's geology, Gulf Coastal Plain geology, and North American geology (available from our Publication Sales, University Press of Mississippi, and Amazon.com).



GEOLOGIC MAPPING

Geologic maps of Mississippi created by Office of Geology staff are fundamental to characterizing the environment and have applications in water resources, pollution prevention, mineral resources, and protecting property from geologic hazards such as landslides, swelling clays, and floods.

The geologic mapping program for FY2018 was funded in part by a USGS State Geologic Survey Mapping (STATEMAP) grant of \$63,555. The STATEMAP component establishes the geologic framework of areas that are vital to the welfare of individual states. Each State Geologist determines the state's mapping priorities in consultation with a State Mapping Advisory Committee. These priorities are based on state requirements for geologic map information in areas of multiple-issue needs or compelling single-issue needs and in areas where mapping is required to solve critical Earth science problems.

Deliverables for the STATEMAP grant include the Pascagoula North, Three Rivers, and Harleston 7.5-minute quadrangles in southeastern Mississippi, published in color at a scale of 1:24,000. A "quadrangle" refers to a USGS 7.5-minute quadrangle map, which are typically named after a local physiographic feature. Geologic units mapped and correlated in the subsurface on the maps' associated cross sections, include the Miocene-age Pascagoula Formation, the Pliocene-age Graham Ferry Formation, Pleistocene-age coastal and river terraces, and Holocene-age alluvium.

A composite geologic map of Jackson County including portions of George, Stone, and Harrison counties were published, compiling the last three years of STATEMAP grant work in Southeast Mississippi, in cooperation with MDEQ's Office of Land and Water Resources.

PUBLICATIONS

MDEQ's Office of Geology staff published twenty-seven geologic papers in FY18. These include five articles in *Environmental News*, nine articles in the *Mississippi Geological Society Bulletin*, seven abstracts in the *Journal of the Mississippi Academy of Sciences*, a paper in *Southeastern Geology*, two abstracts in the *Botanical Society of America*, and three geologic quadrangle maps as Open File Reports OF 287-289.

Great progress was made this year in our continued efforts to scan existing Office of Geology literature that either is out of print or only exists as paper copies. Much of this important, but previously unavailable literature is essential for site characterization, groundwater aquifer assessments, and geological background. It is now available for free download on our MDEQ website in a high-quality, searchable PDF format.

FLOOD MAPPING

The mission of the Geospatial Resources Division is focused on remote sensing and geographic information systems activities for the State of Mississippi. The division manages the Mississippi Flood Map Modernization Initiative (MFMMI) and the Mississippi Risk Mapping, Assessment, and Planning (Risk MAP) Program.

The Federal Emergency Management Agency (FEMA) began its new Risk MAP program in 2010. The Risk MAP program develops and updates digital flood insurance rate maps (DFIRMs) for the 82 counties under funding by FEMA. The program has shifted to Hydrologic Unit Code 8 (HUC_8) sub-basin flood studies, while adding flood risk assessment, flood hazard mitigation, and planning activities and products. As of mid-2017, there are ten HUC_8 Risk MAP projects and one LAMP (Levee Analysis and Mapping Procedure) project on the Tennessee-Tombigbee Waterway in northeastern Mississippi. Preliminary mapping for Monroe and Itawamba Counties was released to the local communities in December of 2016 and are expected to become effective in early 2018. This project is one of 25 pilot LAMP projects for mapping

Association of American
State Geologists



Mississippi
Department of
Environmental
Quality



United States
Geological Survey

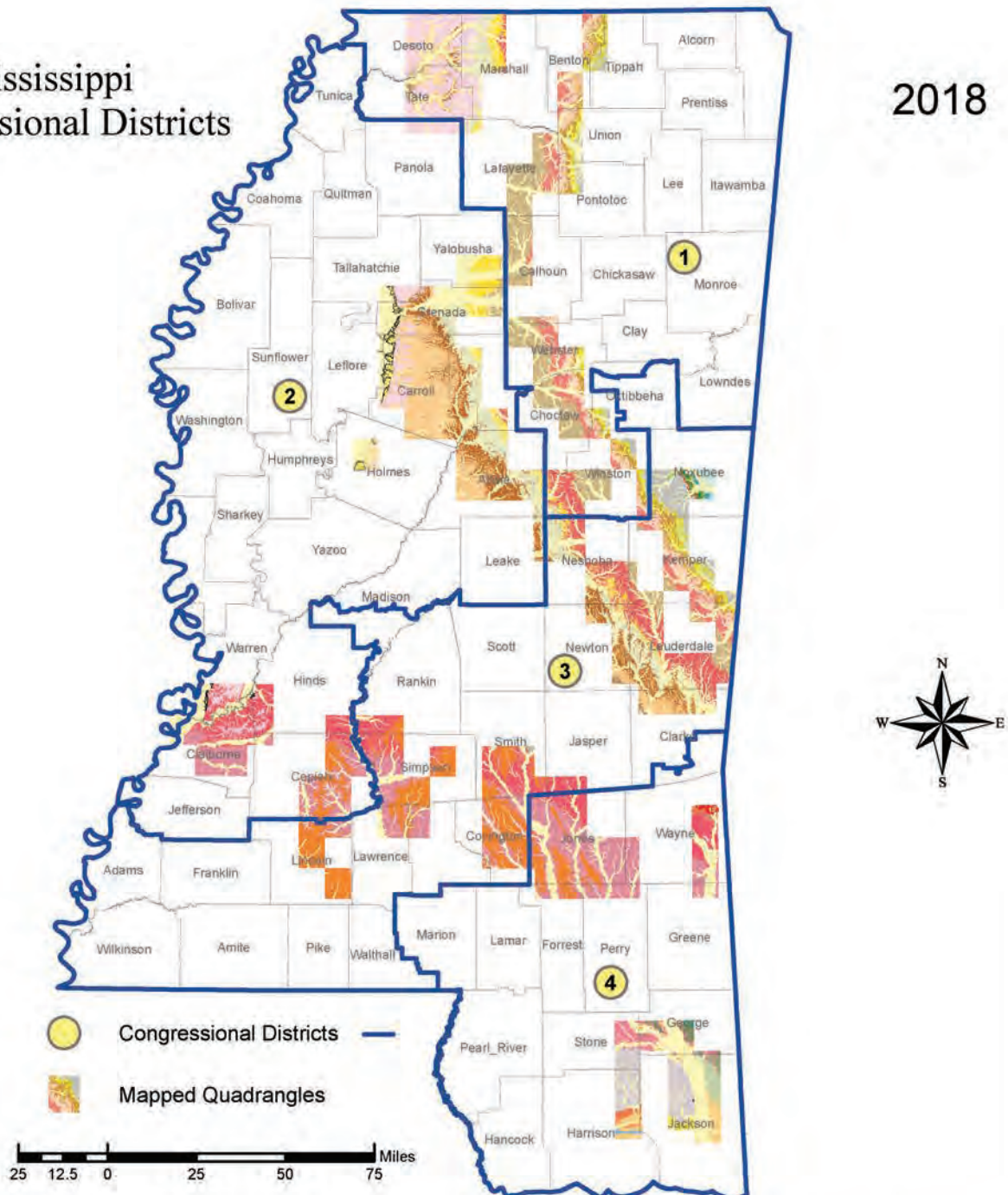


National Cooperative Geologic Mapping Program

STATEMAP Component: States compete for federal matching funds for geologic mapping

Mississippi Congressional Districts

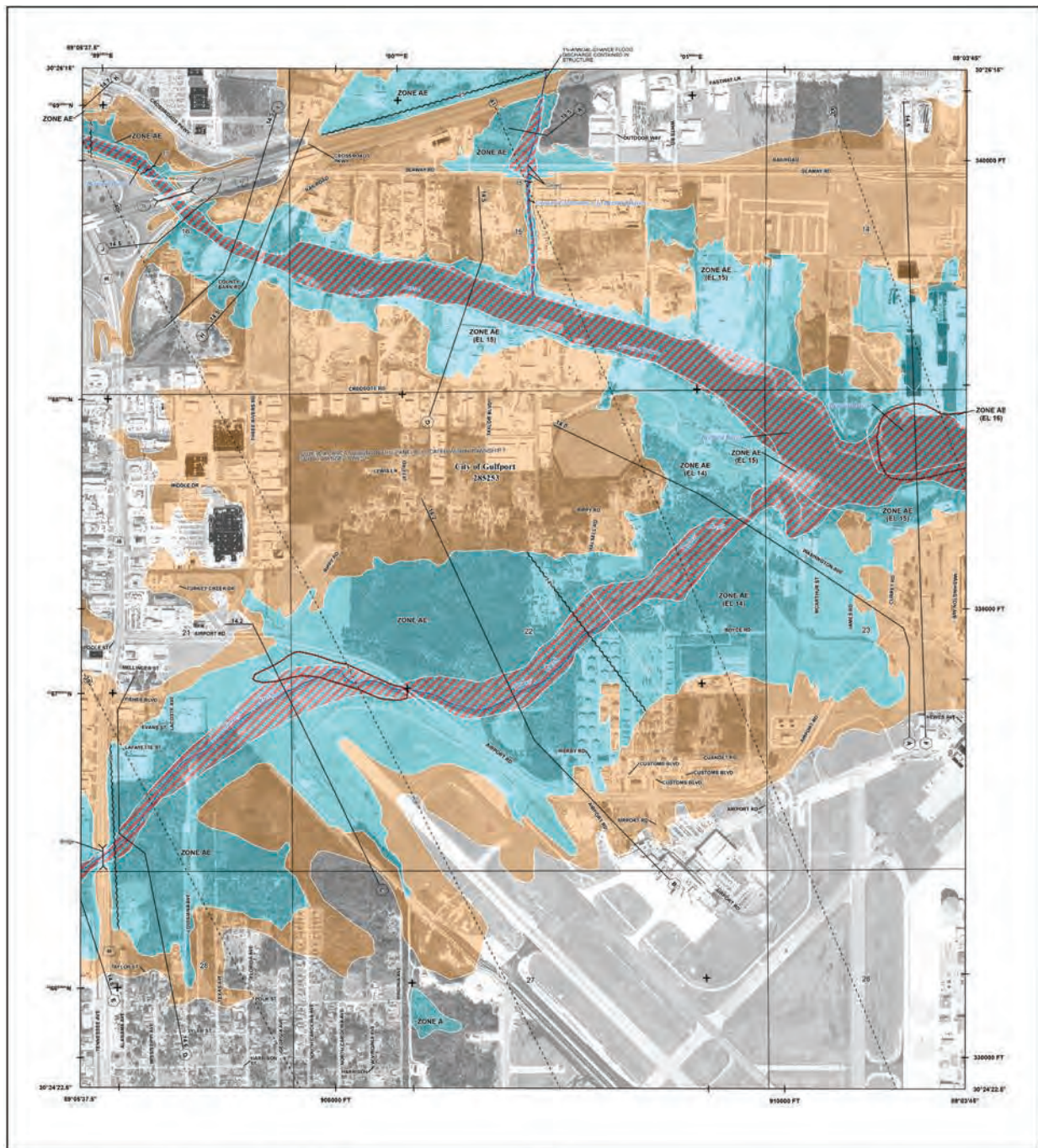
2018



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<http://www.deq.state.ms.us>

National Cooperative Geologic Mapping Program
United States Geological Survey
Program Coordinator: John Brock (703.648.6053)
Associate Program Coordinator: Darcy K. McPhee (703.648.6973)
Program Analyst: Michael J. Marketti (703.648.6976)
<https://ncgmp.usgs.gov/>



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT
 THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING
 DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT
[HTTP://MSF.FEMA.GOV](http://msc.fema.gov)



NOTES TO USERS

For information and questions about this map, available products developed with the FIS, including those
 versions of the FIS, from the information on the National Flood Insurance Program or general information on
 the FIS, visit the FIS website at msc.fema.gov or call the FIS Service Center at 1-877-226-2627. For more information on the FIS, visit the FIS website at msc.fema.gov or call the FIS Service Center at 1-877-226-2627. For more information on the FIS, visit the FIS website at msc.fema.gov or call the FIS Service Center at 1-877-226-2627.

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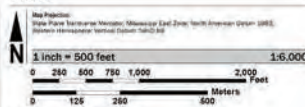
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SCALE



PANEL LOCATOR



FEMA
 National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
 FLOOD INSURANCE RATE MAP
 HARRISON COUNTY,
 MISSISSIPPI
 Panel 262 of 575

FEMA
 National Flood Insurance Program

PRELIMINARY
 FEB 23 2018

VERSION NUMBER
 2.3.3.3
MAP NUMBER
 28047C0262H
MAP REVISION

de-accredited levee systems chosen by FEMA from across the nation.

A website for the MFMMI is available for public and local government officials to learn the status of each county's DFIRM mapping project. In addition, when a county's new preliminary flood maps are available, the public and local government officials will be able to download and review individual DFIRM map panels.

MISSISSIPPI DIGITAL EARTH MODEL

MDEQ is involved with the Mississippi Coordinating Council for Remote Sensing and Geographic Information Systems, which sets policies and standards that promote the sharing of information, as well as facilitate the cost-sharing potential. The Council is also charged with oversight of the development of the Mississippi Digital Earth Model (MDEM).

The Office of Geology is responsible for MDEM's development, and the Geospatial Resources Division handles the assignment. MDEM consists of developing digital geographic information that will serve as the state base map. MDEM consists of eight layers of digital information that will be available online: (1) geodetic control; (2) elevation and bathymetry; (3) orthoimagery; (4) hydrography; (5) transportation; (6) government boundaries; (7) cadastral; and (8) the Gazetteer. MDEQ is responsible for the management and monitoring of MDEM data development contracts and the Quality Assurance of the MDEM mapping products

that result from this work. Products from this work may be used by state and local governments, engineering firms, and construction companies involved in planning, development, construction, or regulatory work throughout the state. During FY18, MDEQ continued monitoring and managing contractors completing work on MDEM datasets. These data included hydrography, elevation/topography lidar data, and high-resolution orthoimagery covering different areas of the State. In FY18, the Geospatial Resources Division took delivery of new high-resolution orthoimagery for 10 counties and made a significant effort in quality assurance for high-resolution hydrography covering multiple HUC_8 watershed in southern and southeastern Mississippi. All data developed are of MDEM quality and will be made available for distribution through the Mississippi Geospatial Clearinghouse website.

SURFACE MINING AND RECLAMATION OF SURFACE-MINED LANDS

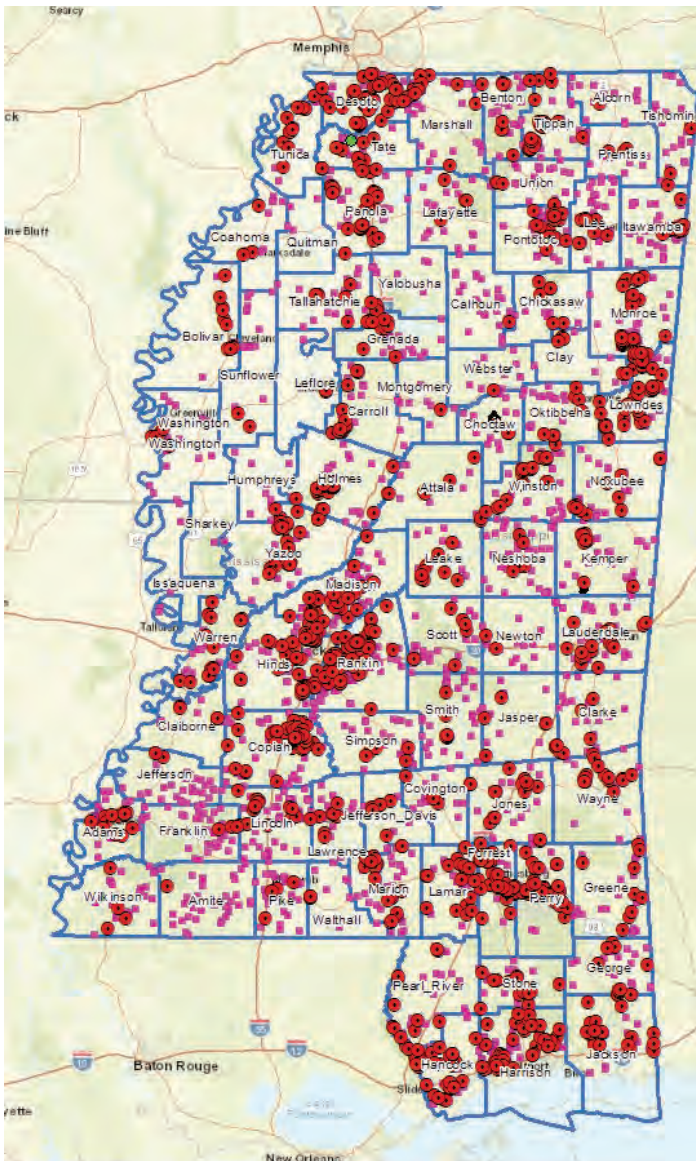
Reclamation Objective: Ensure lands impacted by mining activities are restored to reclamation standards that are protective of human health and the environment.

MDEQ regulates all non-coal surface mines in the State as provided for in the Mississippi Surface Mining and Reclamation Act of 1977. This includes issuing surface mining permits and notices of exempt operations, inspecting permitted areas and complaints, overseeing the reclamation performed by operators, and enforcing the law as per the promulgated Rules and Regulations and Commission orders. Additionally, coal and lignite mines are regulated under the Mississippi Surface Coal Mining and Reclamation Law of 1979, with oversight of the program by the federal Office of Surface Mining (OSM).

In FY18, the Mining and Reclamation Division performed 711 inspections (of which 106 were bond release inspections), recommended to the Permit Board the issuance of 14 initial and 14 amended permits, and received 61 Notices of Exempt Operations (operations less than four acres in size). A total of 2,065 exempt operations are on file, covering approximately 8,260 acres. A total of 1,162 bonded acres were completely reclaimed as a result of the Division's efforts to oversee reclamation. The State currently has 651 permits covering approximately 35,010 acres. The Office of Geology's Mining and Reclamation Division continues to update the mining database that provides valuable mining information in a GIS format so mining sites can be located and viewed by anyone using the online Mining Viewer.

The Mining and Reclamation Division provides the required Mine Safety and Health Administration (MSHA) training for mining operations in the state. MSHA regulations require an eight-hour refresher training course for all mine workers. In FY17, staff provided training to 110 miners and 63 contractors working in the mining industry.





The Mining and Reclamation Division continues to focus on the complexities of coal mine regulation. Mississippi has an industry-estimated five billion tons of surface mineable lignite, a low-grade coal ranked just below sub-bituminous coal. The Mississippi Lignite Mining Company is mining lignite at the Red Hills Mine in Choctaw County to supply fuel for an adjacent 440-megawatt (MW) mine-mouth power plant. The mine produces over 3.5 million tons of lignite per year and has permitted 6,090 acres. This permit was initially issued in 1998, and was renewed in February 2018. The planned life of the mine is 30 years.

The Liberty Fuels, LLC mine permit in southwestern Kemper County was issued in December 2011 for 2,299 acres. This permit was renewed in 2016. The Liberty Mine was to produce an average of 2.2 million tons of lignite per year for the initial five-year term, and 4.5 million tons per year for the planned 40-year life of the mine. In 2017, Mississippi Power Company discontinued the coal gasification process and elected to operate the power plant strictly on natural gas. The Liberty Mine has ceased all mining activities and has scheduled meetings with Mining Division staff to discuss permanent closure and reclamation of the mine. In the

summer of 2018, MDEQ approved a modification to the permit, fostering the reclamation of the site.

Staff inspections of both coal mines are conducted at least monthly. One or more joint inspections of each mine are conducted annually with OSM. One permit revision and one permit modification were finalized during FY18. It is anticipated that at least three applications for permit revisions will be submitted during FY19. At least two bond release applications are anticipated during FY19.

Work under Mississippi's Abandoned Mine Land Program to identify and locate abandoned historic coal mines has identified four sites—two in Choctaw County and one each in Winston and Lauderdale counties. All of these sites are believed to have been active sometime in the period from the mid- to late 1800s to the late 1920s. Necessary reclamation work at the sites is complete.

ENVIRONMENTAL GEOLOGY

Since the 1950s, the Office of Geology has been collecting subsurface geological information by sending scientific instruments down test holes and water wells to record data on the rocks and groundwater (wireline logging). In FY18, geologists have wireline logged a total of 54 test holes and water wells in 27 Mississippi counties (total footage logged of 25,870 ft). Eleven water well contractors, two state agencies, one water management district,



and two federal agencies have taken advantage of this essential program. The shallowest test hole wireline logged (total depth of 110 ft below ground surface) was drilled in coordination with the Office of Land and Water Resources as a MRVA monitoring well. The deepest test hole wireline logged was drilled to a total depth of 1,930 ft for Mid-South Water. Private wells comprised almost half of those wireline logged, followed by wells for industrial and commercial entities. The log files produced by these wireline logging activities are an essential data reference for investigations of geology, water resources, potential for contamination, and mineral resources.

This year, the Environmental Geology Division's drilling program assisted two MDEQ offices, a federal agency, and a local water management district in attaining subsurface geological and hydrological data. Nine test holes were drilled by the Division's drilling crew in support of mapping activities for Surface Geology division's USGS STATEMAP grant in Jackson County and for the Office of Land and Water Resources and their continuing Delta Drilling Project. The nine test holes were drilled to a cumulative depth of 1,770 ft and were all logged by the Division's wireline logging program. Three of the drill holes in the Delta had monitoring wells installed. These wells were set with 500 ft of casing.

Staff analysts pulled, shipped, and refiled samples for seven geoscientists during FY18. These visitors to the Core and Sample Library included three in-state universities, as well as members of the oil and gas industry. These researchers looked at approximately 320 boxes of cores and cuttings that comprised 66 different boreholes totaling 72,350 ft of samples. Staff re-boxed 85 boxes of cores samples representing 13,620 ft of core and cuttings, received two pallets, and archived 45 boxes of new core samples. In addition, sample splits were provided to researchers amounting to approximately 9,300 ft representing 21 wells.

MISSOURI

MISSOURI GEOLOGICAL SURVEY

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INTRODUCTION

The Missouri Geological Survey (MGS) was established in 1853 through an act established by the general assembly allowing the governor to appoint the first State Geologist. The State Geologist was allowed to select several staff to initiate a thorough geological and mineralogical survey of the state. Fast forward 163 years to see that MGS continues this mission by collecting and distributing information about Missouri's water, mineral, and energy resources. The Survey also provides Earth science information and services that support stewardship and beneficial use of Missouri's natural resources and that benefit public health and safety. MGS supported this work in FY18 by employing 116 FTE that utilized a budget of \$13 million. Functions of the Survey include geologic mapping, geologic resource assessment, groundwater protection through well construction, groundwater level monitoring, major water use monitoring, surface water observation and planning, dam and reservoir safety, and mined land reclamation. Goals for the year included coordination and collaboration of critical natural resource issues; providing better service; and balancing financial, scientific and strategic coordination. These efforts better position the state for safe and timely resource assessment, protection, development, economic viability, and natural hazards planning.

MGS headquarters is located in the city of Rolla, where the majority of staff have official domicile. Most of the core geologic functions are based at that location. This includes the Geological Survey Program, Dam and Reservoir Safety Program, and groundwater functions of the Water Resources Center. Land Reclamation and surface water resource functions are based in DNR's main office building in Jefferson City. The McCracken Core Library and Research Facility is located off-site within a few miles of the Buehler Building in Rolla.

GEOLOGICAL SURVEY

Amber Steele recently became director of the Geological Survey Program, overseeing the activities of three groups with unique disciplines and 40 total staff.



Figure 1. Photo of the Buehler Building that houses MGS headquarters in Rolla, Missouri.

Missouri State Rock: Mozarkite
Missouri State Mineral: Galena
Missouri State Fossil: Crinoid

Geologic Resources

This section of 11 staff supports traditional geological activities, including geologic mapping through the National Cooperative Geologic Mapping Program, mineral and energy resource assessments, and data collection management and preservation. Staff conducted geologic mapping activities in central Missouri to support infrastructure and transportation needs among many others. Other information collected and managed involved industrial and metallic minerals, coal, geothermal, hazards, mining, and bedrock core and cuttings stored in the McCracken Core Library and Research Center. The core facility accepted 25,981 additional feet of core and cuttings in 2018, a decrease of 12 percent compared to FY17. Staff supported activities of the State Oil and Gas Council, Industrial Minerals Advisory Council, and the Geologic Mapping Advisory Committee.

Environmental Geology

This section of 14 staff provides geologic and hydrologic support for solid and liquid waste disposal, and remediation of hazardous waste sites where aquifers have been impacted. Staff evaluated the geologic characteristics of 107 proposed animal and domestic wastewater treatment systems and 36 solid waste disposal sites for potential groundwater impacts. They investigated petroleum-contaminated sites to locate the source of the contamination where aquifers have been degraded. They conducted 92 geologic evaluations of sites where hazardous wastes are present or suspected, including Superfund, RCRA, Federal Facility, and Voluntary Cleanup Program sites. In addition, 67 geologic hazards assessments involving karst features or mine collapse were conducted.

Well Installation

This section of 13 staff oversees construction and plugging of wells associated with water use, monitoring, minerals, and ground source heat pumps through regulatory standards. The section provides technical assistance on well construction, aquifers, and hydrology to thousands of businesses, farmers, and citizens on an annual basis. This year they conducted oversight of 4,645 newly drilled wells and 2,259 well pluggings. Fees charged for well installation support this section.

LAND RECLAMATION

The Land Reclamation Program is managed by Larry Lehman. It ensures proper stewardship of Missouri's resources during and



Figure 2. Mapping and field analysis using the latest technology.

after surface mining of minerals. Activities include issuing mining permits, conducting inspections and responding to complaints, overseeing construction of restoration projects for surface coal-mined lands, and overseeing construction of the permanent sealing of dangerous mineshaft openings for both coal and metallic mining activities. The 17-person program does this through the three overarching disciplines described below.

Industrial Minerals

The Industrial and Minerals Mining Unit of four staff provides support and oversight to more than 800 industrial mineral operations that mine aggregate for residential and commercial use. The program issues permits and performs inspections for coal and industrial minerals (barite, tar sands, clay, limestone, sand and gravel, granite, trap rock, etc.). This unit also implements the Metallic Minerals Waste Management Act (lead, iron, zinc, copper, gold and silver), which regulates the metallic minerals waste management disposal areas of mining operations.

Abandoned Mine Lands

The Abandoned Mine Land and Permit Unit utilizes seven staff to oversee the implementation of the Surface Mining Control and Reclamation Act (SMCRA). This group designed three new coal reclamation projects, passing \$1,825,771.35 to contractors for recovery of private lands from past coal mining activities. They also worked to remediate seven dangerous metallic mineral mine shafts at a cost of \$100,146.81.

Coal Mining

The Projects and Inspection Unit consists of two staff that provide oversight services to coal companies through permits to comply with department of interior SMCRA permitting and inspection requirement. Coal production has declined to a \$15 million industry in Missouri.

WATER RESOURCES

The Water Resources Center is managed by Jennifer Hoggatt and supported by 22 staff. The mission is to understand water stor-

age and availability based on water use needs, and protection vulnerabilities. This is implemented through the four overarching areas described below.

Big River Basins

The Center protects the interests of Missouri citizens as it relates to planning, operation, and use of the Mississippi and Missouri Rivers. Those staff engage in discussions with other states, federal agencies, and stakeholders to provide information, inform citizens, and make timely decisions regarding the State's policy on interstate water issues. The Center actively works to provide citizens security regarding adequate flood control and navigation flows on the Missouri River.

Comprehensive Statewide Water Planning

Work to wrap up a multi-year, comprehensive update to the Missouri Water Plan continues, and will conclude in fall of 2019. The Missouri Water Plan inventories water use and availability, projects future water needs, and gathers stakeholder input to develop water resource priorities. This update will help to ensure that the quality and quantity of water resources in Missouri meet future needs. The plan will provide recommendations for projects and initiatives to implement at a state and local level, and will continue to serve as a guide for water resource decision-making, setting a clear vision for water resources management for our state over the next 30 years.

Water Supply

The Center provides financial, technical, and planning support for regional water supply projects. It fulfills a unique and critical role in the study of regional water needs and provides direct financial and technical assistance in the planning and development of regional water supply projects. Over the last four years, the center provided assistance to develop two new drinking water reservoirs in north Missouri, a wholesale water pipeline project, and studies for a large water resources coalition in southwest Missouri.

Groundwater

The Center provides real-time data regarding groundwater levels through one of the largest groundwater observation networks in the nation, with 149 wells. It also tracks major water use across the state.

DAM AND RESERVOIR SAFETY

This program is overseen by Ryan Stack and supported by three additional engineers and two support staff. The mission is to protect public safety through oversight of dam and reservoir construction, operation, and maintenance. It provides critical information to emergency responders and field staff in preparation for and during flood events. The program responds to overtopping and flood-related damage to dams, providing equipment

and technical support in the case of serious structural threats, monitors reservoir and river/stream levels, and maintains awareness of actual flood levels and forecasts. The regular updates that they provide enable timely decision-making and awareness of urgent on-the-ground conditions.

ADMINISTRATION

The Missouri Geological Survey's administration program of nine staff provided operational support to the Survey. Administration staff responsibilities include operations management, budgeting, personnel management, building maintenance and improvements, custodial services, communications and the distribution of maps and publications. Survey director Joe Gillman fulfilled the duties of State Geologist, overseeing all activities of the Survey and representing it on several councils, boards and commissions including the State Oil and Gas Council, Board of Geologist Registration, Well Installation Board, and Missouri Mining Commission. Survey deputy director Jerry Prewett fulfilled the duties of Assistant State Geologist and was responsible for oversight of program activities, legislative actions, information technology governance, and was involved in many other statewide initiatives. Kim Ward fulfilled functions of Planning and Performance Manager, overseeing planning, coordination, and operation of critical services and mission objectives. Nona Lancaster oversees activities of five administrative support staff.

SIGNIFICANT FY18 ACOMPLISHMENTS

Additional Mapping Efforts

The Survey was responsible for completing six new geologic quadrangle maps along the I-70 corridor, a geologic compilation map in southeast Missouri, and a series of maps of the Lamotte Sandstone including three statewide and three regional. Each set of three comprises an isocore, drill thickness map, an overburden thickness map, and a structure contour map. Also developed was the first in a series of county geologic resource maps for use in economic and infrastructure planning, and a debris management map for central Missouri to use following major catastrophic events. Finally, the Survey is currently mapping bedrock in the central St. Francois Mountains to characterize the setting of four iron-oxide deposits. A compilation map will be produced of Precambrian exposures to improve understanding of the St. Francois terrane and metallogenic province.

Additional Funding

MGS secured \$3.75M in new funding for water supply development projects. These resources will be utilized to provide planning, engineering, and construction of two water supply reservoirs in north Missouri.

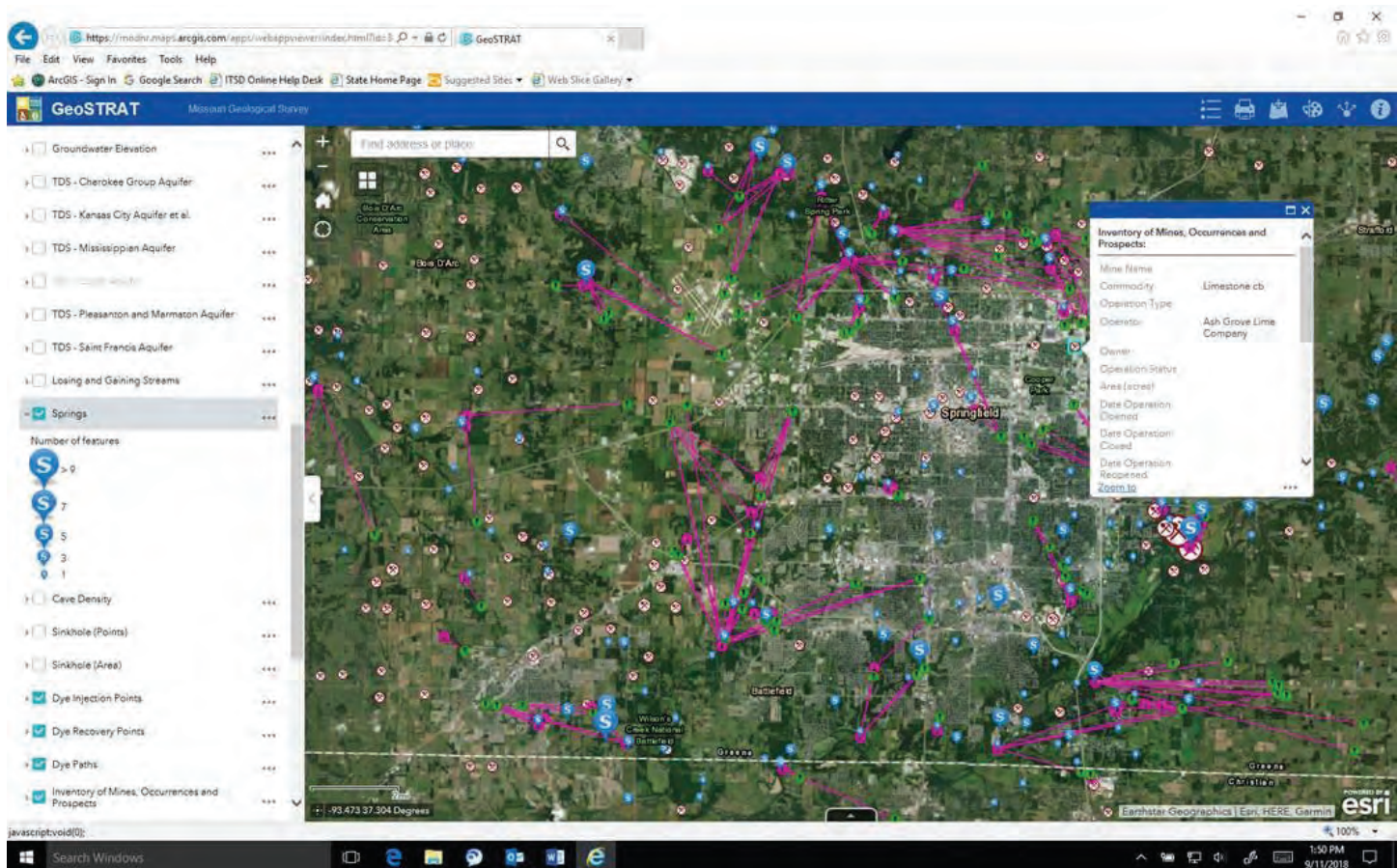


Figure 3. Screenshot of the Missouri Geosciences Technical Resource Assessment Tool (GeoSTRAT)

Drought Support

On July 18, 2018, the governor signed an executive order activating a drought assessment committee as part of a response plan that is overseen by MGS. The committee made recommendations to the governor concerning state-level and regional response and recovery. Through those, efforts support was provided for drinking water supplies and agricultural needs.

GeoSTRAT Redesign

The Missouri Geological Survey maintains 69 data layer files to implement the mission of collecting and distributing information about Missouri's water, mineral, and energy resources. The Missouri Geosciences Technical Resource Assessment Tool (GeoSTRAT) is a web-based application that allows access to 51 of those layer files through a newly designed interactive ArcGIS Online platform that provides improved performance and applicability. The system enables users to more easily and quickly visualize and explore the information about Missouri geology and associated applications. Data can also be downloaded as KMZ and Esri layer files for additional analysis. The application can be used with PCs and hand-held devices for data assessments in various disciplines such as hazards assessment, mineral resource evaluation, environmental consulting, engineering, local and regional planning, insurance assessment, and education.

MONTANA

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INTRODUCTION

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

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

PROGRAMS

Ground Water Assessment Program (GWAP)

Montana's 1991 Ground Water Assessment Act provided a three-part program (groundwater characterization, long-term water-level monitoring, and a groundwater database) designed to systematically assess Montana's groundwater resources on a statewide level. Characterization studies are conducted on a drainage-basin scale and result in maps and atlases summarizing the hydrogeology of the basin. The core of GWAP's monitoring program is a statewide network of about 950 wells where water levels are collected at least quarterly. About 75 wells are sampled for water-quality analysis annually. The Ground Water Information Center (GWIC) database contains all GWAP data, including that obtained from driller's logs, published reports, field measurements, laboratory analyses, and other sources for about 250,000 sites; groundwater data collected from other MBMG projects; and more recently, groundwater data collected by some private entities. Water-well drillers can now submit their well records directly to the MBMG. The GWIC database is available publicly at: <http://mbmgtgwic.mtech.edu>. Scanned images of well logs are also being added. GWIC users average about 40,000 queries per month. At the end of 2014, the Ground Water Assessment Program will have completed fieldwork in eight areas (22 counties) and released 60 maps and reports and eight other maps and reports are in progress.

Ground Water Investigations Program (GWIP)

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

the Ground Water Investigation Program. This program operates at the sub-basin scale to investigate local issues related to groundwater development. Since its inception in 2009, GWIP has produced more than 11 MBMG publications related to five project areas. Both groundwater programs, GWAP and GWIP, were strongly supported in recent meetings of basin advisory councils throughout Montana and are integral to the new Montana State Water Plan.

Other Groundwater Projects

The MBMG works in concert with state and federal agencies, conservation districts, water-quality districts, tribes, and local communities across the entire State on many relatively short-term projects that address local issues such as water supplies, water quality, or effects to groundwater resulting from land-use changes. These projects constantly change in response to need. Longer term, the MBMG performs monitoring and local investigations in the Butte-Anaconda area through contracts with regulatory agencies and the Montana Department of Justice. This area has been subjected to releases from mining, milling, and other industrial sources over many decades that resulted in the designation of the Upper Clark Fork River basin as the largest Superfund site in the U.S.

Another long-term commitment is monitoring in the Controlled Ground Water Area along the northern and western boundaries of Yellowstone National Park, which was established by compact between the National Park Service and the State of Montana to protect the geothermal resources in the Park. The MBMG is maintaining this long-term monitoring program with funding provided through the NPS. The MBMG also continues monitoring that was started in the 1970s in the Powder River coalfields. This serves a variety of purposes, from documenting the effects of coal mining on aquifers, to mine reclamation, to effects of coalbed-methane production on aquifers and surface waters.

Geologic Mapping

The first priority of MBMG's geologic mapping program is 1:100,000-scale digital coverage of the State's 94 30 x 60-minute quadrangles. Including several USGS products, 77 quadrangles are now publicly available; two more are imminent. Quadrangles lacking coverage are in the western part of the State. With support from STATEMAP, selected 1:24,000-scale quadrangles are being mapped to: (1) resolve the complex structural features and immensely thick stratigraphic sequences of western Montana, leading to eventual 1:100,000-scale coverage, or (2) provide more detailed mapping in valleys and urban areas that are experiencing high growth rates and land-use pressures. The inevitable encroachment of development on mountainsides is commonly accompanied by severe problems with water resources and slope stability. PDF versions of our digital maps are viewable and downloadable from the MBMG's website: <http://www.mbmgt.mtech.edu/grm/research-geology.html>.

In addition to the MBMG's mapping, the EDMAP section of the National Geologic Mapping Program is very active in Montana.

These projects provide valuable detail and interpretations that greatly augment and improve our own mapping. About two to three projects are conducted in most years.

Earthquake Studies

The MBMG's Earthquake Studies Office monitors earthquake activity in Montana and surrounding areas using the 45-station Montana Regional Seismograph Network, plus data from several networks in bordering states. Data are exchanged with seismic research centers in surrounding states, the USGS National Earthquake Information Center, and archived at the IRIS Data Management Center, to rapidly provide the public and emergency responders with information about the location and severity of significant earthquakes affecting the State. The largest earthquake to strike Montana in more than half a century occurred near Lincoln in a mountainous region about 30 mi northwest of the state capital, Helena, on July 6, 2017. The M5.8 earthquake shook all of western Montana, causing minor damage, but no structural damage or injuries due to the sparsely populated epicentral area. The Lincoln main shock focal mechanism and principal aftershock trend indicate sinistral slip on a vertical, NNE-trending strike-slip fault, a surprising result because the largest nearby mapped faults trend WNW. More than 4,000 aftershocks have occurred so far and activity is ongoing. The MBMG assisted University of Montana Geosciences Department personnel to deploy a 10-station temporary network surrounding the

epicentral region and analyze data it has recorded. The majority of Montana seismicity occurs along the northern Intermountain Seismic Belt between Yellowstone National Park and north-western Montana. For this reporting period along the Montana portion of the Intermountain Seismic Belt, 192 earthquakes had magnitudes of 2.5 or larger, 20 earthquakes had magnitudes of 3.5 or larger, and 68 were reported as felt.

Energy Resources

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

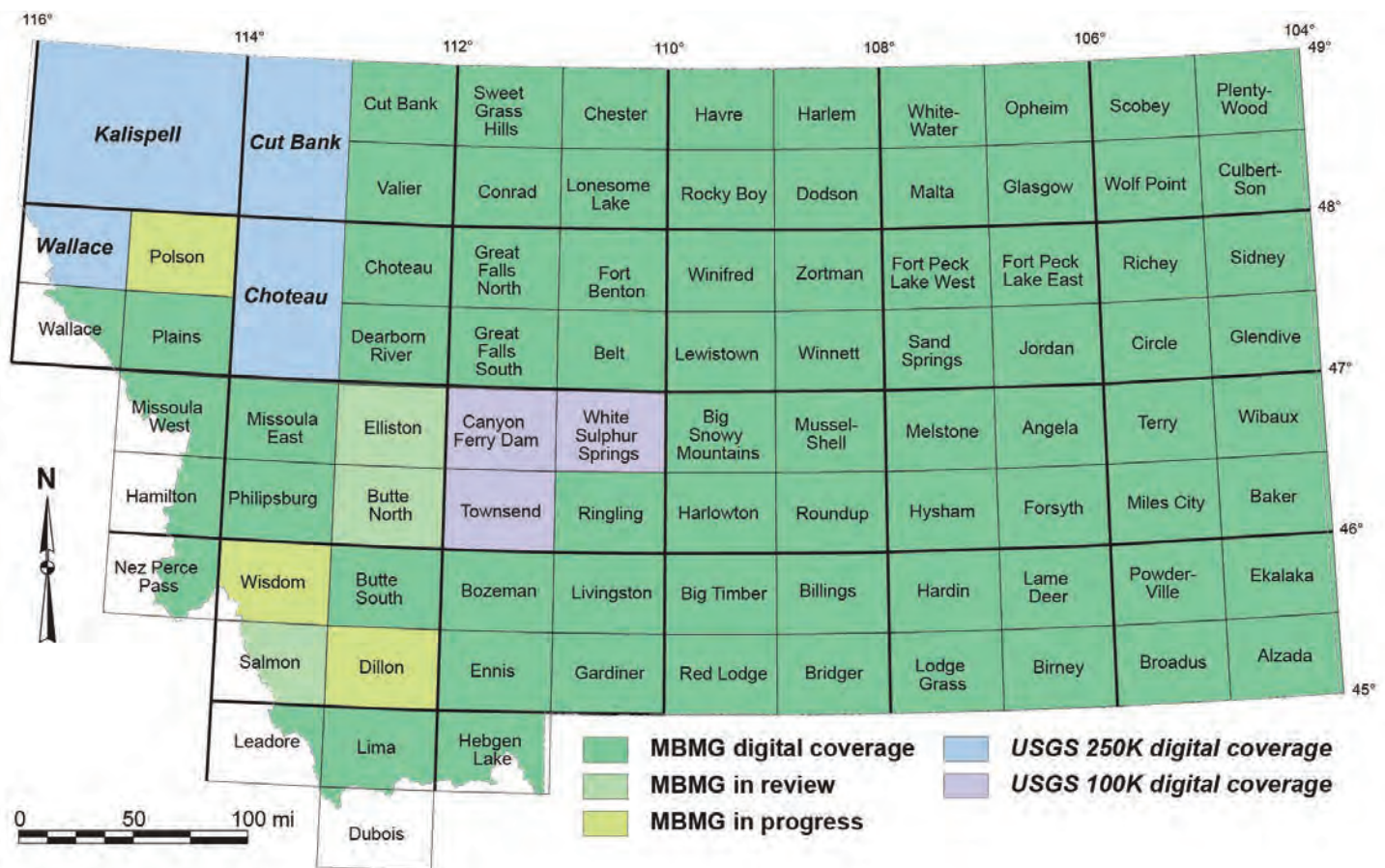


Figure 1. Status of 1:100,000-scale geologic mapping as of October 2018.

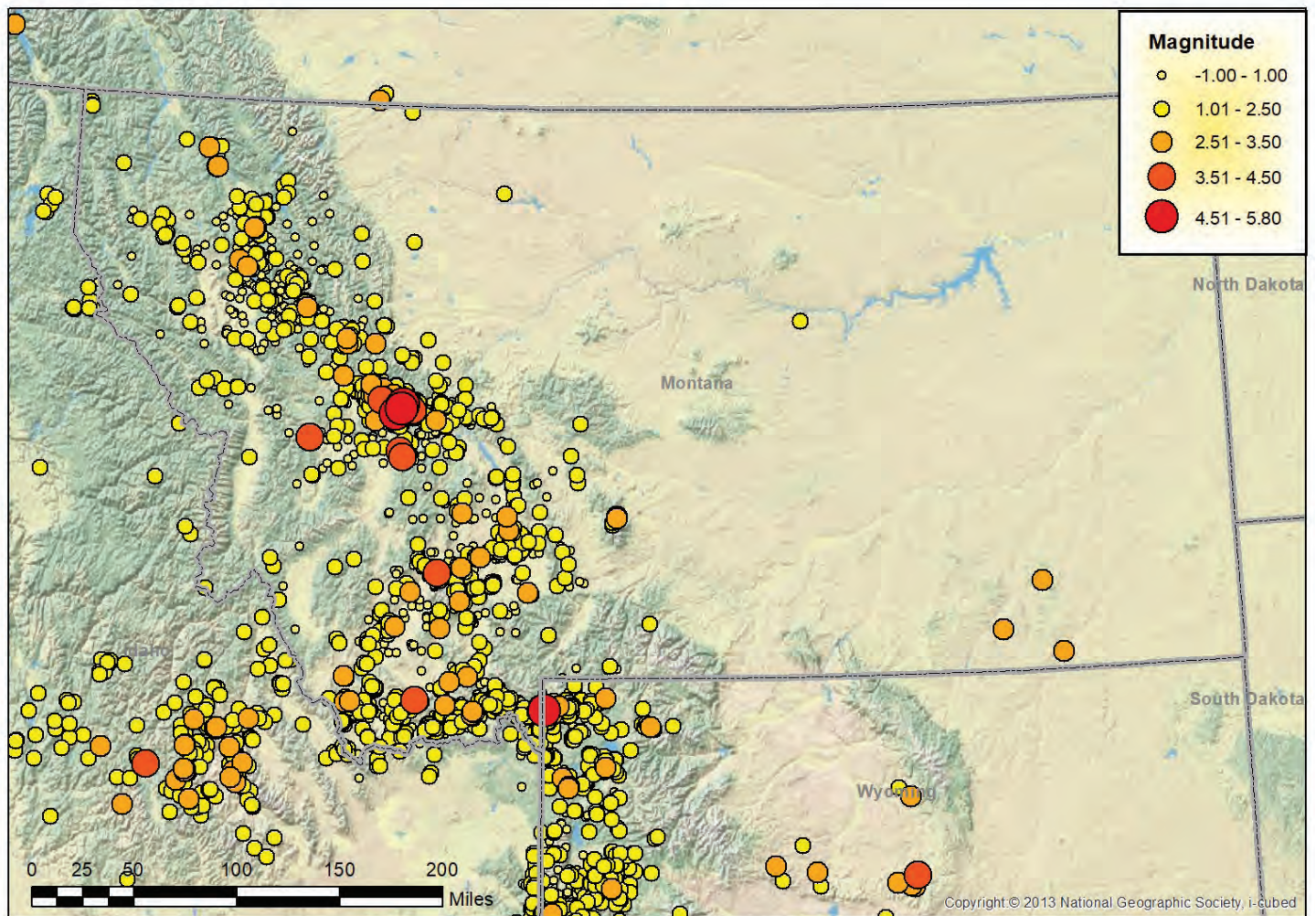


Figure 1. The Montana Regional Seismograph Network provided data used to locate 7,970 earthquakes in Montana and surrounding areas with magnitudes ranging from less than 0.0 to 5.8 for the period January 1, 2017 through September 30, 2018. More than 4,000 of these earthquakes are aftershocks of the July 6, 2017 Lincoln earthquake, the largest of which is magnitude 5.0.

Mineral Resources and Data Preservation

The MBMG provides technical information on mineral resources through our mapping and archival records as well as through personal communications, mineralogical determinations, petrographic analyses, and information on recent developments in industry. The MBMG's mining archives contain more than 4,000 mineral property files and more than 20,000 entries in the historical claim-map and mine database. These documents are regularly used by the public for a wide variety of interests, many of which are not geologic. In addition, the Anaconda Research Collection of specimens from the Butte mines is available to qualified researchers.

Analytical Laboratory

The Analytical Division provides multi-element inorganic and organic analyses of waters, rocks, soils, sediments, and biological materials for MBMG scientists and affiliated researchers, using methods that conform to USGS and EPA protocols. Most of the work is related to groundwater, and the resulting data are entered directly into the GWIC database. In addition to

service work, the Analytical Division participates in geochemical research. Major instruments in the lab include ICP/AES, GC/MS, GC/ECD, ICP/MS, ion chromatographs, liquid scintillometer, and hand-held XRF. Instruments for stable isotope analyses in water have been added. Analyses include δD and $\delta^{18}O/^{16}O$ as well as deuterium and protium. A new stable carbon isotope analyzer has just been installed this fall. Additions to the rock lab include new minerals separation and microscopy capabilities.

Geographic Information Systems

The GIS/Computer Services Division is a key component in meeting the MBMG's continuing efforts to provide digital data, databases, and web-based information. This division develops and maintains the computer infrastructure, captures and converts data into an electronic format, identifies methods by which researchers can analyze and interpret data using GIS technology, and assists with the efficient dissemination and distribution of electronic data. Nearly all new maps are now provided either digitally or as print-on-demand products. Improvements in map delivery are in progress.

Public Information and Services

The MBMG's Publication Division oversees the editing, preparation, release, and distribution of research results as reports, bulletins, maps, or other publications. Additionally, MBMG staff provide information through talks, personal contacts, and responses to informal requests for information. Through an agreement with the USGS, the MBMG maintains an Earth Science Information Center for the sale of USGS publications. Increasingly, our publications are released in a digital format, with paper copies as an option. Direct download of our digital products is nearly 250,000 copies per year.

Mineral Museum

Montana Tech's Mineral Museum, administered by the MBMG, houses one of the best mineral collections in the Pacific Northwest. About 1,500 fine specimens are on display and new acquisitions are added based on their significance to the collection and to the region. Major advances in lighting and new displays have been made during the past year and are continuing. The Museum sponsors a popular workshop and lecture series devoted to aspects of regional geology. In addition, schools and special interest groups frequently request tours and special workshops.

Data Center

The MBMG hosts 10 online public databases, including surface water (real time and archival), groundwater (water levels, quality, and construction data), coal, proppant, earthquakes, and mines data. Many of these MBMG databases are available through our interactive mapper at: <http://mbmg.mtech.edu/datacenter>. The Data Center maintains connections to many private and government entities through web services. The MBMG hosts data connections for the National Ground Water Monitoring Network (ACWI/SOGW), National Geothermal Data System (DOI), National Coal Resource Data System (USGS), and others.

NEBRASKA

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**CONSERVATION AND
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School of Natural Resources

INTRODUCTION

As Nebraska's geological survey, the Conservation and Survey Division (CSD) celebrates its 125th year in 2018, although Nebraska has had a state geologist since 1871. CSD is a part of the School of Agriculture and Natural Resources in the Institute of Agriculture and Natural Resources at the University of Nebraska-Lincoln. CSD personnel engage in research, monitoring, data and sample archiving, outreach and extension, scholarly service, informal education, the granting of continuing education units to professionals, and in University classroom teaching. CSD employed a staff of 20 individuals in 2018, including geologists, hydrogeologists, engineers, a drilling crew, and a soil scientist. Seven members of the CSD staff hold faculty rank within the University.

GEOLOGIC MAPPING

Surficial Mapping

CSD has been involved in the USGS STATEMAP cooperative mapping program since its inception, and CSD personnel produce at least two surficial geologic maps each year. These maps are available on part of the CSD website (<http://snr.unl.edu/data/geologysoils/STATEMAP/index.aspx>). CSD personnel produced three surficial geologic maps as part of the Nebraska STATEMAP program in 2018: two in the Rainwater Basin region by Hanson and others and Young and others, and one in the Niobrara River valley by Joeckel and others. Personnel are also mapping the surficial geology in all or parts of 14 USGS 7.5-minute quadrangles encompassing a major part of the Missouri National Recreational River through a grant from the National Park Service.

GROUNDWATER MAPPING

CSD personnel produce an annual water levels report, as well as groundwater atlases (typically at the county scale), and bulletins describing specific aquifers in detail. In 2018, CSD personnel mapped aquifer properties at the scales of individual counties and river basins.

RESEARCH

Ongoing research at CSD emphasizes unique aspects of Nebraska's bedrock and surficial geology and its landscapes. Projects involve work with personnel from other state surveys and universities. Bedrock stratigraphic research is being conducted on Pennsylvanian cyclothems and incised valley fills, Cretaceous strata, and the hydrostratigraphy and sedimentology of the Paleogene and Neogene successions of northern and western Nebraska. Quaternary research focuses on Nebraska's dune fields, deflation basins, river valleys, and loess hills. Many of these projects involve training graduate and undergraduate students.

CSD personnel conduct a variety of research projects related to groundwater quality and quantity and maintain several related databases. Current projects include: analysis of nitrate movement downgradient from a large groundwater mound created by leakage from canals, mapping potential aquifer units using airborne electromagnetic surveys, methods to estimate groundwater recharge and evapotranspiration rates, and the potential for geologic carbon sequestration. The associated databases include the following: Nebraska GeoCloud; Quality-Assessed Agricultural Contaminant Database, Nebraska Real-Time Groundwater Monitoring Network, and Historic Nebraska Statewide Groundwater Levels. CSD is participating in the USGS-led initiative to establish a national network of water level and water quality wells. Multiple CSD personnel are involved in the Eastern Nebraska Water Resources Assessment (ENWRA), which conducted airborne electromagnetic flights over approximately 11,000 line km (6,835 mi) of the eastern Nebraska in 2018. ENWRA also drilled a series of test holes to better characterize the Dakota aquifer, one of which exceeded 335 m (1,100 ft) in depth.

CSD personnel have contributed the addition of Nebraska soils data to the Soil Explorer application, including the development of the Nebraska Dominant Soil Parent Materials map. Work has also begun on a USDA-funded project on soil development in depressional wetlands in the Todd Valley and research on pedagogical methods for teaching field texturing techniques, preliminary results of which were presented at the 2018 Earth Educator's Rendezvous.

RECENT FIELD TRIPS, CONFERENCES, AND EDUCATIONAL EVENTS

CSD has traditionally run the annual Geology Tour in cooperation with the Nebraska Well Drillers Association (NWDA) every one to two years. Those field trips provide CEUs for professionals from Nebraska and nearby states. Survey personnel also conduct the yearly Nebraska Water Leaders Academy, which includes a geologic and hydrogeologic field trip and other activities performed across a time span of several months. In 2018, CSD personnel were instrumental in the highly successful 2018 Midcontinent AAPG Field Conference, held in Lincoln over October 12–14, which some 110 professionals attended. CSD personnel presented scientific papers at multiple conferences in 2018. CSD personnel presented CEU-granting talks on geology and groundwater at the Nebraska Water Industries Convention. Furthermore, CSD personnel have contributed to several educational programs and training activities focused on field techniques in soil science. These activities include coaching the soil-judging team at the National contest in Tennessee and the Regional contest in Manhattan, Kansas (where the team earned their second successive overall win). In addition, CSD personnel contributed to soil training offered at the Nebraska Rangeland Short Course and the Nebraska Well Drillers Association and Nebraska Onsite Waste Water Association workshops.

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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, and is the state geological survey for Nevada. Established by the Nevada Legislature as a department within the public service division of the University and Community College System of Nevada, NBMG is part of the Mackay School of Earth Sciences and Engineering within the College of Science. It is one of the statewide programs at the University of Nevada, Reno. NBMG's mission is to provide the state's needs for geological and mineral-resource information and research, as defined in its enabling legislation.

NBMG scientists conduct research and publish reports that focus on natural resources, geologic hazards, and the overall geologic framework of the state in order to facilitate economic development, public safety, and enhancement of the quality of life in both urban and rural areas of Nevada. These include reports on mineral, geothermal, and petroleum resources; engineering geology; earthquakes, floods, land subsidence, and other geologic hazards; environmental geology; groundwater; and geologic mapping in Nevada. NBMG has no regulatory function but assists other state agencies in matters concerning geology, natural resources, and geologic hazards. NBMG also has cooperative research and information programs with numerous local, state, and federal agencies.

Geological highlights in Nevada in recent years have involved mineral-resource, geothermal, natural hazards, and environmental issues. Current focus areas for NBMG include: 1) detailed geologic mapping and assessments of geologic hazards and natural resources in Clark County in southern Nevada, particularly the Las Vegas metropolitan area; 2) detailed geologic mapping and assessments of natural resources (mineral, oil-gas, and geothermal) in northeastern Nevada; and 3) detailed geological mapping and assessments of geologic hazards and natural resources in the Reno-Carson City-Lake Tahoe urban corridor in western Nevada.

MINERAL AND ENERGY RESOURCES & GEOLOGIC FRAMEWORK STUDIES

Current NBMG activities include detailed geologic mapping; investigations of the stratigraphic and structural framework of the State; research on the origin of gold and other metal deposits; geochemical investigations of mining districts; resource assessments on public lands; investigations of geothermal resources; and monitoring mineral and energy production, resources, and reserves. Major geologic resources in Nevada include mined and quarried mineral resources, geothermal power, petroleum, and water. In 2016, Nevada led the nation in the production of gold and barite, and was the only state that produced lithium. In most recent years, Nevada has led the nation in overall nonfuel mineral production. Mining in Nevada helps place the U.S. in the midst of its biggest gold boom in history. Nevada is also rich in geothermal energy, and NBMG research is facilitating expansion of

this renewable energy resource across Nevada and surrounding regions. NBMG hosts both the Center for Research in Economic Geology (CREG) and Great Basin Center for Geothermal Energy (GBCGE). Both CREG and GBCGE are at the forefront of national and international research in mineral and geothermal resources, respectively, and also play important roles in education through teaching courses and workshops.

GEOLOGIC HAZARDS & ENVIRONMENTAL, ENGINEERING, AND URBAN GEOLOGY

Major projects include investigations of earthquake hazards, crustal strain, and related aspects of neotectonics; investigations of flood hazards on alluvial fans, rivers, and major streams; and studies of land subsidence. NBMG is spearheading a major project analyzing the seismic hazards of Las Vegas Valley. The Nevada Geodetic Laboratory (NGL) resides within NBMG and has built a network of 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 forefront of global research in geodesy. Satellite-based interferometric synthetic aperture radar (InSAR) is also being used to evaluate geologic hazards. Programs are also underway to increase public awareness of earthquakes in Nevada and to prepare for emergency response when a major earthquake occurs.

GEOLOGIC INFORMATION

Activities include: 1) producing and updating databases on mining districts, active mines and prospects, abandoned and inactive mines, geologic maps, geochemical samples, and geothermal and petroleum exploration and production; 2) building layers and metadata for statewide geographic information systems (GIS); and 3) maintaining core and cuttings facilities, rock and mineral collections for research, aerial photographic imagery and maps, and extensive files on Nevada geology and resources.

Paper records are progressively scanned and served to the public on the Web, and new geologic maps and reports are released in digital form with options for printing on demand. NBMG's Information and Publication Sales Office serves as a one-stop shop for geological information in Nevada, both electronic and hard copy. NBMG's public outreach and information program is directed at K-12 teachers and the general public. NBMG scientists frequently lead field trips and present talks, demonstrations, and slide shows for schools, universities, civic groups, and professional organizations.

The NBMG home page (nbmg.unr.edu) serves thousands of users per week and contains information on NBMG products and staff, publications available for ordering, holdings in the NBMG information office, and electronic versions of many publications.

An updated index to all publicly available geologic maps in Nevada is also available on the webpage. NBMG maintains the Great Basin Science Sample and Records Library, which serves as the repository for geological samples and reports from Nevada and houses the information and publication sales office for NBMG.

NBMG chairs the State Mapping Advisory Committee (SMAC), which advises the U.S. Geological Survey on priorities for mapping in Nevada. The GIS Subcommittee of SMAC has helped to create a Virtual Clearinghouse for Nevada Geographic Information. The Geologic Mapping Subcommittee of SMAC advises NBMG on geologic mapping priorities. NBMG also chairs the Nevada Hazard Mitigation Planning Committee and participates in the Nevada Earthquake Safety Council, the State Clearinghouse, and activities of the Geological Society of Nevada, Nevada Mining Association, Nevada Petroleum and Geothermal Society, and local sections of the Association of Engineering Geologists and Society for Mining, Metallurgy, and Exploration. NBMG organized and supports a working group to facilitate the use of the HAZUS loss-estimation model developed by the Federal Emergency Management Agency (FEMA) for natural hazard risk reduction and emergency response.

external grants and contracts. In addition, NBMG employs about 20 graduate student assistants, several undergraduate student assistants, and one post-doctoral scholar. Ten emeritus staff members and three adjunct faculty are also engaged in various professional activities. More information about products, programs, and staff is available on the Web (www.nbm.unr.edu).

PUBLICATIONS AND ELECTRONIC PRODUCTS

Research results are published as NBMG bulletins, reports, maps, and special publications, as well as in federal publications and scientific journals. Authors of NBMG publications include not only NBMG scientists but also geologists from industry, academia, the USGS, and other government agencies. In addition, NBMG has updated several computer databases and lists on oil and gas, geothermal, and mining activity. A current list of publications on Nevada Geology is available on the NBMG website. The sales office serves several thousand customers per year with the sale of reports, bulletins, geologic maps, and topographic maps. Sales over the web continue to increase. NBMG scientists also publish papers in the peer-reviewed literature and in symposium proceedings, abstracts, and contract reports. NBMG is in the process of electronically scanning all of its unpublished files, including thousands of mine maps and reports. The materials are served to the public over the Web. In addition, NBMG has scanned oil, gas, and geothermal well logs and aerial photographs.

STAFF

NBMG employs ~30 geoscientists and support staff. This includes 12 faculty positions in the geosciences, five professionals in support of publication production (cartographers and GIS specialists), two data managers, one information specialist, three management assistants in support of publication sales and administrative and clerical needs, and one development technician. About half of these positions are funded directly by the state through the University, with the other half funded by

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INTRODUCTION

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

NHGS conducted a web-based survey in 2017–2018 to elicit feedback from stakeholders on its programs and inform strategic planning. The results clearly highlighted the primary importance of the Geologic Mapping Program and its products.

GEOLOGIC MAPPING

Surficial geologic maps completed under the most recent STATEMAP scope of work included the Bartlett and New London 7.5-minute quadrangles in 2017 and Bradford, Center Sandwich and Mount Chocorua 7.5-minute quadrangles in 2018. These new surficial quadrangle maps increase the total number of completed quadrangles to 129, representing 60 percent of the 213 7.5-minute quadrangles that comprise New Hampshire. Bedrock geologic mapping was completed for the northern half of the Jefferson 7.5-minute quadrangle in 2017 and the southern half of Mount Crescent in 2018.

The annual Geologic Mapping Workshop, hosted since 2001 by NHGS as a venue to present the most recent STATEMAP and FEDMAP products and other topics of interest, attracted more than 80 geoscientists.

FLOOD AND GEOLOGIC HAZARDS

The Flood and Geologic Hazards Program within NHGS continues to assess earth-related hazards in New Hampshire. Through the program, NHGS leads stream crossing (culvert) assessments statewide, a function that has become an integral part of NHGS. NHGS performs all quality control review of data collected, performs annual spring training of data collectors, and publishes collected and reviewed data. Although this effort continues to have a central flood hazards component, the interests of four other state agencies are represented, broadening the focus to address fish passage issues and structure condition concerns. These four state agencies include the NHDES, Department of

Transportation, Division of Homeland Security and Emergency Management (NH HSEM), and Fish & Game Department. The effort has recently expanded, with NHGS taking the lead in developing methods for the hydraulic modeling of culvert failures. In the summer of 2018, NHGS hired an intern, which allowed for this effort to progress, using two culverts in the Concord area. A key goal of these efforts is to provide data to towns and agencies on culverts that pose hazards, allowing local officials to maximize their chances of successfully applying for limited funds in support of replacements.

NHGS continues to chair the New Hampshire Silver Jackets, in partnership with NH HSEM and state Floodplain Management, with the Army Corps. The team is currently building efforts to work with towns to provide them with technical assistance that will lead toward the completion of local hazard mitigation plan items, as related to flooding and river/stream erosion concerns.

In partnership with NH HSEM, this year NHGS has launched the first version of a statewide flood hazards geodatabase. One of only a handful of its kind nationally, it incorporates known flood hazards in every town in the state based on interviews with town officials, and extracted from local hazard mitigation plans into a spatial geodatabase, housed in ArcGIS Online. The goal is not only to capture local data as background for future events, but also to construct accurate chronologies of past flooding that document site vulnerabilities and enhance the ability of towns to qualify for hazard mitigation funds to address issues. Thus, NHGS performs updates after flood events. The next phase of this effort is to integrate use of the geodatabase into the statewide local hazard mitigation planning process so that it becomes institutionalized as the authoritative statewide flood hazards layer.

In response to the NHGS stakeholder survey, the program has developed a protocol and template to provide post-hazard event summaries that explain the situation, location, site history, and reasons for occurrence of a site-specific or regional concern, if known. The purpose is to provide information to state agencies, town officials and the public after an event. NHGS is now ready to begin creating these summaries when needed.

WATER RESOURCES AND GIS

NHGS continued its active stewardship of both the National Hydrography Dataset and the Watershed Boundary Dataset for New Hampshire under a formal Memorandum of Understanding with USGS. A five-year challenge cost share agreement between the NHGS and the White Mountain National Forest (WMNF) was made on July 5, 2017. Under this agreement, the NHGS supplies synthetic lidar-derived flowlines to WMNF hydrologists who field check streams. The NHD steward then makes the appropriate changes based on the WMNF field classifications. The NHGS is also actively engaged in aligning NHD flowlines to New Hampshire’s lidar-derived digital elevation datasets by hydro-enforcement in concert with synthetic network extraction. Another year of stream permanence monitoring was completed in headwater channels using state sensors at six sites with varying hypsography and surficial geology in the general area of our Concord

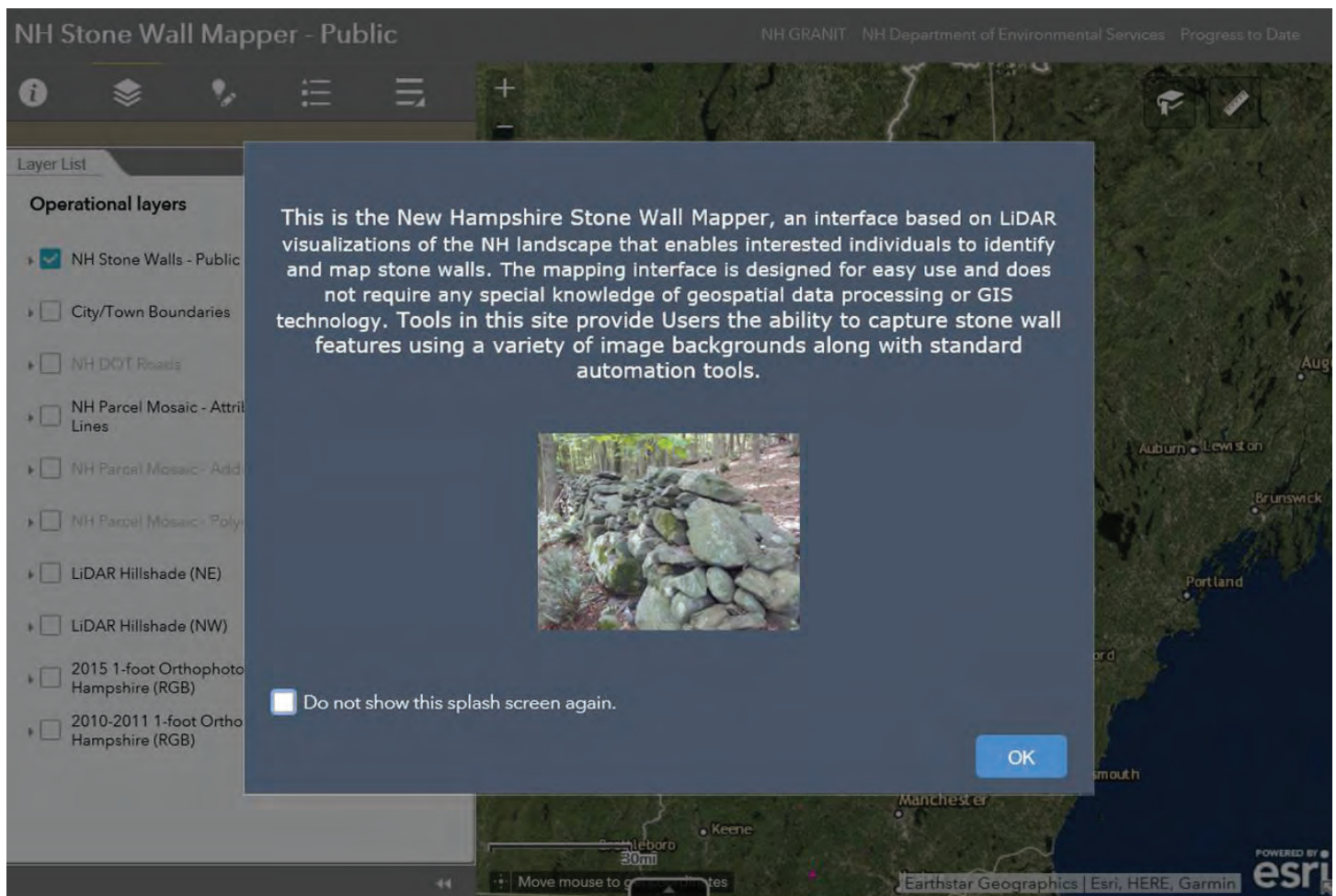
office, following several consecutive years of monitoring in the Seacoast region. Web services for statewide stream temperature and groundwater level data have been completed as part of multi-year projects to enhance data access. The statewide groundwater level monitoring network has remained stable with the critical assistance of volunteers who make measurements and download data on a monthly basis.

Lidar data were acquired in spring 2018 for the final 14 percent of the state following weather-related delays during 2016 and 2017, completing statewide coverage. The State Geologist is currently seeking a legislative Capital Budget appropriation during the FY20–21 biennium to acquire higher-resolution lidar (QL-1) in the Seacoast region of the state to supersede data acquired as part of a New England regional project more than eight years ago. Matching funds are being sought under the USGS 3D Elevation Program. The State Geologist successfully applied for a grant from the NH Humanities Council to develop and implement a web-based crowdsourcing application to enable interested individuals to map the State's extensive network of historic stone walls using lidar visualizations. The project is envisioned as an opportunity to create a unique cultural preservation asset and learning experience. The objective is to encourage public exposure to lidar data and landscapes with the expectation that the discovery and mapping of stone walls will lead to deeper explorations into NH history, both cultural and geological.

The mapping application is scheduled to launch before the end of the year. The State Geologist is currently serving as state champion to support the 3D Nation Elevation Requirements and Benefits Study sponsored by USGS and NOAA, and continues to promote expanded and innovative use of lidar data at every opportunity.

Although the largest water well drilling companies in the state file well completion reports electronically, the majority of licensed water well contractors still report using paper forms. NHGS lacks staff resources to perform manual data entry, resulting in the accumulation of a significant data entry backlog. This past year, NHGS was fortunate in enlisting the help of a part-time employee to enter and scan approximately 1,200 reports from the estimated backlog of approximately 4,200 reports.

NHGS has been participating in the National Groundwater Monitoring network program since 2016. On a monthly basis, NHGS and its volunteers collect data from the network wells (32 wells). The data comprises a monthly hand measurement and hourly data for the month, if a transducer and data logger are installed at a well. Following collection, the data are loaded into a MS SQL Server database management system. Once finalized, these data are then shared to the internet via web services. In cooperation with USGS, these data are currently available through the ACWI portal. Over the next year, NHGS will develop its own web application to serve out these data in a way that targets



our local audience, particularly the New Hampshire Drought Management Team. NHGS has also revised our monthly reporting format to include monthly period of record statistics for each well, providing greater context for the monthly measurements.

EARTH SCIENCE OUTREACH AND EDUCATION

The Education and Outreach Coordinator routinely replies to numerous requests from both the public and private sector for geologic information on a wide range of topics. Some of these requests are invitations from schools for classroom presentations. The Coordinator oversees the organization and availability of all of the NHGS publications.

A complete list of NHGS Maps and publications is available at: <http://des.nh.gov/organization/commissioner/pip/publications/geologic/index.htm>

Hard copies of any of these publications can be ordered by contacting the NH Department of Environmental Services Public Information Center, at pip@des.nh.gov; NHDES – PIC, PO Box 95, Concord, NH 03302-0095; (603) 271-2975; or FAX (603) 271-8013 or by emailing geology@des.nh.gov

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INTRODUCTION

The end of this AASG Journal reporting period is at about the time of our last annual meeting in Rehoboth Beach, Delaware. This was my first annual meeting as State Geologist and I wish to thank my colleagues for being so welcoming to this “newer” State Geologist. Following are some of the New Jersey Geological and Water Survey (NJGWS) programmatic accomplishments for June 2017–2018.

AMBIENT GROUNDWATER QUALITY NETWORK

NJGWS continued to evaluate anthropogenic and geogenic impacts on the groundwater resources of New Jersey. The New Jersey Ambient Groundwater Quality Monitoring Network, part of the National Groundwater Monitoring Network, evaluates and tracks trends from non-point source impacts to the water table. We successfully completed another sampling cycle. Survey staff used a subset of these wells to assess PFAS (per- and polyfluoroalkyl substances) occurrences in the ambient groundwater table in the NJ Coastal Plain.

AQUIFER FRAMEWORK AND PROPERTIES

NJGWS published *Framework and Properties of Aquifers in Burlington County, New Jersey*. The map, consisting of two plates, is the third in a series of county environmental geologic maps updating the hydrogeologic framework of critical Coastal Plain aquifers in the southern half of New Jersey. The map includes nine deep cross sections, eleven aquifer tests, two graphs of annual groundwater withdrawal, and two piper diagrams showing water chemistry of two major aquifers. The map is an important resource for water planning on the state, county, and local level, in addition to geologic and engineering studies necessary for environmental compliance in Burlington County.

BEACH REPLENISHMENT

Delineation of offshore sand shoals as part of New Jersey's beach replenishment program continued in conjunction with the State's Division of Coastal Engineering and in cooperation with the federal Bureau of Ocean and Energy Management.

DATA PRESERVATION

NJGWS has participated in the National Geological and Geophysical Data Preservation Program for ten years. During the

reporting period, we scanned and created associated metadata for our collection of zinc exploration maps and soil logs from the New Jersey Zinc Company, formerly of Ogdensburg, Sussex County. We also scanned a complete set of Interstate 80 construction borehole maps.

GEOPHYSICS

NJGWS provided programmatic support by collecting and interpreting downhole and near-surface geophysical data. Our capabilities were used to assist tracking the source of sodium and chloride impacting private wells in Warren County, support the NJGWS STATEMAP program, and delineate sinkholes at Spruce Run Wildlife Management Area in Hunterdon County. We provided technical expertise and assistance to other programs in the state Department of Environmental Protection.

HYDROGEOLOGIC ANALYSES

NJGWS provided analysis of hydrogeologic testing performed on behalf of public community water suppliers and other private entities requesting new or increased diversions from both ground and surface water sources throughout the state. We completed reviews of thirteen projects to determine the potential impacts that these proposed diversions may have on existing users, streamflow depletion, and movement of saltwater and anthropogenic contaminants using analytic and numerical modeling methods. As a result of some of these reviews, various regional simulation projects were undertaken to determine the overall effects that multiple diversions have created on both ground and surface water sources, including the effects of regional diversions in Cape May County as they pertain to the fresh water/salt water interface, and the effects of regional diversions in Ocean County to the cone of depression in the Piney Point aquifer.

We began working to determine if certain public community water systems throughout the state should be classified as groundwater under the direct influence of surface water (GWUDI) systems. Methodologies developed as part of the NJGWS well head protection area program have been incorporated into the GWUDI analysis to determine time-of-travel and its relation to completion of the microscopic particulate analysis.

PUBLIC HEALTH OUTREACH

NJGWS continued partnering on a public-health outreach study, sponsored by the state Department of Health and the federal Centers for Disease Control. A series of outreach events were conducted to determine public health impacts of the state Private Well Testing Act and how to increase private well testing and water treatment in areas identified as high risk from geogenic impacts. Geogenic compounds such as arsenic, radium, radon, uranium, and boron were targeted in these studies.

PUBLICATIONS AND WEB

NJGWS published seven maps during the reporting period. In addition to an aquifer framework and properties map of Burlington County, STATEMAP quadrangles were published for the bedrock geology of Lakewood, Perth Amboy–Arthur Kill, Trenton West–Trenton East, and Weehawken–Central Park; surficial geology of Lambertville–Pennington; and bedrock and surficial geology of Oswego Lake.

We also published a report documenting our use of lidar to determine the highest elevation accessible to the public in each of our 21 counties, an information circular about the Stockton Formation and its namesake town of Stockton in Hunterdon County, and a second information circular about a large rock in front of the New Jersey State Museum that contains a dinosaur track.

The Survey website, njgeology.org, averaged 56,000 hits per month.

STATEMAP

NJGWS completed five geologic quadrangle maps and an offshore geologic map at 1:80,000 for the 2017 STATEMAP grant. The quadrangle maps included a bedrock map in the folded and thrust-faulted Paleozoic rocks of the Appalachian Valley and Ridge province in northwestern New Jersey, and bedrock and surficial maps of four quadrangles in the Outer Coastal Plain in southern New Jersey. The Paleozoic bedrock map updated an earlier quadrangle map with additional field data, balanced cross sections, joint and fracture data displayed on stereonet, and a revised stratigraphy that now matches to adjoining areas mapped under previous grants. The Outer Coastal Plain maps were in areas with no previous detailed mapping. Staff used hand augering, power-auger drilling, and existing well data, including some wells with downhole geophysical logs, to map clay beds in a Miocene marginal-marine sand that forms an extensive unconfined aquifer. Deeper Coastal Plain formations, including several important confined aquifers, were mapped in cross section using existing deepwater wells and research coreholes. Neogene fluvial gravels on uplands and Quaternary fluvial and estuarine deposits in valleys and along the modern coast overlie the unconfined aquifer and were mapped using hand augering, lidar imagery, stereo airphotos, and well and boring records. The offshore map shows Quaternary deposits on the inner shelf to a depth of about 200 ft and out to about 15 mi offshore of Cape May County in southern New Jersey. This map is based on seismic data and vibracores collected since 1994 as part of our sand-resource exploration for beach replenishment.

WATER SUPPLY AND MODELING

NJGWS provided technical support to planning and permitting groups within and external to state government. Projects during the reporting period included data preparation and technical support for the New Jersey Water Supply Plan 2017–2022, review and modeling of water supply permit modification requests, water quality monitoring in the Passaic River Basin, review of regional water supply plans, modeling and negotiation of interstate water management agreements under the auspices of the Delaware River Basin Commission, and the oversight of the development of bathymetric data for water supply reservoirs.

NEW MEXICO

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INTRODUCTION

Established by legislation in 1927, the New Mexico Bureau of Geology & 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 serves 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 interest in the exceptional geology and natural resources of New Mexico. Our multifaceted organization consists of a number of interwoven programs. During the past year, we had a total of around 54 full and part-time employees, supported by a mix of state appropriation as well as funds obtained from grants and contracts.

We are continuing to settle into our relatively new building on the New Mexico Tech campus. In the past year, we have had the pleasure of selecting and purchasing a range of art for our building. Funding for these purchases came from the New Mexico Arts “Art in Public Places” program, which requires that one percent of the cost of a new, publicly funded building go towards art purchases. An example of one of our geologically relevant art pieces is shown in Figure 1. The two showpieces of the building continue to be our Mineral Museum and Publications Bookstore, which are located to either side of the main entrance to the building. We expect both of these important components of our organization, described below, to thrive in their new settings. Our laboratory personnel are also enjoying working in their purpose-built lab spaces (Fig. 2).

MINERAL MUSEUM

With more than 20,000 visitors in the past year, the Mineral Museum (Figs. 3a, b) is the flagship for Bureau outreach to the public. The museum hosts tours, scientific competitions, and classroom

instruction, in addition to traveling educational exhibits and presentations around the state. The museum also provides invited displays at the largest mineral shows in the U.S. Each year, the museum staff hosts the New Mexico Mineral Symposium, one of the largest meetings of its kind in the U.S., attracting participants from around the world. A total of 251 people participated in 2018. Funding for the symposium (approximately \$25,000) is raised entirely by donations from mineral clubs, local government, registration fees, and a benefit auction concurrent with the event.

Materials displayed by the museum are acquired by donation, purchase, and trade. Private donations of in-kind materials, which may include mineral specimens, gemstones, fossils, literature or art, totaled 20 donations in 2018 with an aggregate value of \$365,000. Pieces not accessioned into the collections are held for a requisite period of time and then sold in the gift shop or traded for display-quality specimens. No state-appropriated money is used to acquire new material for the collections or exhibit infrastructure; all purchases are made with funds generated through sales in the museum gift shop or via private/public donations. During the FY2018, direct monetary donations and sales from the gift shop generated approximately \$63,700.

The success of the museum’s outreach activities has allowed the museum to implement procedures for private individuals and public groups to tangibly support museum infrastructure, staff, and programs. Monetary gifts to the museum are accomplished through two mechanisms: a gift fund for directed acquisitions and a long-term endowment capable of accepting estate donations. The founding of the “Friends of the Museum” group provides an avenue for focused giving for specific museum projects. In the past year, monetary goals were defined to fund two projects: a case-building initiative, and additional display lighting improvements inside the facility. The museum outreach programs, coupled with the enthusiastic support of its supporters and patrons, have created a synergy that will help sustain the museum into the future.



Figure 1. Public art purchased for the New Mexico Bureau of Geology and Mineral Resources building.



Figure 2. Panoramic view of the Argon geochronology laboratory.

PUBLICATIONS BOOKSTORE

Our new building includes a large, inviting space for our Publications Bookstore (Figs. 4a, b), placed just inside the main entryway, opposite the Mineral Museum. We are experiencing good sales of geologically relevant, but non-traditional items, such as bandanas, earrings, and mugs inspired by geological maps, jigsaw puzzles with geological pictures, gold panning kits, posters, postcards and mineral jewelry. In order to appeal to younger people, the bookstore now sells an expanded selection of children's books, as well as stuffed animals, dinosaur learning kits, and crystal growing kits. We continue to offer the more traditional geological products, such as geologic, topographic, and resource maps, as well as New Mexico Bureau of Geology and New Mexico Geological Society technical publications. During the past year, our publication group achieved a near-record level of sales (~\$120,000), placing us second in publication sales for all state surveys around the country. We also continue to hire a number of New Mexico Tech students to help run the bookstore.

GEOLOGIC MAPPING

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

During the past year, our mapping group completed ~590 mi² of mapping under the STATEMAP program. Nine maps were completed, and 21 maps were digitized. We received \$161,959, awarded through the National Cooperative Geologic Mapping Program. We were successful in winning several additional

awards, mainly geared towards understanding geological hazards. Our geological mapping program website received a large number of visits (472,083), and supported 844 gigabytes of downloaded data.

HYDROGEOLOGY AND AQUIFER MAPPING

The quantity, quality, and distribution of groundwater in New Mexico are the focuses of this research group. Understanding and evaluating water resources requires a good grasp of the complex geology of the state, using tools such as geological mapping, drill hole data, geophysical surveys, hydrological and geochemical data, and groundwater modeling. Making data and products available to the public, researchers, and industry is our core goal. Ongoing projects include focused research in a large number of New Mexico counties and municipalities.

The hydrogeology studies group received an important gift this year from the Healy Foundation to support research on New Mexico's water and natural resources. The funds will be used for ongoing work on two water-focused, multi-year programs for the state.

The first of the two programs is strongly focused on rural communities. Many single-well, community water providers lack robust scientific data on local hydrogeology and groundwater conditions that could be used to better understand and inform decisions about their water future. The first program's goal is to provide communities with reliable groundwater level data to better manage their water resources. Some ideally constructed wells will be instrumented with real-time water-level measurement devices. These water-level data will be collected, stored and accessed through the New Mexico Bureau of Geology's data repository, and will be publicly available on our website.

The second project focuses on the development of digital maps of aquifers. New Mexico is the fourth leading state in terms of dependency on groundwater for drinking water, following Florida, Idaho, and Hawaii—notably wetter regions of the world. A state as arid as New Mexico, with as little as 0.24 percent of our land surface covered with water, needs (but currently lacks)



Figure 3. The New Mexico Bureau of Geology and Mineral Resources Mineral Museum.

detailed maps of aquifers and groundwater resources. This project will compile multiple large datasets, including geologic maps, well information from the Office of the State Engineer, and reports from regional studies. Region by region, these aquifer maps will be publicly available and web accessible.

Other high-profile, ongoing projects active in the past year include long-term monitoring of the Animas River alluvial aquifer in the wake of the Gold King Mine spill; studying the useful lifetime of the High Plains aquifer in Curry/Portales basins; and hydrological investigation of the San Agustin Plains.

ENERGY AND MINERALS

Energy and mineral resources, including petroleum, coal, uranium and geothermal, all contribute to New Mexico's economy. Our petroleum research group carries out research that supports the petroleum industry in New Mexico, along with curating and making publicly available an extensive collection of cores, cuttings, and well-logging records. Research by our economic

minerals group has recently focused on uranium research, producing a detailed resource map for the state, studying hazards associated with abandoned mine lands and the Gold King mine spill, updating coal resources, and investigating occurrences of rare-earth-element-bearing minerals. We also maintain archives of mine core and mining records. In the arena of geothermal resources, we operate equipment for measuring deep bore-hole temperatures, which can be used to evaluate geothermal resources around the state. During this year, NSF funding was granted for a project entitled "Can Electromagnetic Surveys Image Deep Crystalline Basement Flow Systems in Extensional Terrains?" which examines the possibility of fluid mobility in rocks deep in the Earth's crust. Funding was obtained from the U.S. Geological Survey to continue to archive a variety of types of data. Research in a wide range of topics, in the areas of petroleum geology, oil/gas/mineral potential, induced seismicity, helium reserves, rare earth elements, uranium and gold resources, mining districts, geothermal resources, underutilized water and energy resources, and heat flow investigations, were carried out during this FY.



Figure 4. The Bureau's Publications Bookstore.

During the past year, seven New Mexico Tech undergraduates were employed by the Energy and Minerals group, and our staff served as primary advisors for four graduate students. Staff members also mentored the Petroleum Engineering Design Team, and as faculty advisor for the student chapter of AIPG.

LABORATORIES

Our strong analytical laboratory group operates facilities that can produce mineralogical, geochemical, and geochronological analyses on a wide range of materials. Most of our large collection of analytical equipment, whose collective value is in the millions of dollars, was purchased using federal, state, or private external funds. Our laboratories support geological research in New Mexico and beyond, by working with our employees, other researchers at New Mexico Tech, as well as at other universities or private entities. Our laboratories also contribute to the educational mission at New Mexico Tech and other academic institutions through support of student research projects, and classes on analytical methods. Lab facilities, operated as cost centers, are largely self-supporting. We continue to provide excellent analytical services to students, researchers, and others. During the past year, we provided analytical services to 225 users, including 57 students from New Mexico Tech, and 32 from other universities. The laboratories brought in a total of \$248,000, which goes to support laboratory personnel and maintenance.

Multiple research projects are on-going in the laboratories. As examples, our chemistry lab provided data and research opportunities for a Navajo undergraduate student learning how toxic metals are extracted by lung fluids, a project that was supported by the STEM Advancement Program. Several other undergraduates were involved with uranium research funded by the National Science Foundation. The Argon Geochronology Lab has multiple projects from around the world and has a major focus on western U.S. river systems (for example, Rio Grande, Colorado, Green, Virgin, Red) that record landscape evolution related to climate and tectonics. We also have ongoing research



related to geological hazards in New Mexico. The Argon lab also recently received a \$500,000 gift from a private individual. These funds will be used for student research, as well as maintaining state-of-the-art equipment and technical salaries.

OUTREACH AND EDUCATION

An important part of the mission of the Bureau of Geology is to distribute accurate geoscience information about the natural resources, hazards, and geologic history of New Mexico. We serve a broad audience, from professional geoscientists and university professors to grade-school children and their teachers, as well as influential decision makers and the general public. Our world-class museum, described above, supports a large visitor population and runs programs for teachers and students. Our outreach-focused publications, such as *Earth Matters* (Fig. 5) and *Lite Geology* as well as other, more technical publications, and other geological materials can be purchased at our store or through our website. We also support and advise graduate student research and teach classes at New Mexico Tech.

Our annual Rockin' Around New Mexico field conference and workshops were held in 2018, in Truth or Consequences, New Mexico at Hot Springs High School (Fig. 6). There was full-capacity, K-12 teacher participation with 28 teachers, representing school districts from across the state. In another educational activity, 9 of our geologists ran a geology field trip for 65 middle school girls, under the auspices of the Association of American University Women "Tech Trek" program. This is the first year that a geology field trip was offered for Tech Trek girls, and the activity was well-received. We have received funding from Halliburton to expand our geoscience-oriented Tech Trek activities in summer 2019.

Our website is a central component of all of our activities, but is particularly important to our outreach and education mission. We provide free access to most of our publications, maps, educational resources, and data to a broad audience of people. Our site is optimized to work well with the wide variety of

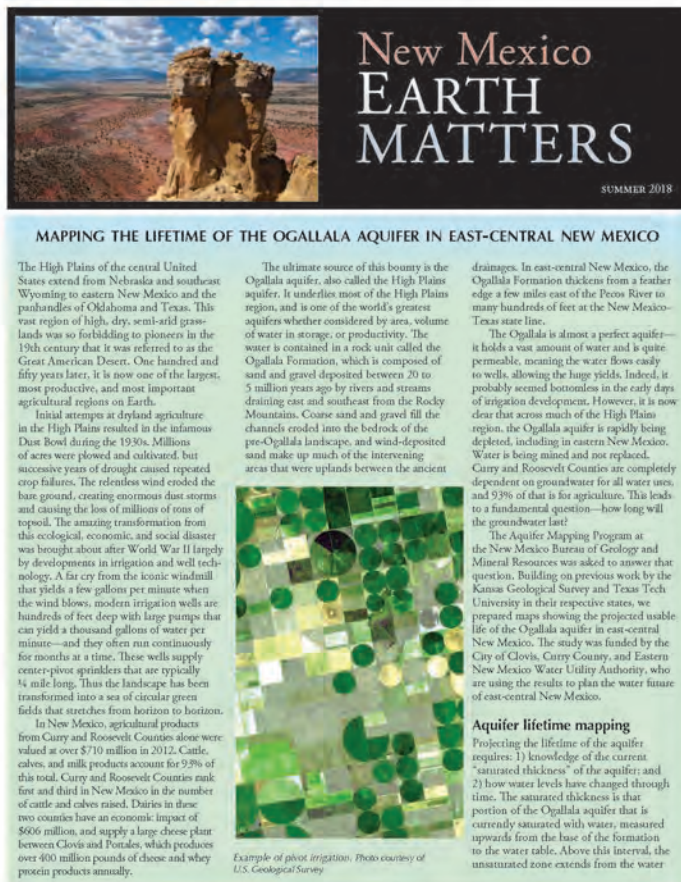


Figure 5. The Earth Matters publication.



Figure 6. Rockin' Around New Mexico field conference and workshops.

desktop and mobile platforms used by our audience. Our goal is to provide web access to increasingly sophisticated databases, providing not only data but the interpretation needed to use those data. During the past year, we had 810,538 distinct visitors to our website, and there were more than 11.36 million website page requests. A total of 22.78 TB of data were downloaded.

As the New Mexico Bureau of Geology and Mineral Resources is a research subdivision of New Mexico Tech, our staff are active in the University's educational mission. Twenty of our staff members are adjunct faculty in academic departments. We taught 117 credit hours at the 500 level, and 58 at the 400 level. We served in 16 graduate thesis committees, and were research advisors for 8 graduate students.

INFORMATION TECHNOLOGY

Our Information Systems capabilities provide a current, efficient, and reliable technology infrastructure that supports our mission. These services integrate with all our research, laboratory, outreach, and administrative roles, requiring a broad and flexible technology portfolio. Some key areas include: GIS—Geographical Information Systems geospatial analysis and mapping, Web—A robust and interactive web presence with highly-customized internal tools, Database—Enterprise databases that maintain critical data for a variety of applications, Storage—Large data storage cluster to house administrative, research and geospatial datasets. Network—Fast fiber optic backbone network that allows efficient access to our large datasets.

HONORS

Our staff received a number of honors and awards in the past year. Susan Welch, our outreach coordinator who retired during the past year, was recognized by New Mexico's governor for "outstanding accomplishments and invaluable contributions to the state of New Mexico" upon her retirement. Geochemist Bonnie Frey received an "IMPACT!" award for a "New Mexico woman who encourages women to enter into science, technology, engineering, mathematics, and allied professions." Director Dr. Nelia Dunbar was featured in a NOVA program on "Killer Volcanoes". Dr. Matt Zimmerer was selected as a finalist for the 2018 NSF "Vizzies" competition for a drone imagery submission entitled "A Drone's view of the Earth's Surface". Dr. Virginia McLemore received an SME/AIME Environmental Stewardship Distinguished Service Award "for actively promoting the sharing of technical information, via publications, technical sessions, and alliances with other industry groups, for the betterment of the mining industry and the environment." She was also named as "Editor-in-Chief for Exploration" of a new SME journal. Dr. McLemore, along with Stacy Timmons and other staff members Dr. Maureen Wilkes (ret), Ron Broadhead, Dr. Virgil Lueth, Gretchen Hoffman (ret), and Dr. George Austin (ret) were authors and (or) editors on a six-part volume entitled *Energy and Mineral Resources of New Mexico* that recently won the AASG Charlie Mankin award, presented at the 2018 Geological Society of America annual meeting.

NEW YORK

NEW YORK STATE GEOLOGICAL SURVEY

New York State Geological Survey
New York State Museum
222 Madison Avenue
Albany, New York 12230



[Position Vacant]
State Geologist and Director

Andrew Kozlowski
Curator of Quaternary Landscape Materials



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BACKGROUND

The organization that became the New York State Geological Survey (NYSGS) was established by the New York State Legislature in 1836 as the New York State Geological and Natural History Survey. The agency has operated continuously since then. It is currently a bureau of the New York State Museum (Fig. 1) in the New York State Education Department.

INTRODUCTION

The mission of the New York State Geological Survey (NYSGS) is to conduct geologic research, evaluate mineral resources and geologic hazards of the State of New York, and make the data and advice derived from that research available to state agencies, the educational community, and the public for the health, safety, and economic welfare of the citizens of the State. Responsibilities of the NYSGS include maintaining a comprehensive inventory of the geologic resources, conducting research into the characteristics of, and processes operating in, the Earth's crust, and making the resulting geologic knowledge readily available. The guiding principles require that the work of the NYSGS be synoptic and comprehensive throughout the State, be applicable to addressing the geologically related issues facing the citizens of the State and be assembled in useable formats. Descriptions of various aspects of the State's geology are presented in the Museum Bulletin, Memoir, Map & Chart, Miscellaneous Publications, and Circular series publications.

GEOLOGIC MAPPING

Geological mapping has been a primary focus of the NYSGS since the Survey's inception. The first statewide geologic maps were produced prior to the mid 1880s, and by 1940, two generations of updated geologic maps were produced providing better details on the distribution of mineral resources. The most recent bedrock maps were completed by 1972, and the Survey completed a parallel set of 1:250,000 map sheets for the surficial geology by the early 1990s. Beyond these statewide maps,

mapping of individual quadrangles has been ongoing and often resulted in publications in the New York State Museum Bulletin series. Since 1993, the NYSGS has participated cooperatively with the USGS STATEMAP Program to produce both quadrangle- and county-scale maps.

Bedrock Mapping

Recent bedrock mapping has focused on Devonian formations along the eastern front of the Helderberg Escarpment. Devonian rock formations cover approximately 40 percent of the state, the emphasis on this revised mapping serve as an update to mapping completed in the 1940s and provides modern geologic maps that complement the nationally recognized region of John Boyd Thatcher State Park in Albany County, (eastern) New York. John Boyd Thatcher State Park has been designated a National Natural Landmark and was the birthplace for the development of early stratigraphic principles.

Additional bedrock mapping is currently underway in the eastern Adirondacks, this mapping is being done in the vicinity of the old Iron mining districts as part of a FEDMAP led effort to re-evaluate the potential for strategic mineral resources (REEs).

Surficial Mapping

A resurgence in surficial mapping by NYSGS staff has been underway since 2010 primarily as STATEMAP projects. Current efforts are focused in the Finger Lakes region of central New York and the Hudson Valley region of eastern New York. Detailed 7.5-minute quadrangle mapping is being completed prior to compilation on a county basis as part of a long-term strategy (Fig. 2). Mapping justifications are many but center around water resource issues, traffic corridors and suburban development, geologic hazards, and natural resources.

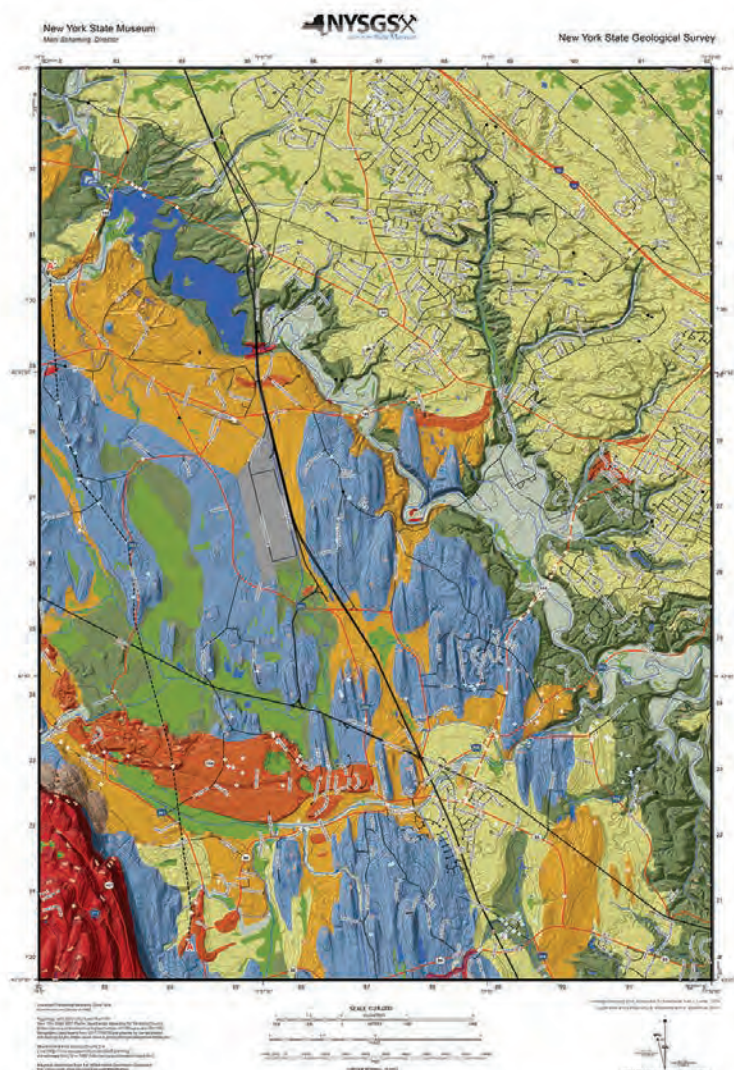
3D Mapping

As part of our surficial mapping program, the NYSGS has been developing 3D mapping protocols since 2012. Over the last three years, controversy has arisen around several proposed and ongoing issues including aggregate extraction, underground gas storage, and underground salt mining in the Finger Lakes region. There is a lack of detailed subsurface geologic mapping to provide an empirical basis for analysis by governmental agencies, academia, and the public. The 3D mapping program is intended to address this lack of data. To characterize and understand the geologic framework of thick glacial deposits in the Finger Lakes region, deep (600 + ft/192 m) exploration boreholes are being contracted to investigate large-scale regional stratigraphy. When possible, these boreholes utilize continuous PQ wireline soil coring techniques. For borings less than 20 m we typically utilize Geoprobe direct push coring methods if suitable. Our recent field experiences have shown this to be a prudent and cost-effective method to gain substantial geologic information. However, this technique can be limited when indurated glacial till deposits are encountered. In such instances larger drilling platforms are utilized to obtain crucial subsurface data.



In addition to our drilling and coring program, the NYSGS has been utilizing near-surface geophysical methods such as GPR and passive seismic (HSVR) to collect subsurface data. More recently as part of a new collaborative field program, the NYSGS has partnered with students and faculty from the Department of Earth and Atmospheric Sciences at Cornell University to collect geophysical data such as seismic reflection, gravity, and electrical methods. This initiative provides the opportunity to engage students in pragmatic geologic mapping with direct ties to societal benefit. Further, the expertise of the NYSGS staff provides students opportunities to assist in the construction of modern geologic maps. Equally appealing is the opportunity for the NYSGS staff to collaborate with faculty having geophysical expertise outside that currently available to the Survey and Museum. Cornell University is a globally recognized research entity and serves as the designated Land Grant Institution for the State.

More recently our 3D mapping efforts in the Albany area of eastern New York have proved the value of our 3D approach to mapping. Our wireline coring has revealed deeper and more complex glacial stratigraphy than previously known. The high-resolution coring investigation has identified a shallow high-quality glacial aquifer capable of five times the yield of bed-rock aquifers at depth that have poor water quality (high sulfur and iron content). The newly discovered aquifer units were capitalized on immediately and used by a craft brewery operation. Such breweries and distilleries represent an industry that has expanded more than 260 percent in New York State since 2011—so much so that the Governor has targeted this industry as a major component of the state's economic development strategy. These new surficial maps and 3D data are a direct benefit to this expanding industry that relies on high-quality groundwater.



SURFICIAL GEOLOGY OF THE VOORHEESVILLE 7.5-MINUTE QUADRANGLE, ALBANY COUNTY, NEW YORK

Andrew L. Kozlowski, Robert J. Dineen, Karl J. Backhaus and James A. Leone
2018

SURFICIAL GEOLOGY OF THE VOORHEESVILLE 7.5-MINUTE QUADRANGLE, ALBANY COUNTY, NEW YORK

prepared by
Andrew L. Kozlowski and Karl J. Backhaus

Supported in part by the U.S. Geological Survey Cooperative Agreement Number G17AC00295
National Cooperative Geologic Mapping Program (STATEMAP)

Holocene

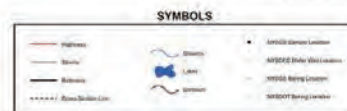
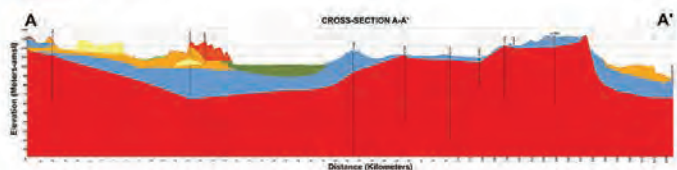
- Af** Artificial Fill (Af)
Surficial sediment composed of coarse/fine and/or crushed rock anthropogenically transported and used for construction purposes.
- Ha** Stratified silt, sand and gravel (Ha)
Sorted and stratified silt, sand, and gravel, deposited by rivers and streams. May include cobbles and boulders. Inferred as post-glacial alluvium and includes modern channel, over-bank and fan deposits.
- Hw** Wetland Deposit (Hw)
Peat, muck, marl, silt, clay or sand deposited in association with wetland environments. Various sediments can be present at transitional boundaries from one facies to another.

Pleistocene

- Ps** Stratified Sand (Ps)
Well sorted and stratified sand, deposited by fluvial, lacustrine or eolian processes. Inferred as deposits associated with distal glacial environments.
- Pisc** Silt and Clay (Pisc)
Stratified, fine-grained sediment consisting of fine sand, silt and clay size particles. Inferred to be deposited in mid-shore to deepwater settings of glacial lakes. May include marl, rhythmites, and varves.
- Pics** Cobbles to Sand (Pics)
Stratified ice-contacted deposits, variable coarse-grained sediment consisting of boulders to sand size particles. Inferred to be deposited along an ice-margin. May include, interbedded coarse lenses of gravel and clast supported diamictions (flow till).
- Psg** Stratified sand and gravel (Psg)
Well-sorted and stratified sand and gravel. May include cobbles and boulders. Inferred to be delta, fan or lag deposits in glacial channels or near ice margins.
- Pd** Diamiction (Pd)
An admixture of unsorted sediment ranging from clay to boulders. Generally matrix supported, massive and clast-rich.

Pre-Pleistocene

- Br** Bedrock (Br)
Non-glacially derived, hard rock, pre-pleistocene in age. May be covered up to a meter in diamiction, sand and gravel, or sand and clay in areas marked as Br.



ADJOINING QUADRANGLES



Foot-cm 1:75,000 scale; 6x vertical exaggeration
Elevation derived from 1984-1985 USGS National
Digital Elevation Model (DEM) data and by the New York State
Topographic Survey

New York State Museum Map & Chart No. 103
ISSN 0097-3793 / ISBN 978-1-55887-304-1



carbonate rocks in New York State also sets the stage for karst processes that episodically result in subsidence issues. While most subsidence occurs slowly, these conditions do pose episodic problems for construction and engineering projects.

DATA PRESERVATION

The NYSGS has participated in the USGS data preservation program and in the last two years has focused mainly on digitization and stabilization of the NYSGS Open File database. The collection archives notebooks, maps, reports, and other vital data associated with geological mapping and research projects. More recently, the NYSGS has been focusing on preservation of rock core associated with the Rock Core Collection.

MINERAL RESOURCES

Mineral resources remain an important component of NYSGS reporting and research, New York generally is roughly fifteenth in mineral production value of the fifty states. NYSGS monitors the status of each specific mineral commodity produced in New York. This information is published in cooperation with the U.S. Geological Survey. Currently there are ongoing projects to investigate geochemistry and geochronology of ore bodies in the Adirondack Mountains as part of a collaborative effort with USGS FEDMAP program. This research seeks to improve an understanding of the distribution of apatite and other REE-bearing minerals. In 2018 zinc mines in St. Lawrence County reopened and are now scaling up for increased production. Further, aggregates and limestone mining remain as large-scale operations across the state. Most studies center on industrial minerals as these comprise greater than ninety percent of the annual mineral production value. Recently, the monetary impact of the mineral and construction industries on the State's economy has been a focus of research. Conservatively, \$5 billion of economic activity and 30,000 jobs are dependent on the mineral industry.

GEOLOGIC HAZARDS

The principle geologic hazards in New York State are landslides and subsidence. The entire state has experienced multiple glaciations and with each deglaciation, extensive proglacial lakes formed, depositing thick (>100 m) accumulations of silt and clay. During the Holocene, fluctuations in base level lead to deep incision while modern stream systems established themselves. The result of these geomorphic and climatic fluctuations is an abundance of steep slopes on lake clays. The NYSGS estimates that 200 slope failures occur annually; 90 percent are under an acre in size but some have exceeded 82 acres in area. In addition to slope failures on soils, bedrock failures occur all too often, usually as a result of physical weathering. The NYSGS monitors and records landslides across the state and provides advisory services to municipalities when requested. The abundance of

ENERGY RESEARCH

In the last five years, energy research activity at the NYSGS has diminished as a result of staff changes. However, the NYSGS still maintains a digital database associated with the Empire State Organized Geologic Information System (ESOGIS). In the last few years the NYSGS has received 138 core donations, accessioned 168 cores into the Rock Core Collection and maintains a comprehensive database of more than 30,000 well logs.





EDUCATION AND OUTREACH

The NYSGS maintains a number of educational activities. The NYSGS, in cooperation with the New York State Museum, will run the eighteenth annual Donald H. Cadwell Earth Science Teachers Workshop in July 2018. This program is designed to facilitate hands-on investigation of the geologic evolution of New York State; establish close, continuous working relationships between New York State Earth Science teachers and the professional geologists from the NYSGS; and help Earth Science teachers obtain additional experiences and prepare materials for use in teaching Earth Science. NYSGS staff members also give lectures and seminars, run field trips within of New York State, teach geology courses at local colleges, present workshops for secondary school teachers, and perform other public awareness functions. NYSGS staff present research results and scientific seminars and meetings, serve as research advisors for MS/PhD candidates, give interviews to the news media, and support student volunteers and geological professional and scientific societies. NYSGS staff, on a continuing basis, serve as content specialists in the development of exhibits for the New York State Museum.

NORTH CAROLINA

NORTH CAROLINA GEOLOGICAL SURVEY

North Carolina Geological Survey
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Dr. Kenneth B. Taylor P.G.
State Geologist



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kenneth.b.taylor@ncdenr.gov



Phone: (919) 707-9210



JULY 2017

FEMA-NEHRP Grant submitted by NC Emergency Management (NCEM) with the NCGS as the agent to deliver four Earthquake Education Workshops to school teachers by a cadre of four award-winning Outstanding Earth Science Teachers. The grant would pay for the presenting teachers and for the printing/purchasing of two sets of materials (workbook, posters, maps, publications, and classroom materials—slinkys and silly putty) for each of the 120 attending teachers. The second set of materials is to share with other teachers in the same school district.

STATEMAP 2018 started.

NGGDPP grant for data preservation and archive awarded to the NCGS.

FEMA Project Worksheet from Hurricane Matthew for the emergency work of the NC Department of Environmental Quality (NC DEQ) in the amount of \$78,436.10 was received. The State Geologist serves as the NC DEQ Disaster Response and Recovery Coordinator and Agent for FEMA reimbursement for costs/losses from the Department's response and recovery efforts.

AUGUST 2017

Twelve Open File Reports were posted on our website. Most of these documents were professional meeting posters, research reports, and digital geologic maps.

The State Geologist was interviewed on the *Exploring North Carolina* educational television series of hour-long programs. The interview focused on *Coal and Gold*.

SEPTEMBER 2017

The State Geologist conducted a day-long joint NC DEQ/NC DPS Tabletop exercise on Electromagnetic Pulse (EMP) for EM leadership, DEQ leaders, representatives from other state agencies, invited federal agency partners, the utilities, and other private sector organizations.

The final NCGS Oil and Gas program employee moved to a new job in NC DOT.

OCTOBER 2017

The State Geologist signed two letters of support to faculty members for their EDMAP proposals.

NOVEMBER 2017

NCGS Assistant Section Chief Phil Bradley co-led with Dr. Jim Hibbard, NCSU (retired) the Carolina Geological Society (CGS) Fieldtrip in the Hyco Shear Zone of the North Carolina Piedmont.

DECEMBER 2017

The State Geologist updated the N.C. 322 (Hazard Mitigation) Plan with additional information on geologic hazards: earthquakes, sinkholes, and landslides.

JANUARY 2018

The N.C. Geological Survey administration was moved from the Office of the Department Secretary back to the Division of Energy, Mineral and Land Resources (DEMLR).

FEBRUARY 2018

Reviews of numerous publications and EDMAP maps were conducted.

MARCH 2018

Salvo Cemetery restoration project was started on the Outer Banks of North Carolina. This project was to be managed by the State Geologist.

APRIL 2018

NCGS staff attended and presented at the Southeastern Section Meeting of the Geological Society of America in Knoxville, TN. Thirteen oral presentations or posters were presented at the meeting.

MAY 2018

Emergency callout for NCGS to respond to landslides in Polk County on the Blue Ridge Escarpment by NCEM. Five fatalities from the two-day event. Activities undertaken by the NCGS included safety zone delineation for responding rescue personnel, detailed mapping of landslide features, and mapping from a NC Forest Service helicopter over the impacted area to provide responders with detailed observations.

The new Senior Geologist for Oil and Gas Regulation joined the NCGS.

Data rescue activities were conducted by NCGS staff to move cores/cutting/files out of a building in which part of the roof collapsed. Contracted building demolition personnel and temporarily hired NCGS staff removed the bulk of the material to two steel shipping containers.



Nothing Compares

JUNE 2018

Hurricane Alberto impacted western North Carolina. Funding was appropriated by the N.C. General Assembly in the amount of \$3.6 million to restart the N.C. Landslide Mapping Program.

Fourteen Open File Reports were posted on our website. Most of these documents were professional meeting posters, research reports, and digital geologic maps.

NORTH DAKOTA

NORTH DAKOTA GEOLOGICAL SURVEY

North Dakota Geological Survey
600 East Boulevard Avenue
Bismarck, ND 58505 - 0840

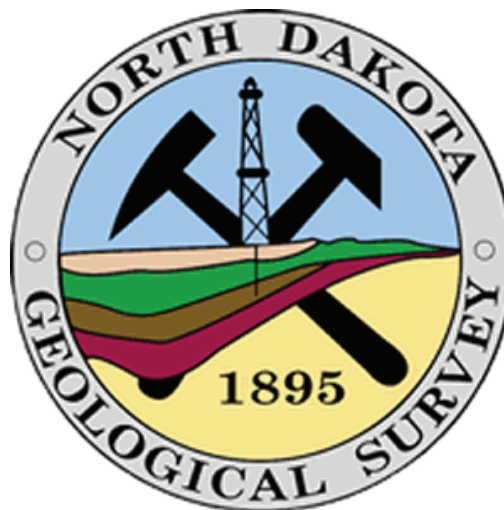
Edward C. Murphy
State Geologist and Director



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INTRODUCTION

Mission

The North Dakota Geological Survey (NDGS) serves as the primary source of geological information in the state of North Dakota. The North Dakota Century Code lists sixteen responsibilities for the NDGS including: 1) investigating, describing, and interpreting the geology of the State with special emphasis on the economic minerals, geologic hazards, energy resources, and the impacts of geologic conditions on the health and safety of the citizens and environment; 2) to maintain a public repository for fossil and rock specimens, rock cores, and well cuttings; and 3) aid in the regulation of the state's mineral resources.

History

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 ND, 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) and geothermal energy production (implemented in 1984). In 1981, the ND Industrial Commission Oil and Gas Division was split from the Geological Survey. In 1989, the Geological Survey was placed under the ND State Industrial Commission and moved to Bismarck. In July, 2005, the Geological Survey became a division and both it and the ND 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.

Facilities

The NDGS shares an office and warehouse with the ND Oil and Gas Division in Bismarck. We also maintain the Johnsrud Paleontology Laboratory in the North Dakota Heritage Center (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.

NDGS ACTIVITIES

Williston Basin Petroleum Conference

The 26th annual Williston Basin Petroleum Conference (it originally began as the Horizontal Well Conference) was held

from May 22–24 in Bismarck. Our three subsurface geologists presented a core workshop on the Spearfish, Charles, Mission Canyon, Bakken, and Three Forks Formations. These same three geologists gave presentations on the Spearfish, Charles, Birdbear, Duperow, Stonewall, and Interlake Formations at a session emphasizing the multiple oil-producing formations in the Williston Basin. There were 2,500 attendees this year, roughly equivalent to the attendance in 2016. Session themes at this year's conference included the Williston Basin's multi-pay zones, optimization, gas capture, cybersecurity, breakthrough technologies, and growing the workforce. The conference also featured a dozen keynote addresses and CEO panel discussions.

Inyan Kara Formation

In June, the Survey published the eighth in a series of 1:100,000-scale map sheets of the Inyan Kara Formation of the Dakota Group (Cretaceous). The Inyan Kara Formation is the primary rock unit for produced water disposal in North Dakota and consists of sandstone, shale, and mudstone deposited in both marine and nonmarine settings. Current rates of saltwater disposal in North Dakota are roughly 1.7 million barrels per day.

Rare Earth Elements

We released our second report on rare earth elements in North Dakota lignites in June. That report focused on Slope County where two different coals in three different areas contain some of the highest concentrations of rare earth elements that we have found to date. While this additional work elevated the highest concentration from 600 ppm to 1,026 ppm (on a whole coal basis), it did not provide us with consistently high concentrations from which we could identify lithologic patterns that would lead to an exploration model. So far, we have collected 1,109 rock samples (primarily lignite), more than half of which have been analyzed. A third rare earth report will be out by early next year.

Sand and Sandstone Potential for Proppant

In 2011, we published a report on the properties of North Dakota sands and sandstones as they related to the oil and gas industry specifications for proppant sand. Since that time, the industry has relaxed those standards and we are currently collecting additional sand and sandstone samples from across North Dakota to determine if any of these layers or deposits will fulfill industry needs. We published a report this spring on the proppant potential of windblown deposits. An initial sieve analysis is being utilized as a relatively cheap means of weeding out the majority of sand samples. Approximately 50 sand and sandstone samples were collected in the first half of 2018.

Geologic Mapping

We completed surface geology of seven quadrangles in north-eastern North Dakota in 2017. Due to budget cuts, we recently consolidated our surface mapping to the greater Bismarck–Mandan area to minimize travel costs. We published two quadrangles of the area this spring and are currently working on four others.

Landslide Mapping

Two years ago we accelerated our landslide mapping program. In addition to consulting a complete set of USDA aerial photographs (stereo pairs flown between 1957 and 1965) we also evaluate GoogleEarth images and images from our Phantom 4 Pro drone. We have focused our efforts in areas of oil and gas infrastructure, wind farms, pipelines, and transmission lines. To date, we have completed 663 of the 1,400 quadrangles in North Dakota, identifying 22,000 landslides and a total disturbed area of 193,000 acres.

Paleontology Program

The NDGS manages North Dakota's fossil resources through development of the State Fossil Collection (established in 1989) and has three paleontologists on staff. We manage the resource by monitoring paleontological activities on public lands, by performing paleontological assessments of lands being impacted by ground-disturbing activities, and by conducting paleontological investigations. The State Fossil Collection is housed in the Clarence Johnsrud Paleontology Laboratory in the North Dakota Heritage Center. The State Fossil Collection contains millions of fossils including microscopic specimens such as pollen grains and foraminifera as well as leaves, clams, snails, and tens of thousands of vertebrate fossils (Cretaceous dinosaurs, Tertiary mammals, ice age mammals, etc.). Our paleontologists supervised five public fossil digs during this time period (four in western ND and one in northeastern ND). In July 2017, the New York Times ran a three-page article on our public dig program and in August the NBC Today Show filmed a segment that aired in September of last year. As a direct result of that news coverage, we not only filled all 600 available spots for the 2018 digs on the first two days of registration, but also had 300 people on a waiting list.

Wilson M. Laird Core and Sample Library

Our core and sample library is located on the campus of the University of North Dakota. It was built in 1980 and contains roughly 85 mi of core (150,000 three-ft core boxes) and 50,000 sample boxes. In addition to the cores and samples, we have approximately 22,000 thin sections made from these cores. We have photographed each thin section as well as 152,000 ft of core and placed the resulting 375,000 photos on the Oil and Gas Subscription site. In 2016, we completed a \$13.2 million expansion and renovation of the core library (Fig. 1). Since we have sufficient storage for the next 40–60 years, we are allowing the University of North Dakota to store items on some of the shelving units until we are in need of that space.

Regulatory Programs

The North Dakota Geological Survey regulates coal exploration, subsurface mineral exploration and production, the Class III wells in the underground injection control program, geothermal production, and paleontological resource assessment permits



Figure 1. The Wilson M. Laird Core and Sample Library contains three large core laboratories for use by visiting scientists.

on state-owned land. Over the past 12 months, we issued 29 permits under these programs.

Earth Science Outreach

We produce a variety of educational materials—guidebooks, maps, non-technical publications, and exhibits. We work with schools, providing various kinds of Earth Science information. During this twelve-month period, our geologists gave 84 presentations to 3,800 people and answered more than 2,700 enquiries. In addition to the traditional service club breakfasts and luncheons, schools, and technical conferences, we also give tours of our paleontology laboratory and core workshops. Typically, more than half of our outreach is through our Paleontology Program.

Earth Science Information Center (ESIC)

The NDGS maintains a complete collection of USGS topographic maps and land-management maps for sale to the general public. We oversee the state's Digital Data Clearinghouse, which contains DEM, DRG, DLG, DOQQ, and other information on the web for access by other state and federal agencies and the general public. Sales of paper topographic maps are a fraction of what they were ten years ago due to the availability of digital files of these maps on the North Dakota GIS hub. Over the years, we have purposely kept our publication fees low and have distributed large numbers of our publications, without charge, to other state agencies, schools, visitors, etc. Some series, such as our county bulletins, newsletter, and postcards are free to the public. In addition, we have placed all of our out-of-print publications and our Geologic Investigations series onto our website so that they can be downloaded for free.

GPS Community Base Station

The NDGS chairs North Dakota's Global Positioning Satellite (GPS) Steering Committee, a public-access site. The base station was established by the NDGS in 1993 for state and federal agencies and was available to others on a subscription basis before

it was offered freely to the public. The site is part of the National Geodetic Survey's Cooperative CORS (Continuously Operating Reference Station) network.

Geologic Reviews

The NDGS does a number of environmental reviews, as well as paleontological and mineral assessments for both state and federal agencies. Survey scientists reviewed the geology for 153 environmental assessments of infrastructure (transmission and pipeline corridors, highway and bridge construction, wind farms), three solid waste permits, and paleontological assessments on 265 Trust Land tracts during this time frame.

Geologic Projects

During this twelve-month period, we published 236 articles, maps, and reports on various aspects of North Dakota geology. The majority of these were landslide maps.

OHIO

OHIO DIVISION OF GEOLOGICAL SURVEY

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INTRODUCTION

The Ohio Department of Natural Resources (ODNR), Division of Geological Survey was founded in 1837 and has been continuously authorized since 1869. The Division's mission is to provide geologic information and services needed for responsible management of Ohio's natural resources. It researches and reports on the geology of the state and is Ohio's archive for geologic information. Main offices are located on the ODNR main campus in north Columbus and at the Horace R. Collins Laboratory (HRC) at Alum Creek State Park. The Division's staff of 28 provides technical expertise to citizens, industry, and other agencies of government concerning coal, oil and gas, minerals, and geologic hazards. During the FY17 reporting period, the Division's budget consisted of severance tax income on fuel and non-fuel commodities; federal and state grants; departmental-allocated funds; and income generated from the sale of publications, maps, and data. Increased oil-and-gas production from the Utica-Pt. Pleasant shale play has increased the overall severance income of the Division by 10 percent from July of 2016 to June of 2017.

The Division is organized into six groups: Administration, Energy Resources, Geologic Mapping and Industrial Minerals, Ground Water, HRC/Lake Erie Science (HRCLES or "Hercules"), and Publications/Geologic Records Center. The Ground Water Group was added to the Division in June of 2017, whereas it was previously housed in the ODNR Division of Water Resources. This marks the first time that the Division of Geological Survey has contained a groundwater section since the 1970s. The Groundwater Group greatly expands the mission, importance, and visibility of the Division.

ADMINISTRATION

The increased severance income associated with the Utica shale play allowed then-State Geologist Thomas Serenko to focus on replacing retired staff with enthusiastic new staff, obtaining needed field vehicles, and purchasing necessary field equipment and software. Chief Serenko continued to expand the Division's efforts in two main areas: developing research areas for new employees and focusing on archiving projects. Degreed librarian/archivists were hired and the Division acquired considerable floor space in a neighboring building to host its archives. The archivists will systematically archive, catalog, and preserve the Division's abundant paper and digital collections of maps, reports, and other records. Acting Division Chief Mike Angle handles many of the day to day operations tasks including budgetary, fiscal, contractual, and legal matters. He also helps review geologic reports and proposals, and oversees grants. Chief Angle mentors the new Quaternary geologists on staff and assists with numerous public outreach activities.

ENERGY RESOURCES GROUP

Staff continued efforts with the Midwest Regional Carbon Sequestration Partnership (MRCSP) on delineating suitable target formations for CO₂ sequestration in eastern Ohio. Much of the work targeted deep Silurian carbonates. A field trip guide was completed that discussed correlating core from subsurface units in eastern Ohio to outcrops of equivalent units in western Ohio. The goal of this study is to determine how Silurian-age units change as they move from a near-surface setting along the Cincinnati Arch, eastwards into a deep-subsurface setting within the Appalachian Basin.

Geologist Michael Solis worked on a report analyzing deep seismic lines in eastern Ohio, delineating subsurface structural trends for an article in AAPG, and is mapping salt deposits of the Silurian-age Salina Formation in eastern Ohio. The salt deposits reflect a resource, a potential barrier or cap rock for CO₂ sequestration, and a potential deep gas storage area in southeastern Ohio. Geologists Kyle Metz and Chris Waid completed PG-6: Structure Contour and Isopach Maps for the Devonian Cleveland, Huron, & Rhinestreet Shales in Eastern Ohio (Fig 1). Waid also completed an extensive series of Open File Maps delineating stratigraphic sequences based on organic pay zones in the Devonian shale sequence in eastern Ohio. New geologist Julie Bloxson assisted Michael Solis with work on the Silurian salt project and mapped the Oriskany Sandstone and various other Devonian- and Silurian-age units in northeastern Ohio.

Metz and Bloxson completed Ohio's portion of a three-state, ethane storage project. The project included producing several maps and cross sections to best determine target zones for ethane storage in far-eastern Ohio, bordering Pennsylvania and West Virginia. The group also helps review the geologic framework for both Class I (hazardous waste) permits for the Ohio EPA and for Class II (oilfield brine) injection well permits for the ODNR Division of Oil & Gas Resources Management.

GEOLOGIC MAPPING AND INDUSTRIAL MINERALS GROUP

The Mapping Group continued detailed bedrock and surficial mapping for the 2016–2017 USGS STATEMAP project. Senior geologist Frank Fugitt and geologist Audrey Blakeman performed detailed mapping of Mississippian-age units adjacent to the Scioto River valley near Portsmouth. Together, they mapped the bedrock geology of the Waverly South and Lucasville 7.5-minute quadrangles at 1:24,000 scale. Their observations revealed that the nomenclature previously applied to this region was inaccurate and names applied to rock units just south of the Ohio River in Kentucky were adopted. Blakeman completed Geologic Note 12: Correlating Mississippian stratigraphic relationships between southern Ohio and north-central Kentucky, which described these changes in stratigraphic nomenclature. For the 2017–2018 STATEMAP project, Fugitt and Blakeman will continue mapping Mississippian-age strata to the north and east, covering the Bea-

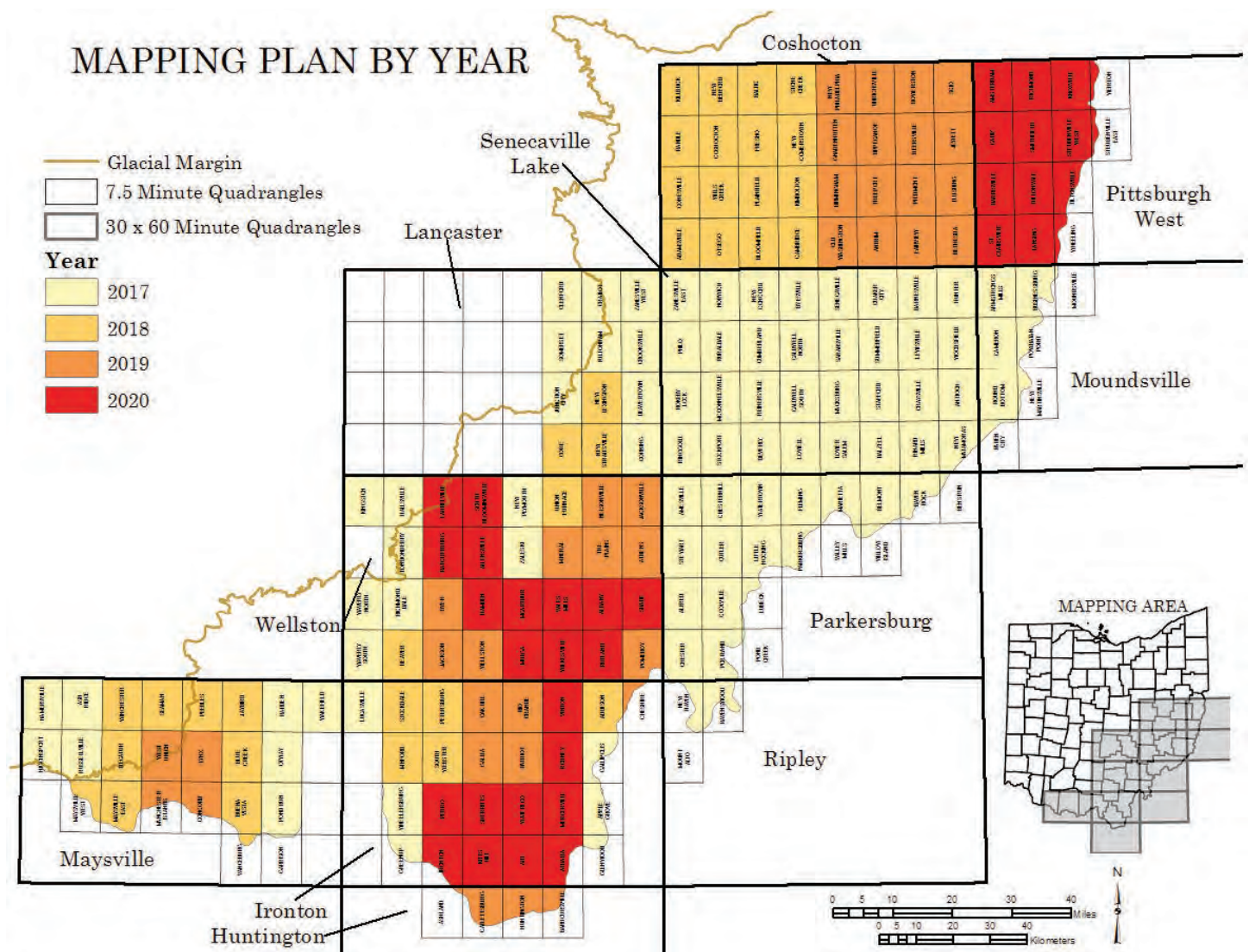


Figure 1. Surficial mapping area to be completed by year for southeast Ohio.

ver, Stockdale, and Minford 7.5-minute quadrangles. As part of the 2016–2017 STATEMAP project, geologists Fugitt and Blake-man also mapped the surficial geology of the Waverly South and Lucasville 7.5-minute quadrangles at 1:24,000 scale.

The USGS-sponsored Great Lakes Geologic Mapping Coalition (GLGMC) is another long-term funding source for the Division. In 2016 to 2017, geologists Nate Erber, Andy Nash, and Douglas Aden mapped the surficial geology of five 7.5-minute quadrangles in the eastern portion of Ross County in south-central Ohio. Erber and Aden are also helping to create a Quaternary sediment database and GIS interface that will geospatially locate thousands of till samples with particle grain size and carbonate content analysis. These data will prove helpful for future mapping and research initiatives. Aden is leading the Division's karst mapping program and recently produced Open-File Report OFR 2017-2: Karst of the Sinking Spring 7.5-minute Quadrangle, Ohio.

In the spring of 2017, the Division hired geologists Chris Wright and Shane Smallwood to generate resource estimates for the Lower Kittanning (No. 5) and Middle Kittanning (No. 6)

coal seams in eastern Ohio. Funding for this was provided by the Ohio Coal Development Office (OCDO). Geologist J. D. Stucker compiled the 2015 Report on Ohio Mineral Industries which was released in November of 2016 and is finalizing the 2016 Report on Ohio Mineral Industries to be released in November of 2017. Stucker has streamlined and updated this process and, along with former-Chief Serenko, represented the Division at the Forum of Industrial Minerals Conference in southern Indiana in August.

Geologists Paul Spahr and J.D. Stucker initiated an ambitious plan to complete the remaining unmapped (approximately 170) quadrangles within the next five years (Fig. 2). The entire Mapping group, along with support from the Ground Water group, will be working on this project as time allows.

Brittany Parrick is the geology technician for the group and has been busy scanning slides for the USGS data preservation grant, scanning geophysical logs, and working on archiving the Division's collection of Quaternary cores.

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

D. Mark Jones is the supervisor of this group, which includes three other full-time geologists and one intermittent geologist. The H. R. Collins Core and Sample Repository (HRC) continued to acquire core and sample collections to augment the 300,000 linear feet of core currently stored at the facility. The interest of the visitors to the facility has migrated from industry to academic-related research. Geology technician Jeff Deisher serves as curator and works to lay out core and collected samples for visitors. Deisher has recently obtained additional core from northeast Ohio. Jones and Deisher are kept busy making necessary repairs and maintenance to the core repository. Some needed upgrades were made to the OhioSeis network, and some essential displays, furniture, and equipment were purchased.

Files and maps at the HRC are being organized and scanned to create a Lake Erie Science Center and a data archive for Division information. New records officer Lisa Long is making progress archiving and cataloging the vast number of maps, charts, files, and digital records associated with the former Lake Erie Geology Group that was housed in Sandusky, Ohio. Ann Rogers, a MSL student of Library Science, completed a practicum over the summer of 2016 in which she helped archive and organize a large volume of side-scan sonar data. This effort is critical to helping the Division determine how much of the nearshore portion of the lake has been analyzed with this technique. Jones, geophysicist Daniel Blake, and geologist Amy Spaziani investigated purchasing some newer software for processing side-scan sonar and determined how to best set up the equipment and boat for the fieldwork. They prepared for running the sonar and doing some bottom profiling for the Mentor Lagoons area along the coast of northeastern Ohio. They also took some measurements along the shoreline and neighboring bluffs. These data will help predict formation or loss of beaches, effectiveness of shore protection, and other related factors in nearby Mentor Lagoon. Jones is also involved in the periodic Coastal Erosion Area (CEA) mapping, which is a mandated program that requires the Division to examine shoreline recession and erosion rates along thousands of transects. These transects run perpendicular to the shoreline and are spaced at 100 ft intervals. Mapping Group staff Erber and Aden are helping determine and digitize the shoreline recession. Erosion rates are calculated for the entire coastline and areas with significant erosion are placed into a CEA designation which carries implications for deeds, transactions, and building permits. The process also involves disseminating the findings in public meetings and addressing objections or concerns from the public. Jones also finalized Geological Note 11: Comparison and Analysis of Ohio Coastal Recession Data from Two Periods.

The Ohio Seismic Network (OhioSeis), headquartered at the HRC, continued its mission of monitoring for earthquakes. The group has installed several Guralp seismometers in vaults and works closely with the IRIS U.S. Transportable Array (TA)/Earthscope (now USGS N-4) Network. Geophysicists Jeff Fox, Sara Kowalke, and Daniel Blake are managing all the OhioSeis-re-

lated activities. The OhioSeis program has made great strides at implementing new IT developments, seismometers, data downloading, storage, and archiving. The OhioSeis staff visited most of the network stations to troubleshoot current instrumentation and determine likely sites that can be upgraded to newer and more sensitive seismometers. The group began a lengthy project with hosting a server that can provide them continuous monitoring and alerts. When a seismic event occurs, they must determine if it is an actual event (vs. a mine blast for example), determine the exact location, depth, and magnitude and help decide if the event was naturally occurring or perhaps induced. They work closely with the ODNR Division of Oil & Gas on these determinations. Senior geophysicist Fox has been working on numerous outreach-related activities. One such activity was working with The Ohio State University and Miami University to record “FanQuakes” at The Ohio State stadium during large football games. The crowd activity simulates the equivalent shaking of a small earthquake when important plays and scoring occurs. Blake has obtained a pair of Trominos, small passive seismic devices that allow shallow seismic data acquisition. These will be used to refine the bedrock topography and drift thickness for Ohio’s many deep buried valley systems. The Group also helped with the editing and publishing of an Earthquake Catalog that captures information on every major recorded seismic event through Ohio’s history. The Catalog reflects several years of hard work by the now-retired founder of the OhioSeis network, Dr. Michael Hansen.

PUBLICATIONS AND GEOLOGIC RECORD CENTER (GRC) GROUP

This group is responsible for the final editing, layout, production, and release of reports and maps. It also updates the Division website, scans records, and designs databases. In addition, this group manages the Division’s sales office and records center and handles incoming requests for information and publications. Chuck Salmons, the Division’s Technical Publications Editor remains an important entity in this group by providing support for outreach activities, updating website content, facilitating printing and publishing tasks, and performing editorial duties. Salmons serves as a liaison with the Creative Services Section of the ODNR Office of Communications and helps the Division administration track progress on projects and publications. Creative Services helps produce and layout presentations, posters, displays, announcements, proposals, and other short-term products. Dave Orr at Creative Services helps with many of these tasks for the Division and provides technical web support.

Long-term Customer Service Assistant Madge Fitak has over 35 years of experience with the Division and oversees the Geologic Records Center (GRC) which is the Division’s direct connection with Ohio citizens and industry. Maps, geologic records, and data are made available to walk-in and online customers as well as via phone and e-mail requests. The GRC has assisted 220 counter customers, processed 370 miscellaneous sales transactions, taken over 400 phone calls, responded to 280 emailed requests, and distributed over 15,000 free handouts such as leaf-

lets, pamphlets, and 8.5 x 11 in. geologic maps on various topics. Digital copies of downhole geophysical logs for oil and gas wells remain the largest selling item at the GRC. Income from the sales of maps, reports, and digital information was over \$70,000 for calendar year 2016 to date. Madge also performs a myriad of behind-the-scenes tasks for the Division ranging from organizing all our social and meeting events such as our annual winter and summer picnics to handling our petty cash account.

Archivist Lisa Long continues the relentless effort of examining Division files and records at both the Columbus office and the HRC. Lisa has made great strides in organizing the Survey's numerous physical collections, along with evaluating the Division's digital files and looking for duplicate and corrupt files. Lisa wrote a small grant through the Library Services and Technology Act that provides funding for boxing and archival supplies. The supplies were used to re-box hundreds of historical seismograms ranging from 1909 to 1992 and obtained from John Carroll University. These seismograms have captured numerous major world-wide historical events.

The Publications and GRC Group, along with the geological and administrative staff, has had a busy year of public outreach, which included participating in several major rock-and-mineral and fossil shows (Akron, Cincinnati, Columbus), participating in the Cincinnati Fossil Fest in November, and helping conduct a fossil and building stone tour at the Ohio State House. The Division had a large presence during Earth Science Week in mid-October, including leading hikes at several state and metro parks and nature preserves, and hosting a number of presentations at universities and primary schools. The group also assists the Ohio Aggregates and Industrial Minerals Association (OAIMA) with some of its educational outreach opportunities and at its annual conference in November. The Division also participates in OAIMA's annual legislative reception at the Ohio state house every spring.

The Publications and GRC Group did considerable editing and layout to produce Guidebook 22: Guide to the Serpent Mound Impact Structure, South-Central Ohio which was authored by Keith Milam, a professor at Ohio University in Athens, Ohio.

using the DRASTIC system, and statewide Aquifer Maps in GIS. The group answers hundreds of data requests per year and its website averages 60,000 hits per year. The Ground Water Group manages investigations pertaining to the groundwater quantity in water stressed areas, and reviews mining permits for the Division of Mineral Resource Management to determine if the mining will impact the water table for nearby residents. The Group also oversees the Water Well Observation Network, which consist of more than 140 permanent wells that continuously monitor groundwater levels across the state. The wells monitor groundwater-stressed areas with high water usage and ambient conditions for various aquifers in different physiographic areas. These wells are critical for monitoring climate change, especially incipient drought conditions.

GROUNDWATER GROUP

As of this writing, in June 2017, the Ground Water Group has just been transferred from the ODNR Division of Water Resources to the Division of Geological Survey. The Division of Geological Survey acquired three hydrogeologists and two hydrologists that perform many critical tasks. The Division obtained one of the most critical databases in that state, the Ohio Water Well Log System. This database includes the images and data for over 800,000 water well logs (about half of which have GIS locations). It also accepts newly completed water well and sealing report records. The Ground Water Group has several series of maps including Ground Water Resources Maps (water availability or well-yields), Potentiometric Surface (water-table) Maps, Ground Water Pollution Potential (aquifer vulnerability) Maps created

OKLAHOMA

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INTRODUCTION

The Oklahoma Geological Survey (OGS) is a state agency for research and public service located on the Norman Campus of the University of Oklahoma and affiliated with the OU Mewbourne College of Earth and Energy. The Survey is chartered in the Oklahoma Constitution (70 OK Stat § 70-3310 (2014)(RTF) http://webserver1.lsb.state.ok.us/os/os_70-3310.rtf) 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. The OGS has no regulatory authority.

To carry out this mission, OGS develops and executes both short-term and ongoing projects to map significant geologic features (at the surface and in the subsurface), characterize relevant geologic units, such as oil and gas reservoirs, source rocks and aquifers, define geologically relevant resources and development activities, and identify and characterize significant hazards. The OGS also provides a variety of outreach activities, including publishing the Oklahoma Geology Notes and other reports of its results, conducting workshops on geologically relevant topics, and making presentations at a variety of industry, government, and public meetings.

OGS's funding has characteristically been derived wholly from state funds. In recent years, a number of alternative sources have been sought with some success, especially in the areas of seismicity and hydrology. STATEMAP projects are also an important source of funding. OGS employs 27 staff, including those working at the Oklahoma Petroleum Information Center (OPIC), our core and oilfield data repository.

The response to the elevated frequency of seismic activity continued to be an important activity in 2017–2018 for the OGS, despite an ~30 percent drop in earthquake rate since last year. The OGS continues to monitor its network of seismometers and has begun the transition to a more stable software platform for tracking and cataloging of earthquakes. OGS completed two geologic maps as part of the STATEMAP Program, and initiated work on two more. In addition, subsurface maps for three stratigraphic horizons (Top Basement, Top Arbuckle Group, Arbuckle Group Isopach, and Top Woodford Formation) were released as OGS Open File Reports. The Survey hired a Petroleum Geologist, a Quaternary Geologist/Hazards Geologist, and a Petroleum Geologist/Organic Petrographer. Two members of the seismic team left to join the U.S. Geological Survey's Hawaii Volcano Observatory.

GEOLOGIC MAPPING

OGS conducts diverse geologic and derived mapping efforts, through participation in the U.S. Geological Survey STATEMAP program (mainly bedrock mapping at this time), through efforts to characterize important oil and gas plays, and through projects related to understanding seismic hazard in Oklahoma.

Bedrock Mapping

From July, 2017 through June, 2018, the Oklahoma STATEMAP program, led by Tom Stanley, completed two mapping products: 1) a 1:24,000-scale map of the LeFlore quadrangle, and 2) a 1:100,000-scale map of the Bristow 1° sheet. The LeFlore quadrangle is part of a project to digitize and release maps of 1:24,000-scale geologic quadrangles completed during 1984 through 1997, but available only as hand-drawn versions. These quadrangles lie at the northern front range of the Ouachita Mountains and southern extent of the Arkoma Basin.

Mapping of the Bristow sheet is part of a longer-range plan to provide Oklahoma with full, 1° reconnaissance map coverage. Overall, the geology of the Bristow sheet falls within the Northern Shelf geologic province of Oklahoma, which is characterized by gently westward dipping red-bed sedimentary rocks of Lower Permian through Upper Pennsylvanian age. Mapping was intended to improve characterization of Quaternary deposits under-represented on previous maps (but important to local farmers as aquifers), inventory industrial mineral resources, and delineate the interfingering of north- and south-derived sedimentary rocks. For both projects, mapping was performed from November 2016 through early April 2017. The maps were finalized during summer 2017, and all deliverables were submitted in August 2017.

The 2017–2018 STATEMAP project includes mapping at 1:100,000 scale of the Shawnee sheet, which continues the trend of the previous year's project on the Bristow sheet. The Shawnee sheet is the next step in the 1° sheet effort, following the Bristow sheet completed this year. It also falls within the Northern Shelf geologic province of Oklahoma, characterized by gently westward dipping sedimentary rocks of lowest Permian through Upper Pennsylvanian age. Mapping objectives are the same as for the Bristow sheet. In addition, the OGS will submit another digitized 1:24,000-scale geologic map from the northern front range of the Ouachita Mountains and southern extent of the Arkoma Basin, the Blackjack Ridge quadrangle.

Surficial Mapping

As noted above, an important aspect of the STATEMAP program over the last two years has been better mapping of Quaternary deposits that serve as aquifers for local farmers. The OGS also published the Preliminary Soil Amplification Map of Oklahoma (Geologic Map 41, available at <http://ogs.ou.edu/docs/geologicmaps/GM41.pdf>), which identified seismic hazard levels based on soil character. The publication included a supplement containing Geographic Information System (GIS) files for the map. The OGS also reissued two maps of active coal mines from the 1970s as digital Open File Reports (Map of Eastern Oklahoma Showing Location of Coal Mines Active in 1975, OFR 2017-3 and Map of Eastern Oklahoma Showing Location of Coal Mines Active in 1976, OFR 2017-2)

Subsurface Mapping

The OGS published three Open File Reports that consisted of maps of subsurface units as part of a larger effort to develop a

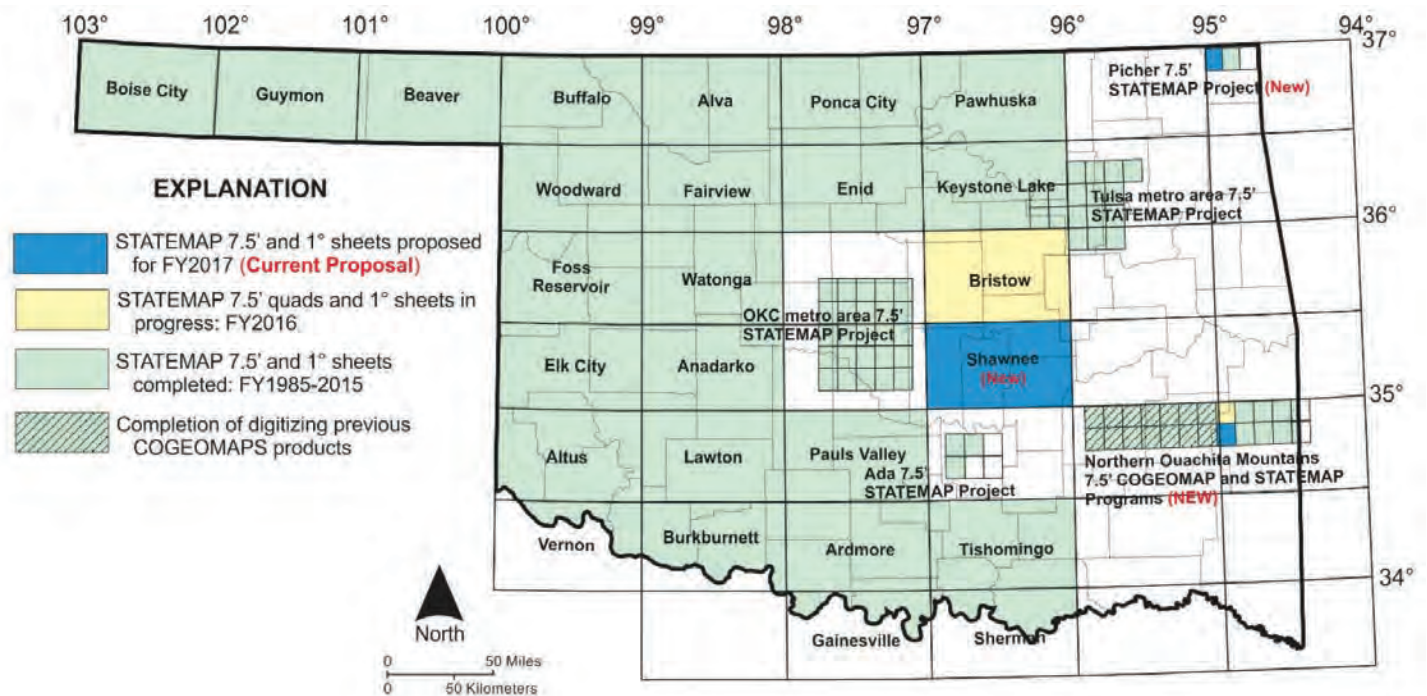


Figure 1. Map showing National Cooperative Geologic Mapping Program activity in Oklahoma in 2017–18. Quadrangles and sheets in yellow were submitted in August 2017, and those in blue were mapped during 2017 and 2018.

3D geologic and lithofacies model in support of a gravity model of the entire state. The maps included *Preliminary Structure Map of the Woodford Shale of Oklahoma*, (OFR 17-2018), *Elevation and Thickness of the Ordovician Arbuckle Group in Oklahoma and Surrounding States*, (OFR 2-2018), and *Elevation Map of the Top of the Crystalline Basement in Oklahoma and Surrounding States* (OFR 1-2018). Each report included a supplement containing GIS files for the mapped surfaces.

Historic Map Preservation

In July 2017, OGS Staff Members Brittany Pritchett and Jim Anderson unveiled the first geological map of Oklahoma, hand drawn by Charles N. Gould in 1904 (the Gould Map), which has been repaired, conserved, and framed for display in the Lawrence S. Youngblood Library at the Sarkeys Energy Center. The efforts Brittany and Jim contributed saved an important piece of Oklahoma history, and brought to light not only a reminder of from where our science has come, but where it has yet to go.

Suriamin started work as the senior petroleum geologist for OGS in February 2018, and Abbas Seyedolali began work in July 2018 as a petroleum geologist and organic petrographer to work with both Suriamin and Brian Cardott.

This team was instrumental in assembling the STACK (Sooner Trend, Anadarko Basin, Canadian and Kingfisher Counties) Oil & Gas Play workshop, which included one day of presentations and two half-day core workshops at the OPIC facility. The background work on OPIC cores from the STACK play has been a major effort for Suriamin and Seyedolali since their arrival at OGS.

Brian Cardott maintains several tables of well completions in unconventional oil and gas fields of Oklahoma as part of his Oklahoma Coal database. The Coalbed Methane completions table (<http://www.ou.edu/content/ogs/data/coal.html>) currently contains 6,006 records and the Gas Shale completions table (<http://www.ou.edu/content/ogs/research/energy/oil-gas.html>) contains 4,897 completions. The Analytical Coal Header and Data table contains 1,562 records.

ENERGY RESEARCH

OGS conducts research on aspects of extractive energy resources such as oil, natural gas, and coal, and has investigated the potential for sequestration of carbon from use of these resources. Studies in this broad area have included mapping of oil and gas fields, tracking of oil, gas, and coal development and production activity, characterization of the organic material in coal and source rock for oil and gas, sub-surface mapping of relevant stratigraphic horizons, and characterization of reservoir and source rock formations as a part of play analysis. “Ming”

HAZARD ASSESSMENT

Research on hazards in Oklahoma received a boost when the OGS hired Netra Regmi in early 2018 to serve as hazards/quaternary geologist. He mapped more than 100 shallow landslides in Le Flore County and determined their relative ages based on the analysis of historical aerial photographs (1995–2018). He is using available lidar elevation data to characterize hillslope dynamics by evaluating lidar-based surface geometries of slopes with and without landslides, and by computing the flux of sediments generated and transported by landslides.

GEOPHYSICAL INVESTIGATIONS

Aeromagnetic Survey

Kevin Crain worked with USGS geophysicist Anjana Shah to conduct an aeromagnetic survey of parts of Oklahoma to develop structural and rock property models. There are three survey areas tied to earthquakes and one connected to mineral resources. The earthquake study areas are in the northwest (Woods and Woodward Counties) and in the vicinity of Prague (Payne and Lincoln Counties); the mineral resources survey is in the Southern Oklahoma aulacogen region. After the initial processing, these data will be released by the USGS as public data. These data need integration with current and updated geophysical data and geological models to improve understanding of the past geologic setting, and recent earthquake activity.

Seismicity

The Oklahoma Geological Survey monitors approximately 100 seismometer stations in and around the state. These include stations that OGS owns, some that are on loan from the Portable Array Seismic Studies of the Continental Lithosphere (PASSCAL) program, and others that belong to the U.S. Geological Survey or other research organizations. The OGS recorded 2,557 earthquakes between July 1, 2017 and June 30, 2018. Of these, 255 were magnitude 3.0 or greater (M3.0+); 72 were M3.5+, and 9 were M4.0+. This represents a decline of ~30 percent from the previous year (July 2016–June 2017), when 3,550 earthquakes were recorded, of which 373 were M3.0+, 100 were M3.5+, and 12 were M4.0+. The OGS catalog contains more than 30,000 earthquake records located by OGS staff.

OGS took an official position in early 2015 that the earthquakes were triggered when saline formation water was injected into the Arbuckle Group. Pressure transmitted from the Arbuckle into the underlying basement triggered earthquakes on faults, many of which were previously unrecognized. The very large volume of produced water came from high water cut wells in two limestone plays, the Hunton Dewatering Play, (in Oklahoma, Lincoln, Logan, Okfuskee, Payne, Pottawatomie, and Seminole Counties), and the Mississippian Limestone Play (in Alfalfa, Garfield, Grant, Logan, Pawnee, Payne, and Woods Counties).

The OGS seismology team, led by State Seismologist Jake Walter, have interacted regularly with staff of the Oil and Gas Conservation Division of the Oklahoma Corporation Commission, which is charged with regulating disposal of produced water from oil and gas wells. The water is mainly disposed of in underground injection control wells, many of them completed in the Arbuckle Group. OGS staff also attend monthly meetings of the Governor's Coordinating Committee on Seismicity, where industry, government, and researchers discuss issues of mitigation of the earthquakes.

The OGS seismology team also organized and hosted the Eastern Section of the Seismological Society of America annual meeting in Norman in October and conducted a field trip for the meeting.

HYDROGEOLOGIC INVESTIGATIONS

The OGS conducted water level sampling in shut-in injection wells in the Arbuckle Group as part of a program with the Oklahoma Independent Petroleum Association (OIPA) to understand the connection between deep injection and induced seismicity

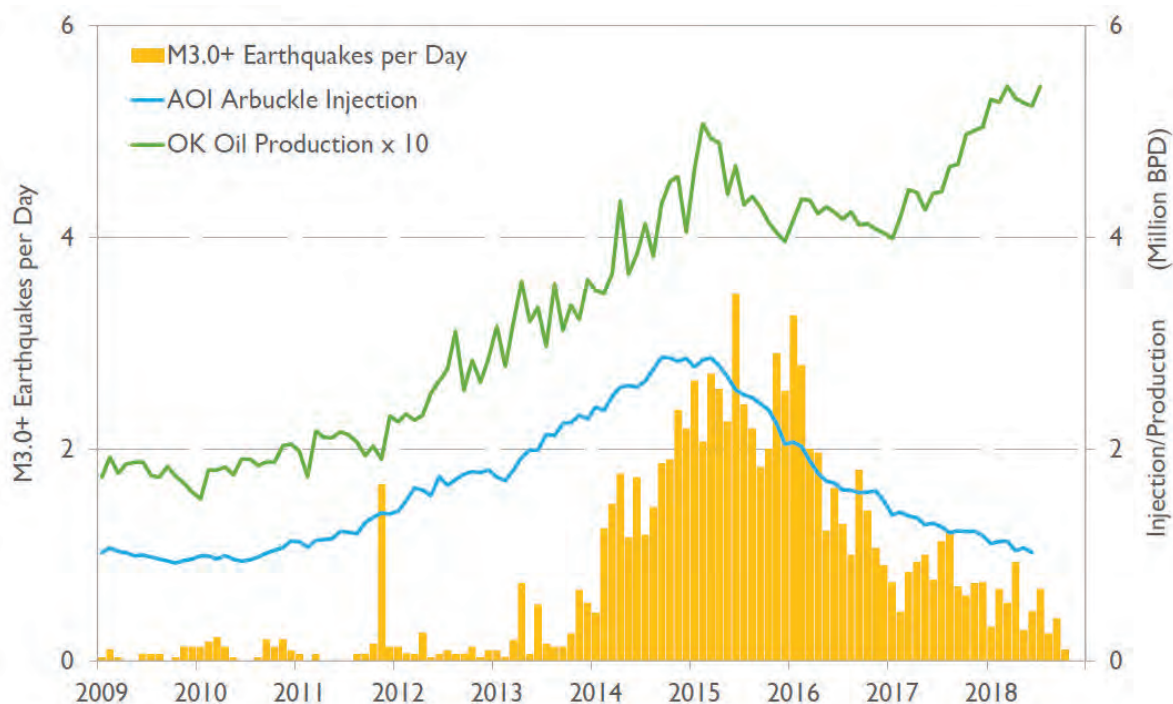


Figure 2: Frequency of M3.0+ earthquakes in Oklahoma, 2009 to present; Produced water injection volumes into Arbuckle Group disposal wells in the earthquake Area of Interest defined by the Oklahoma Corporation Commission; Oklahoma oil production (multiplied by 10 for graphic clarity)

in north central and western Oklahoma. Hydrogeologist Kyle Murray and his team instrumented 15 wells and recorded data from them over the course of the year. Earth tidal signatures in elevation data have been analyzed to provide larger scale hydrologic properties of the Arbuckle Group essential to modeling the behavior of pressure effects on stress in the deep basement. Inferred properties differ from those commonly used in current models.

Murray and his team also completed a study on Contaminants of Emerging Concern in Lake Thunderbird for the Central Oklahoma Master Conservancy District Board. The study investigated a wide range of potential contaminants that do not yet have regulatory limits but have potential to cause environmental impacts in the near future.

DATA AND COLLECTIONS MANAGEMENT

The OGS-OPIC facility is the largest and most comprehensive well data and core repository in the state of Oklahoma—a state where oil and gas exploration has been a primary industry going as far back as statehood. Very few states see the staggering amount of physical and digital data derived from oil and gas exploration that can be found in Oklahoma. As a result, many historically unique collections housed at OPIC are not replicated elsewhere in the country. These materials, in combination with OGS's legacy of research and publications, present an opportunity for the dissemination of data to the public that cannot be duplicated by any other well data service, subscription or otherwise.

OGS Associate Director David Brown and OPIC and OGS Data Collections Manager Richie Tarver have recently initiated an effort to develop a comprehensive database of Oklahoma's geoscience and natural resource data that will be free and accessible to the public via a map-based web application. Contents of the database will include digitally preserved images of OPIC core and data holdings, OGS publications, and research that will be synthesized with a master record of georeferenced Oklahoma oil and gas wells and associated production values. In addition to digitized in-house collection data, the OGS has partnered with the Oklahoma Corporation Commission and Oklahoma Tax Commission in order to serve as the comprehensive online source for state natural resource data.

As stakeholders of Oklahoma's natural resources, citizens and energy industry professionals alike will finally have a single online source to access a wealth of information relating to the state's natural resources, including: oil and gas production data, geophysical well logs, completion reports, core and sample data, geology publications, aerial photography, and other data pertaining to the state of Oklahoma's geology and energy resources. Providing access to the data will have a positive impact on the economic development of Oklahoma's natural resources through best practices and environmental stewardship.

OUTREACH ACTIVITIES

OGS Outreach activities ramped up with the hiring of Molly Yunker to serve as Outreach and Workshop Coordinator in May 2017. In her first year, Molly coordinated two workshops, one on Induced Seismicity and one on the STACK (Sooner Trend, Anadarko Basin, Canadian and Kingfisher Counties) Oil & Gas Play. She also took over operation of the BLOSSM (Bridging Local Outreach & Seismic Signal Monitoring) Project, a citizen seismology project. The OGS published four issues of the Oklahoma Geology Notes, five Open File Reports, and three geologic maps. In addition, many members participated in workshops, presentations and interactions with school, public, government, and industry groups across the state and out-of-state.

Induced Seismicity Workshop

The Oklahoma Geological Survey (OGS) hosted a workshop for seismicity researchers on Feb. 21 and 22, 2018. Approximately 100 researchers attended, despite an ice storm in the area. Attendees represented the oil and gas industry, universities, and state and federal government agencies, including state geological surveys, the U.S. Geological Survey and U.S. Department of Energy national laboratories. The purpose of the workshop was to gather researchers who often work and collect data independently of each other to share early stage research in hopes of forming collaborations, cooperation, and best practices. Presentations covered a wide range of topics, with a focus on patterns of induced seismicity, its causes, and means to reduce earthquake severity.

STACK Play Workshop

The OGS hosted the STACK Play Workshop on September 6-7th, 2018. The STACK (Sooner Trend Anadarko Canadian Kingfisher) Play was discovered in 2011. The play has quickly become one of the hottest resource plays in North America. Despite extensive drilling activity in this play, our understanding of the petroleum geology of the play is limited. Therefore, the main objective of this workshop was to learn from researchers and operators in the STACK Play, with an emphasis on the Meramec Limestone and Woodford Shale. Presentations focused on the depositional system, stratigraphy (biostratigraphy and chemostratigraphy), geochemistry, petrophysics, facies analysis, and fracture characterization. Understanding of these features requires comprehensive evaluation of the play and commercial production of hydrocarbons from these low porosity and low permeability reservoirs. The workshop also included a half-day core workshop element, conducted at the OPIC facility, and examining core in the OPIC collection. Demand was so high for this part of the workshop that a second half-day session was added, and OPIC installed projection equipment so that the attendees could see all of the core as it was being discussed.

BLOSSM (Bridging Local Outreach & Seismic Signal Monitoring)

Molly took over operation of the BLOSSM Project, whose objectives are to promote seismology as a part of Science, Technology, Engineering and Math (STEM) education, and to collect scientific data to supplement the state earthquake monitoring network. BLOSSM in Oklahoma is deploying 100 seismographs into K-16 educational institutions, and public learning spaces such as museums and libraries. OGS will support participants in BLOSSM through mini-workshops to provide time for teachers to work with one another, and to have time with OGS's seismic analysts and curriculum experts. The project team developed a three-phase rollout plan, with pilot, regional, and statewide phases. Phases one and two are complete.

OREGON

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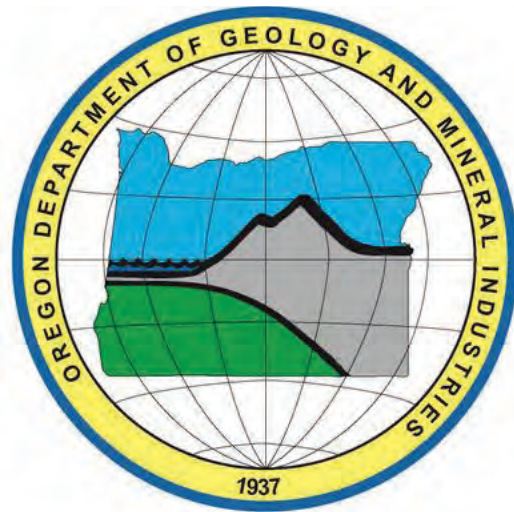
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INTRODUCTION

The Oregon Department of Geology and Mineral Industries (DOGAMI) increases understanding of Oregon's geologic resources and hazards through science and stewardship. The Agency's mission is to provide Earth science information and regulation to make Oregon safe and prosperous. Our Geological Survey & Services program develops maps, reports, and data to help Oregon manage natural resources and prepare for natural hazards such as earthquakes, tsunamis, landslides, floods, volcanoes, and coastal erosion. Our Mineral Land Regulation & Reclamation program oversees the State's mineral production and works to minimize impacts of natural resource extraction and to maximize the opportunities for land reclamation. An independent executive agency of the State of Oregon, DOGAMI assists in the development of state policy related to geologic materials, natural resources and hazards, as well as policy related to mining, oil, gas and geothermal exploration, production, conservation, and reclamation. DOGAMI's current funding ratio is 27 percent state general funds, 32 percent federal funds, and 41 percent other funds. Limited general fund support has led the Agency to seek partnerships with local, state and federal governments and organizations that need our services. DOGAMI's business plan can be best defined as cooperatively funded, mission-related projects.

GEOSPATIAL DATA COLLECTION, COMPILATION, AND DISTRIBUTION

Since 2007, DOGAMI has been working toward the goal of providing high-quality, high-resolution lidar coverage for the entire state through the Oregon Lidar Consortium. The State's lidar coverage expanded modestly in 2016, with funding provided by FEMA, the Confederated Tribes of the Umatilla Indian Reservation, the Oregon Department of Forestry (ODF), and the USFS. In 2016 DOGAMI also developed a partnership with FEMA, ODF, and the USGS 3DEP program for a 1,000 mi² flight in early 2017. More than 24 million acres of data have now been collected, covering 98 percent of the State's population and 39 percent of the state's area. DOGAMI's interactive Lidar Data Viewer at <https://www.oregongeology.org/lidar/index.htm> offers a look at bare earth digital elevation models, free downloadable lidar data, and a project area information layer. As interest in the many practical applications of lidar continues to grow, DOGAMI has successfully leveraged the State's modest initial investment in lidar acquisition with funds from a variety of partners including local, state, and federal government entities and private sector and non-profits.

GEOLOGIC MAPPING AND RESOURCE ASSESSMENTS

In 2018, DOGAMI continued geologic mapping in the Middle Columbia Basin of north-central Oregon, working in collaboration with USGS mappers and the Oregon Water Resources Depart-

ment. This work is significantly refining the understanding of stratigraphic and structural controls on groundwater availability and the potential for geologic hazards such as earthquakes and landslides, and is identifying new potential rock resources. This work is also developing a more detailed stratigraphy for volcanic rocks of the northern Oregon segment of the Cascades volcanic arc and helping to refine our understanding of its petrologic and structural evolution through time. DOGAMI also continued a mapping program to characterize the geologic controls on groundwater for the Harney Basin of southeastern Oregon. Both projects are high priorities of the Oregon Geologic Mapping Advisory Committee. Work was supported in part by the U.S. Geological Survey STATEMAP component of the National Cooperative Geologic Mapping Program.

COASTAL PROCESSES AND HAZARDS

The Oregon coast has experienced periods of significant coastal changes over the past century. The most recent phase of major erosion occurred in the late 1990s when a combination of extreme storms and enhanced ocean water levels (associated with an El Niño) produced significant erosion at multiple sites on the Oregon coast. The erosion led to many homes on the north coast requiring expensive remediation to protect the homes from the effects of future storms.

To better understand the spatial and temporal variability of changes taking place on the coast as well as their causes, DOGAMI geologists established the Oregon Beach and Shoreline Mapping Analysis Program (OBSMAP). This network of monitoring stations includes ~178 core sites that are observed on a seasonal basis, and several hundred more that are monitored as funding permits. Funding for this effort is made possible through a partnership with the Northwest Association of Networked Ocean Observing Systems (NANOOS); NANOOS is a cooperative venture funded by NOAA to establish a regional coastal ocean observatory for the estuaries and shores of the Pacific Northwest. To date, these data have provided important insights in the response of U.S. West Coast beaches to the effects of major El Niños and with respect to multi-decadal changes in the alongshore movement of sediment on the northern Oregon beaches. Additionally, these data were instrumental in securing support from FEMA to complete updated coastal flood hazard maps for the entire Oregon coast. These reports used state-of-the-art wave modeling and lidar topographic data to map areas at risk from ocean flooding during large storms.

DOGAMI continues to work closely with local government, particularly in areas relating to dune management. For example, DOGAMI staff completed a major study that examined historical coastal changes occurring in the Cannon Beach littoral cell. The impetus for this work was the long-term accumulation of sand at the north end of the cell, which had become a nuisance for homes built adjacent to the growing dunes. Results from that study are being used by decision makers as they develop new dune management plans for the community. DOGAMI staff have also worked with the USACE to monitor and understand the

response of a dynamic revetment or cobble berm constructed at the south jetty at the mouth of the Columbia River. This ‘design with nature’ approach utilizes cobbles instead of conventional riprap boulders to mitigate wave runoff during storms. DOGAMI’s role was to document how the structure has responded to major storms and to identify any potential design improvements.

By far the biggest hazard facing the Oregon coast is a great earthquake and accompanying tsunami on the Cascadia subduction zone. To address this hazard, DOGAMI completed 89 new tsunami inundation maps, covering the entire Oregon coast, along with 42 tsunami evacuation maps. Mapping was fully completed in June 2013. Since then, DOGAMI coastal staff have focused on completing new evacuation modeling for coastal communities to identify the best and fastest routes out of harm’s way. This modeling, termed “Beat the Wave” tsunami evacuation maps, shows residents of coastal communities how fast they need to travel from any starting point to reach safety ahead of the wave. The approach allows for scenario planning that can be used to evaluate the effects of hardening existing routes, and (or) for the evaluation of siting of vertical evacuation structures. To date, evacuation modeling studies have been completed for Seaside/Gearhart, Warrenton/Hammond, Rockaway, Pacific City, and Reedsport/Florence; modeling is currently ongoing in another dozen communities. Major work has also been completed to evaluate maritime tsunami hazard guidelines for the Oregon coast. This study examined the offshore tsunami current velocities and potential for wave amplification as a result of both local and distant tsunami hazards in order to identify offshore staging areas for maritime evacuation. Similar work has recently been completed for the Columbia River system. This study involves an entirely new modeling effort that incorporates dynamic tides, different river flow regimes, and friction, providing the most realistic understanding of both a Cascadia earthquake and tsunami hazard to date; similar modeling was completed for a maximum-considered distant tsunami originating in the eastern Aleutian Island chain.

GEOLOGIC HAZARDS MAPPING AND DATA

DOGAMI continues to map landslide hazards and risk throughout the state. Studies are underway to complete coverage of Oregon largest urban area, the Portland Metro region, as well as in the Eugene–Springfield urban area, Oregon’s second largest. DOGAMI is collaborating on a NEHRP-funded project with the University of Oregon to study the age of landslides that may have been triggered by past subduction megaquakes. DOGAMI continues to work with FEMA to revise Flood Insurance Rate Maps (FIRMs) and development of maps and web tools for understanding exposure to flood hazard. FIRM revision, which also involves outreach to communities as they review the maps for incorporation into their flood hazard ordinances are often supplemented by multi-hazard and risk analyses of communities that will use detailed earthquake, flood, landslide and tsunami hazard data and Hazus software to estimate losses from multiple hazards. DOGAMI is also working on a Hazus-based earthquake loss estimate for the

Portland urban area that will assess the potential damage due to a M9 subduction quake. The project includes estimates for over 750,000 discrete buildings and has required development of novel tools to handle the scope.

OUTREACH & EDUCATION

The Agency’s website continues to be the primary way we make information widely available. Some categories of content saw substantial increases in viewers: publication content pageviews were up 38 percent, and lidar pageviews were up 223 percent. DOGAMI’s interactive hazards maps continue to be popular. The Agency’s first StoryMap, associated with our Portland metro landslide publication, was extremely popular, with 9,700 pageviews the first two days it was up. Spikes in user numbers occurred on:

- September 21, 2017—10,577 pageviews—mostly for SLI-DO, DOGAMI’s interactive landslide map, after the agency issued Open-File Report O-17-03, Landslide inventory of eastern Multnomah County, Oregon, a new landslide risk publication for the Columbia Gorge area, coincidentally after the devastating Eagle Creek fire.
- January 23, 2018—9,738 pageviews—mostly due to views of tsunami inundation and evacuation maps after a tsunami alert was issued (and subsequently cancelled, after a 7.9 earthquake off Alaska).
- March 15, 2018—15,069 pageviews—due to views of just released DOGAMI Open-File Report O-18-02, Earthquake regional impact analysis for Clackamas, Multnomah, and Washington counties, and HazVu, DOGAMI’s natural hazards viewer, after a coordinated media blast.
- April 12, 2018—11,697 pageviews, release of IMS-57, Landslide hazard and risk study of central and western Multnomah County, Oregon, and its StoryMap.

Additionally, sixteen publications were released, all available for download.

MINERAL LAND REGULATION AND RECLAMATION

DOGAMI’s Mineral Land Regulation and Reclamation Program (MLRR) is the lead program for mine regulation in Oregon and works with other states agencies, local governments, Oregon’s federally recognized Indian tribes, industry, and the public to minimize the impact of mining and optimize opportunities for reclamation. The fee-based, statewide program has the authority to regulate all surface mining on lands within the State (<https://www.oregongeology.org/mlrr>). MLRR oversees mineral exploration; surface and chemical process mining; oil, gas and geothermal wells; and ensures disturbed land is reclaimed and put to secondary, beneficial use. There are no coal mines, oil wells or

chemical process facilities currently permitted. Exploration permits have been issued for precious and base metal in several locations in southeastern Oregon. Exploration drilling and geologic work have also occurred in far southeastern Oregon for uranium resource potential and are underway for a chemical process gold mine in eastern Oregon at Grassy Mountain. MLRR also regulates the exploration and development drilling for oil and gas and geothermal resources.

Surface mining includes aggregate, industrial minerals, and precious metals (non-chemical process). The majority of surface mining permits (more than 900) are for aggregate mines in uplands and floodplains. In addition to sand and gravel and quarry rock, there is significant diatomaceous earth production, an industrial mineral with a variety of commercial uses. To improve and streamline government efficiency, MLRR also administers for the Oregon Department of Environmental Quality the federal Clean Water Act General Stormwater and the state Water Pollution Control Facility Permits at 218 mine sites.

Natural gas production in Oregon is currently limited to 90 wells in the Mist gas field in Columbia County. Exploratory activities are permitted in Malheur County and coal-bed methane wells in Coos County are undergoing flow testing to determine their economic viability. At the present time, there is no fracking occurring in Oregon. Geothermal energy includes the Neal Hot Springs power plant in Malheur County and a geothermal district heating system in Klamath Falls. There are presently 36 geothermal permits in Oregon.

MLRR coordinates with many state and federal natural resource agencies, the nine federally recognized Tribes of Oregon, and local and county land-use jurisdictions during the permitting, operation, regulation, and closure of surface mine sites. As part of the Agency's ongoing efforts to encourage best management practices in mining, MLRR presents an annual awards program for operators that recognizes operation and reclamation above and beyond the requirements of regulation.

PENNSYLVANIA

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INTRODUCTION

While we are commonly known as the Pennsylvania Geological Survey, our official title is the Bureau of Topographic and Geologic Survey (BTGS), a bureau within the Pennsylvania Department of Conservation and Natural Resources (DCNR). The Survey 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, BTGS has a complement of 34 staff members: 22 geologists plus three vacant geologist positions, five clerical staff, three IT staff, and one librarian. We are experiencing the leading edge of a wave of retirements (half the bureau is currently eligible to retire). That's a lot of institutional knowledge walking out the door, but at the same time, it is an opportunity to add new skill sets and take on different types of projects. The bureau is engaged in developing a new strategic plan, to be completed in December 2018, which will help to guide new hiring.

BTGS is organized into three divisions: Geologic Mapping, Economic Geology, and Geologic and Geographic Information Services. Because our work crosses organizational lines, this summary is organized by topic.

GEOLOGIC MAPPING

Bedrock Mapping

In August 2017, BTGS delivered draft bedrock geologic maps of six quadrangles to the USGS for the FY16 STATEMAP grant. These maps focused on the Upper Devonian interval in an area of active Marcellus gas drilling in northeastern Pennsylvania. The area is underlain almost entirely by the Catskill Formation, with the underlying Lock Haven Formation exposed only in the deepest valleys of the Susquehanna River and its tributaries. Bedrock mapping, core drilling, geophysical logging, and correlation of subsurface data were used to characterize the bedrock. A core hole targeting the Lock Haven Formation was sited to provide the best control for correlation; however, it reached a depth of 1,705 ft without encountering the target unit. Part of the project's purpose was to sub-divide the Catskill Formation into mappable members. No marker horizons or patterns emerged to differentiate the thick package of fining-upward sequences into separate members.

Field work began for FY17 STATEMAP projects in north-central Pennsylvania. In the Rich Valley 7.5-minute quadrangle in Cameron County, data for hundreds of stations were collected, a core hole was drilled to 1,199 ft, and 1-mile electrical resistivity and

Multichannel Analysis Surface Wave 2D surveys were conducted to investigate subsurface geologic structures. The geophysical tools were chosen to identify subsurface formations, top of bedrock, fracture zones, and bedding and fault inclinations. In the Farrandsville 7.5-minute quadrangle in Clinton County, field work and a core hole drilled to 554 ft were done to initiate a new block of geologic mapping. Main goals included the investigation of the Mississippian–Pennsylvanian unconformity, the complex stratigraphy of the Burgoon Formation and the Loyalhanna Member of the Mauch Chunk Formation along the Allegheny Front, and the Devonian–Mississippian boundary in this area.

Geologic research on the stratigraphically and structurally complex Broad Top coalfield in south-central Pennsylvania (Fig. 1) was initiated in 2017 through a memorandum of understanding (MOU) with the Pennsylvania Department of Environmental Protection (PADEP). PADEP asked BTGS to undertake a comprehensive geologic study to assist its staff in their decision-making for future coal-mine permit and reclamation activities for the region. The MOU included grant funding to acquire subsurface and outcrop geologic data held by private individuals and organizations that had not been previously available. This initial project was completed by October 2017, resulting in hundreds of scans of mine maps, boreholes, and analyses. Activities continued through June 2018, including field work for measured sections and sampling coals for standard and rare earth element analysis. Broad Top was approved as a formal STATEMAP project for FY18–19.

SURFICIAL MAPPING

Work continued through the Great Lakes Geologic Mapping Coalition (GLGMC) to map bedrock topography and drift thickness for glaciated counties of northwestern Pennsylvania using data from more than 50,000 water well records. GLGMC grant funds were used to improve the quality of water well records by the



Figure 1. Strip mine in western Broad Top coalfield on Kelly coal (7 ft thick) along limb of third-order, northeast-trending syncline. Beds in photo dip about 40°NW.

digitization of data and determination of accurate well locations. Bedrock topography and drift thickness maps for the Pittsfield and Youngsville quadrangles in Warren County, northwestern Pennsylvania were delivered to the USGS in September 2017. Draft maps of bedrock topography and drift thickness were in development for the Edinburg, New Castle North, and the Pennsylvania portion of the Campbell quadrangles in Lawrence County, western Pennsylvania.

ECONOMIC GEOLOGY

Carbon Capture and Storage

BTGS participates in two multi-state consortia to study carbon capture and storage. The 10-state Midwest Regional Carbon Sequestration Partnership has been conducting geologic characterization research in the Appalachian Basin since 2003. As the third and final phase wraps up, our efforts have focused on reducing uncertainties associated with data availability, means of reservoir characterization, and resource estimate methodologies. The Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment Project is a three-year collaboration designed to assess potential carbon storage areas between the Georges Bank Basin and the Baltimore Canyon Trough. BTGS supports this project by digitizing geophysical logs; technical support through thin section, SEM and XRD analyses; and outreach meeting and document preparation.

Appalachian Storage Hub for Natural Gas Liquids

The Governors of Pennsylvania, West Virginia, and Ohio have entered into a regional collaboration for cross-border promotion of the economic opportunities presented by Marcellus and Utica shale resources. Under the umbrella of this agreement, the state geological surveys of Ohio, Pennsylvania, and West Virginia, in cooperation with the National Research Center for Coal and Energy (NRCCE) at West Virginia University, conducted a study to identify potential reservoirs for the secure storage of petroleum hydrocarbons that could support the growth of petrochemical industries in the tri-state region. The study area included 50 counties centered along the Ohio River, proximal to a proposed pipeline extending from areas of shale gas production in southwestern Pennsylvania to end users in southern West Virginia. Survey geologists from the three states collaborated to complete the study within one year, assessing three types of storage opportunities (mined-rock caverns, salt caverns, and depleted sandstone gas reservoirs) through a desktop evaluation of ten geologic intervals. Multiple prospects for stacked natural gas liquid storage opportunities were identified and recommended for further investigation at the site level. The final report—A geologic study to determine the potential to create an Appalachian storage hub for natural gas liquids—is available through the website of the Appalachian Oil and Natural Gas Research Consortium at West Virginia University.

TECHNICAL ASSISTANCE

Part of the mandate of BTGS is to provide technical assistance to our sister bureaus of State Parks and Forestry within DCNR. One way that BTGS fulfilled its mandate this year was by siting new water-supply wells. A new well for Moraine State Park was drilled in June 2017 to 300 ft in a pre-glacial valley and underlying bedrock. It was developed at 2.8 million gpd. Water quality was determined to be excellent with minimal treatment needed. The well provided significant cost savings to the park because it negated the need to replace an aging surface-water treatment system. Another water-supply well was drilled in Buchanan State Forest in June 2018 to 140 ft in the Oriskany Sandstone (Fig. 2). Yield is acceptable at 40 gpm, and water quality is excellent with minimal treatment required.

BTGS also provides technical assistance to other government agencies. As one example, the Bureau Director is co-leader of the Lidar Working Group, a group of state agencies, Pennsylvania offices of federal agencies, and professional societies, working together to promote acquisition and use of lidar data within the state. The first priority of the group is coordination of funding from state and federal sources to acquire statewide QL2 lidar data. About one-third of the state has been covered over the last several years using mostly federal funds. Prospects are good for a submission to 3DEP in Fall 2018 with a combination of state and federal funds. Once the new coverage is complete, the priority of the Working Group will shift to establishing a mechanism for ongoing maintenance and updating of elevation data, and providing a public forum to promote and share data applications.

After unprecedented rainfall in the first five months of 2018, the city of Pittsburgh experienced more than 200 documented landslides, causing more than \$18 million in damage. BTGS geologists worked with the State Meteorologist at the Pennsylvania Emergency Management Agency to petition FEMA for a disaster declaration to help with recovery. Our geologists provided information on landslide mechanisms, the relationship of landslides to soil moisture, and historical records and statistics to confirm the unusual nature of a winter “landslide season.” FEMA initially denied the request on the grounds that the precipitation could not be considered as a single event. An appeal is being filed based on a more geological argument that the repetitive rainfall events caused a “single event” of increased soil moisture, which in turn triggered the landslides over a period of time. Results of the appeal are pending.

BTGS continues to manage Pennsylvania’s 30-station seismic network (PASEIS). The network is operated by Penn State under a contract with DCNR. The Pennsylvania Department of Environmental Protection shares the cost of operation. PADEP’s interest stems from the necessity of monitoring any seismic activity due to shale gas extraction. PASEIS is designed for detecting and locating magnitude 2 and larger events, although events of smaller magnitude have been recorded. All data are openly available from the IRIS Data Management Center under the PE network code.



Figure 2. Rig set up to drill water well for a new maintenance building in Buchanan State Forest.

Over the course of the year, BTGS geologists responded to hundreds of geologic, groundwater, and geohazard service requests from homeowners, consulting and energy companies, academia, and other government agencies.

DATA MANAGEMENT

Progress was made on a number of fronts to improve the organization and accessibility of geologic data, both for our own internal use and for external users. Work continued on the Pennsylvania Groundwater Information System (PaGWIS), the State's water well database. During the time period of this report, more than 22,000 water well records were created or edited, and more than 100 springs were added to the database through site visits and record searches. Several million individual objects were added to the Exploration and Development Well Information Network (EDWIN), the database of oil and gas well information. A new version of the Bureau's Stratigraphic Database provides a modernized platform to store and access all of our geologic field observations. Bureau geologists partnered with summer interns to populate two specialized databases of historic field books and karst data. Geologists and interns continue to work on identifying and organizing core and cuttings collections in the Bureau's three storage facilities.

FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

BTGS's premier outreach event is the annual Field Conference of Pennsylvania Geologists. In October 2017, BTGS and Penn State hosted 245 geologists for two days of field trips in the area surrounding State College in the geographic center of Pennsylvania. On the first day, the trip visited the Shale Hills Critical Zone Observatory, examined joint structures in the Devonian Brallier and Marcellus Formations, and observed fold-thrust belt defor-

mation. On the second day, the trip divided into two groups. One group focused on stratigraphy and sedimentology of Ordovician carbonates, and examined environmental and engineering problems caused by exposure of extensive sulfide-mineralized veins during construction of I-99. The other group concentrated on groundwater and environmental concerns in karst terrain, visiting the Penn State Living Filter, one of the largest springs in the state (19 million gallons/day), a limestone quarry with an unexpected relationship to groundwater flow, a sinking stream, and a chlorinated solvent remediation site.

SOUTH CAROLINA

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GEOLOGIC MAPPING

The South Carolina Geological Survey (SCGS) is the sole-source provider of geologic map information to the public in the State. Geologic mapping is partially supported by the federal STATE-MAP program. Geologic mapping, which represents original research, and digitization of that geologic information, are core competencies. Collection and distribution of geologic information also continue to be long-term baseline measures in the operation plan.

Piedmont Mapping

Piedmont mapping continues to be a priority for SCGS. Under STATEMAP, one half-quadrangle was completed within the Carolina terrane, and one quadrangle was completed in the Inner Piedmont. Map compilations are an additional goal of our Piedmont program, particularly in the Carolina and Charlotte terranes. Digitization of reconnaissance mapping in both terranes is complete, and efforts are now being directed toward the incorporation of detailed 1:24,000-scale maps and field checking. With the increased popularity of outdoor recreation in South Carolina in recent years, SCGS has invested energy into producing geologic information for popular recreation areas in the Piedmont and Upstate regions. First pass Inner Piedmont and Blue Ridge map compilations are another benefit resulting from these projects.

Coastal Plain Mapping

SCGS continues to map in the Lower Coastal Plain and is focused on mapping in Horry County from the coastline to the northwest along the North Carolina state line. To date, 19 of the 31 quadrangles covering Horry County are completed. These new maps were completed under STATEMAP. The impetus for this work came from a request by SCDOT because they are seeking information on local sources of borrow material for the planned construction of I-73, connecting Myrtle Beach into the interstate system. This new mapping also provides insight into the

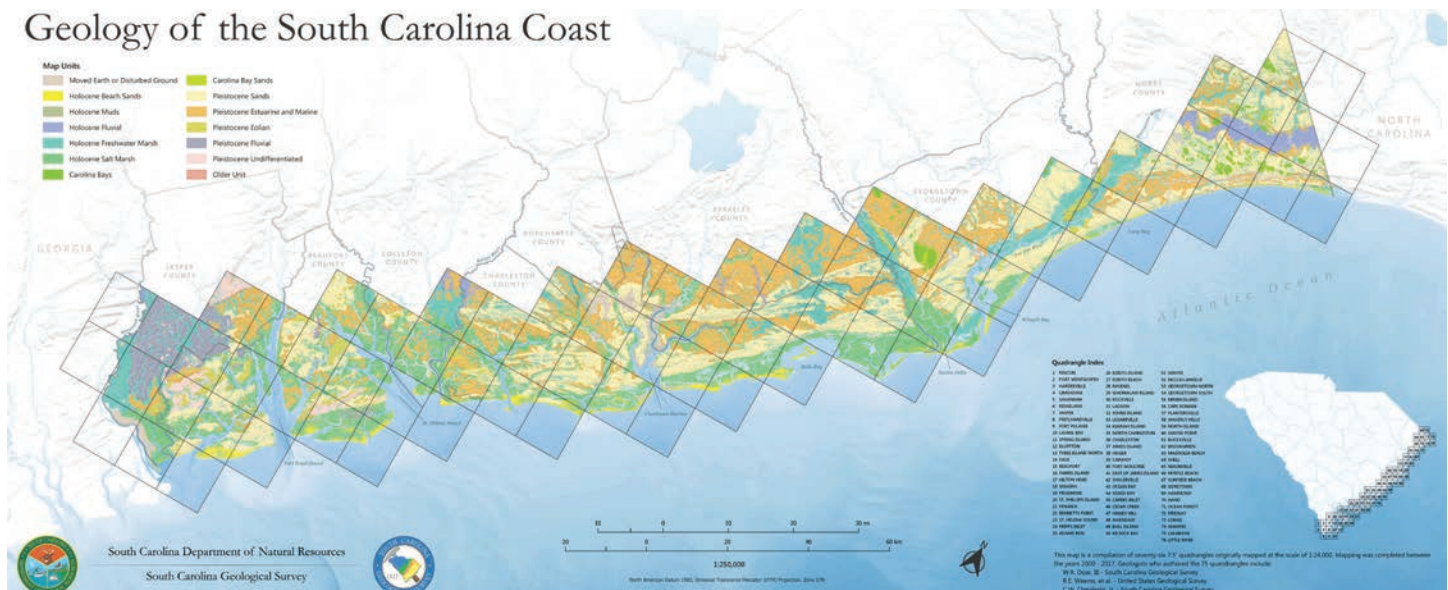
progradational nature of Pleistocene deposits and relative age constraints on the evolution of the Little Pee Dee and Waccamaw river systems.

Offshore Mapping

Offshore geophysical (sidescan, Chirp seismic) and geotechnical (vibracore, grab) datasets collected for a BOEM-funded Atlantic Sand and Gravel Assessment Project (ASAP) have been processed by the College of Charleston and are being interpreted by SCGS to better understand the composition and spatial extent of offshore sand resources in Federal waters. A BOEM-funded, regional partnership with North Carolina (East Carolina University) and Georgia (Skidway Institute of Oceanography) has formed over the past two years to collaborate on questions related to the shallow geology of the near offshore Continental Shelf (3-8 nm). Specific research on mineralogy, age dating (through amino acid racemization, ^{14}C , and U-Pb detrital zircon), and grain size have produced valuable data from the ASAP vibracores. Continued onshore-to-offshore mapping efforts in coordination with Coastal Carolina University in the Santee Point Quadrangle, just south of Winyah Bay, also are underway, and SCGS now has the capacity to process many of these offshore datasets. Continued collaboration with South Carolina's university programs will help us advance these offshore mapping efforts in areas of interest.

Geologic Information and Data Management

SCGS continues to implement mapping standards and procedures for Piedmont, Coastal Plain, and Offshore mapping projects. Digital field-data collection procedures are in place for Piedmont mapping. A recent GIS data migration project converted more than 120 GIS databases for geologic maps into the Geologic Map Schema (GeMS). Further, the GeMS data model is being integrated into current mapping procedures and will be the standard data model for SCGS geologic map GIS data. Finally, SCGS is preparing to make digital map data available as agency-level upgrades are made to GIS software and hardware.



SOUTH DAKOTA

GEOLOGICAL SURVEY PROGRAM

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INTRODUCTION

The South Dakota Geological Survey is a Program in the Division of Financial and Technical Assistance, Department of Environment and Natural Resources. The mission of the Geological Survey Program is to perform scientific investigations that are designed to generate information on South Dakota's geologic and hydrologic resources. Fundamental aspects of those investigations are to include the collection, interpretation, and dissemination of geologic and hydrologic information leading to (1) a better understanding of the geology and hydrology of South Dakota, (2) better and easier use of the information by government, industry, and the public for decisions related to resource development and protection, (3) greater economic development, and (4) a better quality of life for South Dakota's citizens.

GEOLOGIC MAPPING IN THE BLACK HILLS REGION

The need for 1:24,000-scale geologic maps has become crucial in parts of the Black Hills of South Dakota. However, geologic map coverage at this scale ranges from good quality published maps to areas that have little or no mapping. The Geological Survey is producing geologic maps in areas of the Black Hills where these maps are needed. Partners in this effort include the South Dakota School of Mines and Technology, the U.S. Geological Survey EDMAP Program, and the National Park Service.

The primary use of these maps is to:

- Address concerns regarding quantity and quality of water in the aquifers in the Black Hills region.
- Perform source water assessments for public water supplies that obtain water from these aquifers.
- 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.
- Provide base information that can be used in digital form in a statewide geographic information system.

Three new quadrangles were published in the past year. A status graphic of geologic mapping in the Black Hills and links to the published maps are available at <http://www.sdgs.usd.edu/currentprojects/geomap.aspx>.

AQUIFER DELINEATION

Work related to understanding and documenting groundwater resources in the glaciated part of South Dakota continues to be a primary focus for the Geological Survey. The Geological Survey's drilling resources were used to drill test holes and install observation wells in six counties this past year. New data generated from this drilling program, as well as review of historical data, is 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

Much of this work is done in cooperation with the Water Rights Program, Department of Environment and Natural Resources, to address specific questions related to the management of the State's groundwater resources. Two new publications were produced in the past year as a result of this work.

STATEWIDE GROUNDWATER QUALITY MONITORING NETWORK

This network presently consists of 144 wells at 79 locations that allow collection of water from 25 aquifers. The purpose of the network is to examine ambient water quality and assess non-

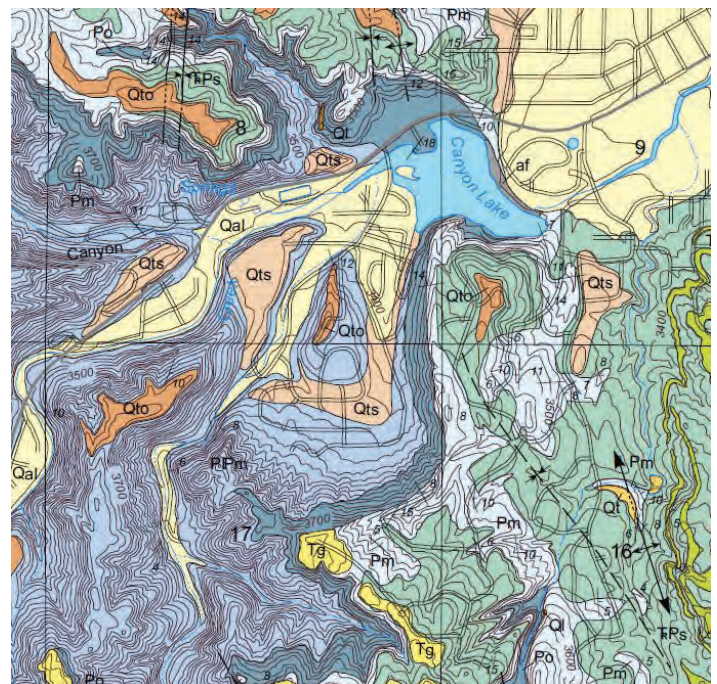


Figure 1. Example from a published geologic quadrangle map in the Black Hills region.

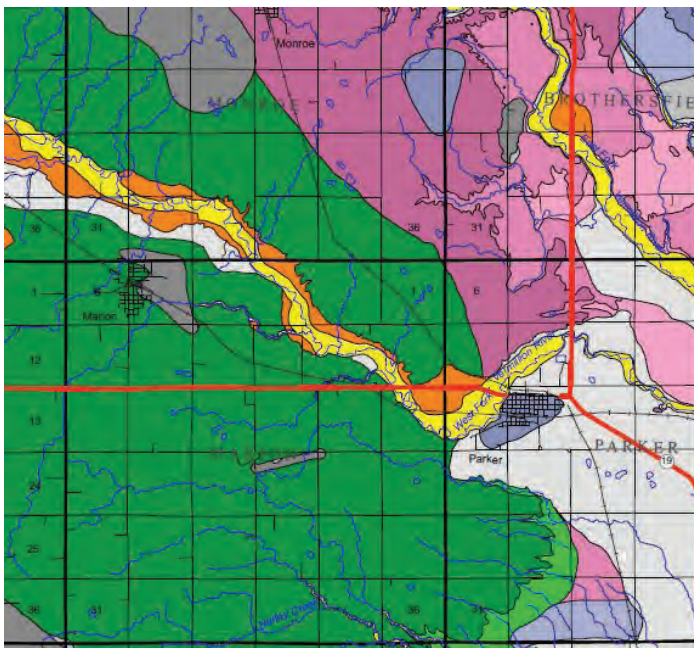


Figure 2. Example from a recently published aquifer map.

point-source pollution in many of the surficial aquifers across the State. An important difference between South Dakota's state-wide Ground Water Quality Monitoring Network and others in the country is that South Dakota's was designed and installed by the Geological Survey specifically for this purpose. The locations of wells in the network and their construction, including dedicated sampling equipment, ensure high-quality information regarding some of the State's aquifers that are most vulnerable to human activities at land surface. The network has historically been monitored for common inorganic constituents (including nitrogen compounds), pesticides, trace metals, volatile organic compounds, and radionuclides. Sampling of the network is done on a two-year cycle where one half of the network is sampled each year.

OIL AND GAS INITIATIVE

The purpose of the initiative is to promote the exploration and development of South Dakota's oil and gas resources. The effort includes the compilation and dissemination of all relevant state-held information through online, searchable databases and interactive maps. The Geological Survey has the responsibility of creating and maintaining a database of oil and gas related information that will meet the needs of Geological Survey staff, regulatory agencies, and industry. The Geological Survey is producing additional reports, maps, and cross sections pertaining to South Dakota's oil and gas resources. Work performed includes the slabbing (cutting lengthwise) and photographing of core. Photographs of the core are available through an online database and are part of a larger effort to promote more exploration in South Dakota.

BIG SIOUX RIVER FLOOD INFORMATION SYSTEM

After recent major floods in the Big Sioux River Basin of eastern South Dakota, an effort was led by the Geological Survey to develop new, more accurate hydrologic and hydraulic models of the basin that could be linked to a real time online flood information system to better predict inundated areas during high flow events. The result was an online mapping application tied to the basin's streamgaging network that can be used by local, state, and federal officials, as well as the public, for planning and to assess immediate flood conditions to determine appropriate response actions for the protection of communities and critical infrastructure. The Big Sioux River Flood Information System can be accessed at <http://bigsiouxfis.org>.

ONLINE INFORMATION

In an effort to continually provide more information and to make our information more accessible, the Geological Survey has built and maintains several online databases containing information about lithologic logs, water quality, oil and gas wells, the state core repository, and our publications database. These databases are free and open to the public. They are searchable on a variety of data fields.

The Geological Survey has built and maintains an ArcGIS Online Interactive Map which contains GIS layers of test holes and observation wells, oil and gas wells, oil field boundaries, private well completion reports, water quality sample locations, and geologic map units. All layers are linked to scanned documents and database records related to the layer features.

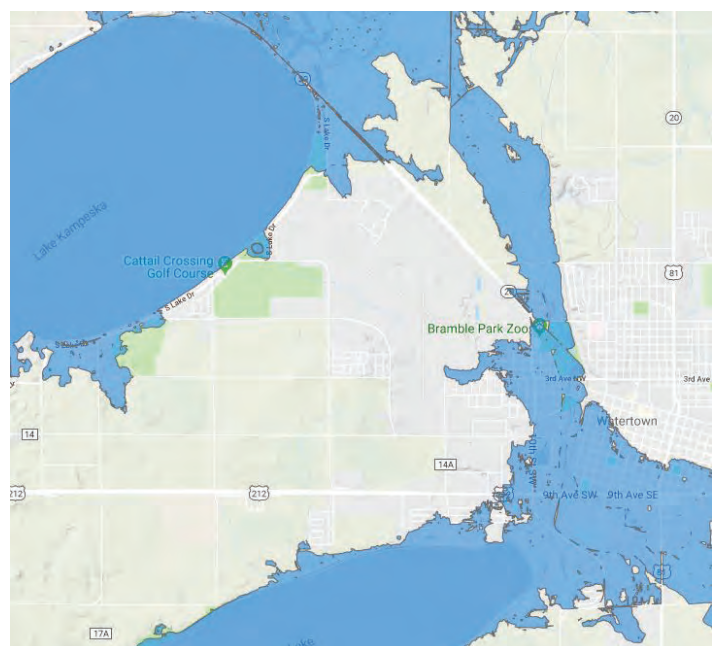


Figure 3. Inundation mapping in the Big Sioux River Flood Information System.

Recently the Geological Survey has consolidated the lidar data available for the state and loaded it onto a high speed server. Lidar users can download the state lidar data on a county-by-county basis from this server at no cost.

PUBLIC OUTREACH

Public outreach continues to be an important part of the Geological Survey's activities. In the past year, dozens of presentations were given to various groups including students (elementary, high school, college, and older adults), state agency boards, tribal entities, and the general public.

PUBLICATIONS FROM THE PAST YEAR

Fagnan, B. A., 2018, Geologic map of the Signal Hill Quadrangle, South Dakota.

Fahrenbach, M. D., 2018, Geologic map of the Rapid City East Quadrangle, South Dakota.

Redden, J. A., 2018, Geologic map of the Piedmont Quadrangle, South Dakota (revised edition).

Khrohe, N. J., Investigation of a Granite Wash Aquifer in Grant County, South Dakota.

Iles, D. L.; Rich, T., 2017, Examination of isotopes in selected waters in eastern South Dakota.

TENNESSEE

TENNESSEE GEOLOGICAL SURVEY

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INTRODUCTION

The mission of the Tennessee Geological Survey (TGS) is to encourage and promote the 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.

ADMINISTRATION

TGS is part of the Bureau of Environment in the Tennessee Department of Environment and Conservation. The state geologist reports directly to the Department’s Deputy Commissioner for Environment. The main office in Nashville covers middle and west Tennessee and a regional office in Knoxville covers east Tennessee. Originally established in 1831, TGS serves as advisor to state agencies and federal and local organizations on matters relating to Tennessee geology. The Survey’s work includes geologic hazards research, public service and education programs, basic and applied research on geology and mineral resources, and publication of geologic information. The Survey also maintains a well cuttings and core sample library. Survey staff includes six geologists and an administrative services assistant, with expenditures of \$773,900 during FY17–18, of which \$248,800 came from state appropriations. The remaining \$525,100 came from federal cooperative projects, interdepartmental funds, and the sale of maps and publications.

GEOLOGIC MAPPING AND MINERAL RESOURCES ASSESSMENT

Bedrock Mapping

Geologic mapping is a primary function of the Survey, and TGS is the only state agency that publishes and distributes geologic maps. Mapping requires knowledge of various fields in geology, including stratigraphy, structural geology, paleontology, remote sensing, geomorphology, and environmental geology. Survey

staff perform basic geologic mapping and mineral resources identification and evaluation 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 the final geologic map product. The resulting maps are printed on demand or distributed electronically. This saves printing, storage, and inventorying costs.

Tennessee has a history of mining a greater variety of mineral resources than any other state east of the Mississippi River except North Carolina, dating back to the late 18th century. Files for public use are maintained on nearly 3,000 old mines, prospects, drill holes, trenches, and natural exposures of mineral occurrences, as well as active mining operations. Searches for such information are a routine part of the geologic mapping process, and information collected is published in a mineral resources summary (MRS) that accompanies each published geologic map. Each MRS includes an environmental geology section that contains information about natural geologic hazards such as earthquakes, flooding, landslides, radon, and sinkholes.

TGS has been engaged in detailed geologic mapping and mineral resources assessment at the 7.5-minute quadrangle scale since 1960. These maps cover about 60 mi². They 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. Mineral deposits including metals (zinc), non-metals (clays, limestone, sand and gravel), and fossil fuels (coal, natural gas, and oil) play an important role in the state’s economy.

There are 804 7.5-minute quadrangles covering Tennessee, of which 531 have been mapped and either published or released in open-file format to date. This places Tennessee among the top states in the nation in terms of percentage of quadrangles mapped (more than 66 percent) at this scale. The Survey’s long-term goal is to have available for the public geologic maps at the quadrangle scale for the entire state. Completing field work and compiling the final geologic map for release to the public takes between one and two years, depending upon the complexity of the geology, accessibility of the area, and other considerations.

Released Quadrangle Geologic Maps in FY17–18		
Quadrangle	County	Authors
Birchwood (119-SW)	Meigs	R. L. Wilson
Friendship (429 NW)	Crockett, Dyer, and Gibson	Vince Antonacci
Huntsville (128 NW)	Scott	Ronald J. Clendening and Albert B. Horton
Locke (403-SE)	Crittenden, (AR), Shelby, and Tipton	Daniel Larson, Randy Cox, Haley Gallo, and Lauren Ferriera

COOPERATIVE PROJECTS

State Geologic Mapping Program

During FY17–18, TGS was approved for funding under a \$79,034 cooperative agreement from the U.S. Geological Survey (USGS) under the State Geological Mapping Program element (STATE-MAP) of the National Cooperative Geologic Mapping Program. Since 1994 the Survey has received more than \$996,000, completing 50 new geologic maps and converting 24 previously completed geologic maps to digital coverages under this program. The TGS website has a National Cooperative Geologic Mapping Program fact sheet updated through September of 2017 under the STATEMAP Fact Sheet Link on the Geology Programs page.

STATEMAP is a federal grant program designed to assist the states in accelerating the process by which geologic maps are made available to the general public. In order to qualify for funding under this program, a Tennessee Mapping Advisory Committee meets annually to prioritize the geologic maps that will be included in the Survey's STATEMAP proposal for the following fiscal year.

The purpose of the FY17–18 project was to map the geology of the SE ½ of the Bacon Gap (123-SE), Brazil (429-NE), SE ½ of the Madisonville (131-SE) and Winfield (337-SW), Tennessee 7.5-minute quadrangles in Gibson, Monroe, Roane, and Scott counties, and to complete digital compilation of the Johnsonville Geologic Map in Benton and Humphreys counties. Chief Geologist Dr. Peter Lemiszki and staff geologist Barry Miller from the Survey's Knoxville office worked on the Bacon Gap and Madisonville quadrangles. Staff geologists Vince Antonacci, Ron Clendening, and Assistant State Geologist Albert Horton from the Survey's Nashville office were responsible for the Brazil and Winfield quadrangles, and Ron worked on Johnsonville.

National Geological and Geophysical Data Preservation Program

TGS also worked under a \$27,743 cooperative agreement for FY17–18 from the USGS under the National Geological and Geophysical Data Preservation Program (NGGDPP). Since 2007, the Survey has received nearly \$164,000 under this program. 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. Common standards, procedures, and protocols for metadata have been established and the holdings of each collection will be accessible through an Internet-based catalog, the National Digital Catalog (NDC).

The work during FY17–18 consisted of four projects:

1. To continue the process of creating metadata records for 500 documents in the Mineral Resources Collection housed in the Tennessee Geological Survey's Nashville Office. The outcome of the project was that 374 new

records were appended to the existing metadata records for this collection.

2. To continue the process of creating metadata records and converting to a digital format 500 documents in the Coal Geology Maps Collection. The outcome of the project was that 546 coal maps were scanned and the new records were appended to the existing metadata records for this collection.
3. To create metadata records and convert to a digital format 17 maps and 553 pages of measured sections in the Coal Reports Collection. All of the documents were scanned and the metadata records created.
4. To complete the conversion to a digital format all of the remaining documents in the Tennessee Valley Authority Reports Collection. A total of 140 documents were scanned and the existing metadata records for this collection were revised to indicate that the documents are now available in digital format.

Additional benefits resulting from implementing all of these projects include:

1. We continued to evaluate and organize the material in our collections;
2. Scanning the documents limits deterioration incurred by physically handling them;
3. The scanned maps can be georeferenced in GIS and digitized to create shapefiles that can be combined to produce statewide web-based interactive maps;
4. Our in-house databases contain additional information fields, not required for the National Digital Catalog, to assist TGS staff with the querying and sorting of records, as well as indicating the storage location of documents in our collections.

The importance of accurately cataloging TGS's collections and creating digital versions of the documents in them continues to increase as potential users expect to have the ability to remotely query collection records and to obtain them electronically through various digital media. This is a goal worth striving for because the outcome helps ensure the preservation of historical documents, as well as decrease the staff time and the expense required to fulfill requests for information contained in these collections. For example, nearly all of TGS's coal mining and zinc mining maps and reports collections are unpublished and in paper/mylar form. The thousands of documents in the coal and zinc mining collections are a valuable source of information that can be used to improve estimates of the state's remaining coal and zinc reserves and to help companies evaluate potential areas for future exploration.

TGS has not yet reached the point where it can provide the online presence needed for its collections. Therefore, preparing metadata records for uploading into the NDC is the first step

toward providing the public with a method to search for, locate, and evaluate the type of information that is available in them. There has clearly been an increase in the public's awareness of the documents in our collections as a result of this effort. We are now receiving inquiries that specifically refer to a documents metadata record, which was obtained as a result of a web search of the National Digital Catalog.

As a result, companies, government agencies, and the general public are unaware of the abundant site-specific data available. Some of the items in these collections are 50 to 100 years old and rapidly deteriorating. It is therefore imperative that every effort be made to preserve the information contained in them.

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 and a secondary broadband sensor. These sensors are recording on 26-bit channels of high-resolution digitizers. There is also a strong-motion sensor that is recorded on three 24-bit digitizer channels. 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. The station has a satellite transmitter with digital processing unit, and is accessible by computer dial-up. Data are uplinked to Golden, Colorado. Because of its quiet location, which allows for better seismometer response in the low-frequency range, and its proximity to the NMSZ, WVT is considered to be an important part of the Global Seismic Network. Albert Horton is currently in charge of this facility.

In November of 2017, the USGS moved two of the broadband sensors from inside the building to two boreholes (covers are shown in Fig. 1), at depths of 324 and 328 ft. Recent data have shown better noise level performance over the previous surface locations, with the data now tracking with the low noise level threshold for each seismometer.

CORE AND WELL CUTTINGS STORAGE AND MAINTENANCE

Subsurface Geologic Repository

TGS manages the State's only repository of subsurface geologic samples in the form of well cuttings and rock cores. The cores and well cuttings are stored at several sites across the State, although the main proper storage facility is in Waverly, Tennessee. 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. Recent investigations include exploring for natural resources (mineral and hydrocarbon), identifying potential subsurface carbon sequestration sites, and analysis of the petrophysical characteristics of Tennessee's oil and gas reservoirs. TGS considers it a high priority to acquire rock core when it becomes available because we are cognizant of the time, effort, and expense companies have undertaken to collect it. As a result, storing and managing our expanding inventory is a never-ending task that requires foresight and flexibility of Survey staff.

Adding the third dimension is an important component to our geological mapping projects. Survey staff examines rock core, cuttings, and related geophysical well logs from oil and gas and mineral test wells in order to guide geologic map interpretations to draw the geologic cross sections that accompany our maps. The Survey continues to compile and distribute oil and gas-related maps and reports when requests are made. The current location of all driller's logs, geophysical logs, production records and related information for oil and gas wells in the state, formerly maintained in the Survey's Nashville office, is at the Nashville Environmental Field Office, at 711 R.S. Gass Blvd., Nashville, TN.

MAPS AND PUBLICATIONS SALES

During FY17–18 the Survey reprinted Bulletin 64, entitled Caves of Tennessee, by Thomas C. Barr, Jr. All of the Survey's publications are distributed through a maps and publications sales office in Nashville. Carolyn Patton oversees over 1,450 inventory



Figure 1. Waverly core storage facility with covered boreholes installed.

items, including maps, reports, and books from division activities and outside sources. Our Catalogue of Publications was updated to include recently released color geologic maps and a listing of out-of-print publications that are available as PDF files. A printed catalogue is available upon request or can be accessed online at https://www.tn.gov/content/dam/tn/environment/geology/documents/geology_catalogue.pdf. The site also includes an order form, instructions for ordering, and a listing of titles for which discounts are available for multiple copies of the same title. We accept American Express, Diners Club International, Discover, MasterCard, or VISA.

Sales of more than \$2,000 in FY17–18 accounted for about 0.3 percent of the Survey's revenue. We collected more than \$1,300 from the sale of 139 bulletins, \$410 from the sale of 41 digital geologic maps, and \$108 from the sale of 18 topographic maps. Sales tax collections totaled \$64. We served a total of 41 customers.

PUBLIC OUTREACH AND GEOLOGIC HAZARDS ASSISTANCE

Educational Outreach

TGS maintains active public outreach by furnishing speakers on Tennessee geology, mineral resources, and geologic hazards to schools, civic groups, and other organizations. Survey personnel gave 22 lectures, led 2 field trips, and manned survey booths at Archaeology Day at Bells Bend State Park, the Knoxville Gem and Mineral Show, National Earth Day Festival at Centennial Park, National Wild Turkey Federation convention, Middle Tennessee Gem and Mineral Society's Dig IT! Gem, Mineral, and Fossil Festival, and Murfreesboro Earth Day Celebration during FY17–18, involving more than 9,200 individuals. TGS's Nashville office also distributed 150 American Geological Institute Earth Science Week toolkits to science teachers across the state and secured a gubernatorial proclamation and press release for Earth Science Week 2017.

Geologic Hazards Investigations

Survey personnel respond to requests for field inspection of geologic hazards. Homeowners, builders, and investigators frequently call upon us for assistance in evaluating such geologic hazards as landslide potential, old and newly opened sinkholes, and the potential for groundwater contamination. Prospective landowners often ask us to examine property for potential geologic hazards, and members of the public frequently bring in rock and mineral specimens for identification. Survey staff answered nearly 400 geologic information requests, performed 7 environmental evaluations, and conducted geohazard inspections involving 4 sinkholes during FY17–18. Knoxville office staff also performed geologic hazard evaluations for 9 East Tennessee Development District projects.

PUBLICATIONS LIST

Antonacci, V., 2017, Digital geologic map of the Friendship quadrangle, Tennessee: Tennessee Geological Survey DGM 429-NW, scale 1:24,000, 1 sheet.

Clendening, R. J.; Horton, A. B., 2017, Digital geologic map of the Huntsville quadrangle, Tennessee: Tennessee Geological Survey DGM 128-NW, scale 1:24,000, 1 sheet.

Larsen, Daniel; Cox, Randy; Gallo, Haley; Ferreira, Lauren, 2017, Digital geologic map of the Locke quadrangle, Tennessee: Tennessee Geological Survey DGM 403-SE, scale 1:24,000, 1 sheet

Wilson, R. L., 2017, Digital geologic map of the Birchwood quadrangle, Arkansas and Tennessee: Tennessee Geological Survey DGM 119-SW, scale 1:24,000, 1 sheet.

TEXAS

BUREAU OF ECONOMIC GEOLOGY

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ABOUT THE BUREAU OF ECONOMIC GEOLOGY

The Bureau of Economic Geology is part of the John A. and Katherine G. Jackson School of Geosciences at The University of Texas at Austin and is the Texas Geological Survey.

The Bureau conducts basic and applied research related to energy and environmental issues. Our mission is to serve society by conducting objective, impactful, and integrated geoscience research on relevant energy, environmental, and economic issues. Our vision is to be a trusted scientific voice to academia, industry, government, and the public, whom we serve.

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

ENERGY RESEARCH

The Energy Division focuses on research involving energy resources, primarily oil and natural gas, but other subsurface resources as well. Several industrial research consortia pursue basic research on issues of significant importance to their corporate sponsors. Additional support is provided through numerous sponsored research projects funded by the State of Texas, the U.S. Department of Energy, individual energy companies, and foundations.

Main areas of focus include salt tectonics, carbonate and clastic reservoir characterization, mudrock systems, fracture characterization and prediction, multicomponent seismic applications, advanced seismic processing and imaging, oil and gas risk reduction in Texas, geothermal energy in Texas, subsurface nanosensors, and energy economics.

Energy research produces results that support successful development of unconventional oil and gas reservoirs (shales, tight carbonates, and sandstones). Its researchers are noted for bringing insight from direct rock observation (model development based on outcrops and cores) to the rapidly evolving field of 3D quantitative analysis of sedimentary rock properties. With 70 percent of in-place reserves typically remaining in the ground at the time of oil field abandonment, this research has enduring economic and societal importance.

ENVIRONMENTAL RESEARCH

The Environmental Research Division conducts a wide range of basic and applied research in environmental geosciences. These topics include groundwater resources, vadose-zone hydrology, coastal studies, carbon sequestration, earthquakes, near-surface geophysics, landscape processes, and geologic mapping.

It strives to avoid studying these processes in a vacuum and to understand how interconnected they truly are. Its researchers also seek to connect environmental systems to energy systems—vital for understanding and addressing today's complex issues. Its scientists have developed substantial strengths in the water/energy/land nexus, and they are well-known worldwide leaders in geological sequestration of greenhouse gases such as CO₂.

The Environmental Research Division investigates characteristics and processes of shallow Earth systems and the impacts of human activities on those systems. Many of its projects address the needs of Texas, although it also conducts research in other states, countries, and continents. Researchers collaborate with faculty and other researchers and students in the Department of Geological Sciences and the Institute for Geophysics in the Jackson School of Geosciences and across the University of Texas at Austin. The Division has an active outreach program for broadly communicating and disseminating the results of its scientific research projects.

The Bureau owns and operates an airborne laser terrain and bathymetric mapping (lidar) system, a high-resolution offshore 3D seismic imaging system, and substantial laboratory facilities. Bureau researchers have access to the wealth of resources at the Jackson School and UT-Austin. Environmental Research projects are well supported by appropriate hardware and advanced software for data analysis and modeling, and its scientists apply related technologies in GIS, GPS, and remote sensing.

STATEMAP PROGRAM

The Bureau provides Texas with a geologic map database and related information that serves as a primary data source for applied Earth science investigations. Bureau mapping projects include the STATEMAP program, which is a part of the National Cooperative Geologic Mapping Program administered by the U.S. Geological Survey and a component of the Bureau's STARR (State of Texas Advanced Oil and Gas Resource Recovery) program, which studies mineral and Earth resources.

In 2017, researchers Eddie Collins, Brent Elliott, Jeff Paine, and Chock Woodruff completed five new STATEMAP Open-File Maps (OFMs) of the following areas: Mansfield Dam, Pontotoc, Shingle Hills–Dripping Springs–Driftwood–Rough Hollow–Henly–Hammetts Crossing Area, Seadrift NE, and the Port Lavaca East quadrangles. See the “Bookstore” section below for more information on these maps.

SERVICE TO THE STATE OF TEXAS

The Bureau of Economic Geology has a long-standing working relationship with state agencies that request Bureau expertise when studying many energy issues that affect Texas. For example, Project STARR is funded by the State to increase royalty income to the Permanent School Fund through working with operators of state land leases to: (1) improve the efficiency of

producing fields; (2) consider new venture studies where regional fairways for drilling exploration wells will be emphasized; and (3) utilize CO₂ sequestration studies to promote profitable sequestration of CO₂ in oil fields through CO₂-enhanced oil recovery. In addition, Project STARR now includes research in geothermal energy, energy and environmental economics, mineral resources mapping, the water–energy nexus, and geologic hazards mapping.

In 2015, the Texas Legislature tasked the Bureau with helping to map and determine the origins of earthquakes in Texas. To this end, and possibly to prevent future earthquakes in Texas, the TexNet Seismic Monitoring Program was established. As part of the program, the TexNet research team has developed the TexNet Earthquake Catalog, a dynamic mapping web page that provides information on the locations of monitoring stations and recorded earthquakes across the state.

The Bureau Environmental group works closely with the Texas Commission on Environmental Quality (TCEQ) on issues related to water quality, groundwater/surface-water interactions, and the feasibility of injecting concentrates from desalination plants into depleted oil or gas fields. State regulations require that operators drilling for oil and gas have a Railroad Commission of Texas (RRC)-approved plan for well design that includes use of surface casing and cement to protect fresh water; thus, with technical support from the Bureau, TCEQ and RRC have developed a web-searchable database that provides oil and gas operators with an estimate of required casing for all oil and gas wells.

Bureau staff also serve on the Texas Groundwater Protection Committee, which was created by the Texas Legislature to bridge the gap between State groundwater programs, improve coordination between member agencies, and work to protect groundwater as a vital resource.

The U.S. Department of Energy (DOE) and the Texas General Land Office (GLO) provide funds to the Bureau's Environmental group to identify possible CO₂ plays and to estimate capacity in the Miocene formations in Texas state waters. These research areas include evaluating regional containment and fault/seal leakage, selecting suitable sites, and conducting risk assessments.

Researchers from the Bureau operate a hybrid airborne lidar instrument capable of simultaneously mapping topography and bathymetry to depths of 10 m or more in favorable environments. The system also acquires high-resolution color and color-infrared imagery. This system, acquired through a grant from the GLO, has been used in multiple projects in Texas to aid coastal geologic mapping, determine beach and dune sediment budgets, and analyze bay shoreline change and storm susceptibility. The new instrument significantly upgrades the Bureau's capability to assess the susceptibility, determine the impact, and monitor recovery from multiple geologic hazards affecting diverse environments around the State. In addition to the GLO, other Bureau partner agencies include the Texas Department of Transportation, Texas Parks and Wildlife Department, TCEQ, and Texas Water Development Board.

In addition to the seismic monitoring network, Bureau researchers established the Texas Soil Observation Network (TxSON), which provides hydrologic monitoring for improved flood and drought management, weather forecasts, emergency response, and numerous related scientific and public processes. The initial effort covers a 500-sq-mi area around Fredericksburg, Texas, in partnership with NASA's Jet Propulsion Laboratory, the Lower Colorado River Authority, and the Hill Country Underground Water Conservation District. TxSON will also provide necessary calibration data to NASA's Soil Moisture Active Passive (SMAP) program.

ACCOLADES

In late December, Associate Director (Environmental Division) Michael H. Young was honored by UT's Jackson School of Geosciences (JSG) with the 2017 Joseph C. Walter Jr. Excellence Award. The Walter Award—the highest honor that the JSG bestows on faculty members and research scientists each year—recognizes demonstrated excellence in any or all of the areas of the school: research, teaching, service, professional activity, and administration.

Each year, the Bureau of Economic Geology recognizes its authors during the First Author Publication Awards dinner, which was held on April 27, 2018. Bureau researchers again proved their productivity, with 174 publications in 2017—24 more than in the previous year. Of these, 76 were written or co-written by 47 Bureau first authors, and another 13 were written by student first authors directly supervised by Bureau researchers. This year, Bureau researcher Sergey Fomel was noted for co-authoring 8 papers first-authored by 7 of his Ph.D. students. Researchers Bill Ambrose and Bob Loucks tied for the most years honored for first author publications, now 10 times each.

The winners of the 2017 Tinker Family BEG Publication Award were the late Martin P.A. Jackson and co-author Michael R. Hudec. The Tinker Award was bestowed "In recognition of innovative and seminal contributions to the science of salt tectonics for their book, *Salt Tectonics: Principles and Practice*. The book stands out in its breadth, quality of the writing and illustrations, and novel contributions." Members of Dr. Jackson's family accepted the award on his behalf.

Jay Raney received the Bureau's Alumnus of the Year Award for 2016 during the Jackson School of Geosciences Friends and Alumni Reception at the Geological Society of America annual meeting in Seattle in October 2017. Given annually since 2003, this award honors former Bureau employees for significant career accomplishments after leaving the Bureau. Jay has provided ongoing assistance with GeoFORCE outreach in Oregon.

UT Austin professor and Bureau senior research scientist Ellen M. Rathje is the 2018 recipient of the William B. Joyner Lecture Award, announced in October 2017 by the Earthquake Engineering Research Institute (EERI) and the Seismological Society of America (SSA) to honor outstanding Earth science contributions. Dr. Rathje is the Warren S. Bellows Centennial

Professor in UT Austin's Department of Civil, Architectural, and Environmental Engineering. At the Bureau, she serves as co-principal investigator in the Center for Integrated Seismicity Research and the TexNet Seismic Monitoring Program.

In June 2018, the annual Staff Awards Reception showcased the wealth of talented people, and the strong motivation to succeed that are so important to the work of the Bureau of Economic Geology. At the event, Director Scott Tinker announced the promotions of Bill Ambrose, Tim Dooley, and Tip Meckel to Senior Research Scientist, effective September 2018. Other highlights included major individual awards presented by other organizations, and the naming of former associate director Eric Potter as the Bureau's Alumnus of the Year for 2017. University of Texas Staff Service Awards representing extended years of service at the University were presented to many staff, notably the Bureau's Eddie Collins, for his 40 years of service.

Dr. Tinker also presented the Bureau's Staff Member of the Year Award to Senior IT Manager Poe Chen. Chen received the award for the outstanding effort that he and his team have made over the last year to keep the organization's computer operations among the best at UT-Austin through his innovative and customer-oriented leadership.

After 27 years with the Bureau of Economic Geology, preeminent geophysicist and Senior Research Scientist Bob Hardage retired at the end of January 2018. At his retirement party in February, Bob received a gift from Bureau Associate Director Mark Shuster, recognizing Bob's many contributions to geophysics at the Bureau and beyond.

BOOKSTORE

Having published more than 2,700 publications since 1909, the Bureau continued enlarging and enhancing its online bookstore, The Bureau Store, as a complement to the physical store located in Austin. The online store allows customers worldwide to place orders for Bureau publications and to pay by credit card or check.

The Bureau recently issued five new (2017) STATEMAP open-file maps (OFMs), which are available for purchase at The Bureau Store:

Woodruff, C. M., 2017, *Geologic map of the Mansfield Dam quadrangle, Texas*: Texas Bureau of Economic Geology Open-File Map OFM0229, scale 1: 24,000.

Elliott, B. A., 2017, *Geologic map of the Pontotoc quadrangle, Texas*: Texas Bureau of Economic Geology Open-File Map OFM0230, scale 1: 24,000.

Collins, E. W., 2017, *Geologic map of the Shingle Hills–Dripping Springs–Driftwood–Rough Hollow–Henly–Hammetts Crossing area, central Texas*: Texas Bureau of Economic Geology Open-File Map No. OFM0231, scale 1: 50,000.

Paine, J. G.; Collins, E. W., 2017, *Geologic map of the Seadrift NE quadrangle, Texas Gulf of Mexico Coast*: Texas Bureau of

Economic Geology Open-File Map No. OFM0232, 2 sheets (sheet 1: map, scale 1: 24,000; sheet 2: digital-elevation model, geophysical logs, time-domain electromagnetic induction soundings, and frequency-domain electromagnetic induction measurements).

Paine, J. G.; Collins, E. W., 2017, *Geologic map of the Port Lavaca East quadrangle, Texas Gulf of Mexico Coast*: Texas Bureau of Economic Geology Open-File Map No. OFM0233, 2 sheets (sheet 1: map, scale 1: 24,000; sheet 2: digital-elevation model, time-domain electromagnetic induction sounding, and frequency-domain electromagnetic induction measurements).

Book-length Bureau publications that became available in digital format in 2017 are:

Hentz, T. F.; Ambrose, W. A.; H. S. Hamlin., 2017, *Upper Pennsylvanian and Lower Permian shelf-to-basin facies architecture and trends, eastern shelf of the southern midland basin, west Texas*: Texas Bureau of Economic Geology Report of Investigations RI0282D, 68 p., 40 figs., 2 tables, 2 appendices, 1 plate and 1 CD, 2017. [<https://doi.org/10.23867/RI0282D>]

Treviño, R. H.; Meckel, T. A., editors, 2017, *Geological CO₂ Sequestration atlas of Miocene strata, offshore Texas State Water*: Texas Bureau of Economic Geology Report of Investigations RI0283D, seven chapters, 1 appendix, 74 p. [<https://doi.org/10.23867/RI0283D>]

Ambrose, W. A.; Zeng, Hongliu; Zhang, Jinyu; Olariu, M. I.; Smith, David; Clift, Sigrid, 2018, *Depositional history and stratigraphic evolution of the Upper Wilcox Group and Reklaw Formation, northern Bee County, Texas*: Texas Bureau of Economic Geology Report of Investigations RI0284D, 87 p., 43 figs., 10 tables. [<https://doi.org/10.23867/RI0284D>].

Released in book format in 2017 is:

Woodruff Jr., C. M.; Collins, E. W.; Potter, E. C.; Loucks, R. G., with contributions by Wong, Corinne; Banner, J. L.; Casteel, Richard; James, Eric, 2017, *Canyon Dam Spillway Gorge and Natural Bridge Caverns—Geologic excursions in the Balcones fault zone, central Texas*: Texas Bureau of Economic Geology Guidebook 29, 56 p., 29 figs., 1 appendix, 2 appendix figures, 1 color plate at scale: 1 in. = approximately 385 ft.

The Bureau bookstore also promotes and sells GCAGS Transactions, GCAGS Journals, and other publications, as well as books, maps, and CDs from these geological societies: Alabama, Austin, Corpus Christi, Houston, Lafayette, Mississippi, New Orleans, South Texas, and GCS SEPM.

EDUCATION AND OUTREACH

The Bureau of Economic Geology's educational programs reach a broad group of citizens—the general public, elected officials,

government employees, scientists and engineers in industry, undergraduate and graduate students, and K–12 students and teachers. The Bureau's funded programs include the Texas High School Coastal Monitoring Program, which engages students, teachers, and residents of the Gulf Coast in the study of their natural environment. In 2017, the Bureau partnered with the Texas Department of Transportation (TxDOT) to post geologic information signs at two TxDOT Safety Rest Areas in Bell and in Pecos Counties. The GeoSigns work is part of a new initiative to engage the public and promote the understanding of geologic information.

Expanding its mission to reach as many people as possible with accurate and educational geoscience information, the Bureau of Economic Geology launched a new radio program in 2017, EarthDate, which provides a fun and informative way for listeners to discover the natural wonders of the Earth. Hosted by Director Scott W. Tinker, EarthDate airs on more than 340 NPR stations in all 50 states, as well as on stations in Canada, New Zealand, and the Philippines.

GeoFORCE is an outreach program of the Jackson School of Geosciences, designed to encourage students from minority-serving high schools in rural South Texas and inner-city Houston to take on the challenges of a rigorous math and science curriculum, to pursue higher education in these fields, and to enter the high-tech workforce. Each summer, GeoFORCE takes more than 600 high school students on educational geologic field trips in Texas and throughout the U.S. Bureau staff members play a significant role in the program by serving as instructors and writing guidebooks that students use to learn about geological features and processes.

Other Bureau outreach programs include the annual Austin Earth Science Week Career Fair for middle-school students; field trips for students, teachers, and professionals; classroom visits; educator workshops; and tours of Bureau facilities.



Figure 1. EarthDate is a weekly radio program launched by the Bureau of Economic Geology in 2017. The companion website for this radio program is EarthDate.org.

UTAH

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INTRODUCTION

The UGS had a budget of \$7.6 million in FY18 and completed the year with a small increase to its carry-forward into FY19 of close to \$100,000. The three main components of revenue are General Funds appropriated by the legislature (55%), Mineral Lease royalties from oil, gas, and coal production on federal land (19%), and contracts (26%). Staff numbers were stable at 67 FTEs, with personnel costs comprising 86 percent of total costs. Despite the appearance of stability in these metrics, several trends have been occurring in recent years. Mineral Lease royalties have decreased slightly due a combination of lower production and lower prices of oil and gas; contract revenue for fossil fuel research has decreased; funding for groundwater research, especially wetlands, has increased. In FY18, the largest source of contract revenue was for characterizing the Frontier Observatory for Research in Geothermal Energy (FORGE) site near Milford. This culminated with the announcement from the U.S. Department of Energy in June that the Milford site would become the national field laboratory for the next six years for the testing and development of new techniques for power generation from enhanced geothermal systems. The UGS is an important sub-contractor to the prime contractor, the University of Utah.

In January 2017 the UGS Paleontology Group was moved from the Groundwater and Paleontology Program to the Geologic Mapping Program. This was primarily an administrative move to better balance and match management duties and did not significantly change the duties or operations of any of the affected groups. The name of the Geologic Mapping Program did not officially change; however, “Geologic Mapping and Paleontology Program” is frequently used informally to show and remember the importance of paleontological resources, especially dinosaurs, to Utah’s heritage, economy, science, and image. The realignment is a better fit as both mapping geologists and paleontologists are frequently involved in mapping, describing, and improving understanding and correlation of Utah’s strata.

The UGS played a key role in helping to run the 2018 American Association of Petroleum Geologists’ Annual Convention and Exhibition, hosted by the Utah Geological Association (UGA) and held in Salt Lake City. UGS staff serving on the volunteer organizing committee included Michael Vanden Berg (General Chair), Tom Chidsey (Short Course Chair), Stephanie Carney (Social Event Co-Chair), and Jim Davis and Mark Milligan (Educator Program Co-Chairs). Numerous other UGS staff participated by leading field trips, giving presentations, staffing the UGS/UGA exhibit booth, and organizing a massive well core display and large display of Utah dinosaurs. The meeting was a huge success, drawing nearly 4,000 professionals from over 50 countries and contributing an estimated \$4 million to Utah’s economy.

The UGS’s Crawford Award went to Steve Bowman and William Lund (editors), and Gregg Beukelman, Richard Giraud, Michael Hylland, and Tyler Knudsen (contributing authors) in recognition of their work on Guidelines for Investigating Geologic Hazards and Preparing Engineering-Geology Reports, with a Suggested Approach to Geologic-Hazard Ordinances (UGS Circular 122).

The Crawford Award is the UGS’s most prestigious award that recognizes outstanding achievement, accomplishments, or contributions by a UGS scientist(s) to the understanding of some aspect of Utah geology or Earth science. UGS Circular 122 also received national recognition as the recipient of the Association of Environmental & Engineering Geologists’ 2017 Claire P. Holdredge Award.

The UGS/UGA’s 2017 Lehi Hintze Award—which recognizes outstanding contributions to the geology of Utah—went to UGS Senior Scientist Tom Chidsey for his geologic contributions over a 40-year career including petroleum exploration in Utah with Celsius Energy Company from 1980 to 1989, research with the UGS since 1989, and volunteer activities for numerous professional organizations and boards. Tom also received the American Association of Petroleum Geologists’ 2018 Public Service Award, in recognition of his career in petroleum geology that has included a dedication to the geologic education of the public, government officials, regulators, stakeholders, tribal representatives, and others in Utah.

ENERGY AND MINERALS PROGRAM

The Energy and Minerals Program (EMP) encourages prudent energy and mineral resource development through a variety of studies that inventory, characterize, and model the State’s deposits. These projects have been funded in part by the U.S. Department of Energy (DOE), the U.S. Bureau of Land Management (BLM), the U.S. Geological Survey (USGS), the Utah Division of Forestry, Fire, and State Lands (FF&SL), the Utah School and Institutional Trust Lands Administration (SITLA), and the Research Partnership to Secure Energy for America (RPSEA). Several projects include industry, academic, or consulting partners. Project results help operators, the general public, and other local, state, and federal agencies make decisions about managing and developing energy and mineral resources in Utah.

Some ongoing and recent EMP projects include: (1) studying Utah’s potential tight (shale) oil and gas reservoirs; (2) defining potential geologic reservoirs for geothermal energy in deep sedimentary basins; (3) compiling a stratigraphic and reservoir properties database for the National Coal Resource Data System; (4) evaluating energy and mineral resources on state-owned lands; (5) collecting and compiling new data on the salt crust under the north arm of Great Salt Lake; (6) developing an extensive digital database of Uinta Basin wells with core and (or) cuttings stored at the Utah Core Research Center; (7) studying microbial carbonates in both modern (Great Salt Lake) and ancient environments (Eocene Green River Formation); (8) maintaining and updating the Utah Mineral Occurrence System (UMOS) database; (9) creating 200+ mining district summaries and presenting the data on a web-based interactive map; and (10) preserving in digital form old paper information from non-petroleum exploration drilling in Utah.

During the past year, the UGS was a major partner on the team that was awarded Department of Energy funding to develop a Frontier Observatory for Research in Geothermal

Energy (FORGE) site at Milford, Utah. This will be a dedicated site where scientists and engineers will be able to develop, test, and accelerate breakthroughs in enhanced geothermal system (EGS) technologies and techniques. EMP geologists also recently wrote the Mineral Potential Report for lands now excluded from Grand Staircase–Escalante National Monument. This mineral report, which analyzed all extractable commodities (metals, industrial minerals, coal, petroleum, etc.), was a vital step in the land-management process for those areas that have reverted back to BLM control.

The EMP also maintains the Utah Core Research Center (UCRC), which contains cuttings from more than 5,400 wells (57 million cumulative feet), cores from over 1,500 wells (2.8 million cumulative feet), and representative samples of oil, coal, minerals and rocks from various producing areas in Utah (<https://geology.utah.gov/about-us/geologic-programs/energy-minerals-program/utah-core-research-center>). Annually, the UCRC welcomes nearly 400 visitors and hosts about 20 workshops.

GEOLOGIC HAZARDS PROGRAM

The Geologic Hazards Program (GHP) helps protect Utah citizens by reducing losses from geologic hazards; works to characterize significant earthquake sources, landslides, and other geologic hazards; prepares geologic hazard maps for urban areas or areas subject to development; responds to geologic hazard emergencies; provides scientific advice to local governments; and promotes hazard reduction through information dissemination.

This year, the GHP: (1) continued urban geologic hazard mapping along the Wasatch Front, Cedar Valley, and Moab as part of the Geologic Hazard Mapping Initiative; (2) published a new statewide earthquake and Quaternary fault map; (3) continued detailed geologic mapping in urban areas for subsequent geologic hazard mapping; (4) under a cooperative agreement with the USGS, held annual Utah Earthquake Working Group meetings to set priorities, review research results, and update plans for future earthquake hazard investigations; and (5) continued landslide inventory mapping with the Manti–La Sal National Forest on the Wasatch Plateau.

The GHP continued to work on USGS/UGS-funded geologic data preservation projects. This year's work consisted of inventorying and digitally scanning geologic maps, plates, and accompanying booklets, and cataloging, digitally scanning, and entering metadata for our engineering geology and geologic hazard document and photograph collection (<https://geodata.geology.utah.gov>).

GEOLOGIC INFORMATION AND OUTREACH PROGRAM

The Geologic Information and Outreach Program (GIOP) answers public inquiries; performs public, teacher, and media outreach; prepares translated publications for a non-technical audience;

manages the Natural Resources Map & Bookstore and the UGS Library; and maintains the UGS website (geology.utah.gov) and the bookstore's online store (mapstore.utah.gov).

The GIOP tracks UGS outreach statistics; this year the UGS responded to 4,500 public inquiries (telephone, email, and walk-in). The UGS Library, which maintains more than 14,000 publications, assisted nearly 500 patrons. The Natural Resources Map & Bookstore's inventory includes UGS publications, other Department of Natural Resources Divisions' publications, USGS topographic maps and publications, Utah Geological Association guidebooks, and other related publications and maps. This year's bookstore sales volume totaled over 26,000 geologic and related items.

Education outreach this year included loaning out 132 Earth Science teaching kits; giving 15 presentations at public schools and to industry, professional-society, and enthusiast groups; and providing hands-on activities for 785 students from 14 schools during Earth Science Week. We also developed and led a teacher training course as part of the AAPG Earth Science Educator Program. The workshop, which comprised a classroom session and field trip, was presented during the AAPG Annual Convention and Exhibition in Salt Lake City and provided participants with a classroom-ready rock kit and locally oriented supplementary educational materials.

A major focus of the GIOP is constructing, maintaining, and enhancing interactive maps and databases on the UGS website. We now have 25 interactive maps providing data related to geologic mapping, Quaternary faults, mining districts, wetlands, geothermal wells and springs, rock and mineral collecting sites, the Utah Core Research Center inventory, and many other subject areas. This year, our interactive maps received a total of 5.3 million user requests.

GEOLOGIC MAPPING PROGRAM

The Geologic Mapping Program (GMP) comprises two groups, the Mapping Group and the Paleontology Group. The Mapping Group produces printed and digital GIS geologic maps at popular intermediate and detailed scales. The primary intermediate-scale program goal is to complete at least preliminary GIS map coverage of all 46 of Utah's 30-minute x 60-minute quadrangles at 1:62,500–1:100,000 scale by 2025, and complete new map coverage by 2035. The preliminary GIS data is created from new field-based geologic mapping and by producing GIS versions of old maps. The primary long-term 1:24,000-scale goal is to map all 1,512 of Utah's 7.5-minute quadrangles. Because this will require many decades, the Utah State Mapping Advisory Committee (SMAC) has identified about 300 quadrangles as top priorities, most in areas of rapid urban growth.

This year, in the 30-minute x 60-minute quadrangle series, the GMP completed another block of mapping on four ongoing, multi-year projects: the Duchesne, Loa, Beaver, and Bonneville Salt Flat quadrangles. We also supported USGS work on the Tremonton and Newfoundland Mountains quadrangles. We

open-filed new temporary geologic maps of parts of four of these quadrangles to make recent mapping available pending formal publication of the final maps. We also produced GIS databases of 10 older (1970s–90s) geologic maps that provide moderate-quality GIS of parts of unmapped quadrangles. Currently about 75 percent of the state now has at least preliminary geologic maps that meet most of our standards, and about 65 percent has intermediate-scale GIS coverage. In the 7.5-minute quadrangle series, the GMP published or open-filed 10 geologic maps. Most are in rapidly urbanizing parts of the greater Wasatch Front area of northern Utah, growth areas of southwest Utah, high-use recreation areas of northern and eastern Utah, and areas having valuable geologic resources. We are now in the fifth year of a new priority emphasis defined by our SMAC to significantly increase detailed mapping in the Wasatch Front area, by far the most populated part of the state.

As part of our effort to make geologic maps more accessible to our users, we continue to post geo-referenced images of 7.5-minute quadrangle maps to our interactive geologic map website (<http://geology.utah.gov/apps/intgeomap>). To speed up completion of geologic map GIS databases, we continue to support student GIS projects of various older maps. These GIS products temporarily fill holes in our GIS databases pending future new mapping, and provide excellent training for students. This program was quite successful this year with 10 student-generated maps posted to our website.

The Paleontology Group continued the excavation, preparation, and scientific description of several new dinosaur species from Utah sites; made substantial progress on a statewide potential fossil yield classification system; and promoted Utah fossil resources at several major events. We ran a large and very popular exhibit at the AAPG Annual Convention and Exhibition that featured replicas of some of Utah's most important dinosaurs and mammals. We also continued a cooperative project with Thanksgiving Point Institute's Museum of Ancient Life to prepare in a public interpretive display the "megablock," an 8-ton plaster-jacketed block containing hundreds of Utahraptor and other fossil bones. We authored or coauthored at least 11 papers on Utah fossils, mostly dinosaurs; provided fossil information to land management agencies on dozens of proposed construction and disturbance sites to help agencies regulate and protect fossil resources; and maintained a digital paleontological locality database in partnership with the U.S. Bureau of Land Management.

three major studies of groundwater and surface-water resources in rapidly growing communities: Ogden Valley and Round Valley east of the Wasatch Front, and Goshen Valley along the Wasatch Front. We have also implemented watershed monitoring aimed at quantifying the hydrologic response to large-scale pinyon-juniper cutting programs by other agencies that aim to restore sage grouse habitat and reduce wildfire risk. The Wetlands Group is completing a detailed wetland map of the northeast Great Salt Lake shore and a report on wetland condition and function in the Jordan River watershed. Our results will help local, county, and state water managers to make scientifically informed decisions on important growth, natural-resource, and environmental issues.

GROUNDWATER PROGRAM

The Groundwater Program (GWP) comprises two groups, the Groundwater Group and the Wetlands Group. The GWP evaluates the quantity and quality of Utah's groundwater resources, and performs mapping and functional assessments of critical wetlands. The GWP partners with local, state, and federal agencies to perform a wide variety of groundwater and wetland studies, and makes the data available to the public through its publications as well as the UGS and National Groundwater Monitoring Network websites. The Groundwater Group has recently completed

VERMONT

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INTRODUCTION

The Division of Geology and Mineral Resources, also known as the Vermont Geological Survey (VGS), is the source for geologic information, maps, and data used to assess and solve environmental and natural resource issues in Vermont. Our responsibilities are defined by Vermont Statute, Title 10, Chapter 7, Section 101: to provide aid and advice, provide geologic expertise to regulatory programs, conduct research related to geology and mineral resources, and publish and disseminate geologic reports. In 2016 to 2018, our major accomplishments included publication of the online landslide inventory (GIS database) of Vermont (three counties), publication of geologic and hydrogeologic maps for seven quadrangles, significant work on PFOA contamination issues and leadership of an emerging contaminants session at NEGSA 2018, securing funds for a third position in our office, and providing geologic services to state government Divisions and Agencies.

GEOLOGIC MAPPING

Geologic mapping is the foundation of our work in Vermont and provides base maps for hazard avoidance and mitigation, evaluation of sites for groundwater contamination, planning for groundwater supply and source protection, and geologic resources and land use. Following publication of the Bedrock Geologic Map of Vermont in 2011, our mapping focus shifted to 1:24,000-scale surficial geologic maps. Geologic mapping is intrinsically linked to GIS data development and analyses of geologic data in three dimensions. The VGS is actively developing and adopting new data formats and standards for geologic data. We are also expanding our ability to display and interpret geologic information in 3D. In 2017, we standardized surficial map units, began to transfer and edit map data on lidar basemaps, and began compilation of the Montpelier one-degree sheet.

STATEMAP, a component of the USGS National Cooperative Geologic Mapping Program, is an important source of funding for our mapping projects. Funds are further leveraged through field-based student intern projects ranging from water chemistry to tectonics. Maps and GIS data are posted on the VGS website, the Vermont Open Data Portal, and the NGMDB for easy access.

The following are a sampling of maps released in 2017–2018:

DeSimone, D. J., 2017, Surficial geology of the Bennington area, Vermont: Vermont Geological Survey Open-File Report VG2017-1, scale 1:12,000, 3 plates. GIS Data.

Kim, J. J., 2017, Preliminary bedrock geologic map of the Bennington area, Vermont: Vermont Geological Survey Open File Report VG2017-4A, scale 1:12,000.

Kim, J. J.; Dowey, C. W., 2017, Derivative maps generated from water well data logs in the Bennington area, Vermont:



Figure 1. Setting up for a drone flight at the Champlain Thrust in northwest Vermont. The drone is useful for mapping and interpreting fractured bedrock at specific sites.

Vermont Geological Survey Open File Report VG2017-3, 4 plates, scale 1:12,000.

Springston, G. S., 2018, Surficial geology and hydrogeology of the Joes Pond 7.5-minute quadrangle, Vermont: Vermont Geological Survey Open File Report VG2018-3, scale 1:24,000, report plus 8 plates. GIS Data.

Springston, G., 2017, Landslide inventory of Washington County, Central Vermont: Vermont Geological Survey Open File Report VG2017-7, scale 1:100,000, report plus 1 plate.

Van Hoesen, J., 2018, Surficial geology and hydrogeology of the southern half of the Proctor 7.5-minute quadrangle, Vermont: Vermont Geological Survey Open File Report VG2018-2, scale 1:24,000, report plus 10 plates.

Wright, S., 2018, Surficial geology and hydrogeology of the Bolton Mountain Quadrangle, Vermont: Vermont Geological Survey Open File Report VG2018-4, scale 1:24,000, report and 5 plates. GIS Data.

Wright, S.; Dowey, C. W., 2018, Surficial geology and hydrogeology of the Jeffersonville quadrangle, Vermont: Vermont Geological Survey Open File Report VG2018-5, scale 1:24,000, 4 plates. GIS data.



Figure 2. Alluvial fan deposited on the north shore of Lake Mansfield. Toe of fan extends beneath the lake surface.

GROUNDWATER

The VGS and our university and government partners develop geologic data, maps, and information for the public, to inform decisions about groundwater use and protection related to public health concerns (arsenic, radioactivity, asbestos, radon, nitrates). We also conduct site-specific aquifer characterization studies. For example, arsenic levels above health-based standards in drinking water supplies were investigated by integrating mapping with water and bedrock geochemistry. During the past two years we have contributed to the newly adopted Vermont Department of Environmental Conservation (DEC) Groundwater Management Plan, produced water supply maps for towns, investigated PFOA in groundwater, worked with farms to understand best management practices to avoid groundwater nitrate contamination, served on the Drought Task Force, and upgraded private well locations through the USGS Water Use Grant.

PFOA Project

Dr. Jon Kim (VGS) leads the VGS's work on PFOA contamination of groundwater in southern Vermont. An informal consortium, based on shared research interests, includes SUNY Plattsburgh, Middlebury College, Bennington College, UMASS, and EPA. The consortium began studies of the PFOA issue in 2016 and shared results at sessions at NEGSA in Burlington in Spring 2018. The group investigated surface water and groundwater contamination

through comprehensive water chemistry, hydrogen and oxygen isotopes, mapping, and geophysical well logging.

Water Use Project

The VGS, in coordination with other divisions in DEC, received a U.S. Geological Survey Water Use Data and Research program grant to assess and inventory the state of water withdrawal and consumptive use data in Vermont. The work plan includes improvement of water well location information for eight counties, a review and update of the 2010 USGS water use report and database for Vermont, and development and population of standardized databases within DEC, including snowmaking data.

Colin Dowe, staff geoscientist, updated data for wells in four counties, thereby increasing the number of wells with E911 or GPS locations from 20 percent to 46 percent. Data, available on the ANR Atlas, is used for groundwater resources and to inform decisions about wastewater. Colin and staff in other divisions, designed and populated a database which incorporates hourly to sub-hourly snow-making water use information and allows for detailed analysis of natural and downstream streamflow through the snowmaking season.

Other Groundwater Activities

The State Geologist is a member of the broad-based Groundwater Coordinating Committee (GWCC), a group which produced a plan for managing and protecting Vermont's source waters. GWCC is composed of government agencies, individuals from



Figure 2. Sampling surface water in Bennington for tritium, isotopes and water chemistry. Age dates are a component of the aquifer characterization project in Bennington.

the private sector, consultants, and non-profit organizations. Specific work is outlined for the VGS in the adopted Groundwater Management Plan and is aligned with our groundwater resource mapping and strategic plans. The document recognizes the importance of geological information in evaluating water supply and contamination issues.

The State Geologist was contacted by the Groundwater Protection Council (GWPC) for input into the development of an information sheet on how State Source Water Coordinators nationwide can collaborate with their geological surveys. Specific examples of assistance provided by geological surveys were provided including investigation of PFOA contamination of groundwater in fractured bedrock (VT) and participation in state strategic planning for water resources (VT). A draft document was subsequently forwarded by GWPC to other geological surveys for review. Since most geological surveys are not regulatory agencies, regulatory groups are often unaware of the role their state surveys can play in groundwater protection. Vermont was a partner in development of the information sheet due to our participation at the national GWPC forum in September 2017.

HAZARDS

The VGS conducts significant work on natural hazards and develops and distributes public information concerning these hazards. We provide seismic hazard information and communicate seismic risk to the Department of Public Safety and the public, partner with the Northeast States Emergency Consortium and with Regional Planning Commissions, conduct landslide hazard mapping, and serve on work groups to develop state hazard mitigation and prevention plans.

Landslide Hazards

Landslide hazard mapping and monitoring of landslide and rockfall sites to reduce public exposure to hazards are the goals of the hazard work. The Landslide Inventory Geoform was launched online at: <http://dec.vermont.gov/geological-survey/hazards/landslides>. Since past failures are an indicator of future slope instability, the form is a crowd-sourced tool to help us locate existing landslides, including rockfalls, debris flows, gullying and other mass failures.

George Springston (Norwich University), under a grant from DEC, completed landslide hazard inventory maps for Washington and Chittenden Counties. The maps identify existing and relict landslides, including falls, topples, slides, and flows. The map, drawing heavily from lidar, also incorporates river corridor assessment data for gullies and mass failures. A statewide GIS database with 43 attributes was developed and shows data collected to date: <http://anrgeodata.vermont.gov/datasets/landslides>. Data is distributed as point data although companion maps at 1:24,000 scale show polygons.

OUTREACH

Survey staff is active in education and outreach through school visits, field trips for towns and local officials, lectures, and our website. Presentations at professional meetings such as the National Groundwater Association, Northeast Geological Society of America, and local non-profit organizations are important venues for sharing our geologic expertise and contributing to the science community. We also gave numerous presentations to other government agencies and non-profit organizations including lifelong learning programs, planning commissions, scouts, university seminars and classes, and conservation groups.

The Northeast Section Geological Society of America was held in Burlington, Vermont in 2018. The meeting was hosted by



Figure 3. Student interns preparing core material for x-ray diffraction as part of the Bennington aquifer characterization project.

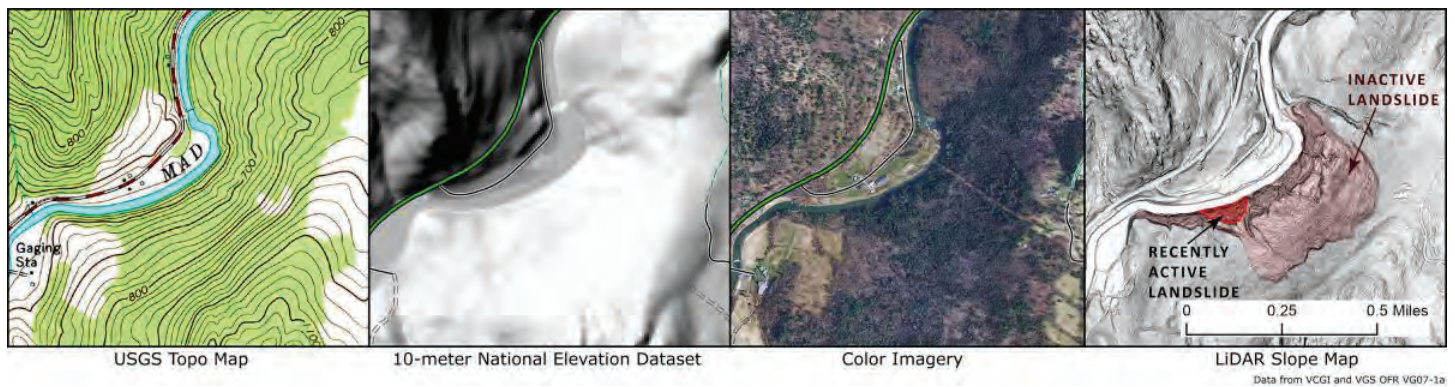


Figure 4. Comparison of topographic maps, imagery and lidar. Lidar is used to distinguish previously unrecognized slope instability areas.

University of Vermont, Middlebury College, Norwich University
 SUNY Plattsburgh, and the Vermont Geological Survey, DEC.
 Technical sessions featured DEC groundwater and contamination,
 private wells and health, tectonics of the Appalachians and
 Adirondacks, river restoration, engineering geology, lake studies,
 hazards, and government issues. Staff from the Geology Division
 gave presentations, chaired or co-chaired several technical
 sessions, participated as mentors in student luncheon events
 with more than 300 attendees, and served on the organizing
 committee.

VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY

Department of Mines, Minerals and Energy
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INTRODUCTION

The Division of Geology and Mineral Resources (DGMR) is one of seven divisions in the Department of Mines, Minerals and Energy (DMME), a Commonwealth of Virginia agency whose mission is “to enhance the development and conservation of Virginia’s energy and mineral resources in a safe and environmentally sound manner to support a more productive economy.” DGMR serves as Virginia’s geological survey. Other divisions within DMME deal with mining and drilling safety and reclamation, energy programs, and administration. Located in Charlottesville, DGMR performs geological and mineral resource investigations aimed at reducing the risk from geologic hazards and encouraging sustainable economic development through the wise use of mineral, land, water, and energy resources. Division staff includes seven full-time geoscientists, four hourly support staff, and several external contractors. In FY18, funding for DGMR came from state-appropriated recurring general funds (62%), federal grants (33%), and proceeds from publication sales (5%).

DGMR continues to expand the availability of its digital datasets by placing them in a web-based map viewer available on our home page. Powered by the ArcGIS Viewer for Flex, the interactive map allows users to zoom, pan, and query layers depicting bedrock geology, geologic hazards, mineral resources, available geologic publications, and many of our other holdings.

GEOLOGIC MAPPING

All geologic mapping by DGMR is conducted under the STATE-MAP program, funded by the USGS National Cooperative Geologic Mapping Program with a 50–50 percent state-federal match. Projects are prioritized pursuant to the Division’s long-range mapping plan and approved by our Geologic Mapping Advisory Committee, a panel composed of representatives from the mining industry, academia, the consulting community, land-use planners, and state and federal government agencies. Two continuing mapping projects are underway: the Interstate 81 corridor and the greater Richmond Metropolitan Statistical Area (MSA). In the I-81 corridor, geologic maps were completed for the Eagle Rock, Looney, and Peaks of Otter quadrangles. In the Richmond MSA, geologic maps were completed for the Beach, Buckner, Goochland, and Hallsboro quadrangles. A portion of the mapping was carried out in collaboration with James Madison University. All mapping was at 1:24,000 scale and compiled in ArcGIS version 10.5 using the GeMS geodatabase data model.

Under a cooperative agreement with the National Park Service, DGMR continued a mapping project in Petersburg National Battlefield. The project will produce geologic maps to facilitate the park’s management of geologic resources such as rock outcrops, fossils, and minerals, as well as landscape elements that played a role in the Civil War. The entire area is within the Richmond MSA; therefore, the mapping will complement our STATEMAP project work.

GEOLOGIC HAZARDS

Work on geologic hazards is managed under our Geologic Mapping Section. In FY18, DGMR responded to landslide events that resulted in the destruction or condemnation of three homes in two counties, and a rainfall-triggered mudslide in the City of Richmond. Our geoscientists worked with emergency responders, local government, and the Virginia Department of Emergency Management to understand the geology of the slope failures and recommend remedial action. Virginia’s inventory of modern landslides has grown to nearly 6,000. DGMR also continued to work with the Virginia Tech Seismological Observatory to monitor earthquakes in the Central Virginia Seismic Zone.

ECONOMIC GEOLOGY

The Economic Geology Section wrapped up several grant-funded projects in the past year. The section assisted in preparing the final report on a Virginia Tech-led carbon dioxide injection demonstration project. Approximately 20,000 tonnes of carbon dioxide were injected into coal seams of the Pennsylvanian Pocahontas and Lee formations in the Southwest Virginia Coalfield. Nearby coalbed methane wells were monitored to determine if the injection contributed to increased natural gas production and to assess the mobility of the injected gases in the reservoir. The Economic Geology section also contributed a comprehensive dataset of coalbed elevation and thickness information as a deliverable to the USGS National Coal Resources Data System (NCRDS). DGMR also participated in the DOE-funded Southeast Offshore Storage Resource Assessment led by the Southern States Energy Board and the Mid-Atlantic Offshore Carbon Storage Resource Assessment led by Battelle Memorial Institute.

The offshore sand and heavy minerals resources assessment funded by the Bureau of Ocean Energy Management (BOEM) is moving forward with results that are expected to compel additional investigations and BOEM funding. The project’s focus is on quantifying offshore sand resources available for beach nourishment and determining the fraction of heavy minerals in the sand that could possibly be separated for industrial use.

This was the first year in which a full-time staff member was dedicated to support county and regional land-use planning offices. The Economic Geology Section met with several county planning offices, the Virginia Transportation Construction Alliance, the Virginia Association of Counties, the Hampton Roads regional advisory group, and several other groups in the comprehensive planning community. Another important accomplishment of the Economic Geology Section was the updating of production and value statistics for most of the mineral and energy commodity pages on our website.

DATA PRESERVATION

Under the USGS National Geological and Geophysical Data Preservation Program, DGMR continued to inventory and preserve its collections, create metadata, and share the information through the online ScienceBase catalog. In this past project year, the focus was on unpublished field maps and a collection of lantern slides rescued from the University of Virginia. These fragile glass transparencies represent a vast archive of black and white photographic images of geologic features as they appeared in the early 20th century. In many cases, the outcrops represented in the photos no longer exist. The slides were cleaned, photographed at high resolution, and stored in acid-free boxes. Location and other information about each image was uploaded to ScienceBase.

TENTH VIRGINIA GEOLOGICAL RESEARCH SYMPOSIUM

In April, the Division hosted the 10th Virginia Geological Research Symposium at our office in Charlottesville. This free, informal meeting brings together geoscientists from academia, government, and industry for one day to hear presentations on topics of current state and regional interest. Topics encompassed climate change, structural geology of the piedmont, and non-invasive methods for stability analysis of Natural Bridge, a natural limestone arch that supports U.S. Route 11. The day also included a poster session and breakout sessions on the 2020 Geologic Map of Virginia (in preparation!) and Earth Science Week. Nearly one hundred people attended.

WASHINGTON

WASHINGTON GEOLOGICAL SURVEY

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INTRODUCTION

Since 1890, the Washington Geological Survey (WGS) has provided geological data and services that benefit the people of Washington. The Survey's vision is to foster a safer, more productive and resilient society that incorporates geology into its regular thought and decision-making processes. WGS is Washington's primary state science agency for earthquake, tsunami, volcano, and landslide research, environmental geology, geological 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.

As part of the Washington State Department of Natural Resources, the WGS office is located in the Natural Resources Building in Olympia, Washington. From FY17–18, the Survey changed its name (from Division of Geology and Earth Resources to Washington Geological Survey), developed a new strategic plan, and significantly revamped its emergency response plan.

To carry out its responsibilities during the period of July 2017 to June 2018, WGS employed 45 full-time staff. The Survey consists of the Geologic Hazards Group, the Landslide Hazard Program, the Geologic Mapping Program, the Surface Mining Reclamation Program, the Washington Geology Library, the Lidar Program, and the GIS, Editing & Publications Section.

GEOLOGIC MAPPING PROGRAM

In 2017–2018, the Geologic Mapping Program (GMP) began a new five-year project near Chehalis in southwest Washington to assess the seismic hazard of the Doty fault to nearby communities. Two 1:24,000-scale maps were completed in this area this year. The GMP was able to secure additional funding for a topical neotectonic study of the Willapa and Doty Hills areas, to aid in understanding the uplift and faulting history as it relates to the proposed siting of a dam facility on the upper Chehalis River. Because of this additional funding, the program was able to hire additional geologists and now consists of four full-time mappers, two part-time field assistants, and a part-time manager.

In addition to traditional mapping approaches and geomorphology, we are applying ground magnetic and gravity anomaly mapping to accurately locate the Doty fault in the subsurface, identify associated faults, and model their geometries. In the summer field season, we collected more than 150 km of ground magnetic lines, and more than 900 new gravity measurements to create new maps of the area. In the preliminary maps, we see evidence for segmentation of the Doty fault, north- and northwest-trending subsidiary faults, and an enigmatic gravity anomaly closer to the dam site that should be more closely investigated.

TSUNAMI HAZARD PROGRAM

The Tsunami Hazard Program works to provide scientific information to both emergency managers and the public to prepare for the eventual Cascadia subduction zone earthquake and tsunami. Survey geologists have published 14 inundation models for various parts of the Washington coastline. These inundation models include simulations of the 1700 AD event that last struck our coastline, the L1 scenario simulating an approximate 2,500-year event, and other local crustal faults such as the Seattle and Tacoma faults. We anticipate that future work will focus on developing additional inundation models for distant events, probabilistic modeling, and filling gaps where no inundation models have yet been completed.

Additional products to help the public prepare for these devastating events are evacuation brochures for the most vulnerable areas. These brochures inform communities of the risk they face and, more importantly, where to go to avoid tsunami waves. These older brochures are being revamped using more informative pedestrian evacuation modeling for major communities. Five evacuation models are currently in development in Washington, with many more planned in the coming years (Fig. 1).

Survey staff are also heavily involved in outreach efforts, joining other state partners in events that communicate risk and preparedness on how to survive “the big one” to the public. This year's Tsunami Roadshow brought in nearly 1,000 members of the public to see presentations by various experts in the field. Additional presentations were also given to other special interest groups and state, federal, and tribal entities. This outreach effort has overturned the previously fatalistic mentality of several coastal communities, leading to a number of new vertical evacuation structures planned for development in vulnerable areas. It has also prompted additional discussion of the hazard posed to the maritime community.

LANDSLIDES

The Landslide Hazard Program (LHP) is a group of five geologists that have begun mapping landslides on a county-by-county basis under a vetted and consistent protocol. This methodology requires high-resolution lidar and results in accurately located inventories without over-reporting. Landslide susceptibility mapping includes both deep and shallow landslides. Intended users of completed landslide hazards maps include public works, emergency managers, planners, and property owners. Since the formation of the LHP in 2015, the program has completed mapping in Pierce County and the Columbia Gorge, and will soon complete King County. These efforts are focused on heavily populated areas and regions where landslides tend to be large and (or) frequent. Our team also responds to landslide emergencies and assesses post-wildfire debris flow hazards.

SCHOOL SEISMIC SAFETY

WGS received \$1.2 million from the State's Capital Budget in the 2018 legislative session to assess schools in high seismic risk areas and to assess fire stations within one mile of schools. The directive states that there shall be an on-site geologic assessment to determine the seismic site class of soils and a structural and nonstructural seismic evaluation of school buildings. A determination will also be made of costs to seismically upgrade school buildings to life-safety standards and to seismically upgrade fire stations to immediate-occupancy standards. The directive put forth in the Capital Budget appropriation is a first step in the important task of improving the seismic safety of schools in Washington. However, it will take much more funding to accomplish this goal than was allocated this biennium.

WGS formed a steering committee to help guide the project. This committee determined that the allocated funding allows for assessment of approximately 220 individual school buildings, five fire stations within one mile of schools, and seismic upgrade design concepts and cost estimates for 15 school buildings (Fig. 2). The project objective is to evaluate a representative sample of school buildings so that the results from the geologic and seismic evaluations and estimated costs to upgrade can be extrapolated to similar school buildings across Washington. This

will allow us to determine what it may cost to complete these seismic assessments statewide.

This project is well underway—all field work has been completed, data processing and report writing is in progress, and a final report will be finished and submitted to appropriate legislative committees by June 30, 2019. More information about this project can be found at: <https://www.dnr.wa.gov/programs-and-services/geology/geologic-hazards/earthquakes-and-faults/school-seismic-safety>

MINERAL, GEOTHERMAL, AND OIL AND GAS REGULATION

There has been no exploration drilling for oil and gas in Washington this past year. The Jackson Prairie gas storage field continues to operate as the State's only underground gas storage facility. WGS regulates the drilling, plugging, and abandonment of these wells.

One geothermal exploratory well was drilled in the vicinity of Mount St. Helens to a depth of 470 ft. Initial temperature testing did not show high temperature or a high geothermal gradient.

The Surface Mine Reclamation Program (SMRP) continues to make important contributions to reclaiming mines in Washing-



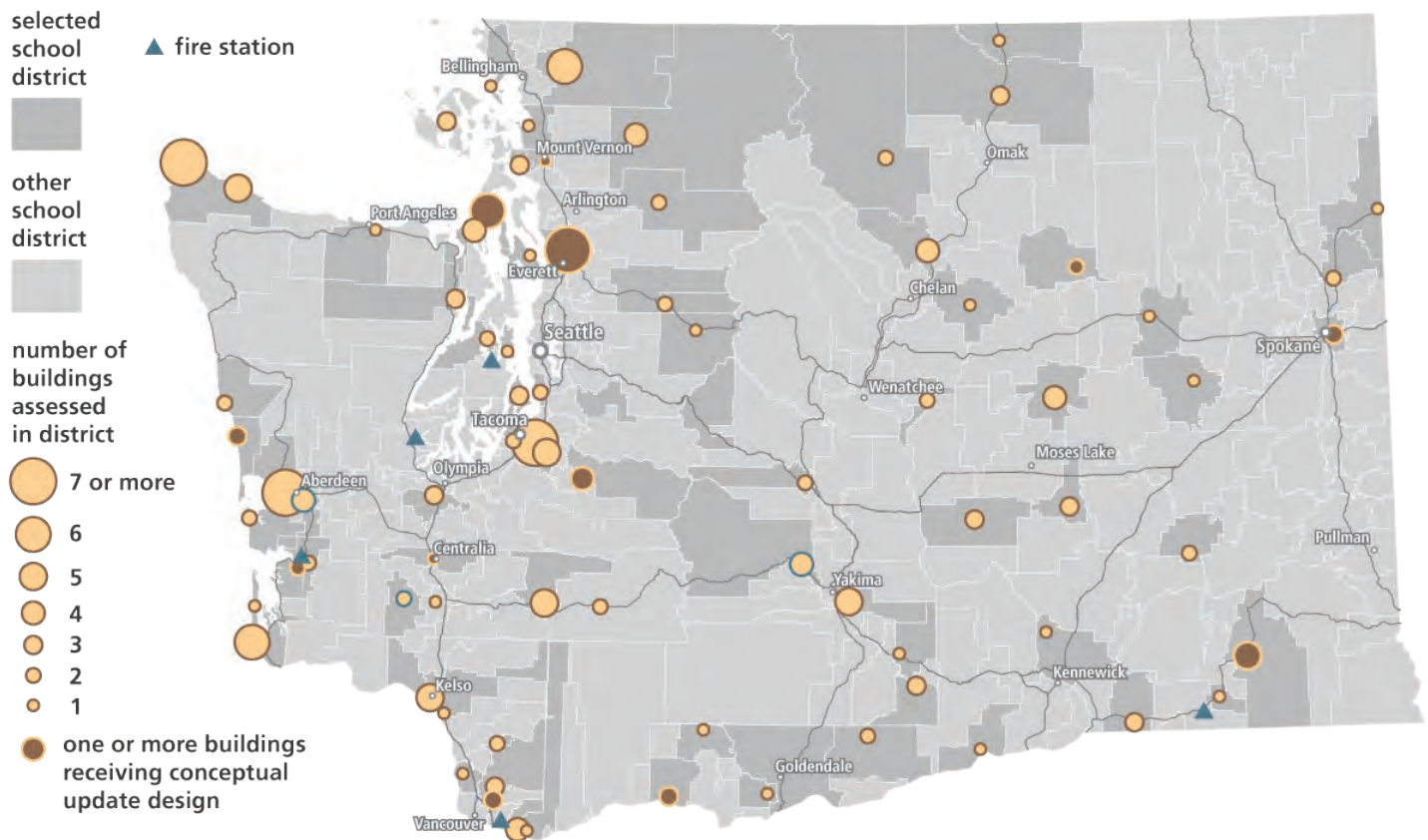


Figure 2. Map showing the locations of the 220 school buildings selected for this project. The map highlights the 15 schools for which seismic update cost and design evaluations will be conducted. The five fire stations assessed for this project are also marked.

ton. In 2017, approximately 3,766 acres of mining-disturbed land was reclaimed throughout the State. New mines and expansions of older properties are constantly in the process of being permitted throughout Washington—2018 saw 51 new, revised, or expanded reclamation permits issued for a total of 930 mining permits in Washington. While most reclamation permits are issued to aggregate sources, other minerals such as precious and base metals, olivine, silica, decorative stone, carbonates, and diatomite are mined in Washington and are regulated by the SMRP.

The Buckhorn Mountain gold mine has ceased production and is finalizing closure of the mine site. Over its nine-year lifespan, the Buckhorn mine produced approximately 15M oz of gold from ore averaging about 11 oz per ton. At the present time, there are no other operating gold mines in Washington.

The use of mobile devices to collect data efficiently and resolve issues with permit holders more quickly has proven to be an invaluable asset to the Surface Mining Program. Improvements in data accessibility from the field continue to improve inspection and program efficiency.

SUBSURFACE DATA

WGS maintains a statewide database of many types of subsurface data. Survey geologists use this data to develop and produce resource maps, to help constrain the subsurface interpretation of geologic maps, to better understand faults and

earthquakes, and to produce 3D models of the geology. The subsurface data also contain the locations and information for water wells, geotechnical borings, oil and gas wells, test pits, and geothermal wells. The centralization of these data represents a significant effort that benefits the entire geologic and geophysical community in Washington. To facilitate centralization efforts, the Survey has begun entering into cooperative agreements with local governments to automatically receive geotechnical reports held and collected by the municipality through their planning and permitting process. In 2018, three municipalities participated in the process and now regularly deliver more than 100 geotechnical reports per month. From these reports and other survey activities 7,800 new records were added to the database, making a total of more than 116,000 records statewide. Future efforts include signing more municipalities onto the program, digitizing a trove of older paper reports donated by a retired consultant, and continued digitization of boring data into the database.

GEOHERMAL

WGS received funding from the U.S. Department of Energy (DOE) Energy Efficiency and Renewable Energy Division. DOE is investing in developing tools and technology to prospect for geothermal resources that lack obvious surface evidence (are 'blind'). The hope is to lower initial exploration costs for areas in which it has historically been very challenging to locate geothermal

resources. With new tools, methods, technology, and data, the hope is to spur the development of new geothermal electricity production. This project started in 2013 and is now in Phase 3.

Phase 1 (2013–2015) was a desktop exercise using existing data to develop a method of identifying the areas most favorable for high-temperature (electricity-generating) geothermal energy throughout the entire state.

Phase 2 (2015–2017) built on this initial work and collected new data with the goal of improving the model strategy and pro-

ducing a higher-resolution prediction of geothermal potential in three study areas.

Phase 3 (2017–2019) is testing the model predictions by drilling temperature-gradient wells. The wells are targeted where the model predicts favorable conditions and there is existing disturbed land (such as gravel pits and previous logging operations) to minimize impact. Drilling commenced in May of 2018 and the first hole near Mount St. Helens did not have sufficient temperature gradient for geothermal energy development.

The next holes will be in 2019 in the Mount Baker study area, and drilling will last for 6–8 weeks next spring. We are targeting a depth of 700–1600 ft below the ground surface. We hope to drill two to three holes in the Mount Baker study area.

We are working with partners at Cyrq Energy, BOS Technologies, Temple University, USGS, and Western Washington University.

GROUNDWATER

The Survey recently gained funding from the USGS to participate as a data provider for the National Groundwater Monitoring Network (NGWMN). WGS partnered with Thurston County to provide data from existing wells and support the development of code capable of linking Thurston County's groundwater database to the NGWMN. The WGS has already received the data feeds from these existing wells and serves as a curator for some of the public groundwater information from Thurston County. Future work (dependent upon future funding) includes expanding the network to other counties in the Puget Sound Aquifer System, augmenting the network with new wells, and adding wells from an existing DNR monitoring network in the southeastern region of the state.

STORY MAPS

The Survey has recently produced two award-winning Esri story maps—*Washington's Ice Age Floods* and *The Bare Earth*.

Washington's Ice Age Floods (Fig. 3) tells the story of cataclysmic outburst floods that shaped the landscape of the Pacific Northwest during the last ice age. With imagery, maps, and video, this story map follows the devastating deluge of the Missoula floods as they tore across the landscape, from their origins in western Montana to their terminus at the Pacific Ocean. Sites along the newly created Ice Age Floods National Geologic Trail are featured, with an emphasis on flood features in Washington State. The story map has been viewed 52,818 times.

The Bare Earth (Fig. 3) describes how geologists in Washington State use lidar to map geology and study geologic hazards. This narrative features more than 50 stunning lidar images that illustrate how geologists are using this technology to study the landscape. The story map has been viewed 74,981 times.

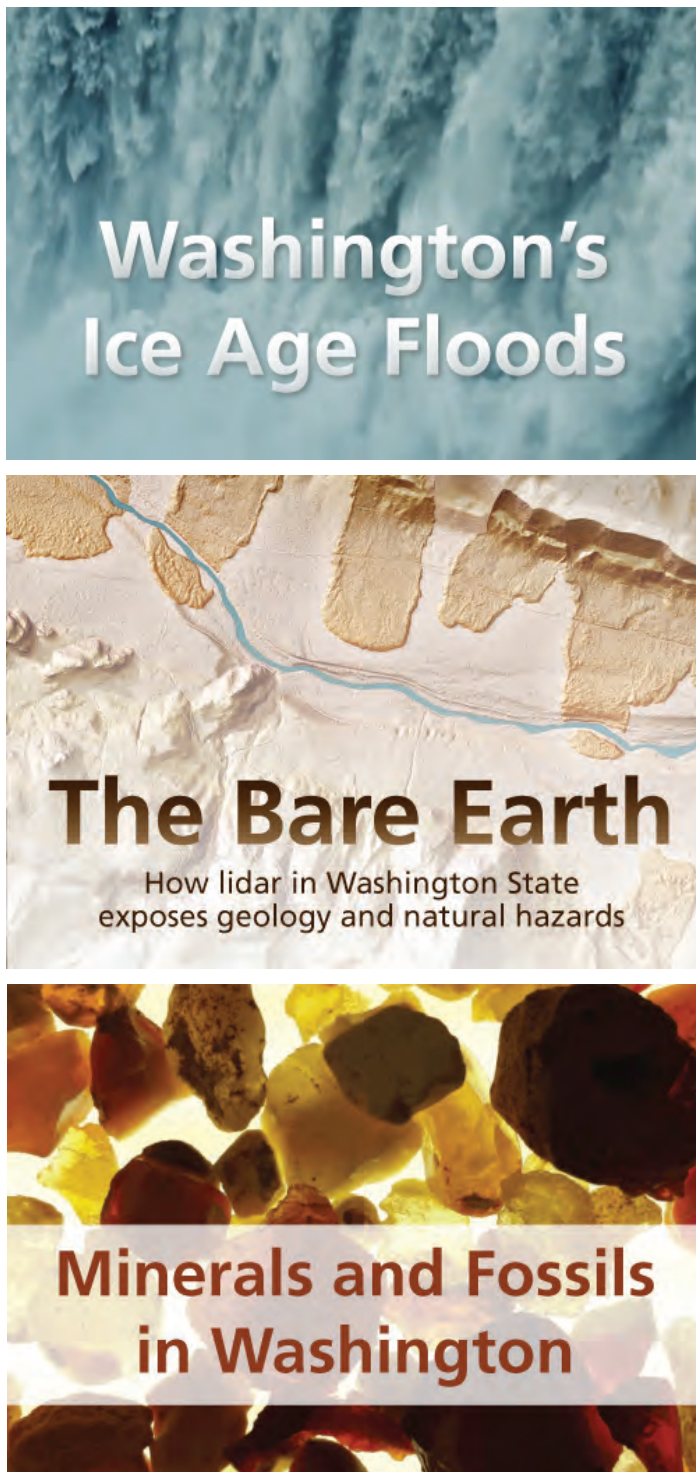


Figure 3. Washington Geological Survey story maps.

These narratives build on the success of our popular *Minerals and Fossils in Washington* story map (Fig. 3), which features photographs and maps of the State's extraordinary rocks and minerals. The story map has been viewed 131,602 times.

You can find our story maps here: <https://www.dnr.wa.gov/programs-and-services/geology/publications-and-data/story-maps>

LIDAR

The Survey's recently established Lidar Program focuses on new lidar collection and quality assurance, public distribution of data, and statewide lidar plans and collaboration. The program provides valuable data products used by a wide range of stakeholders. Using dedicated state funding and federal grant opportunities, the Lidar Program has collected more than 10,000 mi² of either new lidar data or updated, higher resolution data that serves a critical role in geologic hazard identification.

The Lidar Program has forged partnerships with federal, state, and local agencies, public utilities, tribes, and conservation groups to expand collection for a diverse range of applications. The Program performs quality assurance on new acquisitions and works to standardize data for public distribution on the Lidar Portal (lidarportal.dnr.wa.gov/), where users can download LAZ point cloud data, digital surface and terrain models, and hill-shades for their area of interest. The Lidar Portal will be moving from servers in Alaska to the cloud over the next few months, providing the Survey better control over this important data resource. Next up for the lidar team is a federal grant opportunity to expand collection into eastern Washington and developing a statewide multi-year lidar collection plan, targeting total state coverage. Check out the lidar page (<https://www.dnr.wa.gov/lidar>) for lidar resources and screensavers!

UNMANNED AERIAL SYSTEMS

Over the past year WGS has developed an Unmanned Aerial Systems (UAS) Program with three certified remote pilots (Fig. 4) and two Unmanned Aerial Vehicles (UAVs), along with a data processing workflow to generate orthophotos and Structure from Motion (SfM)-derived digital surface models. Currently the program is monitoring a large (20 acres, 4 million yd³), active, translational landslide, producing orthophotos, and creating DEMs for change detection. The UAS Team has also been tasked with capturing imagery of inaccessible outcrops and perspectives for geologic mapping, creating a SfM DEM for fault mapping, and taking video of geologically intriguing locations for a super-secret geotourism campaign (Fig. 5).



Figure 4. The WGS UAS team in action.



Figure 5. UAV footage of the Mima Mounds Natural Area Preserve (NAP) near Olympia, WA.

LIBRARY

During 2018, the Washington Geology Library (WGL) completed a number of projects, as well as expanded educational resources for grade-school children that visit the library. Funded by a data preservation grant, our field notebook and map collection has now been scanned and catalogued. Our Coal Mine Map Collection has now been georeferenced and placed on the Washington Geologic Information Portal. An official circulation system is now in place as a result of barcoding more than 80,000 library items. Six issues of TsuInfo Alert, the National Tsunami Hazard Mitigation Program newsletter, were published.

As part of Earth Science Week (ESW) October 2018, the WGL had a very successful rock auction fundraiser which subsidizes purchases of books and other materials for the library. These funds along with WGS funds have allowed an expansion of educational materials for the various kid's groups that visit (for

example, summer camps, schools, Bring Your Kids to Work Day). The highlight is certainly the augmented reality sandbox (Fig. 6), where kids learn first-hand the concept of topographic mapping. Kids and adults alike love it. Geologically themed Teacher Kits are also in the process of being developed. An open house, also part of ESW, took place in honor of National Geologic Map Day, where new mapping done by the WGS was on display. The event culminated with the eating of our geologically themed cake of Palouse Falls.

WASHINGTON GEOLOGIC INFORMATION PORTAL

In the fall of 2017, the Survey released a totally new upgrade to our old Adobe Flex-based Portal, an interactive mapping application that allows users to view, query, and download the Survey's more than 200 GIS layers. The new Portal (Fig. 7) now uses the latest Esri JavaScript 4.x API with an Angular 2+ framework, and it has many more capabilities than its predecessor. Users can add their own data, re-order the layers, filter the layers based on keywords, view the data in 3D, query layers, view attribute tables, draw, measure, and print. All of this is done with a streamlined and intuitive interface. WGS is currently in the process of further updates, which will allow users to view USGS hydrogeologic framework data in 3D using Local Scenes.

<https://dnr.wa.gov/geologyportal>

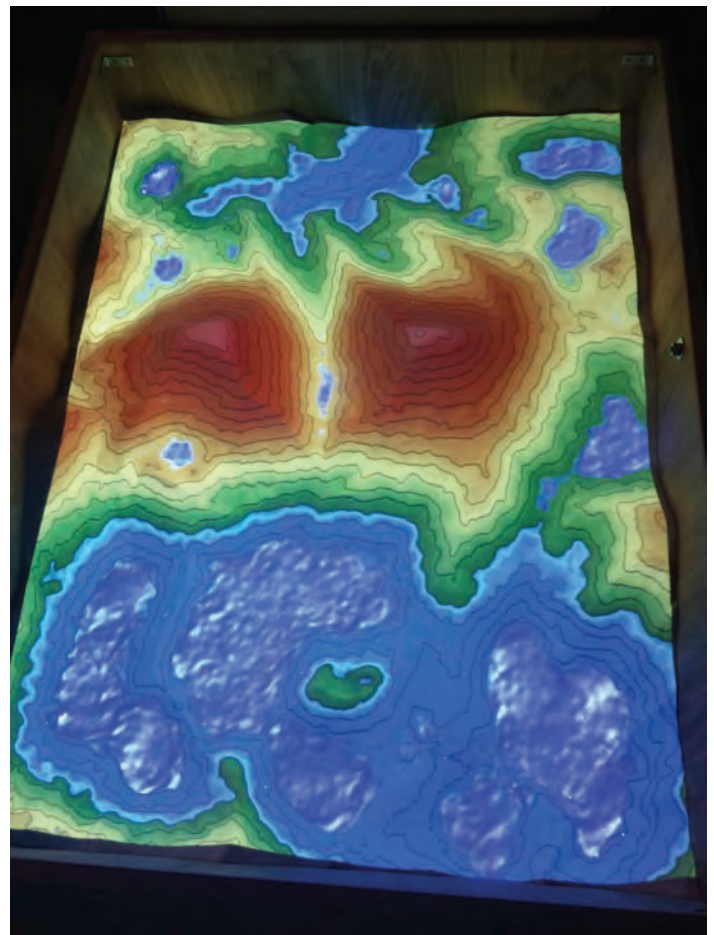


Figure 6. The augmented reality sandbox in the Washington Geology Library.

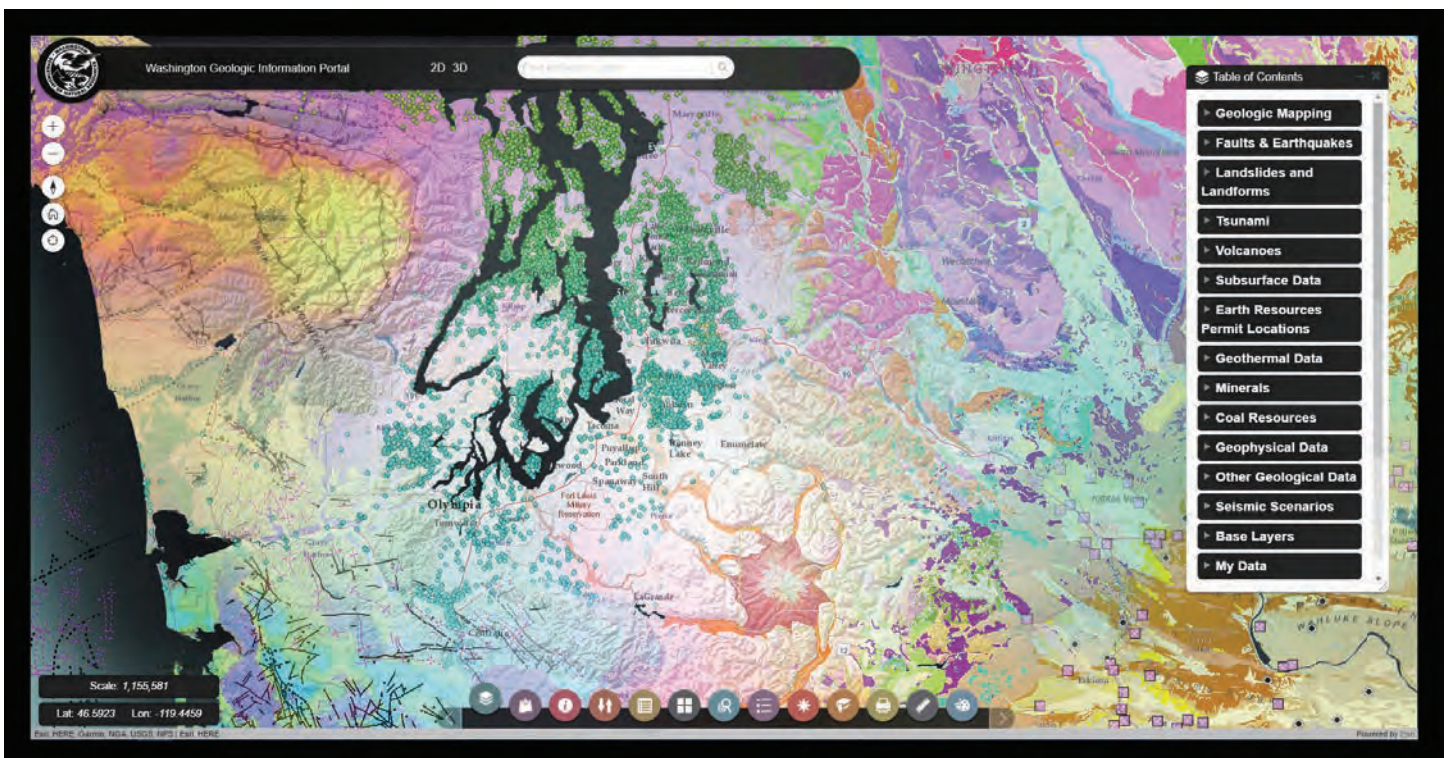


Figure 7. The Washington Geologic Information Portal.

WEST VIRGINIA

WEST VIRGINIA GEOLOGICAL AND ECONOMICAL SURVEY

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INTRODUCTION

The West Virginia Geological and Economic Survey (WVGES) works to acquire and disseminate knowledge concerning the geology of West Virginia, for the benefit for all interested parties. Established in 1897, WVGES is an executive agency within WV's Department of Commerce. The Mission of WVGES is to conduct long-term analysis of the geological resources of the state, especially coal, oil, gas, and non-fuel minerals, and to provide expertise and disseminated information to the citizens of West Virginia regarding geological resources and the environment through direct contact, publications, and web-based applications. WVGES currently has 33 full-time, benefitted employees divided across six sections. During the past fiscal year, WVGES staff responded to more than 4,300 requests for information through personal contact or via internet requests. What follows is an abstracted version of the FY18 annual report. The full report, including figures, charts, graphs, and references, can be viewed at WVGES's website, as can past annual reports.

APPLIED COAL RESEARCH

The Coal Bed Mapping Program (CBMP) is a multi-year project focused on remapping the coal measures of the Mountain State. To date, the majority of the state has been completed with small areas in the central and eastern portions pending. Map coverages for 85 coal seams and splits have been created, which include structural contour maps, mined and remaining areas by mining type, outcrops, study areas with associated grids showing total bed thickness, total coal thickness, and total parting thickness. Currently staff efforts have revolved around updating newly acquired mining, adding new thickness and elevation data, and collecting coal and rock samples to add to our extensive coal chemistry database. These coverages are all available on WVGES's website (<http://wvges.wvnet.edu/www/coal/cbmp/coalims.html>)

Mine Information Database System

Work continues on updating, expanding and improving WVGES's Mine Information Database System (MIDS) as new mine maps, permits and information become available. The MIDS database houses mine map information including location information (county and quadrangle), coal bed seam name, mine names, company names, permit numbers and other notes. MIDS contains records for every mine map publically available at the WVGES and contains more than 48,000 documents with more than 85,000 mines. Comments and submissions by the public are encouraged, to make a better and more complete database.

Underground Mine Mapping Project

Geologists in the Coal Program worked in cooperation with WVOMHST in an employee time-match project, funded by the U.S. Office of Surface Mining to acquire new mine maps for

various identified private repositories. Many of these maps are already in our database, but each one must be checked against existing GIS coverages to ensure completeness. In addition, many maps contain thickness data, drillhole locations or structural data that is subsequently added to the data model. WVOMHST collected, scanned, and verified company information from these vintage mine and property maps and WVGES then incorporates them into the MIDS database. To date several thousand new maps have been added to our system and are available to the public at www.wvgs.wvnet.edu/www/coal/MIDS_Index.htm

Rare Earth Elements (REE)

WVGES geologists partnered with industry to investigate the relationship between Rare Earth Elements, including yttrium and scandium (REE+Y+Sc), and coal seams. The project was funded by a grant awarded by the U.S. Department of Energy (DOE) via the National Energy Technology Laboratory (NETL), focused not only on the coal seams but additionally on the coal byproducts and adjacent associated materials—interbedding, partings, as well as roof and floor rock. The samples were selected from a data collection of more than 50,000 discrete samples in the Coal Bed Mapping Program (CBMP). Material samples were also instrumental in the collaborative REE+Y+Sc testing effort.

Results showed the state divided into two large general regions—Northern and Central Appalachian basins. The highest REE+Y+Sc concentration occurrence of +300 ppm in the NAB were found in Barbour County, primarily in the Lower and Middle Kittanning coal beds. Partings and roof sample represented 14 percent and 13 percent, respectively, of the +300 ppm strata samples. The distribution of REE+Y+Sc in the CAB strata was somewhat different than that of the NAB. The most frequent occurrence in the CAB was in the partings (40% of the +300 ppm samples), followed by the roof material at 28 percent. Overall, the area south of Charleston in the CAB encompassing southern Kanawha, Boone, Logan, and Mingo counties tested for the highest concentration of +300 ppm readings. Additional investigation is likely needed to understand the depositional characteristics of REE+Y+Sc within the coal strata matrix.

APPLIED OIL AND GAS RESEARCH

Appalachian Storage Hub

During FY18, Oil and Gas Program staff members participated in a major research project to identify potential locations for subsurface storage of natural gas liquids (NGLs). The study was funded by the Claude Worthington Benedum Foundation with matching funds provided by thirteen industry partners. Research was conducted by the Appalachian Oil and Natural Gas Research Consortium (AONGRC), a program of the West Virginia University Energy Institute's National Research Center for Coal and Energy.

Dubbed the Appalachian Storage Hub (ASH) project, the research team was comprised of researchers from the Ohio, Pennsylvania, and West Virginia geological surveys and administered

by AONGRC. The goal of the study was to characterize all potential options for subsurface storage of liquid ethane and other NGLs along and adjacent to the Ohio River from southwestern Pennsylvania to eastern Kentucky, with a similar study along the Kanawha River in West Virginia. This involved the mapping and identification of areas of the Greenbrier Limestone that are at least 40 ft thick and suitable for hard-rock mining; mapping and identification of areas where the Salina salt is at least 100 ft thick and suitable for solution mining; and mapping the thickness and extent of sandstone reservoirs in depleted gas fields that could be converted to NGL storage.

The study was completed at the end of July, 2017 and delivered three main products: a regional subsurface geologic investigation of all geologic units of interest; a detailed reservoir characterization effort, including field-level studies, rating criteria used to screen candidate fields, the final ranking of storage candidates and presentation of three prospect areas; and a publicly-accessible website from which the above items are served. The ASH web page has more than 3,000 page views since its launch, with more than 11,000 hits. The website, created and maintained by the WVGES Information Technology Program, can be found by visiting www.wvgs.wvnet.edu/ash.

Tuscarora Sandstone: Natural Analog for CO₂ Storage

The Tuscarora Sandstone forms some of West Virginia's most impressive peaks, including the iconic Seneca Rocks. In that location, the white, mature, quartz arenite is tilted to near-vertical and exposed at the surface, but in FY18 WVGES geoscientists worked on two intriguing subsurface studies of the Tuscarora. The first, a study of the natural occurrence of carbon dioxide in the Indian Creek field in Kanawha County, looks at the reservoir as a natural analog for carbon storage. The CO₂ in this field is generated by natural processes, as part of the gas stream, and is one of the only fields in the eastern U.S. to do so.

Understanding how the CO₂ formed in the Indian Creek field, the mechanisms by which it was trapped, and how production of the CO₂ can affect wellbore integrity is the focus of a three-year study conducted by WVGES and Battelle Memorial Institute and funded by the U.S. Department of Energy. The study, which concludes in September 2018, examines and compares well records, geophysical logs, thin sections and geochemical analyses from wells both inside and outside of the Indian Creek field. An additional component of the proposed research, to test the sustained casing pressure of some of the wells, was unable to be completed due to lack of access to the production wells.

A second study of the Tuscarora, this time in northern West Virginia, looks at another unique feature of the reservoir—its ability to serve as a geothermal heat source for West Virginia University. The Tuscarora sits approximately 10,000 ft in the subsurface near Morgantown and is in proximity to a geothermal hot spot identified in Southern Methodist University's Geothermal Laboratory Heat Flow Map of the Conterminous U.S. Working in coordination with the West Virginia University Energy Institute, WVGES will investigate the porosity and permeability

of the Tuscarora and work with project scientists at WVU, Cornell University, and the University of California at Berkeley to develop geologic and heat flow models of the reservoir.

The Marcellus and Utica Shale Plays

The first oil and gas wells were drilled in West Virginia more than 150 years ago. In the early days of the industry, new drilling locations were chosen with little to no background information or scientific forethought. Drillers devised their own names for the units they encountered, which led to development of highly localized lexicons. Incorporating these naming conventions into formal stratigraphic nomenclature is a difficult task, but is essential to understanding the geologic framework of the state and region.

To this end, a major milestone was achieved in FY18. WVGES Geoscientist Susan Pool, working in collaboration with Dr. Ray Boswell (U.S. Department of Energy–National Energy Technology Laboratory), developed and published a revised lithostratigraphy of Middle and Upper Devonian organic-rich shales in West Virginia. This publication, WVGES Reports of Investigations 35 (RI-35), develops a statewide formalization of the stratigraphic nomenclature and focuses on the Marcellus and other organic-rich shales. Through this detailed characterization of the distribution and thickness of not only the organic-rich shales, but also the intervening siliciclastic and carbonate units, a revised and enhanced lithostratigraphic framework is developed.

One major finding of the research contained in RI-35 is the recognition of several distinct, regional, lithostratigraphic units within the Marcellus in northern West Virginia, including a lower Union Springs Member, a middle Cherry Valley Member, and an upper Oatka Creek Member. Recognition of these regionally mappable units elevates the Marcellus to formation status. Thus, the Marcellus Formation replaces the “Marcellus Shale” in WV's formal lexicon. RI-35 is available in its entirety for free download via the WVGES website (<http://www.wvgs.wvnet.edu/www/MUD-vnnSh/MUDvnnsh.htm>), and includes the report text; 31 figures, including 19 isochore maps; ten gamma-ray geophysical well log lithostratigraphic cross sections; an interactive mapping application; and a Microsoft Excel spreadsheet containing stratigraphic unit depths and interval thicknesses.

Development of the Marcellus Formation continues to lead all other drilling in West Virginia. In FY18, ninety-three wells were completed in the Marcellus, with an additional 473 permits issued. A majority of the wells completed during FY18 were located in Doddridge County. Approximate lateral length ranges from 3,119 ft to 12,391 ft, with an average lateral length of 8,287 ft. Number of completion stages ranges from 14 to 83, with an average of 40 stages per well.

The Utica shale play trails the Marcellus in terms of drilling activity as well as adoption of a formal stratigraphic nomenclature. The drilling target in the “Utica” is actually the Ordovician Point Pleasant Formation and may also include the Logan Shale Member of the Lexington/Trenton Formation. Terminology for these units is adopted from adjacent states such as Ohio and

Kentucky; these names are considered informal drillers' terms in West Virginia.

GEOSCIENCE AND GEOLOGIC MAPPING PROGRAM

Geologic Mapping

Geologic Mapping at WVGES consists of the direct acquisition of new geological information through field reconnaissance and the conversion of existing geological information from hard copy (paper, mylar, etc.) to digital format. Acquisition of new geological data is carried out under the STATEMAP program funded jointly by the United States Geological Survey (USGS) and WVGES. During the summer and fall of 2017 and spring of 2018, WVGES geologists conducted field work on four 7.5-minute topographic quadrangles in central, eastern, and southern West Virginia (Lead Mine, Montrose, Mozark Mountain, and White Sulphur Springs). Published as WVGES Open File Reports, the data are available as paper maps, PDF files, and geographic information system (GIS) geodatabases. In August 2017, the STATEMAP Advisory Committee (Mapping Panel), composed of individuals from industry, government, and academia, met to evaluate new potential map areas within WV for the upcoming 2018 field season. In November 2017, WVGES successfully submitted a multi-project proposal to the USGS and mapping of the Edray and Hillsboro quadrangles will be partially funded for FY2019.

Environmental Geoscience and Geochemistry

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

Geochemical analyses for 47 rock samples were added to the existing stratigraphic geochemical database bringing the number of samples up to 1,153 and covering West Virginia rock units ranging in age from Precambrian through the Pennsylvanian. The database is available as a GIS layer that can be combined with or superimposed on other maps of West Virginia for use in environmental and economic assessments of the near-surface bedrock of a particular geographic location. Because of interest in rare earth elements (REEs), we have increased the number of elements requested for analysis, which will be reflected in all future database entries.

INFORMATION SERVICES PROGRAM

WVGES maintains a large website that is constantly updated, where various reports and geologic data are made available to interested parties. The Information Services Program is responsi-

ble for publications, the agency's website and feedback presence, maintaining the agency's network presence, maintaining the agency's network infrastructure and desktop operations, developing interactive mapping applications, and programming applications in support of other programs' projects. During FY18, WVGES's website delivered more than 3,000 static and dynamic web pages, 823,070 website visits, and 22,680,910 page views.

Public-Access Systems and Services:

Information available and changes made to WVGES's website are too numerous to list herein. To view the entire report, please access the FY18 annual report on the website (www.wvges.wvnet.edu). Changes made during FY18 include:

- 2016 oil and gas well production data
- Various scientific posters with abstracts
- 2016 Marcellus Shale Production and Utica Information—by Philip Dinterman
- Multiple informative website pages were updated
- Several interactive mapping applications were updated, including coal bed mapping, MIDS, and various oil and gas features.

WVGES's website contains much useful information that is beyond discussing here. Topics include earthquakes/seismicity, STATEMAP geologic mapping, geologic maps of West Virginia, WV Broadband map, maps and map files, oil/gas well data DVD, Marcellus/Devonian Shale, Utica Shale Play book, Appalachian Storage Hub Project, summary data, geoscience education resources, visiting geologists at State Parks, news, and mini-museum. Interested readers are urged to examine these exciting changes for themselves.

WISCONSIN

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY

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INTRODUCTION

The Wisconsin Geological and Natural History Survey (WGNHS) provides objective information about Wisconsin's geological, mineral, and water resources. WGNHS was created by the Wisconsin Legislature in 1897, with earlier state surveys in Wisconsin dating back to 1854. The Survey is a unit of the University of Wisconsin Cooperative Extension. In 2017, the staff of the WGNHS consisted of 24 science and support staff and 31 students or interns. They were involved in a variety of mapping, research, and educational projects in the areas of geology, hydrogeology, and mineral resources.

During 2017 WGNHS worked on projects in 69 of Wisconsin's 72 counties, drilled more than 1,600 ft of rock core and nearly 3,500 ft of geoprobe core, measured water levels in 197 monitoring wells, and geophysically logged 20 municipal wells.

Major WGNHS projects and activities in 2017 and 2018 are described below.

GEOLOGIC STUDIES

Dodge County

The Survey continued to map the bedrock geology and topography of Dodge County at 1:100,000-scale. The bedrock geology is comprised 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. Fold geometry and preferential sulfide mineralization along fold limbs similar to that observed in the Upper Mississippi Valley Lead-Zinc District, suggesting similar controls on deformation and mineralization for southwestern and southeastern Wisconsin.



Figure 1: Geologist Eric Carson discussing the history of the Mississippi and Wisconsin Rivers during the WGNHS spring 2018 staff field trip. Photo by Ken Bradbury, WGNHS.



Figure 2: Kink folds in quartzite are remnants of the folding and faulting that built the mountains of the Baraboo Hills in south-central Wisconsin. Photo by Esther Stewart, WGNHS.

Baraboo Hills

WGNHS geologists developed new maps of the surface and subsurface Precambrian geology of the Baraboo Hills, Sauk, and Columbia Counties. This work is constraining the location of several newly identified and previously recognized folds and faults, suggesting minor Paleozoic reactivation of Precambrian structures.

Trempealeau County

The WGNHS completed a new 1:100,000-scale bedrock map of Trempealeau County, in western Wisconsin. This and other recent mapping in Wisconsin's Cambrian sandstone regions is helping inform Wisconsin's frac-sand industry and also has led to studies of naturally occurring sulfides and toxic metals found in some water wells in the region.

Volcanic stratigraphy of the Midcontinent Rift

Working with USGS scientists, we are integrating two-dimensional reflection seismic lines with aeromagnetic and gravity data and onshore geologic constraints to characterize the geometry of volcanic packages of the 1.1 billion-year-old Midcontinent Rift beneath western Lake Superior. Characterizing the geometry and spatial-temporal relationship between the different packages will help address questions about how the Midcontinent Rift formed and its economic resource potential.



Figure 3: Mapping glacial tunnel channels in Waushara County. Photo by Luke Zoet, UW-Madison.

Driftless Area

The WGNHS completed year seven of an eight-year project mapping the surficial geology of all of the lower Wisconsin River valley. The resulting 1:100,000-scale maps and accompanying report will provide new insight into the nature and distribution of unconsolidated sediments at the Earth's surface throughout this portion of the Driftless Area.

Reorganization of Mid-Continent rivers

Based on observations and data collected as part of the Driftless Area mapping project, WGNHS scientists have recognized that numerous landforms in the lower Wisconsin River valley preserve a record that the valley was carved by an eastward-flowing river. This river, which we have named the ancestral Wyalusing River, was part of a drainage system that covered most of Wisconsin and Minnesota.

Chronology of the Green Bay Lobe

To complement surficial geologic mapping, the WGNHS has become a leader in collecting Geoprobe cores from places where lakes formerly existed along the margin of the last great ice sheet. These cores are providing new numeric chronologic control on the timing of the advance and retreat of the Green Bay Lobe. The information is providing new insight into the behavior of the glacier during the peak of the last Ice Age.

Sand Mobility in the Kickapoo River Valley

Surficial geologic mapping in the Kickapoo River valley has identified deposits associated with both alluvial (river) and aeolian (wind) transportation of fine-grained sand derived from the bedrock in the uppermost portions of the valley. Current research is unraveling the relationship between climate conditions during the last glaciation, vegetation cover at that time, and the timing and processes of sand transport.

St. Croix National Scenic Waterway

Working in collaboration with the National Park Service (NPS), the WGNHS mapped surficial geology in areas of the St. Croix National Scenic Riverway that did not already have modern surficial geologic mapping. This included parts of Burnett, Pierce, Sawyer, and Washburn Counties. The resulting data were combined by the NPS with previously completed mapping to produce a seamless 1:100,000-scale map of the St. Croix National Scenic Waterway.

Glacial Mapping of Western Waushara County

We are mapping the surface geology of western Waushara County. To better understand the Quaternary stratigraphy and history of the area, we conducted active seismic surveys of tunnel channels and cosmogenic dating of the Arnott Moraine (in nearby Portage County). The information is being used to help characterize the aquifers that feed lakes in the central sands area of Wisconsin and will support groundwater modeling of the area.

Sediment Delivery from Bluff Erosion on Lake Michigan in Southeastern Wisconsin

Bluff failure on Lake Michigan contributes to lake sediment, but the specifics are not well documented. The absence of these data has resulted in costly and inefficient sand management along southwestern Lake Michigan. This work builds the foundation for future research collaborations between the Wisconsin and Illinois Geological Surveys, which are ultimately aimed at comprehending and modeling the dynamic nature of littoral transport along southwestern Lake Michigan.



Figure 4: Collecting stream data. Photo by Pete Chase, WGNHS.

Figure 5. Drilling to support geologic mapping. Photo by Bill Batten, WGNHS.



Quaternary Geology of Calumet and Manitowoc Counties

The Survey released a new Quaternary map and Bulletin covering Calumet and Manitowoc counties. This bulletin explains the glacial history, interprets the deposits left behind, and portrays the distribution of the deposits on a map and cross sections.

WATER-RESOURCES STUDIES

Springs of Wisconsin

WGNHS is updating the statewide database of springs. The updated inventory aims to include all known springs in Wisconsin that discharge approximately 110 gpm and higher. To understand baseline conditions and to characterize the seasonal variability of different spring types in Wisconsin, we also continue to monitor flow, water quality, and ecology at “reference springs” located in different hydrogeological settings.

Chequamegon-Nicolet National Forest Groundwater Study

The Chequamegon-Nicolet National Forest of northern Wisconsin is home to abundant springs, streams, and lakes. In cooperation with the USGS and the U.S. Forest Service, the Survey developed a hydrogeologic database, maps of hydrogeologic properties, depth to bedrock, and the water table configuration for the forest. The project team has also analyzed groundwater recharge over the forest, characterized water quality, and developed regional-scale groundwater flow models for the forest. This project has fostered related studies on groundwater discharge to the Marengo River and the fractured-rock hydrogeology of parts of the forest.

Bayfield County Groundwater Atlas

This project is developing an inventory and analysis of groundwater conditions in Bayfield County. It is providing technical and educational resources useful to local officials, citizens, and those interested in agriculture and aquaculture, in order to assess and address potential impacts of various land uses on groundwater resources and groundwater quality protection. The Atlas will be an educational resource, with information about the source of groundwater to wells, streams and rivers, for informing land-use discussions, decisions, and planning.

Hydrogeologic Characterization of the Town of Lincoln, Kewaunee County

Keewaunee County has been the site of numerous groundwater contamination events related to land-use practices and shallow, fractured carbonate bedrock. This two-year study developed a series of hydrogeologic maps including depth to bedrock, depth to water table, water-table elevation, groundwater recharge, groundwater contaminant susceptibility, and catchments and closed depressions for use by local residents and local and state officials in addressing contamination issues and to assist future planning.

Wellhead Protection and Nitrate Transport

In cooperation with Wisconsin Department of Natural Resources and the University of Wisconsin-Madison, Survey scientists are investigating transport through groundwater at field sites near municipal water supply wells. The ultimate goal of this work is to develop land-use management approaches that protect water quality while being compatible with the competing land and water users in the area.

Central Sands Lakes Study Monitoring

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

Multi-instrument Stream Surveys

WGNHS scientists and students are collecting dense datasets from representative streams across Wisconsin's physiographic regions. The datasets include water temperature, conductivity, pH, dissolved oxygen, chloride, stream depth, stream-bed electrical conductivity, and stream-bank and stream-bed video. The ultimate objective of this project is to develop a comprehensive methodology for rapid and accurate data collection on streams, as well as to develop a process for interpreting the large datasets to efficiently and readily provide inputs for groundwater models.

Mukwonago Watershed: Simulating Impacts on Wetlands

In cooperation with The Nature Conservancy of Wisconsin (TNC), the WGNHS and the USGS are collaboratively developing a groundwater flow model representing the Mukwonago watershed in southeast Wisconsin, with the goal of improved understanding of the impacts of future development and new high-capacity wells on this highly important wetland system.

Door County Wetlands

Water quality indicators of human impacts. In most of Door County, private septic system effluent and landscape/agricultural chemicals have the potential to move through the thin soil layer into the underlying karst bedrock and groundwater aquifer. WGNHS scientists are collaborating with The Nature Conservancy (TNC) to determine if nonpoint source pollution is impacting the biodiversity and function of these coastal wetlands.



Figure 6. Demonstrating a physical model of karst geology and a state-wide farm show. Photo by Ken Bradbury, WGNHS.

Columbia County

More than 20 percent of well samples from Columbia County have nitrate levels higher than the drinking water standard. WGNHS prepared a groundwater model that provides a tool to determine where nitrate pollution is coming from. These models are tools for policy makers to manage their water resources.

Hydrogeology of the frac-sand mining district in western Chippewa County

This five-year study, commissioned by the Chippewa County Department of Land Conservation and Forest Management in 2012, is a cooperative effort between the USGS and WGNHS. The project evaluates potential impacts to groundwater resources from industrial sand mining and irrigated agriculture. This effort includes development of a groundwater flow model and a series of annual informational meetings to update the public about study results and water resources in this region of Wisconsin.

Radium studies

In 2018, WGNHS scientists completed an investigation of geologic sources of radium to groundwater in Wisconsin's sandstone aquifer. The work demonstrated that geologic sources of radium are common throughout the aquifer stratigraphy, but geochemical conditions, such as dissolved oxygen levels, control radium concentrations in groundwater. These findings and ongoing related studies address a significant problem for many municipal water supply systems, such as the City of Waukesha, where deep wells produce water with elevated radium.

DATA MANAGEMENT AND SUPPORT

Collection of Downhole Geophysical Logs

The WGNHS continually collects and compiles downhole geophysical logs from research wells and "wells of opportunity," such as municipal wells. The logs, including natural gamma radiation, temperature, caliper, fluid conductivity, borehole diameter and optical imaging, are important tools for understanding water-quality problems in individual wells, and for correlating geologic units in the subsurface.

Statewide Groundwater Level Monitoring Network

Since 1946, WGNHS and USGS, in partnership with the Wisconsin Department of Natural Resources, have jointly operated Wisconsin's groundwater-level monitoring network, which currently consists of 93 wells around the state. Scientists and land-use managers routinely use these long-term data to evaluate the response of groundwater levels to drought, floods, pumping, or other changes.

Well Construction Reports

The WGNHS serves as the repository for well construction reports (WCRs) from water wells installed between 1936 and 1989 and provides digital or paper copies to those who request them. In FY16, WGNHS released a new interactive map, providing online access to these historical WCRs for state agencies, consulting firms and private well owners. In addition, WGNHS serves as a point-of-contact for questions about WCRs and updates records when errors are found during project work.

Hydrogeologic Data Viewer

The WGNHS supports the Hydrogeologic Data Viewer, a map-based application to access a statewide catalog of hydrogeologic data. The application provides WGNHS and DNR staff with online access to data and publications.

WGNHS Research Collections and Education Center

The WGNHS archives geologic records, rock samples, core samples and other materials in Mount Horeb, Wisconsin. Our core repository contains more than 2.5 million ft worth of drillhole cuttings, more than 650,000 ft of drill core and more than 51,000 individual hand samples of rock from across the state. Examination tables and basic laboratory facilities allow convenient analysis and study of these materials by qualified individuals.

Data Preservation Projects

In 2017 and 2018 the Survey completed and released, with USGS support, two important sets of historical geologic data in accessible, user-friendly story map formats. The Lake Superior Legacy Collection (<http://data.wgnhs.uwex.edu/lake-superior-legacy/>) provides online access to geologic research conducted by the U.S. Geological Survey between 1882 and 1922. Users can search through 30,000 rock samples using an interactive map, browse 13,000 thin sections (microscope slides made from rock slivers), and read about the history of the collection in over 300 scanned notebooks. The Mineral Exploration in Northern Wisconsin (<http://uwex.maps.arcgis.com/apps/MapSeries/index.html?appid=079ce2d4bf81415098a7ca0b5c4c8580>) site provides links to the maps, field notes, and geologic records of the E.K. Lehmann and Associates company that carried out landmark metallic mineral exploration across northern Wisconsin between the 1970s and 1990s. Access to these materials can facilitate research into the buried Precambrian geology of Wisconsin as well as expedite exploration for mineral resources.

variety of publications, including maps, technical reports, fact sheets, and educational guides.

WGNHS BY THE NUMBERS

Our numbers provide a snapshot of the work the WGNHS did in 2017 across the width and breadth of Wisconsin.

Core repository—*maintaining a rock and core repository*

- 660,000 ft of rock core
- 17,400 rock thin sections
- 11,300 water well cuttings
- 15,100 rock hand specimens

Geologic data—*making our data available*

- 633 mineral reports and historic well records scanned
- 286 legacy drill holes located

Education and outreach—*answering questions from industry, regulators, government, and the public*

- 15,300 educational contacts
- 27,500 publications downloaded (<http://wgnhs.uwex.edu>)
- 3,000 Facebook likes (<https://www.facebook.com/WGNHS>)
- 1,800 Twitter followers (<https://twitter.com/wgnhs>)
- 109 talks and professional papers

EDUCATION AND OUTREACH

The staff of the Wisconsin Geological and Natural History Survey regularly participate in educational outreach activities for the public, industry groups, government, and other state, local, and national stakeholders. The Survey produces and distributes a

WYOMING

WYOMING STATE GEOLOGICAL SURVEY

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INTRODUCTION

For 85 years the Wyoming State Geological Survey (WSGS) has performed the important and critical function of interpreting Wyoming's geology. Our mission 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.

The WSGS is located on the University of Wyoming campus in Laramie, Wyoming, and has 21 full-time benefitted 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

The WSGS, under its STATEMAP program, published five new geologic maps focused on the geology and related energy resources and geologic hazards in Wyoming.

Bedrock Mapping

The 1:24,000-scale Preliminary Bedrock Geologic Map of the Fort Steele Quadrangle, Carbon County, investigates the depositional history of the Mesaverde Group and includes a subsurface type log of this prolific reservoir rock.

The 1:24,000-scale Preliminary Bedrock Geologic Map of the Bridger Pass Quadrangle, Carbon County, furthered under-



Figure 1. WSGS contract geologist, Lauren Broes, examines the Oligocene Wagon Bed Formation, near the Gas Hills in Fremont County, Wyoming, while mapping the Gas Hills 7.5-minute quadrangle.

standing of Cretaceous stratigraphy in the Atlantic Rim area and assessed coal quality in the Almond Formation.

The Gas Hills 1:24,000-scale Preliminary Quadrangle, in Fremont and Natrona counties, investigated structure and uranium host rocks within one of the most important uranium districts in the state of Wyoming.

The 1:24,000-scale Preliminary Geologic Map of the Albany Quadrangle, Albany County, examined the petrologic and structural geologic events that influenced mineralization in the southern Medicine Bow Mountains mining district. Samples were analyzed for rare earth elements, precious minerals, and platinum group elements.

Surficial Mapping

The 1:24,000-scale Preliminary Surficial Map of the Muddy Gap area includes portions of six 7.5-minute quadrangles in northwestern Carbon and Fremont counties. It focuses on constraining the Muddy Gap segment of the South Granite Mountains fault system.

ENERGY RESEARCH

The WSGS published a *Correlation of the Upper Cretaceous Strata of Wyoming* that correlates Upper Cretaceous strata at 25 generalized locations throughout Wyoming to Western Interior biostratigraphy and the most recent chronostratigraphic data. The comprehensive overview of statewide stratigraphy focuses on strata deposited between 100 million and 63 million years ago and covers all Wyoming basins.

MINERAL RESEARCH

The report, *Evaluation of Selected Wyoming Silica Sand Deposits as Potential Sources of Proppant* focuses on the potential of selected silica sand deposits in Wyoming for use as hydraulic fracturing proppant. The report evaluates selected silica-rich sand deposits found in bedrock, dune, and alluvial fan exposures located near Wyoming's major transportation corridors as potential proppant material. The results of the study show the selected sands have potential for use in shallow hydraulic fracturing applications, but investigators didn't find high-quality sands at greater depths, as is the case in most unconventional reservoirs.

WATER RESEARCH

The WSGS published a report that examines the salinity of groundwaters that occur at depths of 7,000 ft or less in the Powder River Basin, where significant oil and gas activity has taken place in recent years. The need for industrial-use water will become increasingly important as oil drilling continues in the Powder River Basin. The report is the first step toward locating

subsurface water that is not suitable for human consumption, livestock, or agriculture.

FOSSIL PREPARATION

The WSGS facilitated the preparation of a fossilized tapiromorph discovered near Kemmerer, Wyoming, which may be the first of its kind and is the largest mammal found to date in the Green River Formation. The fossil was prepared for scientific purposes, and is now available for scientific research and display at museums.

OUTREACH

The WSGS published a pamphlet about the geology of Curt Gowdy State Park. The pamphlet is the first in a series that will focus on the geology of Wyoming's various state parks, thus enhancing park visitors' experience.

AWARDS

DISTINGUISHED SERVICE AWARD

The Distinguished Service Award is presented to particularly deserving living, retired, or retiring State Geologists, Associates, and Honorary Members other than current officers who deserve to be recognized for the excellence of their efforts over the long term, 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.

Sponsored by AASG for service to AASG, the 2018 recipients of this award are:

Maeve Boland, AGI

Derric Iles, South Dakota State Geologist

JOHN C. FRYE MEMORIAL AWARD

Environmental geology has steadily risen in prominence over recent decades, and to support the growth of this important field, the John C. Frye Memorial Award was established in 1989 by GSA and AASG.

John C. Frye joined USGS in 1938, he went to the Kansas Geological Survey in 1942, he was its Director from 1945 to 1954, he was Chief of the Illinois State Geological Survey until 1974, and he was GSA Executive Director until his retirement in 1982, shortly before his death.

John was active in 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, other professionals such as land-use planners and engineers, and ideally also by informed laypersons. The selection committee assesses uniqueness, significance as a model, and overall worthiness.

The 2017 award winner is:

The West Salt Creek Landslide: A Catastrophic Rockslide and Rock/Debris Avalanche in Mesa County, Colorado, 2015, by Jonathan L. White, Matthew L. Morgan, and Karen A. Berry, Colorado Geological Survey Bulletin 55, 57 p.

CHARLES J. MANKIN MEMORIAL AWARD

Geological survey agencies play an essential role in provision of comprehensive, jurisdiction-wide geoscience information. While 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 University of Oklahoma in 1959, and from 1967 to 2007 he was Director of the Oklahoma Geological Survey. He was AASG President in 1975–76, AGI President in 1978–79, 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 Award is given each year to a nominated geological 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.

David Spears, State Geologist of Virginia, and Past President of AASG, announced the winner of AASG's 2017 Charles J. Mankin Memorial Award:

Bedrock Geology of the Kittery 1:100,000 Quadrangle, Southwestern Maine and Southeastern New Hampshire, 2017, by Arthur M. Hussey II, Wallace A. Bothner, and Peter J. Thompson, Maine Geological Survey Bulletin 45.

PICK AND GAVEL AWARD

The Pick and Gavel Award was initiated by 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 D.C. 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 Association of American State Geologists presented the 2018 Pick and Gavel Award to **Senator Maria Cantwell of Wash-**

ington at the Cosmos Club, in Washington, D.C., on March 15. The award ceremony was preceded by a reception for the larger geoscience community followed by the annual Pick & Gavel Banquet.

Senator Maria Cantwell was chosen for the Pick and Gavel Award because of her own enthusiastic support of geoscience and the environment, her ongoing interest in science and technology, and her encouragement of partnerships among the state, local, tribal, and federal government. For example, her efforts led to renewal of the National Tsunami Hazard Mitigation Program and permitted the Hoh and Quileute tribes to begin to move their villages out of the tsunami hazard zone. She is the prime sponsor of the Senate Bill for the National Landslide Preparedness Act that will create a national landslide hazard mitigation program and will authorize the 3D Elevation Program to acquire improved topographic information using Lidar and Ifsar. She is also a co-sponsor of the National Volcano Early Warning and Monitoring System Act, and a cosponsor to reauthorize the National Earthquake Hazard Reduction Program.

AGI MEDAL IN MEMORY OF IAN CAMPBELL FOR SUPERLATIVE SERVICE TO THE GEOSCIENCES

The AGI Medal in Memory of Ian Campbell for Superlative Service to the Geosciences is AGI's highest award, given in recognition of singular performance in, and contributions to, the profession of geology. Candidates are measured against the distinguished career of Ian Campbell, whose service to the profession touched virtually every facet of the geosciences.

The 2018 recipient is **Scott Tinker, State Geologist of Texas**.

The following is an excerpt from the AGI press release:

"The American Geosciences Institute (AGI) is pleased to recognize Dr. Scott W. Tinker, Director and State Geologist of Texas, Bureau of Economic Geology, and Professor at the Jackson School of Geosciences at the University of Texas at Austin, as the 2018 recipient of the AGI Medal in Memory of Ian Campbell for Superlative Service to the Geosciences, AGI's highest award.

Since 2000, Dr. Tinker has led the Bureau of Economic Geology as the premier state geological survey, with more than 250 research and support staff and students working on hundreds of international grants and contracts. His distinguished service—from his start in the petroleum industry to his more recent work as an educator and administrator—is superlative.

Dr. Tinker's public service involves frequent testimony and briefings before federal and state legislatures and executive agencies. He has served on several boards and commissions that influence national energy policies, including the National Research Council's Board on Energy and Environmental Systems (2003–09), the National Academies Roundtable on Unconventional Hydrocarbon Development (2016–present), and the Interstate Oil and Gas Compact Commission (2007–present).

He co-produced the 2012 documentary film *Switch*, which has been viewed by more than 15 million people in over 50 countries, and he is Chairman of the Switch Energy Alliance, a nonprofit 501(c)(3) organization. He is now filming a sequel called *Switch On*, which will focus on global energy poverty. He is passionate about energy education and has given more than 750 lectures in 60 countries.

Dr. Tinker has served the geoscience profession admirably at many levels, including as President of AGI (2015–16), the American Association of Petroleum Geologists (2008–09), and the Association of American State Geologists (2007–08), as well as in various capacities for the Society for Sedimentary Geology and the Society of Exploration Geophysicists. He is the recipient of numerous awards, including the AAPG Halbouty Medal, the Gulf Coast Association of Geological Societies Boyd Medal, and the AGI Award for Outstanding Contribution to Public Understanding of the Geosciences. He is also a Fellow of the Geological Society of America."

THE WILLIAM B. HEROY JR. AWARD FOR DISTINGUISHED SERVICE TO AGI

The 2018 recipient is **Rex Buchanan, Director Emeritus of the Kansas Geological Survey**.

The following is an excerpt from the AGI press release:

"The American Geosciences Institute (AGI) is pleased to recognize Mr. Rex C. Buchanan, Director Emeritus of the Kansas Geological Survey (KGS), as the 2018 recipient of the William B. Heroy Jr. Award for Distinguished Service to AGI.

Mr. Buchanan's contributions to AGI span decades and are among the highlights of his career as a geoscientist and science communicator, and as interim director of the KGS from 2010 to 2016. His service to AGI has strengthened AGI's publications and programs alike.

Most recently, Mr. Buchanan was an active member of AGI's Critical Issues Advisory Committee from its inception in 2013 to his retirement in 2016. In this role, he helped define the mission and structure of the Critical Issues program and provided perceptive guidance and support to AGI staff.

Mr. Buchanan also served on the planning committee for the 2016 Critical Issues Forum, "Addressing Changes in Regional Groundwater Resources: Lessons from the High Plains Aquifer." He moderated a panel on groundwater perspectives from Kansas and Nebraska, and shared his extensive knowledge of the scientific, policy, and social issues associated with groundwater.

An expert on human-caused earthquakes, Mr. Buchanan currently serves as Director of the KGS Consortium to Study Trends in Seismicity. In April 2015, he spoke on AGI's first Critical Issues Webinar, "Induced Seismicity in the Mid-Continent." Since that time, the Critical Issues Webinar series has grown substantially, and has attracted thousands of live attendees from different

states, countries, sectors, and professions. Mr. Buchanan's early support was instrumental in this program's expansion.

Previously, Mr. Buchanan co-edited *Geowriting, a Guide to Writing, Editing and Printing in Earth Science*, 5th Edition—published in 1995 and revised in 2004—and was co-author, with Lisa Rossbacher, of *Geomedia, a Guide for Geoscientists Who Meet the Press*, published in 1988. He served as Chair of AGI's Publications Advisory Committee from 1992 to 1993 and was a committee member for several years prior."

Buchanan writes, "I was pleased to receive the Heroy award. AGI has long served a critical role in representing all of the geosciences. One of the highlights of my career has been working with AGI staff and other geoscience professionals who contribute their time and talent to AGI efforts."

The award is named after William B. Heroy Jr.'s exemplary service to the American Geosciences Institute. Heroy's professional accomplishments were exceeded only by his love of geology and his commendable modesty in the face of such achievements.