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AASG
Association of American State Geologists

ASSOCIATION OF AMERICAN STATE GEOLOGISTS

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Front Row: Dave Norman (WA), Steve Masterman (AK), Bob Marvinney (ME), Scott Tinker (TX), Jon Arthur (FL)

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AWARDS

PRESIDENT'S PAGE
2015-2016

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 each 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, 2016. Much was accomplished during the 108th 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 Jon Arthur (FL); President-Elect David Spears (VA); Vice President Steve Masterman (AK); Secretary Rex Buchanan (KS); Treasurer Derric Iles (SD), and Honorary Members Representative John Price (NV). 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 am confident the executive leadership team will keep us moving forward in the spirit of our vision as an association.

EXECUTIVE COMMITTEE

The Executive Committee met formally during the 2015 Fall Liaison meeting, the 2016 Spring Liaison meeting, and on June 9, 2016, prior to the 2016 Annual Meeting. Additionally, the Executive Committee met 5 times via phone/webex during the business year to plan, discuss, and report on meetings and initiatives associated with the liaison, the mid-year, and the annual meeting. These meetings were informal but very important in allowing AASG leadership the opportunity to have a dialogue on business matters and strategic planning.

AASG BUSINESS

Baltimore served as the host city for the AASG 2015 Mid-Year Meeting with 18 State Geologists in attendance. Business discussion centered around the Liaison model and considering strategies to be more efficient and effective during our spring and fall trips to Washington, DC. Results of the Liaison Survey completed by membership were highlighted and a number of issues were raised and a lively discussion ensued. General consensus from the meeting included: continue with a Liaison model that emphasizes broad attendance and widespread meetings in the spring; smaller attendance with a strategic meeting plan in the fall; refining and focusing our key messages; and continue to explore opportunity for professional assistance.

The 2016 AASG Annual Meeting was held in Girdwood, Alaska. Thirty-three State Geologists were in attendance along with 108 other registrants. The plenary and technical programs were well planned and contributed to engaging thought and lively conversation. The business meeting primarily focused on identifying options the Association might consider for hiring administrative assistance. After considerable discussion, Membership voted and approved the Executive Committee to explore development of a financial model to support administrative assistance. Consensus held that the Association would benefit from permanence in managing our activities and business affairs, with the understanding a dues increase in some capacity would likely be required. The Alaska Geological Survey should be commended for an excellent, well organized, and eventful meeting.

OTHER BUSINESS OF NOTE

- In September 2015, AASG conducted its Fall Liaison in Washington, visiting 28 agencies and organizations over the course of three days. In keeping with the recent Liaison model, emphasis was placed on a smaller AASG team focused on a strategic agenda. Primary topics of discussion centered around NCGMP-StateMap, NGGDPP, National Groundwater Monitoring Network, Critical and Strategic Minerals, 3DEP, and Natural Hazards.

- During the Mid-Year Business Meeting in Baltimore, an excellent discussion was led by Kevin Gallagher, John Brock, and Harvey Thorleifson on the future of the National Cooperative Geologic Mapping Program. Additionally, Heidi Hansen, Counsel at the Senate Energy and Natural Resources Committee, attended and provided some thoughtful insight into the legislative environment in Washington.

- The March 2016 Spring Liaison in Washington was a success, with 30 meetings being held despite a Metro system that was severely limited in service. Much of the focus this spring was to advocate for the benefits of national landslide legislation and reauthorization of the National Geological and Geophysical Data Preservation Program. The annual AASG Pick and Gavel Awards Banquet was well attended with Anne Castle being recognized as a most deserving recipient. Anne graciously attended and shared some thoughts with the membership and guests. Anne was presented with a beautiful specimen of rhodochrosite from Colorado and we were very pleased to honor her.

PRESIDENT'S PAGE
2015-2016

- AASG endorsed the nomination of Ernie Mancini for the AGI Marcus Milling Award. Ernie has since been notified he was selected as awardee. Congratulations on a well-deserved achievement.

- AASG nominated Nick Tew and David Wunsch to each serve another term on North American Commission on Stratigraphic Nomenclature.

- AGI submitted a proposal to the National Science Foundation for the "Innovations at the Nexus of Food, Energy and Water Systems" solicitation. AGI is proposing to develop a dedicated Food-Energy-Water grey literature repository that would preserve and expand the discoverability of digital grey literature. AASG provided a letter of collaboration and support for this proposal.

- AASG co-sponsored the December 2015 AGI Critical Issues Webinar: Making Produced Water More Productive.

- In July 2015, AASG co-sponsored the AGI Critical Issues Webinar: Water as One Resource.

- AASG nominated Harvey Thorleifson for re-appointment to the National Geospatial Advisory Committee.

- We welcomed three new state geologists and bid farewell to those retiring.

- AASG contributed to the AGI/NAGT partnership publication of the *Laboratory Manual in Physical Geology* by volunteering to review specific labs of the 11th edition of this important manual.

- AASG signed on to the Interstate Council on Water Policy congressional letter of support to enable the USGS to fully implement its design for National Streamflow Network.

- A support letter urging Congress to approve the funding requested in the FY17 Department of Interior budget for the Central and Eastern US Seismic Network was sent to the offices of Congressmen Calvert and McCollum, and Senators Murkowski and Udall.

- At our mid-year meeting, AASG recognized the recipient of the Charles J. Mankin Memorial Award: "Geologic Map of the Panguitch 30' x 60' Quadrangle, Garfield, Iron, and Kane Counties, Utah" – Robert F. Biek, Peter D. Rowley, John J. Anderson, Florian Maldonado, David W. Moore, David B. Hacker, Jeffrey G. Eaton, Richard Hereford, Edward G. Sable, Harry F. Filkorn, and Basia Matyjasik, Utah Geological Survey.

- At our mid-year meeting, AASG recognized the recipient of the John C. Frye Memorial Award: "Geology and Hydrology of Groundwater-Fed Springs and Wetlands at La Cianega, Santa Fe County, New Mexico" – Peggy S. Johnson, Dan J. Koning, Stacy S. Timmons, and Brigitte Felix, authors; New Mexico Bureau of Geology and Mineral Resources, Bulletin 161.

REMARKS

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 all members to forge ahead with an eye to the future. We have witnessed a number of changes across the spectrum of state geological surveys recently and I surmise we will see more. I believe as an Association, we must continue to seek opportunity to adapt to changing environs, to become more efficient in our operations, to increase our effectiveness on a national scale, and to provide membership with a quality experience. I strongly encourage membership to move forward with a business model that includes professional/administrative assistance. I believe this would allow increased efficiency and continuity of operations and enhance the association's ability to address important initiatives. Volunteerism is a wonderful model and every current and former member is to be commended for the service they have provided to this organization. But we must also recognize the ever present (and increasing) demands on our time and energy from home states and the changing nature in which business is conducted at the national level.

Finally, I would like to thank all of the members of AASG who made this year a success: to those on the Executive Committee who regularly tackle the enormous jobs of preparing Liaisons, a Mid-Year Meeting, and an Annual Meeting; the Treasurer who keeps our finances in order; the Past-President who identifies candidates for various awards; to those who work to raise money for AASG initiatives; to the Committee Chairs and members; and to the membership at large for your unwavering support of this organization. You are the Association of American State Geologists and it has been an honor to serve as your President.

Joe Gillman

Missouri

ALABAMA

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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 (i.e., director) of the State Oil and Gas Board of Alabama (OGB). The OGB is the state's regulatory agency for all oil and gas exploration, production, and development.

The State Geologist serves as the Governor's representative to the Interstate Oil and Gas Compact Commission 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), serves as the Gulf of Mexico regional representative on the Governance Coordinating Committee of the National Ocean Council, and is a member of the Board of State Oil and Gas Regulatory Exchange 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 chairman of the Alabama Water Agencies Working Group, serves as an Alabama Natural Resources Trustee and an ex officio member of the 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, made up of two sections, *Coal Systems and Technology* and *Petroleum Systems and Technology*, 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.

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 on the second phase of the Energy Investigations Program's involvement with the Research Partnership to Secure Energy for America (RPSEA) was concluded, focusing on the petrology of gas shales within the state.

The goals of the project were to improve understanding of rock-fluid interactions in shale, to improve petrophysical characterization methods, and to develop methodology for the selection of fracturing fluids and additives. Thin section analyses with the scanning electron microscope (SEM) and focused ion beam (FIB) technologies, along with discrete fracture network (DFN) modeling, helped inform the results.

With the renewed interest in expanding energy resource development within the United States, the Alabama Oil Sands Program (AOSP) was 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. This survey will help inform the core drilling locations. Additional work will be done through core analyses, petrologic studies, and evaluation of extraction technologies.

The Southeastern Offshore Storage Resource Assessment project will assess prospective geologic storage resources for carbon dioxide in the State and Federal waters of the Mid-Atlantic, South Atlantic, and the eastern Gulf of Mexico. As part of the project team, the Energy Investigations Program will focus on the eastern Gulf of Mexico, building on previous offshore and onshore resource assessments related to geologic carbon sequestration.

Other projects undertaken by the Energy Investigations Program include exploratory coring of the Hartselle sandstone in cooperation with Advanced Resources International; data rescue efforts in cooperation with the Federation for Earth Science Information Partners; and DFN modeling to support underground injection fluid migration modeling.

Geologic Investigations Program

Geologic Mapping and Hazards Section

The Geologic Investigations Program conducts research, mapping, and data collection of geology, paleontology, mineral resources, and geologic hazards. The Program's director and the State Geologist continue to be involved with state Geographic Information Systems (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.

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 Colvin Gap and Jacksonville West 7.5-minute quadrangles was completed, and mapping of the Weisner Mountain and Piedmont Northwest 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, is mapping the Little River Canyon National Park in the northeastern part of the State. The Little River Canyon mapping project is funded through 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 and Threat and Hazard Identification and Risk Assessments. 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, collaborating with the University of Alabama Huntsville on NASA-funded research for designing disaster response support systems for the web, and integrating karst feature databases with other states and the USGS National Hydrography Data program.

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.

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 mainly includes the acquisition of beach topology and nearshore bathymetry, newly acquired and historical development of orthophotography that leads to the archiving of invaluable shoreline data. Through the Mobile Bay National Estuary Program and directed by ADCNR, the Coastal Resources Section finalized a multi-phase effort to develop the framework and inventory geospatial themes needed to support the Coastal Spatial Planning within Alabama's coastal counties and within State and Federal water bottoms. Planned work involves the final development of the geospatial data—separated into dynamic and legacy data—into subject distinct web-based interactive maps. A coastal GIS users group will be established to help facilitate cross-discipline collaboration with GIS users and maintain the awareness of updated data. With increasing interests in the replacement of suggested alternatives to hard shorelines (e.g., bulkheads, riprap) with living shorelines, working through the Gulf of Mexico Alliance and the Virginia Institute of Marine Science, the GSA finalized the effort begun in previous reporting period for the Mobile Bay shoreline. This modeling effort generated upland and shoreline best management practices for living shorelines or upland modifications and has been presented at professional conferences. It should be noted that within the Gulf of Mexico Alliance, personnel within this group also serve as the state lead for Resiliency and Data and Monitoring Priority Issue Teams.

Groundwater Assessment Program (GAP)

The 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 currently working with the Alabama Legislature through the Permanent Joint Legislative Committee on Water Policy and Management to develop a statewide groundwater hydrogeologic assessment that will be used to develop state water policy initiatives. This assessment includes collecting data concerning stratigraphy, hydrogeological characteristics, current groundwater development and future groundwater development potential, production impacts, and groundwater availability and recharge. To adequately determine the current groundwater conditions throughout the state, employees are actively measuring water wells in each county and compiling data collected in the field into the GAP database. The preliminary results of the statewide assessment will be available in early 2017.

The GAP maintains a groundwater level monitoring program that currently includes 371 wells and 49 springs monitored annually and a real-time monitoring system of 21 wells and 2 springs. The groundwater level monitoring program is currently expanding to include more wells and springs monitored annually through field work for the statewide groundwater hydrogeologic assessment. The real-time monitoring system will be expanded in the future to include more than 30 wells to further expand the need 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 GAP Water Information Section also receives and digitally catalogs drillers' reports every year on new wells, in addition to collecting and filing all related groundwater records for GSA research projects. The GSA well file is the most extensive collection of water well records in the state and is currently being placed online.

An online water resource information database has been 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. This database is currently undergoing rigorous testing prior to launching live on the GSA

website. The GSA GAP website is continuously updated with hydrogeologic data and water resource information, as well as continuously updating the electronic catalogue of well records available to the public.

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 Investigations Program (EIP) has conducted scores of studies in this area including basin-focused surveys of fishes, mussels, crayfishes, and other aquatic invertebrates, status surveys of federally threatened and endangered species, and investigations of fish movements in large rivers. The EIP biologists are continuing several studies and initiating new studies. Mussel and snail surveys in tributaries of the Black Warrior River were completed in 2013 with the aid of ADCNR Wildlife and Freshwater Fisheries Section staff. Surveys of the main channel fauna will be completed in 2017 and a comprehensive report of this data will subsequently be published at GSA. Annual monitoring of the endangered Alabama Cave Shrimp and the candidate Tuscumbia Darter on Redstone Arsenal continued for the 24th year and 17th years, respectively. In 2008, the EIP initiated a cooperative effort with ADCNR and the U.S. Fish and Wildlife Service, which continues 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 and provide information to local landowners, watershed organizations, and local governments to enhance conservation opportunities for species recovery and restoration. Habitat assessment and biological monitoring studies in other strategic habitat units were recently completed for 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, and the Sipsey River in the Tombigbee River system. Summary reports of each of those projects have been initiated and the Murder Creek fish report has been completed as a GSA open-file report. The Big Canoe Creek report has been published at GSA and the Terrapin Creek report is being prepared for publication. Road Crossing data for the Choccolocco Creek system was completed over the past winter, and all road crossing data from recent efforts is being uploaded into a centralized data center managed by USGS. A three-year State Wildlife Grant project aimed at continuing to update our knowledge of crayfish statewide started in late 2013 and numerous new state and drainage records have been secured. That project was extended for an additional year to permit sampling in large rivers and reservoirs. Objectives included filling collection gaps in under-sampled watersheds, ecoregions, and habitats and creating a GIS product to assist in mapping and management of the fauna. A project to assess various aspects of the crayfish fauna in the Bogue Chitto Creek watershed in the Alabama River drainage, a strategic habitat unit, continues, as well as a survey of a candidate crayfish species in the Tennessee River drainage. The EIP maintains voucher fish and freshwater invertebrate collections containing approximately 450,000 and 3,000 specimens, respectively. The invertebrate specimens were recently donated to Auburn University, a move that will provide more long-term and secure curation of the specimens, and a majority of the fish collection has been transferred to the University of Alabama Ichthyological Collection (UAIC) for permanent curation as well. EIP staff is assisting in data transfer to UAIC to complete the transfer.

ALASKA

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Introduction

Mission

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

Background

The Alaska Division of Geological & Geophysical Surveys (DGGS) is part of the Alaska Department of Natural Resources (DNR) and is organized into six program sections: Energy Resources, Mineral Resources, Engineering Geology, Volcanology, Geologic Communications, and the Alaska Geologic Materials Center. The division currently has 38 full-time permanent positions and 14 non-permanent positions. The total FY2016 expense budget for the division was $11.59 million, consisting of $4.59 million state general fund receipts, $2.89 million state capital project funds, $1.91 million federal receipts, and $2.19 million interagency receipts, industry support, and publications 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 each year. The Survey prioritizes the selection of new mapping areas in consultation with other state agencies, appropriate state boards and commissions, its Geologic Mapping Advisory Board, industry resource-interest groups, and other stakeholders. We are committed to delivering the results of our extensive field mapping programs to the public in a timely manner. The total square miles of published mapping in FY2016 was 15,927 and much higher than previous years, because of a concerted effort to complete analysis of and publish a backlog of unpublished data from previous field work. Several large-area maps were released in early FY2016, including a sizable amount of field mapping performed many years ago.

Geophysical Surveys

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

In FY2016, DGGS released 4,552 square miles of new airborne geophysical data from a federally funded survey flown in eastern Alaska (covering parts of the Tanacross, Nabesna, Mt. Hayes, Eagle, and Big Delta quadrangles). In FY2017, DGGS anticipates publishing a new federally-funded airborne geophysical survey for about 3,430 square miles in the Porcupine River area in northeastern Alaska.

The state-funded Strategic and Critical Minerals (SCM) project (FY2013-2015) 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 FY2016 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 FY2016, the Energy Resources Section has:

1. Completed three weeks of helicopter-supported bedrock geologic mapping in the Iliamna–Red Glacier area in lower Cook Inlet and submitted a draft copy of the map to the U.S. Geological Survey in fulfillment of the requirements for Federal STATEMAP funding.

2. Published 11 reports addressing the petroleum geology of lower Cook Inlet basin.

3. Published three reports summarizing the reservoir potential and quality of the Nanushuk Formation in the Wainwright #1 core and its exploration significance for the central North Slope.

DGGS has accumulated a vast amount of relevant petroleum-related geologic data over the past few decades and continues to gather new data. A searchable, digital geodatabase, using ArcGIS, is under construction; once finished, it will allow industry and the public to search for relevant geologic data throughout the North Slope, Cook Inlet, and other Alaska frontier basins. The initial phase consists of Cook Inlet reservoir quality data. This year, the Energy Resources Section developed and implemented a database schema to accommodate all of the data generated by the Energy Resources Section.

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 ounces of gold in the Salcha River–Pogo and Livengood areas since 2004.

DGGS released draft versions of our Bonnifield geologic map, report (doi.org/10.14509/29661), and geochemical data (doi.org/10.14509/29653), which cover a portion of the northern Alaska Range that has high base-metal mineral potential. These products were used by a small mineral exploration company to locate and stake over 30,000 acres of mining claims on state land. The immediate positive impact was increased state revenue through mining claim fees.

The Mineral Resources Section completed their third year of field studies assessing the potential of the western Wrangellia geologic province of south-central Alaska to host deposits of the strategic and critical platinum-group elements (PGEs). The 2015 field program employed geologic mapping and sampling to increase our understanding of the petrology of potentially mineralized igneous rocks. DGGS results show that the target geology can be subdivided into different magmatic series, and that certain intrusions hold higher mineral potential. Additionally, collaborative research with UAF led to a major revision of our understanding of the Alpha ultramafic complex geology, the focal point of recent industry PGE exploration. The Wrangellia project now moves into the publication phase.

DGGS initiated detailed field-geologic mapping and geochemical sampling in the Tok River area, covering 480 square miles 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 FY2017 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.

DGGS released five digital geophysical products in FY2016: (1) a federally funded, 4,500-square-mile airborne magnetic survey of the Tanacross region; (2) three sets of merged airborne magnetic data (Taylor Mountain batholith, Tok, and Salcha River–Pogo areas); and (3) digital release of Bonnifield mining district electromagnetic and magnetic airborne geophysical survey data compilation. DGGS received federal funding, and signed a contract to fly a spring-2017, 6,000-square-mile, airborne magnetic survey in northeast Alaska covering parts of the Colleen, Black River, and Charley River quadrangles. Go to dggs.alaska.gov/pubs/series/dggs/geophysical-report to access the available data.

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 provided scientific and technical expertise in support of coastal resilience and hazard preparedness for vulnerable communities in western Alaska. Key activities included collecting critical baseline elevation and aerial imagery data for 3,500 kilometers (2,200 miles) of coastline and 32 coastal and riverine communities; participating in regional Coastal Resilience and Climate Adaptation workshops held by Alaska-region Landscape Conservation Cooperatives (LCCs; Western Alaska LCC, Aleutian and Bering Sea Islands LCC, and the North Pacific LCC); and collaborating with the University of Alaska and Bristol Bay Native Association to develop creative methods for local residents to monitor erosion in their communities.

DGGS provided rapid-response geologic hazards expertise in the immediate aftermath of the deadly August 18, 2015, landslides in Sitka. We conducted ground- and air-based investigations of the area, provided critical information to on-site emergency responders, and joined the Division of Homeland Security and Emergency Management's hazard mitigation team to gather additional field observations and to map landslide extents in support of community safety, cleanup, and future planning. We also worked with the National Park Service, City of Sitka, and U.S. Forest Service during a subsequent field campaign to collect critical data needed to understand and quantify the landslide hazard potential in the region, and collaborated with the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) to collect high-resolution LiDAR. DGGS has been awarded federal funding through the FEMA Risk Map program to conduct follow-up landslide hazard mapping and analysis in 2017–2018.

DGGS scientists have developed and refined Structure-from-Motion (SfM) aerial photography equipment and field data collection protocols, and have demonstrated its capability to provide critical, timely data for geologic hazards assessment and response through deployment to multiple field sites, including: Alaska Range, Valdez ice-dammed lake, Richardson Highway/Thompson Pass, Mt. Redoubt, Sitka, Haines Highway, and Suicide Basin/ Juneau. In responding to the August 18, 2015, Sitka landslide disaster, DGGS demonstrated we have the equipment and expertise to effectively deploy this tool on short notice for emergency, rapid response, and other high-priority projects.

In collaboration with the University of Alaska, DGGS is conducting cutting-edge research on groundwater interaction with discontinuous permafrost in Goldstream Valley, Fairbanks. Scientists from this high-profile project, funded by the National Science Foundation, are working closely with area residents and are developing new approaches to using airborne and ground-based geophysical methods to map and understand permafrost regimes and behavior in a changing climate. Publication of the data, and the first-ever resistivity models from inversion, are planned for 2017-2018.

DGGS continues to manage the DNR portion of the federally funded Tsunami Hazards Mitigation Program. Inundation maps showing areas that could be affected by future potential tsunamis were published for Dutch Harbor, Akutan, King Cove, Cold Bay, Yakutat, Nikolski, Chignik, and Chignik Lagoon. Results of these investigations have been disseminated to local emergency planners.

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 52 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 continued to play a lead role in monitoring and communication of volcanic unrest and activity, managing information flow both within the observatory and out to the public. During FY2016, DGGS-AVO staff responded to eruptions and unrest at Cleveland, Pavlof, and Shishaldin volcanoes by participating in seismic and remote-sensing watches, answering emails and phone calls from the public, and accurately and efficiently distributing volcanic activity information though the DGGS-managed AVO website (avo.alaska.edu), Facebook, and Twitter sites. In FY2016, the AVO website was visited by more than 42 million people. DGGS-AVO staff also provided helicopter procurement and fuel logistics support for all AVO field projects, including geophysical monitoring station maintenance, geologic field investigations, and eruption response.

Significant advancements were made on the Alaska Tephra Database, including on-line query interface design, and the addition of more than 2,000 tephra glass analyses from major tephra-producing eruptions in Alaska. DGGS-AVO staff published whole-rock, major- and trace-element analyses of Jumbo Dome, Interior Alaska. Section staff were coauthors on two outside publications, including a journal article describing water-magma interaction and plume processes during the 2008 Okmok eruption.

Geologic Communications

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 geologic hazards, helping to save lives and reduce damage to property and critical infrastructure. The Geologic Communications Section's staff design, edit, publish, and deliver division-generated geologic information as authoritative, peer-reviewed maps, manuscripts, geospatial datasets, and easy-to-use online applications. Their publication, GIS, and cartographic services enabled geospatial data analysis and map publication for almost 16,000 square miles of new geologic mapping and airborne geophysical data in FY2016.

The Geologic Communications Section helped generate 36 new publications comprising 949 pages of information, 76 map sheets, 15 digital geospatial data packages, three online applications, and eight posters and presentations. The publications contributed 15,927 square miles of new geologic mapping and airborne geophysical data. The DGGS website saw 36.9 million page views, 11,301 downloads of digital geospatial data, and 895,647 downloads of publications in FY2016. The section continued to add a multitude of data to our public online applications, including elevation data from LiDAR (1,360 sq. mi.), IfSAR (23,706 sq. mi.), and Structure from Motion (SfM) elevation data (181 sq. mi.).

The section was awarded $299,994 in funding for a three-year radon and geology project from the EPA Environmental Information Exchange Network as a result of participating in the CDC National Environmental Public Health Tracking 2nd Radon Pilot Project to create a national standard for radon data in preparation for the EPA-funded project. DGGS is proud to be a part of a committee of geologists and GIS professionals from nine states, USGS, and Geological Survey of Canada tasked with developing database standards for geologic-related organizations. A wiki was created at 137.229.113.30:8080/jamwiki to foster communication and track the progress of the project.

DGGS provides website technical services and routine content management support for the Alaska Seismic Hazards Safety Commission (ASHSC) and Association of American State Geologists (AASG) websites. The ASHSC website provides information about the Commission's work to develop seismic risk mitigation recommendations to improve public safety in Alaska. For the AASG site, in addition to fulfilling information requests and completing general maintenance and content management tasks, DGGS is working with the executive committee to implement their long-term document management and information retention plan.

Alaska Geologic Materials Center

A significant amount of effort and capital has been spent over the past 60 years to obtain rock and mineral samples from locations throughout Alaska. Some of these samples are irreplaceable, or would be extremely difficult and expensive to re-acquire. The Alaska Geologic Materials Center (GMC), operated by DGGS, archives geologic samples and provides a wide range of users (industry, government, academia, and public) access 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 1st, 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-around basis. Other significant changes in FY2016 include a bill, Ch27 SLA2016 (SB 170), signed by the Governor in June 2016 that allows DGGS to "charge and collect fees for facilities, equipment, products and services." After incorporating feedback from the general public, fee collection is expected to begin in the latter half of FY2017.

There were 768 visits to the facility in FY2016 (the 10-year average is 450) and the fiscal year saw several major successes for clients of the GMC. Since entering Alaska in 2011, Repsol/Armstrong utilized North Slope drill samples stored at the GMC to support petroleum exploration and the subsequent recent discoveries of multiple reservoirs that might produce 120,000 barrels of oil per day. GMC sand samples collected near the Icy Bay region of Southeast Alaska were used to provide preliminary evidence for tens of billions of dollars of potentially economically recoverable heavy minerals on Alaska Mental Health Trust lands. Over the last 12 months the GMC has received donations of more than 13,000 boxes from BPXA, Calista Corp., Pure Nickel, Millrock, Alaska Energy Authority, On-Line Exploration, Alaska Earth Sciences, Apache Corp., and the Alaska Oil and Gas Conservation Commission.

During FY2016 there was a drastic shift in tracking client access to the GMC inventory. The Geologic Materials Center's spatially-aware, browser-based inventory search tool went online to the public, available at maps.dggs.alaska.gov/gmc, in January 2016. The new SQL database search engine allows users to quickly and easily view real-time details of the more than 580,000 repository items before visiting the facility. The new inventory search interface combines both map-based and Google-like text searches for views of all public inventoried samples. All search results are downloadable to CSV comma delimited files for input into spreadsheets or to PDF text tables. Additionally, all public search results are encoded in a browser URL that can be saved and shared with GMC staff to replicate client search results. This innovative and complex SQL database and online search engine was developed in-house by DGGS staff and continues to serve user needs and receive positive feedback from industry.

CALIFORNIA

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CGS VISION

The California Geological Survey 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 the California Geological Survey 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 California Geological Survey (CGS) is a division within the Department of Conservation, which is under the umbrella of the Natural Resources Agency. The Survey has its headquarters in Sacramento and six field offices throughout the state. The CGS employs 120 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 seven separate programs authorized by five legislative acts.

GEOLOGIC MAPPING

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 National 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.

MINERAL RESOURCES

The oldest of the 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

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 approximately 400 Timber 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 geologists also provide immediate post-fire geological hazard mapping and assessments for the Governor's Office of Emergency Services, California Forest and Fire Protection, following forest fires. This year, CGS field teams completed assessments of the Valley Fire (burned 76,000 acres) and the Butte Fire (burned 71,000 acres).

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 in California) are zoned where they express surface rupture. Construction of structures for human occupancy across faults within these regulatory zones is prohibited. The CGS has zoned more than 5,000 miles of active surface faults in the state, publishing 589 quadrangles displaying those zoned faults. Approximately 2,000 additional miles of known active surface faults remain to be zoned.

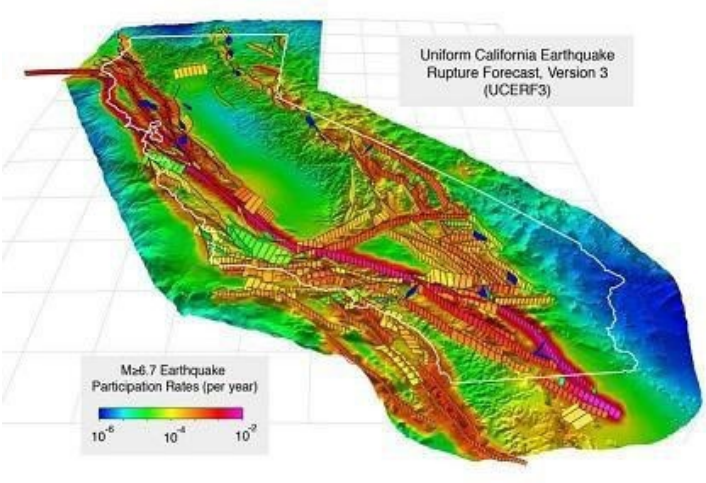
Seismic Hazards Mapping is a major project, authorized by the Seismic Hazards Mapping Act. This project zones the extent and likelihood of secondary hazards after an earthquake, such as ground liquefaction and triggered landslides, in urbanized areas. Under this project, 115 maps have been produced covering more than 7,000 square miles. 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 Hazards 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, the 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 or other geologic hazards will prevent the school from receiving a construction permit. The CGS reviews reports



from approximately 400 school sites each year and makes field checks of sites where fault-trenches are exposed.

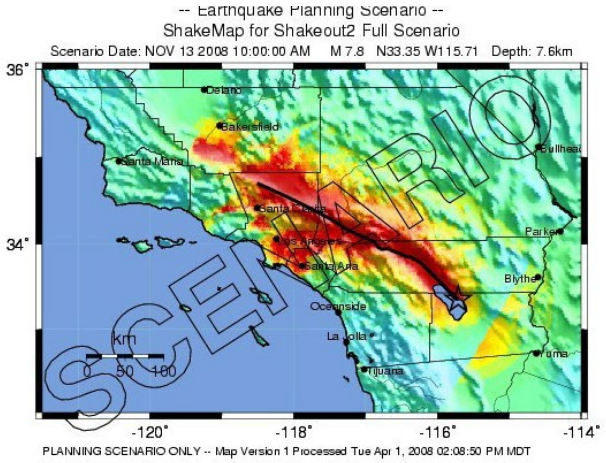
Also under this program, the CGS evaluates the seismic hazards site conditions for hospital construction for the Office of Statewide Health Planning and Development Safety Board (OSHPD). Hospitals must be constructed in strict accordance with OSHPD standards. The CGS reviews consulting reports from approximately 50 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 Instrumentation 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 1,250 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 and others. The CISN is an integral part of the USGS Advanced National Seismic System (ANSS).

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 of an earthquake. Earthquake data from different 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/.

This year, some of the SMIP projects included placing a new type of field instrument along major faults in southern California. These instruments are much more



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

economical than conventional instruments, allowing many to be deployed at close-in distances where there is little recorded data. SMIP also completed installation of instruments on the recently opened East Bay extension of the San Francisco Bay Bridge and in numerous hospitals and other structures. A total of over 200 strong motion sensors were installed on the East Bay extension, from the tip of the piles, beneath the bridge, to the top of the tower, and along the full length of the bridge. The instrumentation was multi-year project, with testing completed in 2016. The motion recorded in future earthquakes will allow design engineers to verify the performance relative to the design. The Bay Bridge is the most extensively instrumented structure in the U.S.

Very detailed seismic data continue to be recovered from instruments recently installed in the One Rincon Hill Building at the end of the Bay Bridge in San Francisco and the Bay Area Rapid Transit (BART) system that lies on the bottom of the San Francisco Bay. The 64-story Rincon building is the most densely instrumented residential high rise building in the U.S. Live monitoring of the building is being conducted by the USGS.

The SMIP is contributing to the development of the California Earthquake Early Warning System (CEEWS), which is the nation's first government sponsored early warning system. Legislation passed by the California Legislature authorized the development and implementation of the CEEWS. Partners include the Governor's Office of Emergency Services (CalOES), the U. S. G. S., Caltech Seismology Lab, and U. C. Berkeley Seismology Lab, and others.

Library/Publications and Outreach

By statute, since 1880 the CGS maintains a geological research library for its staff and conducts public out-reach 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.

COLORADO

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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.

Vision of CERSE

A world where earth, energy and the environment are wisely managed.

Organization of the Survey

The Colorado Geological Survey 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.

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 2015-16, CGS reviewed development proposals on 2700 acres with 2800 proposed building sites.

STATEMAP Program

The CGS STATEMAP program received $164,972 for FY 2015-2016 from the US Geological Survey as part of the National Cooperative Geologic Mapping Program (NCGMP). This is the 18th year that CGS has participated in the NCGMP. The program supports mapping of geologic hazards, and water, mineral and energy resources in critical areas.

With the current grant, CGS mapped four quadrangles, which includes areas with outcrops of coal-bearing strata and deposits of construction materials along major transportation corridors. CGS mapping also included areas of projected high population growth and numerous geologic hazards were identified.

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. Colorado's July 2015 population was estimated at 5,456,584, an increase of almost 100,000 from the previous year. The increase of 1.9% ranked second in the nation, behind North Dakota, and seventh in total change.

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 and where comprehensive county-wide assessments have not been done.

CGS completed a comprehensive assessment all aquifer types within two counties; including near-surface unconsolidated aquifers and bedrock aquifers as well as igneous rocks in rugged mountainous areas. Data will be made available to the public in a web-based viewable format.

Geothermal Program

Colorado has numerous direct-use geothermal applications that range from an alligator farm, mountain resorts with hot springs, a town's heating system, 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.

The Colorado Geological Survey has identified promising deep drilling targets east-southeast of Mount Princeton and north of Poncha Hot Springs in Chaffee County. A widespread, but deeper (~8,000 feet) 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 new, large, hot springs spa has recently opened in Glenwood Springs, Garfield County: Iron Mountain Hot Springs, catering primarily to family recreation. Planning and construction continue for new community and commercial geothermal greenhouses in and around Pagosa Springs, Archuleta County. CGS assisted in an economic study of using direct heat for a variety of potential commercial and industrial businesses in a small rural community in southwest Colorado.

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 destroyed nearly 1,250 homes. There is a growing consciousness that Colorado must systematically adapt to and prepare for natural hazards. 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.

CGS also participated in the creation of hazards planning guide for local communities. This guide provides detailed, Colorado-specific information about how to assess a community's risk of hazards and how to implement several land use planning tools and strategies for reducing a community's risk. The guide can be downloaded at planningforhazards.com.

Minerl and Mineral Fuels Program

CGS published an annual mineral and energy industry report in 2015. Metals mined in Colorado include molybdenum, gold, and silver. The Colorado Geological Survey estimates that the 2015 production value of these metals was about $552 million. This is approximately a 34% decrease compared to the 2014 production value of $893 million. The decrease in value was due to the decrease in molybdenum, gold, and silver prices as well as decreases in molybdenum and gold production.

In 2015, Colorado was the 10th-most productive coal mining state, producing 18.7 million tons of coal. The state's total coal production by year-end 2016 is expected to fall to 12 million tons.

CGS recently compiled isopach (thickness) maps for coal-bearing and shale formations in selected basins in Colorado and is conducting a statewide assessment of potential sand resources suitable for use in hydraulic fracturing and other industrial uses.

List of New Publications Released in 2015-2016

White, J.L., Morgan, M.L., and Berry, K.A., 2015, The West Salt Creek Landslide: A Catastrophic Rockslide and Rock/Debris Avalanche in Mesa County, Colorado: Colorado Geological Survey Bulletin 55, 45 p., 2 plates.

Barkmann, P.E., Sebol, L.A., Fitzgerald F.S., Curtiss, W., 2015, Geology and Groundwater Resources of Park County, Colorado Geological Survey, Open File Report 15-11.

Barkmann, P.E., Fitzgerald F.S., Sebol, L.A., Curtiss, W. Pike, J. Moore, A., and Taylor, B., 2015, Geology and Groundwater Resources of Douglas County, Colorado Geological Survey, Open File Report 15-10.

Noe, D., Barkmann, P.E., McCall, K.J., Zawaski, M.J., Logan, Z.D., and Hosler, D. R., 2015, Geologic Map of the Hayden Quadrangle, Routt County, Colorado, Open File Report 15-05.

Wait, T.C., Morgan, M.L., Fitzgerald, F.S., Morgan, K.S., Berry, K.A., and White, J.L., 2015, Debris flow Susceptibility Map of Larimer County, Colorado: Colorado Geological Survey Open-file Report 15-13.

Morgan, M.L., 2015, Geologic map of the Piney Creek quadrangle, Arapahoe, Douglas, and Elbert Counties, Colorado: Colorado Geological Survey Open-file Report 15-12.

Delta County, Colorado: Colorado Geological Survey Open-file Report 15-08, 1:24,000 scale.

Morgan, M.L., 2015, Geologic Map of the Piney Creek Quadrangle, Arapahoe, Douglas, and Elbert Counties Colorado: Colorado Geological Survey Open-file Report 15-12, 1:24,000 scale.

CONNECTICUT

State Geological and Natural History Survey of Connecticut
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Introduction

The Connecticut 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 data base management systems. The mission of the Connecticut Geological and Natural History Survey is defined in the Connecticut State Statutes (Ch 462, Sec 24-1 to 24-4). In the Department of Energy and Environmental Protection, the Geological Survey is within the Commissioner's Office, 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 Data Base that 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 data sets 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 web site 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 Univ. 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 formatted maps of environmental themes by Town, 7.5 minute Quadrangle, or Statewide. A variety of orthophotography (1990-2010) is also available. CTECO also provides direct connection to desktop GIS or CAD software to 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 4 band color, infrared. Detailed oblique photography is also available for agency use. Statewide LiDAR and the 2014 NAIP imagery are available online through the DEEP/UConn CTECO cooperative http://www.cteco.uconn.edu/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

The Connecticut 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.

Bedrock Mapping

The Connecticut Survey, in conjunction with the State Geologic Mapping Advisory Committee, adopted a long-range Bedrock Mapping Plan in 2015, with the goal of a producing 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 southern portion of the Wallingford 7.5 minute quadrangle bedrock map is in progress. This quadrangle is within the southern Mesozoic Hartford Basin. The mapping includes traditional fieldwork, petrography, and geochemical analyses to support geologic correlations and tectonic interpretations. The completed map product and geologic report will be available online through the Connecticut Geological Survey area of the DEEP website in spring 2017.

Soils

Geochemical Survey of Connecticut Soils and Water Quality Investigations were conducted through a Joint Funding Agreement between the CT Survey/DEEP and the USGS, Connecticut Water Science Center. Soil chemistry from 100 sites in Connecticut collected by CT Survey staff and analyzed through the USGS Geochemical Landscapes Project was compared with the USGS Lithochemical Map, and NRCS soil mapping. The investigation contributed to the understanding of natural background levels for 42 analytical constituents, many of which are environmentally important trace elements, including Iron, Arsenic, Cadmium, Cobalt, Chromium, Copper, Lithium, Manganese, Nickel, Lead, Tin, Uranium, Vanadium, and Zinc. Other elements of note include Silver, Sulfur, and Tungsten. The research summary is available through the online journal Northeastern Geoscience. Further studies documenting soil geochemistry of Connecticut landscapes are planned.

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 share ideas, as well as devise collaborative research and funding strategies.

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 8th – February 24th. 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 1.6km, 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 dip. 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 effecting hundreds or thousands of homeowners. The State Geologist briefed Lt. Gov. Nancy Wyman, providing geologic expertise on weathering of Iron sulfide (especially pyrrhotite) minerals in concrete. Presented mapping on the distribution of active mines and geologic resources containing iron sulfides and pyrrhotite. Responded to media and inquiries from elected officials.

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

An ongoing program of documenting institutional knowledge. Database verification and enhancements are the focus of ongoing Geological Survey field work. Recent components relative 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/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 web site 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, CT DEEP's Teach Out, Earth Day, 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 school, museum, 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

The State Geological Survey opened a new office at the University of Connecticut, in Storrs. The goal of the new 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, ground water, 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 in 2015 included: geophysical data processing to identify microseismic events; well logging to investigate the geologic terrane boundary underlying Hammonassett State Park; assessing coastal erosion hazard vulnerabilities along Long Island Sound.

Connecticut Interstate Fire Crew

The Connecticut Survey's GIS specialist is a 25 year veteran and active member of the CT Interstate Fire Crew coordinated by DEEP's Forestry Division. This crew provides all incident response, as part of a multi-jurisdictional incident management team including professionals from the NFS, BIA, BLM, FWS, State Governments and others. Recent wildfire suppression mobilization for the Carrot Fire & Black Fire in the Jedediah Smith Wilderness Area of the Targhee National Forest, ID. www.NIFC.gov

Biology

In addition to conducting basic inventories of the state's biota, the Natural History Survey maintains the Natural Diversity Data Base (NDDB), 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 list. Biologists provide technical assistance through the environmental review process, and are involved in identifying and protecting significant ecological areas.

Publications

www.ct.gov/deep/geology

Publications List: www.ct.gov/dep/lib/dep/geology/ct_survey_publications_list.pdf

On-line publication sales

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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 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 an office 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.

The FGS is strategically positioned within the Regulatory Programs branch of DEP. Here it can provide the objective geologic research and support required to help address many of the state's geoscience-rooted environmental issues. The geologic structure of Florida forms the "bucket" that holds our freshwater aquifer systems and comprises the foundation of our diverse ecosystems. In 2015-16, 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 a continually-growing state such as Florida. These include continued development of statewide potentiometric surface mapping, detailed geologic and geomorphologic mapping, springshed delineation studies, hydrogeological modeling assistance, and assessing sinkhole vulnerabilty throughout Florida. Many projects are grant funded, employing part-time workers and engaging the skills of interns, efficiently leveraging the best science for the least state dollars.

Organization

The 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, and Special Projects. This section is responsible for administration (budget, department and interagency liaison, etc.), contract and grant tracking, personnel management (travel, leave, benefits, etc.), IT administration and infrastructure support, and building maintenance and repair.

The Geological Investigations Section collects and interprets statewide surface and subsurface geophysical and geological data. It conducts geologic, geomorphic, and mineral resources 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 aquifer vulnerability, aquifer storage and recovery, and arsenic/trace metal assessments. It delineates springshed boundaries and assesses related water quality issues as well as sinkhole vulnerability. The section is also responsible for conducting surface and groundwater interaction studies, and creating potentiometric surface maps. 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 Applied Geoscience Services Section also maintains the subsidence incident

reports database and responds to requests for sinkhole and other geologic hazard assessments.

The Geoscience Information and Data Management Section facilitates access to, organizes, and determines accuracy of FGS geologic information. The section organizes Geographic Information Systems (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 (e.g., geophysical and lithologic logs). The Section maintains and facilitates 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 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 monitoring 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 to acquire geological samples and geophysical log data. It also maintains the R/V GeoQuest, 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, 19 research assistants, and seven interns. Geoscience staff have the support of numerous assets including laboratories for micropaleontology, sedimentology, hydrogeochemistry and scanning electron microscopy; a geologic research library; a sample repository with over 19,400 sets of well cuttings, cores, and outcrop samples; ground-penetrating radar; a Mobile Drill B-31 core and auger rig, a Schramm T450MIIA is capable of a total coring depth of 3,000 feet, a CME 75 drilling rig with associated support vehicles, seven four-wheel drive field vehicles and four research vessels (boats) with data-acquisition equipment (e.g., side-scan SONAR).

Geological Investigations

Section staff continued fieldwork on a new geomorphic map of Florida in 2015-16. The new map builds on much earlier map data and incorporates extensive field investigation with newly acquired LiDAR imagery and the utilization of GIS software. Anticipated publication is during the 2017 calendar year.

As part of a statewide sinkhole vulnerability study, FGS staff continued field verification of topographic depressions (potential sinkholes) within the state during 2015-16. This is part of a three-year project to create a statewide sinkhole vulnerability map that began in 2014. To date, more than 700 sites have been visited, covering much of the state, to verify and document true sinkhole features. This project is a collaboration between DEP/FGS and the Florida Division of Emergency Management, with more than 75 percent of the funding from the Federal Emergency Management Agency (FEMA).

The Geological Investigations Section and other FGS staff continued to collaborate with the Florida Wildlife Conservation Commission (FWCC) in investigating the shallow sea floor off the shores of west and northwest Florida. The FWCC utilized the FGS' 50-foot 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 sea floor also illuminates the geology. The side-scan data is processed into mosaic images. Coupled with video, photographs and sea floor samples, these data will foster production of offshore geologic maps - an understudied part of the state.

The Geological Investigations Section completed and submitted deliverables for a Bureau of Ocean Energy Management (BOEM) grant that was jointly managed by FGS and the DEP Division of Water Resource Management. The grant funding was part of the Hurricane Sandy coastal recovery and resiliency effort where Atlantic coastal states received funding to bolster the coastal zone's ability to withstand future storm events. The Florida Cooperative Agreement provided $199,970 to produce a number of deliverables including updating Florida's Regional Offshore Sand Source Inventory database (ROSSI) http://rossi.urs-tally.com/ and to provide maps showing areas along Florida's east coast and offshore where sand sources for future beach nourishment might be located.

STATEMAP

The Geological Investigations Section's STATEMAP team completed and submitted the 2015-16 grant deliverable which includes a surficial geologic map, cross sections, geomorphology and written report for the Jacksonville 30 x 60 minute quadrangle. The amount

awarded for this mapping was $174,005, which was the second largest funded grant in the nation under the STATEMAP program for 2015-16. The mapping effort is the culmination of a year-long effort which includes field work, data compilation, data analysis and generation of map products and written report. The maps and report will be finalized and available to the public for digital download by December of 2016. 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 45 percent of the state, collected over 1,300 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 24,000 square miles of Florida at an average cost of $205 per square mile, making it one of the most cost-effective programs in the agency. It has also produced 31 new publications in the form of Open File Map Series and Open-File Reports. Each of these publications are available online.

In 2016, 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 the newly dedicated staff will work independently but with the common goal of revising and publishing a revised state-wide surficial geologic map. The newly dedicated staff 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.

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 FY2015-16 STATEMAP Jacksonville mapping project. Data from these wells were utilized in cross sections through low-density data regions of the field area. The Section also continued its support of the Northwest Florida Water Management District, drilling core and installing monitor wells to aid in the establishment of Minimum Flows and Levels in the central portion of the District. The wells were cored, geophysical logs collected, and the samples were added to the FGS research collection. Finally, and just in time, the FGS core repository received nearly 8,000 square feet of much needed expansion space for core and cuttings storage. The existing shelving was nearly full and this new expansion provides for the next 15-20 years of new sample acquisition.

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 2015-16, the section secured a National Geological and Geophysical Data Preservation Program (NGGDPP) grant of $43,000. The FGS used the funds to convert an existing 1,500 hand-written lithologic descriptions to an established Microsoft Access database to preserve and prevent loss of irreplaceable information and provide more efficient, cost effective access by making this data more discoverable to professional and public entities. Staff also worked closely with other ongoing projects at the FGS to ensure the proper long-term management of data. This included work for Florida's five water management districts.

Through the FGS internship program, student volunteers from Florida State University and Tallahassee Community College contributed over 800 hours towards the Survey's efforts to preserve and rescue at risk data during 2015-16. 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 improve distribution of FGS Subsidence Incident Report data and provide more effective responses to information requests. The FGS maintains a statewide database on subsidence incidents which is available to the public and other users through the DEP Map Direct web page. The FGS also improved access to its statewide geology maps and digital data.

Applied Geoscience Services

In collaboration with Florida's Suwannee River Water Management District, Applied Geoscience Services

Section staff successfully executed important hydrogeology projects. FGS and contracted cave divers successfully installed a flow meter at privately-owned Hornsby Spring, in Alachua County. Information from the meter will aid our understanding of local spring flow conditions and will document seasonal spring flow variations or reversals as a function of precipitation and other events. In addition, a fluorescein dye was released into the Dead River Swallet in 2016 to determine if the Alapaha River's water entering the Floridan aquifer system via the Dead River Swallet re-emerges at the Alapaha Rise and/or Holton Creek Rise, both of which flow a short distance into the Suwannee River. The dye was detected and the Suwannee River Water Management District will use the information gained to more effectively manage the minimum flows and levels of the Suwannee River to help maintain water quality.

The FGS released its new Report of Investigations Number 112 entitled "A review of selected Florida aquifer storage and recovery (ASR) sites and their geochemical characteristics." The report summarizes a multi-year study of ASR in Florida and highlights some of the possible challenges and issues in using ASR to address water supply issues. The report is a culmination of research and cooperation among FGS and the DEP Underground Injection Control program, along with the individual site utilities and their consultants.

The Section was also actively engaged in the production of statewide potentiometric surface maps of the upper Floridan aquifer system. The mapping is being conducted in cooperation with the state's five water management districts. The districts provide water-level measurements obtained from 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 both 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.

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

FGS geologists are often consulted as state, if not national 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.

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 (e.g., drought conditions, pumping) and other factors are 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)

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Introduction

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

1. (A) The U.S. DOE Energy Frontier Research Center's Center for Geologic Storage of CO_2 is improving fundamental understanding of critical questions regarding geologic storage of CO_2 and other fluids. The effort includes evaluating mechanisms of injection-induced microseismicity, measuring/predicting mechanical properties of rocks, and then modeling energy transmission through geologic formations.

2. (B) The geologic processes that formed a 6-mile very straight feature along the Wabash River in southeastern Illinois were assessed. Tectonics was ruled as a factor, and the origin was determined to be from bursts of glacial meltwater and sediment through the valley that was constrained by bedrock exposures along the valley edges that locally channelized erosion into the long and straight scarp.

3. (C) A low-cost and simple two-step sorbent activation process (SAP) to reduce air toxic emissions from coal-fired power plants was developed. This resulted in at least a 50% reduction of sorbent costs, and consequently the ISGS and the Electric Power Research Institute jointly have applied for and have been issued six U.S. patents on the technology.

4. (D) Mapping of karst areas in Illinois' sinkhole plain was enhanced considerably by recently acquired LiDAR elevation data that made it possible to conduct a first-time detailed inventory of sinkholes. This led to a better understanding of their morphology and evolution, and improved interpretations of karst geology and hydrogeology.

5. (E) A new initiative has begun with the Illinois Department of Natural Resource's Coastal Management Program to refine sediment management strategies along Illinois' Lake Michigan coastline. This effort includes a regional coalition of communities and non-governmental agencies coordinating sand management efforts and providing a foundation for building regional resilience to sand management and other coastal hazard issues.

The 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.

Program Highlights

Center for Geologic Storage of CO_2: Investigating the Causes of Microseismicity Induced by Geologic Carbon Storage

The Energy Frontier Research Center (EFRC) program sponsors 36 multi-institute, multidisciplinary centers to conduct basic research that addresses scientific energy challenges. Since 2014, the Center for Geologic Storage of CO_2 (GSCO2) at the Illinois State Geological Survey has aimed to improve fundamental understanding of one of the most important questions regarding the geologic storage of carbon dioxide (CO_2) and other fluids. The Center's current research question is "What are the mechanisms of injection-induced microseismicity, and can we control and predict its occurrence?" To address this question, five research themes focus on measuring and predicting the mechanical properties of rocks, and then modeling (computationally and in the laboratory) the transmission of energy through geologic formations from the nano scale to the field scale.

The *Microseismicity Theme* investigates links between induced microseismicity and the stress field by comparing field-scale observations of induced seismicity with acoustic emission data from laboratory experiments. In-situ rock conditions (e.g., the stress field and pore pressure changes) are varied in real and simulated geologic settings to derive relations for stress- and pressure-induced triggering of field-scale microseismicity (Figure 1). Computational experiments are conducted to understand the effect of pressure propagation at the continuum scale, which may cause microseismicity in small clusters as a consequence of very low pore pressure increases.

The *Reservoir-scale Geology Theme* develops new approaches to the geologic aspects of simulating reservoir architecture to address problems presented by geologic heterogeneity. Research on (1) geologic architecture, (2) approaches relating geomechanical properties and seismic velocities to geologic facies, and (3) depositional-based approaches to simulating geologic facies, all provides significant advances in modeling three-dimen-

Figure 1. Reconstruction from micro-CT scans of a Castlegate outcrop plug (left) and a Mt. Simon Sandstone core plug (right), after testing in a triaxial load frame. During testing, a weak fracture plane was created by increasing differential applied stress past the shear strength of a plug, and then the axial stress was reduced and pore fluid pressure was increased. Though the pressure increment in the last step was much reduced compared to the initial stress increase, it still caused large shear deformation accompanied by intense acoustic emission events. The red dots highlight the obtained shear failure plane. The green zone within the Mt. Simon plug indicates a second fracture plane at a different angle.

sional (3D) spatial variation of geomechanical properties and seismic velocities. The 3D models for geomechanical properties and seismic velocities are incorporated into plausible geologic models and used for interpretive forward modeling of seismic velocities.

The *Geomechanical Measurements Theme* uses cutting-edge technology to improve the capability of laboratory-scale studies to represent and understand subsurface properties related to the effects of CO_2 injection on the mechanical properties and dynamic response of the host rock. This theme links a disparate set of existing and novel material measurements in a meaningful way to thermo-hydro-mechanical properties of geologic materials. New (e.g., X-ray computed tomography [CT] scanning, advanced ultrasonics, and magnetometry) and conventional (e.g., acoustic emission and electrical resistivity) experimental measurement methods are included in this theme.

The *Pore-scale Pressure Transmission Theme* aims to understand small-scale processes at the pore and core scale, focusing on how pore-scale heterogeneities in rocks and flow geometry can trigger microseismic events in the presence of brine displaced by CO_2 and two-phase flow of CO_2 and brine. Models of pore-scale heterogeneity are developed based on high-resolution CT scans of rock samples. Pore-scale numerical models that couple multiphase flow and geomechanical responses are used to investigate key mechanisms triggering microseismic events in various stochastic realizations of rock samples. The models are validated by comparing them with experiments conducted at the pore and core scale.

The *Geochemical Reactions Theme* investigates how CO_2-saturated brine affects the geomechanical and fracturing properties of rock by evaluating rock samples for changes in mineralogy, rock mechanical properties, and fracturing after exposure to brine. This theme quantifies mineralogical effects on geomechanical and fracturing properties before and after exposing rock samples to brine saturated with CO_2. High-resolution pore-scale imaging, strain gauge measurements, and nano-to-micro-scale mineralogical analyses are part of the evaluation of the effect of pressure cycling on mineralogical alteration, as well as the effect of mineralogical alteration on stress-strain during pressure cycling.

The GSCO2 is an Energy Frontier Research Center sponsored by the Office of Basic Energy Sciences, which is a division of the Office Science within the US Department of Energy. The Center consists of ten institutions: the Illinois State Geological Survey, University of Illinois at Urbana-Champaign, Wright State University, University of Notre Dame, University of Texas at Austin, University of Southern California, NORSAR, SINTEF, National Energy Technology Laboratory, and Schlumberger.

The Meadow Bank: A Non-tectonic Linear Feature in the Wabash Valley Seismic Zone

The Meadow Bank (MB) is a 6-mile long, 20-foot high, very straight scarp along the west edge of the Wabash River Valley in southeastern Illinois (Figure 2). The length of this straight feature is highly unusual in an active fluvial setting such as the Wabash River valley. Because the MB is within the Wabash Valley Seismic Zone, and parallel to the trend of known faults, we investigated the possibility that it was caused by reactivation of a major, nearby fault. The area east of the MB is known to have been affected by past earthquake activity. Liquefaction was reported in the area from shaking due to the 1811-1812 New Madrid earthquakes, and there is evidence of prehistoric liquefaction as well. However, earthquake-induced landslides are not known to have occurred so far of a distance from New Madrid.

By good fortune, we were able to review mine workings maps from an underground coal mine that extracted coal from directly below and adjacent to the MB, thereby allowing potential direct observation and measurement of subsurface displacements. This is particularly relevant, as fault displacements of as little as 5 to 10 feet can significantly, and obviously, alter mine layouts. However, there was no indication of offsets or mine passageway disruptions as evidenced in mine maps. Therefore, there must be another cause besides earthquakes for the straight MB scarp.

The distinctive linearity of the MB is not expected from normal fluvial erosion, which produces more arcuate patterns. We believe that the MB is a relic of an unusual episode in the history of the Wabash River. During at least the last two Pleistocene glaciations, the Wabash River was a major conduit for meltwater and sediment

from the Lake Michigan, Huron-Erie, and Saginaw lobes

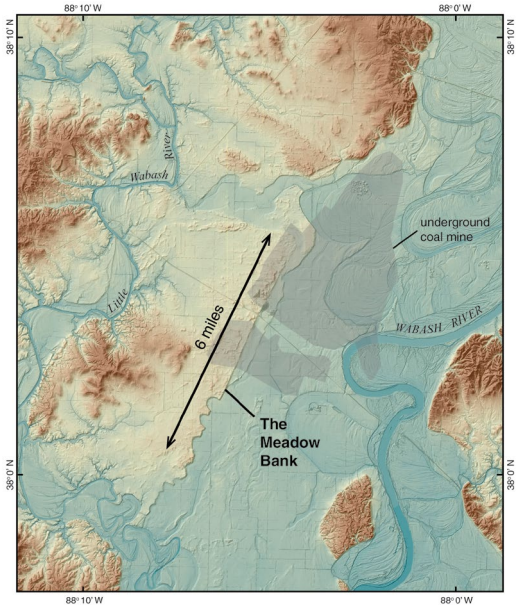

Figure 2. Hill-shaded LiDAR image of southeastern White County, Illinois. Arrow indicates the extent of the Meadow Bank, which is remarkably straight for 6 miles and forms a 20-foot high scarp between glacial slackwater deposits on the west and outwash on the east. The southern end of the scarp was eroded by a meandering creek. The area of an underground coal mine is shown in gray.

of the Laurentide ice sheet (Figure 3). Large volumes of mostly sand-sized sediment filled the main valley of the lower Wabash River. The rapidly aggrading river blocked the flow of tributary streams, including the Little Wabash River, to form slackwater lakes. Deltas building from the main Wabash River distributed sand back into the slackwater lakes. Peak aggradation occurred by 22 ka. Meanwhile, far upsteam, glacial moraines dammed the headwaters of the ancient Wabash River system forming large pro-glacial lakes. Eventually the meltwater overtopped these dams sending enormous bursts of glacial meltwater and sediment coursing through the Wabash valley. The high flows downcut the valley fill and eroded the tributary mouth deltas, ultimately draining the slackwater lakes. Bedrock exposures along the edges of the valley constrained the extent of the erosion, locally channeling the erosion into the long, straight scarp visible today. Soon after these outbursts, the major glacial drainage was diverted eastward through the St. Lawrence River, drastically reducing the volume of water in the Wabash River system. As a result, the MB and similar scarps along other tributary valleys have been left as relics of these great floods.

Development of a Low-Cost Sorbent Process to Reduce Air Toxic Emissions from Coal-Fired Power Plants

Coal-fired power plants are facing stringent regulations intended to reduce the emissions of mercury, acid gases (such as hydrogen chloride and sulfur oxides), and other

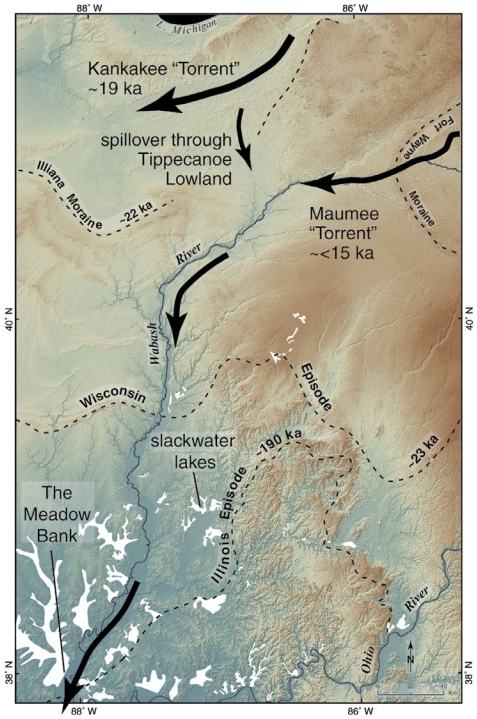

Figure 3. Shaded relief map of parts of eastern Illinois, western Indiana, and northwestern Kentucky showing the paths and timing of late Wisconsin Episode glacial lake outburst floods into the Wabash River basin. Each "torrent" may have been comprised of several events. Dashed lines mark the farthest extent of Illinois and Wisconsin Episode glaciations as well as stillstands that built the Illiana and Fort Wayne Moraines. Largely Wisconsin-age slackwater lakes that filled tributary valleys dammed by outwash are shown in white.

major air toxics from chimney stacks, in compliance with two recent U.S. Environmental Protection Agency regulations: the Mercury and Air Toxics Standards and the Clean Power Plan. The Illinois State Geological Survey (ISGS), in collaboration with the Electric Power Research Institute (EPRI), has taken up this challenge by developing, over the past decade, a unique sorbent activation process (SAP) to control air toxic emissions.

The SAP technology was developed to simplify complex manufacturing of activated carbon, a commonly used sorbent for vapor-phase mercury removal (Figure 4). The conventional process involves multiple steps, including grinding and classifying raw coal, oxidation and pyrolysis of coal, activation of char with steam, and final carbon cooling and pulverization stages. These take over several hours of total production time, in addition to the needs for transportation to and storage at a power plant. By contrast, the SAP technology involves only two steps, completed in either several minutes or several seconds: grinding and classifying fine coal at a power plant, and burning auxiliary gas or coal as a heat source or utilizing power plant heat to activate the carbon before injecting the produced carbon directly into the power plant flue gas.

The SAP technology was further developed to

incorporate removal of vapor-phase mercury and control of other pollutants from coal combustion flue gas by the on-site production of chemically modified activated

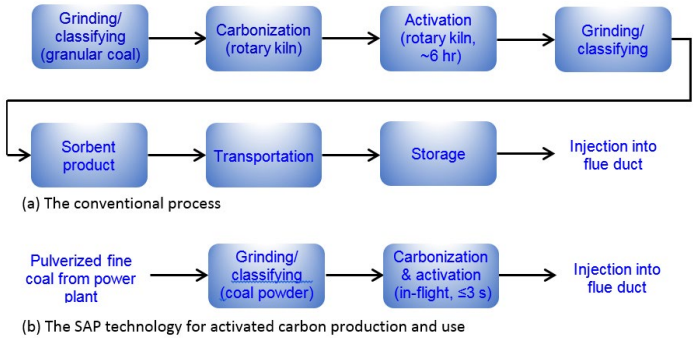

Figure 4. Comparison of the conventional process and the sorbent activation process (SAP) technology for activated carbon production and utilization.

Figure 5. Full-scale demonstration testing of the SAP technology for flue gas mercury removal at a 650-MWe power plant.

carbon- and calcium-based sorbents in the single activation reactor. Calcium-based sorbents such as lime and hydrated lime, are used in the removal of acid gases as well as vaporous air toxic species, including trace metal compounds such as selenium, arsenic, and others found in trace amounts in coal-fired power plant flue gases. Coproduction of activated carbon- and calcium-based sorbents can take full advantage of the SAP technology.

Use of the SAP technology can greatly simplify, and reduce the cost of, sorbent production at utility sites. The SAP technology has been developed in the laboratory and demonstrated at pilot and full scale at several sites over the past 10 years. A laboratory SAP facility was built to produce 1 lb/hr of activated carbon in 2007. A prototype SAP reactor was fabricated and tested at both a 25-MWe and a 75-MWe power plant unit in 2010. A full-scale SAP system was installed and tested at a 220-MWe power plant in 2012. A full-scale demonstration campaign was then commissioned at a 650-MWe scale from 2012 through 2014 (Figure 5). In these tests, bituminous, sub-bituminous, or lignite coals have been used as the feedstock for SAP sorbent production. Overall, the mercury removal performance of SAP-produced sorbents has been comparable to commercially activated carbons, and the costs of SAP sorbents could be reduced by 50% or more. The ISGS and EPRI have jointly applied for and been issued six U.S. patents on the SAP technology, and EPRI is presently pursuing commercial development and licensing agreements with industries.

Insights into the Evolution of Sinkhole Morphology and Groundwater Basin Development in the Sinkhole Plain of Southwestern Illinois using LiDAR Enhanced Elevation Data

Mapping of karst areas in Illinois was initiated in the mid-1990s by the Illinois State Geological Survey. Characterization of features that typify karst terrain is important because of the susceptibility of karst aquifers to groundwater contamination and problems with construction in karst-prone areas. Located on the western edge of the Illinois Basin, the sinkhole plain of Illinois is situated within St. Clair, Monroe, and Randolph Counties and contains an estimated 15,000 cover-collapse sinkholes. Within this area, Mississippian-age carbonate bedrock is exposed at and near the surface and gently dips to the east-southeast. The sinkhole plain is an area of intensive karst terrain, containing a maximum density of 90 cover-collapse sinkholes per km^2, numerous large springs, and long caves. Because a majority of the sinkhole features are situated beneath densely wooded vegetation and obscured on aerial photography, airborne LiDAR elevation data collected in 2012, made it possible to conduct a first-time detailed inventory and analysis of sinkholes within the area. This is leading to a better understanding of sinkhole morphology and evolution, as well as a better interpretation of the karst geology and hydrogeology of the sinkhole plain (Figure 6).

Cover-collapse sinkholes in the sinkhole plain are of several geomorphic varieties. Within groundwater basins, sinkholes are so densely packed that there is no land surface unaffected by sinkholes – there are only sinkhole features and drainage divides. This is particularly true in densely wooded areas where bedrock and drains are exposed at the lowest part of the sinkholes. In upland areas, sinkholes are subtle in appearance and have no obvious drains, possibly due to a combination of selection of areas containing shallow sinkholes optimal for intensive agricultural land use, over decades which has resulted in smoothing of drainage divides and infilling of sinkholes.

Cover-collapse sinkholes are expanding along the

margins of groundwater basins. They appear to be disappearing dendritic streams along groundwater

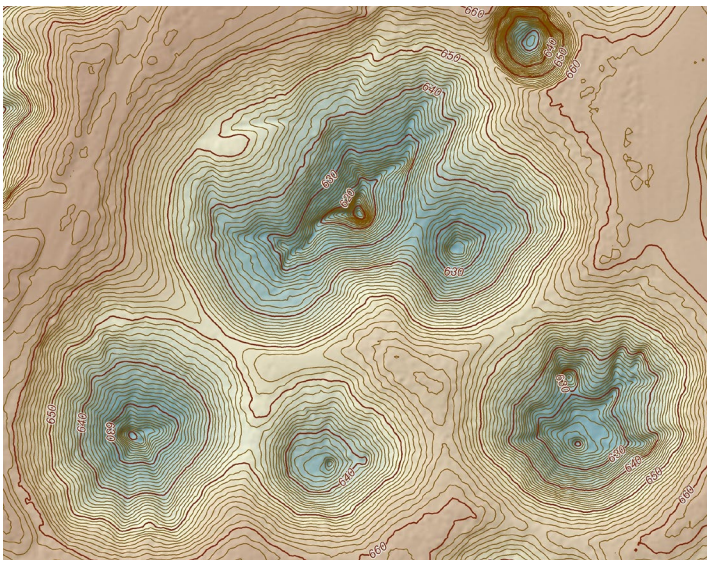

Figure 6. Example of a bare earth LiDAR digital elevation model for a grouping of densely wooded sinkholes in the Illinois sinkhole plain. The large sinkhole feature at the top center of the image measures approximately 550 feet in the long axis and is more than 50 feet deep. The LiDAR nominal pulse density (PD) is 4 points/sq. meter and nominal pulse spacing (NPS) is 0.5 meters, which results in a vertical accuracy sufficient to support a contour interval of one foot. Image scale is 1 in = 100 ft.

divides where the water table transitions from above to below the soil-bedrock interface. With increased drainage, there is lowering of the water table and enlargement of the dendritic stream-shaped sinkholes and unidirectional growth. With time, and isolation from the migrating erosional margin of the groundwater basin, the dendritic-shaped sinkholes become more amoeboid in shape, and due to multidirectional growth, become compound sinkholes with multiple drains (Figure 7).

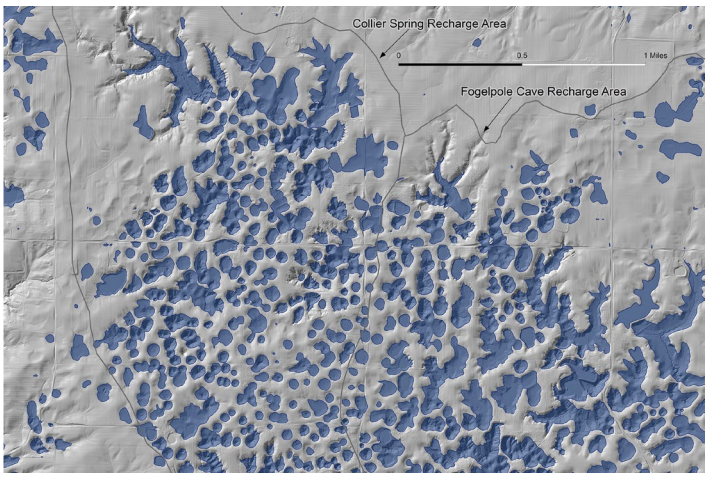

Figure 7. LiDAR-derived shaded relief image of two groundwater basins in the sinkhole plain. Sinkhole areas are shown in blue to enhance their shapes. The largest and more recent sinkholes are forming in dendritic valleys at the basin margins. These will subsequently evolve into the amoeboid-shaped, compound sinkholes within the basin. At latter stages of sinkhole evolution, simple and nearly circular sinkholes remain in the interior of the basin.

Continuing erosion of the overlying loess and glacial diamicton eventually reduces the compound sinkhole to a tight cluster of individual sinkholes, each with its own drain. This is an evolutionary direction that is opposite of what previously has been concluded.

With the availability of LiDAR enhanced elevation data, we are collecting a set of geomorphic variables for each of the sinkhole features, including calculation of the total volume of soil within a single groundwater basin lost to the karst aquifer that ultimately discharged to the Mississippi River. Preliminary estimates based on the void space within each sinkhole suggest that more than 300,000 m^3 of soil per km^2 has been lost within each of the groundwater basins due to karstification.

Development of a Sustainable Sediment Management Program along the Illinois Lake Michigan Coast Based on High-resolution Geomorphic and Geophysical Mapping, Regional Sediment Transport Studies, and Predictive Models

The Illinois Lake Michigan coast has a rich history of geologic studies extending back to the mid-20th century. The Illinois State Geological Survey's (ISGS) involvement in coastal projects over the last several decades has included numerous bottom mapping efforts, lake bottom sampling, beach and bluff shoreline monitoring, and reconstructions of past lake-level fluctuations. While these projects contributed greatly to our understanding of coastal processes, sediment management policies along the coast generally remained unchanged. The newly formed partnership between the Prairie Research Institute (which includes the ISGS and other State Scientific Surveys) and the Illinois Department of Natural Resources Coastal Management Program is aimed at refining sediment management strategies through solution-driven research. Establishing geologic research and data collection priorities based on management needs creates a feedback loop that ensures research results will be used to guide management actions.

Along the Illinois coastline, there is significant variability in rates of erosion and accretion. Some locations are experiencing dramatic erosion and loss of critical habitat and infrastructure (Figure 8). Other coastal reaches are characterized by shoaling and excessive sand accretion. Three primary data and knowledge gaps have been identified by coastal managers that must be addressed to sustainably manage sand resources:

1. The thickness and distribution of nearshore sediments has not been evaluated for over two decades and have never been comprehensively mapped along the entire coast. These data are requisite for locating nearshore

sand deposits and assessing rates of nearshore change. With funding from a National Oceanic and Atmospheric Administration Project of Special Merit the nearshore sand deposits will be mapped in 2017 for the entire coast using helicopter-based electromagnetic surveys.

2. The second gap lies in our understanding of the physical processes that drive coastal change. Long-term beach and nearshore monitoring programs have never existed in Illinois, thus deciphering rates and magnitudes of coastal change has been limited to short-term studies and analysis of historical aerial photographs. Additionally, there is a paucity of wave, current, and water-level observations across the region that can be used to better understand the forces shaping the coast. This year, the ISGS developed a long-term beach topographic monitoring program and is exploring the use of Unmanned Aerial Vehicles for rapid monitoring after storm events. A field study has been proposed for 2018 to gather high-resolution hydrodynamic, bathymetric, and topographic data to connect physical drivers to coastal response.

3. The final gap in our ability to manage sand resources lies in the lack of a coastal geomorphic model for the Illinois coast that is capable of evaluating sand management actions. While gathering empirical data on short-term and long-term hydrodynamic processes and coastal change will improve our understanding of the coastal system, coastal managers need a model that simulates coastal evolution under a range of scenarios. Sophisticated three-dimensional coastal geomorphic and sediment transport models exist, however, they must be refined for this region using high-resolution data. ISGS researchers and colleagues will be refining these models with data gathered during the research and monitoring studies.

Contemporaneously with ISGS-led research and monitoring efforts, a regional coalition of communities and non-governmental agencies has formed to coordinate sand management efforts. This group, the Illinois North Shore Sand Management Working Group, aims to optimize sand management actions such as dredging and nourishment through regional cooperation. Data gathered by the ISGS along with a user-friendly version of a coastal geomorphic model will be used by this group to establish a sustainable sand management program. The partnership between the Coastal Geology Program at the ISGS and the Sand Management Working Group exemplifies the feedback loop between stakeholders and the researchers and it provides a foundation for building regional resilience to sand management and other coastal hazard issues.

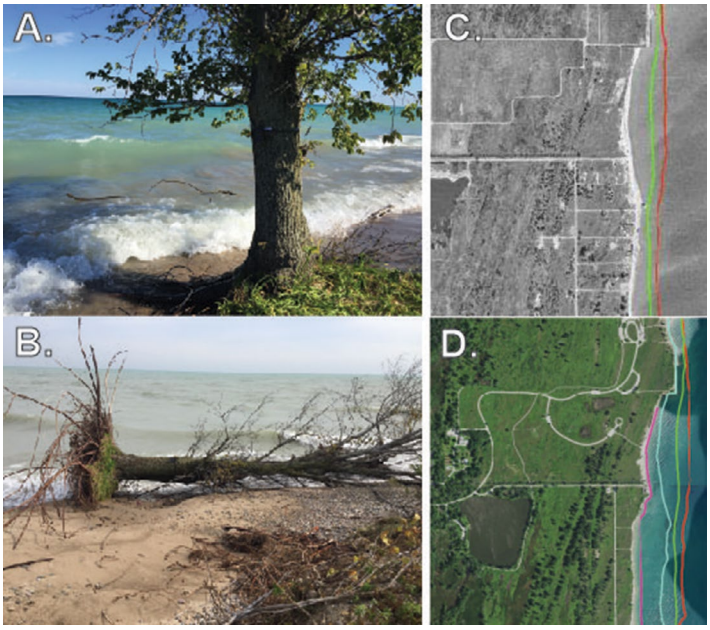

Figure 8. (A) Standing tree along the Illinois Lake Michigan shore at Illinois Beach State Park (IBSP) (9/15/16 photo) (B) The same tree toppled by erosion a month later (10/28/16 photo). (C) 1974 air photo of the Camp Logan area at IBSP showing the 1939 (red) and 1946 (green) shorelines. (D) 2015 air photo of the same area showing the 1939 (red), 1946 (green), 1974 (blue), and 2010 (pink) shorelines. The natural state of the Illinois shoreline is erosional (note the erosion from 1939 to 1946), however, shoreline protective structures have accelerated erosion along stretches of the coast (note the erosion from 1946 to 1974 south of the construction of the Camp Logan headland).

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Introduction

The Indiana Geological Survey 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. 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.

Todd A. Thompson, Ph.D., was named state geologist and new director of the IGS in November 2015. A new assistant director for research (Thompson's previous position) was hired in summer 2016; Lee J. Florea, Ph.D., professor at Ball State University, will begin his duties in December 2016. Several open positions have also been filled: José L. Antinao, Ph.D., surficial geologist; Robert J. Autio, geological field assistant; Alyssa Bancroft, Ph.D., geological technician; and Patrick I. McLaughlin, Ph.D., geologist. A project-based management system was instituted, including a Web-based reporting system for projects and activities. The organizational structure was also changed to reflect this difference in managing IGS activities. Programmatic sections were dissolved and re-formed into three main structural divisions: Research, Information Services, and Business Affairs.

Mapping and Digital Data

Geologic mapping at a scale of 1:24,000 continues in Bartholomew County, a growing population area, and Morgan County, an area of growth and major highway construction (I-69).

IGS glacial geologists are mapping outwash and morphosequences of outwash and moraines to determine the chronology of these deposits relative to the Lake Michigan, Saginaw, and Huron-Erie lobes in northern Indiana. The goal is to develop an absolute chronology for morphosequences and ice margins of the three lobes.

Two new bedrock surface maps of Indiana were published—IGS Miscellaneous Maps 94A and B. Understanding the bedrock surface is an important starting point for many aggregate, coal, petroleum, and general geologic investigations. The interface of the bedrock surface and its overlying sediments is also an important feature to map for well drillers, engineers, and geothermal heat pump designers.

New maps showing the thickness of material overlying the bedrock surface in Indiana were published—IGS Miscellaneous Maps 95A and B. These unconsolidated materials are predominantly Quaternary and Recent in age and consist of glacial till (deposited directly by glaciers), sediment related to glacial processes (deposited during the time of glaciation by rivers, lakes, and wind), and postglacial sediment.

The IGS is always searching out new technologies to present geologic data in ways that make it easy to visualize and use. Using a new Esri format, the IGS has published several story maps on the IGS website; these are online interactive maps that combine narrative text, images, data, and multimedia content. A new publication series for these products—the IGS Digital Information series—was created to encompass these and other digital products. A number of coal bed maps are being converted into the story map format.

The largest sample set of the IGS—the Rexroad conodont collection—is being organized and inventoried, so that it can be fully used by researchers.

Research

The IGS has contracted with state of Indiana to provide a spatial analysis of significant water withdrawal facilities. Hydrogeologists from IGS's Center for Geospatial Data Analysis will provide the state with a data-quality and accuracy assessment of the locations of about 9,000 significant water withdrawal facilities.

IGS glacial geologists and hydrogeologists are studying the effects of tillage practices on near-surface groundwater recharge, a continuation of a previous project. That team has also been funded to begin an investigation to understand the distribution of arsenic, a known carcinogen, in groundwater.

Funding has been received from the USGS National Groundwater Monitoring Network to expand on the IGS's

Center for Geospatial Data Analysis work related to water balance parameters. Data is being collected at several groundwater monitoring stations throughout Indiana as part of the Indiana Water Balance Network.

Funding from the USGS has allowed the IGS to begin expanding their coal trace element database. For a number of years, IGS coal geologists have been analyzing Indiana coals and tracking mercury and other trace elements. They will use their data to map mercury distribution in all the major coal beds in Indiana, as well as collecting and analyzing new coal samples to add to the USGS mercury study. The coal research team also received USGS funding to continue collecting, verifying, and encoding data for the National Coal Resources Data System.

Global carbon emissions from fossil fuel sources have risen steadily for many decades. As part of the US-China Clean Energy Research Center work on this problem, the IGS has been collaborating with Chinese and American researchers on carbon capture, utilization, and storage technology. Working with geologists from the Illlinois State Geological Survey, IGS subsurface geologists are determining if rock systems in the subsurface of the Illinois Basin are strong enough for effective and permanent storage of carbon dioxide. They are evaluating the relationship of stress field and rock mechanics to injection pressures and reservoir performance, and establishing the strength of the seals relative to injection pressures.

Deep saline aquifers also offer a suitable target for carbon dioxide sequestration. With funding from the Battelle Memorial Institute, the IGS is compiling known basic geological attributes of deep oil and gas reservoirs, black shales, coals, and saline aquifers, with the objective of calculating their ability to effectively store large volumes of CO_2.

Educational Outreach

The IGS's robust program of educational outreach continues under the new coordinator, Polly Sturgeon. During the last fiscal year, more than 9,000 people attended various presentations, workshops, conferences, demonstrations, and tours given by the IGS.

The very successful Quake Cottage program, funded by the Indiana Department of Homeland Security and the Central U.S. Earthquake Consortium, is in its fifth year of educating Hoosiers about earthquakes and how to prepare for them. The portable cottage allows people from around the state to experience the shaking from a magnitude 3 to a magnitude 7 earthquake.

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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 Lawrence on KU's west campus, and the KGS Well Sample Library is in Wichita.

Established in 1889, the 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, the KGS was known for research in invertebrate paleontology and cycles of deposition. The 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 113 employees, including approximately 38 student employees, the KGS has an annual state-appropriated budget of approximately $5.9 million. Another $3.5 million in grants and contracts were awarded in fiscal year 2015.

Rex Buchanan, interim director since February 2010, retired in September 2016, and KGS Senior Scientist Rolfe Mandel was named interim director.

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

In 2015, about 45.5 million barrels of oil and 285 billion cubic feet of natural gas were produced in Kansas with activity in the Mississippian Limestone Play adding substantially to the state's production. The Energy Research Section's field studies and research provide insight into the subsurface and stratigraphic settings of oil and natural gas resources.

Energy Research staff are conducting a project to develop the science behind and demonstrate the use of anthropogenic CO_2 for both enhanced oil recovery and safe storage of CO_2 in the Arbuckle aquifer. Between January and June 2016, 22,000 tons of CO_2 were injected into the Mississippian reservoir to recover additional oil in the nearly depleted Wellington Field in south-central Kansas (www.kgs.ku.edu/PRS/Ozark/index.html). Water injection, which also aids recovery, is ongoing, and the CO_2 plume continues to be confined. Monitoring is being carried out to verify the displacement of oil and to identify how CO_2 is stored in the reservoir. Results to date indicate that economic success would be likely in this or similar fields if a nearby supply of CO_2 were available at or near market prices. The component of the study pertaining to safe storage of CO_2 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 numerous 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 CO_2 sequestration in southern and central Kansas.

Figure 1. Core from well in Wellington Field starting just below top of the Mississippian.

The Energy Research section is also investigating whether dynamic changes in the Arbuckle aquifer and underlying basement are taking place and contributing to recent increased seismicity in south-central Kansas; using new approaches to three-dimensional seismic interpretation and geocellular modeling to study CO_2 storage and oil recovery in the Arbuckle oil reservoir in the Bemis-Shutts field; and monitoring shallow coal-bed methane production in eastern Kansas. The KGS has traditionally

engaged in coal research and provided data on coal production, which was discontinued in the state in February 2016 after 140 years.

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.

In 2016, the KGS established a seven-station permanent seismic network in the state. That followed the installation in 2014 of a temporary six-station network in south-central Kansas to investigate the relationship between increased earthquake activity and saltwater disposal wells. Saltwater disposal rose during an uptick of hydraulic fracturing starting in 2013. The number of earthquakes of magnitude 2.0 or higher peaked in 2014 then gradually fell as exploration declined in the region. In the first six months of 2016, 1,858 earthquakes between magnitude 0.0 and 3.1 were recorded in 20 counties.

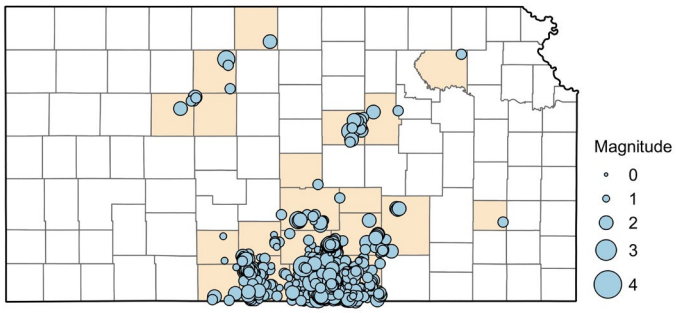

Figure 2. Earthquakes recorded in Kansas by KGS network January through June 2016.

Exploration Services runs the 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. The 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 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 researchers have recently 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.

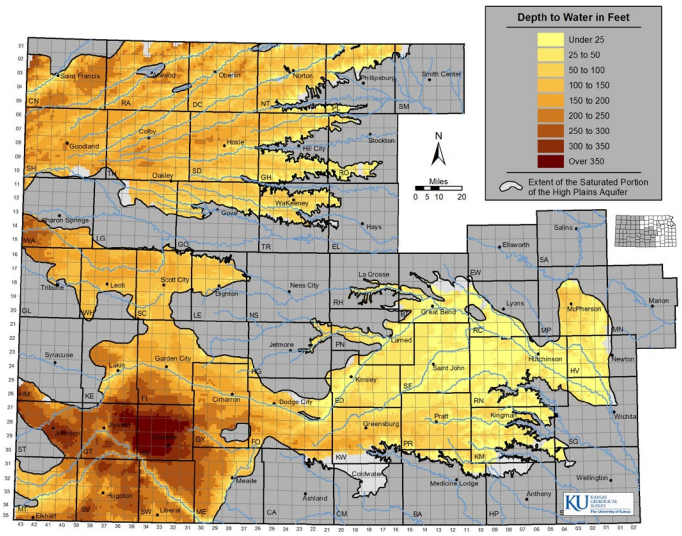

Figure 3. Average 2014–2016 depth to water, Kansas High Plains aquifer.

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 further insights into conditions in the High Plains aquifer. Real-time data from 14 telemetry-equipped wells are available at www.kgs.ku.edu/HighPlains/OHP/index_program/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 recently completed a model for Groundwater Management District #1 in west-central Kansas and another for a portion of the Republican River alluvial aquifer in the north-central part of the state.

Database Development

The KGS developed the Kansas Master Groundwater Well Inventory, a central repository that imports and links the state's primary groundwater well data sets (hercules.kgs.ku.edu/geohydro/master_well/index.cfm). The continuously updated 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).

Geohydrology Section researchers continue work on a variety of groundwater quality issues of significance to Kansas. Recent 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 arising from contamination by oil-field brines.

Section members receive external funds from a variety of federal entities for development of new methods of applied hydrogeology. Recently completed projects include a U.S. Department of Energy funded project with Vista Clara, Inc. and Stanford University on the integration of surface and subsurface nuclear-magnetic resonance (NMR) for measuring and mapping hydraulic conductivity in three dimensions; a USGS-funded study on aquifer storage and recovery in near-surface aquifers using a new recharge approach developed at the KGS; and an NSF-funded project with Michigan State University on the High Plains aquifer. The KGS continues work with Michigan State University and others on a USDA-funded study of the High Plains aquifer and also continues to work with a variety of partners on new applications of direct-push technology for hydrogeologic investigations.

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 STATEMAP component of the National Cooperative Geologic Mapping Program (www.kgs.ku.edu/General/Geology/FY16StateMapupdate.pdf) and the Odyssey Program for Geoarchaeological Research at the University of Kansas (www.kgs.ku.edu/Odyssey/about.html). The Odyssey Program is supported by private endowment funds to investigate evidence for early human occupation of the central Great Plains. In the 2016 field season, Odyssey crews excavated at the Scheuerman Mammoth site in western Kansas and the Two Rivers Paleoindian occupation site in southeastern Missouri.

Figure 4. Odyssey crew casting mammoth skull at Scheuerman site.

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 United States 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—cartographic services, GIS support, the Data Access & Support Center (DASC), and computing services (IT engineering 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 2016 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 Oil and Gas Field Map (maps.kgs.ku.edu/oilgas) and Map of Kansas Earthquakes (www.kgs.ku.edu/Geophysics/Earthquakes/map.html).

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, and Kansas 911 Coordinating Council.

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; Wichita Well Sample Library; Drill Core Library; KGS Library and Archives; public outreach; web design and management; nontechnical writing; editing, design, and publication production; and publications sales.

The Data Resources Library is the State of Kansas repository for oil, gas, and water well records. It houses geologic and production documents for more than 450,000 oil and gas wells and 255,000 water wells. The Data Resources Library is open to the public and many records can be accessed online. The Wichita Well Sample Library (WWSL) is the repository for drill cuttings from more than 148,000 oil, gas, and exploratory wells. In 2015, the WWSL collected, processed, and preserved 1.25 million sample-feet (237 miles) of cuttings from nearly 1,000 wells. Restoration efforts also were completed on deteriorating cutting samples from 3,648 wells. Samples can be viewed in-house or checked out by the public. 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. A grant from the USGS National Geological and Geophysical Data Preservation Program is helping fund the preservation and inventory of at-risk drilling 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. More information about the Data Resources Library, Wichita Well Sample Library, and Drill Core Library is available at www.kgs.ku.edu/PRS/petroDB.html.

Public outreach and communications staff members provide information and services to technical and nontechnical audiences, increasingly online. The KGS continued its annual Kansas Field Conference in 2016, giving state legislators and other decision-makers a first-hand view of the state and its natural resources. The conference, held in west-central Kansas, addressed water technology farms, water quality and municipal treatment plants, dairy farming, feedlot management and water use, transmission line planning, playas and aquifer recharge, and state park resources. The Kansas Department of Wildlife, Parks and Tourism, Kansas Department of Transportation, and Kansas Water Office were co-sponsors.

Figure 5. Kansas Field Conference stop at Lake Scott State Park, August 2016.

FY 2015/2016 Publications

Enigmatic Red Beds Exposed at Point of Rocks, Cimarron National Grassland, Morton County, Kansas: Chronostratigraphic Constraints from Uranium-Lead Dating of Detrital Zircons (Bulletin 261)
J. J. Smith, B. F. Platt, G. A. Ludvigson, R. S. Sawin, C. P. Marshall, and A. Olcott-Marshall

Classification of Red Beds at Point of Rocks, Morton County, Kansas: A Historical Review (Bulletin 262)
R. S. Sawin

Water Resources of the Dakota Aquifer in Kansas (Bulletin 260)
D. O. Whittemore, P. A. Macfarlane, and B. B. Wilson

Surficial Geology of Morris County, Kansas (Map M-125)
R. S. Sawin and R. R. West

Surficial Geology of Pawnee County, Kansas (Map M-114)
W. C. Johnson and T. L. Woodburn

Kansas Geologic Maps (Public Information Circular 38)
R. S. Sawin, C. S. Evans, and J. W. Dunham

Induced Seismicity: The Potential for Triggered Earthquakes in Kansas (Public Information Circular 36, revised) R. C. Buchanan, K. D. Newell, C. S. Evans, R. D. Miller, and S. L. Peterie

KENTUCKY

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Introduction

The Kentucky Geological Survey has investigated the mineral, energy, water resources, and geologic hazards of Kentucky for 178 years. KGS, a research and service unit of the University of Kentucky, has offices, laboratory facilities, and a Well Sample and Core Library in Lexington and a Western Kentucky Office in Henderson. KGS staff members provide technical expertise on coal, oil and natural gas, water, industrial minerals, geologic hazards, and geographic information systems to Federal, State, regional, and local government agencies, private industry, and the public. They also serve on numerous committees, boards, and professional societies. In 2015-16, the Survey employed 48 full-time staff members, as well as student assistants and temporary employees.

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 the most frequently searched information by users of the KGS web pages. The system is accessible at www.uky.edu/KGS/emsweb/data/ogdata.html. It now provides access to more than 752,000 scanned images of records. The database records comes from more than 179,700 entries, which also includes wells drilled before permits were required, permits which 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 over 102,000 wells, including domestic, public, industrial, monitoring, and agricultural wells. In addition, data for over 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. The resulting data can be viewed in tables or on an interactive map, and are valuable to anyone interested in water supply and quality.

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, composed of 15 State and Federal agencies and departments at the University of Kentucky.

Network activities are reported on an annual basis to the governor and legislature. From July 2015 through June 2016, more than 20 investigations and data-collection activities were carried out by ITAC member agencies. Groundwater and related surface-water information was communicated to the scientific and regulatory communities and to the public through various publications and presentations, as well as postings on websites. References were submitted for entry into the ITAC annual report for three groundwater publications and 24 groundwater presentations at various venues across the state.

Initiation of a New Statewide Groundwater Observation Network

The KGS Water Resources Section has been working to create a new long-term observation-well network needed to better fulfill KGS's legislative mandate to collect data to assess the quantity and availability of the state's groundwater resources. Data collected by the planned network will help predict the occurrence and severity of droughts, and evaluate the potential impacts of drought conditions on groundwater and surface-water resources throughout Kentucky. Progress for this year on the network resulted in ten wells being monitored in the new network

A webpage is being created to host hydrographs of water-level measurements obtained from each network observation well. Groundwater samples will be periodically collected and analyzed from the wells to help provide baseline information about groundwater quality in the aquifers being monitored.

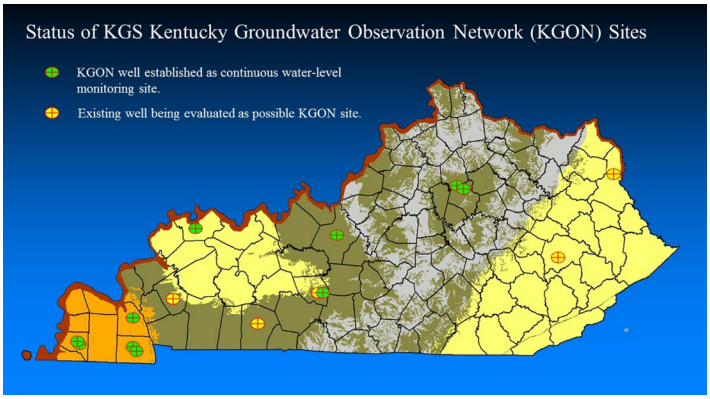

Figure 1. Status of new wells in the Kentucky Groundwater Observation Network

Well Sample and Core Library

The 48,000-square-foot Well Sample and Core Library contains Kentucky's only public collection of well samples and rock cores, storing cuttings from about 18,000 oil and gas wells and core samples from more than 3,000 sites. The library provides a service to individuals, universities, and companies needing direct access to samples for research or investigations. During the fiscal year, 182 petroleum-exploration scientists, professors, research geologists, and students representing eight universities, four state surveys, and 17 companies used the facility. More than 236,254 feet of well cuttings and cores were examined during these investigations. In addition, more than 738 samples were provided for geochemical and physical properties testing.

Major Programs

Energy and Minerals

Berea Sandstone Consortium — Funded by an industry consortium, analysis of the Berea Petroleum System in eastern Kentucky concluded in May 2016. The project was headed by KGS and included the U.S. Geological Survey (USGS), Ohio Division of Natural Resources, and R.J. Lee Group as in-kind technical partners, along with several industry partners. Since 2012, the Upper Devonian Berea Sandstone in northeastern Kentucky has been the target of an oil play that elevated the region to being the leading oil producer in the state. But the play developed in an area in which the primary source rocks, the Mississippian Sunbury and the Devonian Ohio Shales, are immature or in the lower oil window. Thus, the overall motivation for the study was to understand the origin of the oil and gas, and the stratigraphic controls on reservoir quality.

Unconventional Resource Potential of the Cambrian Rogersville Shale — One of the oldest formations in Kentucky is the focus of new exploration to determine its potential for unconventional oil and gas production in the Rome Trough, eastern Kentucky. Previous work by the Rome Trough Consortium at KGS in 2002 identified the Cambrian Rogersville Shale (Conasauga Group) as a mature hydrocarbon source rock, with total organic carbon content of up to four weight percent. This source rock is now being evaluated as a possible unconventional gas or oil reservoir, similar to Kentucky's Devonian black shales. Four recent deep wells have been drilled to test the Rogersville Shale in Lawrence and Johnson Counties, and a fifth well was completed in Putnam County, W.Va. Data from the new wells remain confidential; however, initial reports are encouraging, and significant deep leasing activity has resulted. KGS is continuing to conduct research on the Rogersville Shale to support significant interest in the play from across the country.

Carbon storage partnerships— KGS continued its participation in the Midwest Regional Carbon Sequestration Partnership, funded by the U.S. Department of Energy and managed by the Battelle Memorial Institute. The project now covers ten states, with the addition of Delaware during the past year. KGS involved in phase III research, the regional characterization of reservoirs and confining intervals, and injection testing (in other states) to help prepare for future possible commercialization of carbon storage and potential for CO_2 enhanced oil or gas recovery. KGS is heading up a regional assessment of the potential for carbon storage and enhanced gas recovery in organic-rich Devonian shales. KGS also continues collaborative research to investigate subsurface geology and refine models for estimating carbon storage capacity in deep Cambrian and Ordovician reservoirs. KGS has presented its status of continuing research on the project at partnership meetings at Battelle's facilities in Columbus, Ohio, and in team conference calls during the past year. The next phase of the project has begun on the deeper stratigraphic section. KGS will also assist the partnership with construction of a regional cross section beginning in the Michigan Basin across Ohio and Pennsylvania, and ending in the offshore area of the East Coast. Information and publications about the regional partnership can be found at www.mrcsp.org.

Water Resources

Field sampling of water wells in the Berea Sandstone Oil and Gas Play — Recent interest and increases in the use of horizontal drilling and hydraulic fracturing technology to extract oil and gas from low-permeability reservoir rocks has increased public concerns about possible impacts to the environment, especially shallow freshwater aquifers. In parts of eastern Kentucky, horizontal drilling and fracturing activities are being used to extract gas and oil associated with the Upper

Devonian Berea Sandstone, and exploratory efforts are also underway in limited areas underlain by the Rogersville Shale, a deeper, thicker organic-rich shale projected to also become a major oil and gas play in eastern Kentucky. Given the likely increase in such energy-extraction activities, background information about existing groundwater quality in shallow aquifers in the Berea and Rogersville play areas is critical to help address the public's environmental concerns and protect groundwater resources.

During February-April 2016, KGS staff collected and analyzed groundwater samples from 51 existing domestic and public water-supply wells in six counties or northeastern Kentucky. The samples were analyzed for major cations and anions, trace metals, and dissolved gases including methane. Wells with elevated methane concentration were also analyzed for carbon and hydrogen with the objective of identifying or chemically "fingerprinting" sources of methane, and to determine if thermogenic methane typically associated with oil and gas production was present or detectable in the area's freshwater aquifers.

Karst hydrogeology and sinkholes — Karst hydrogeologic mapping work and mapping and evaluation of sinkhole hazards continued during 2015-16. KGS staff continued to investigate and document the occurrences of cover-collapse sinkholes in the state, examining 13 such features in 2015, and 13 through June of 2016. A report on the distribution of these sinkholes and possible factors that contribute to cover-collapse occurrence is in preparation and is anticipated to be published by early 2017. In addition to these activities, KGS continues to assist the general public by answering inquiries about sinkhole occurrences and conducting site inspections. In 2015-16, staff responded to 64 requests for assistance.

Newly available LiDAR terrain elevation data was used to map sinkhole occurrences in parts of Kentucky. Last year, LiDAR delineated sinkholes were mapped in Bullitt, Jefferson, and Oldham Counties, resulting in an additional 4,140 sinkhole features being added to the KGS online map server. This year, 1821 sinkholes were identified from LiDAR data for Fayette County; these features are still undergoing final processing and review.

(See also Initiation of a New Statewide Groundwater Observation Network and Kentucky Groundwater Data Repository, above.)

Geologic Mapping

Surficial mapping— Mapping efforts in the Geologic Mapping Section were supported by a grant from the U.S. Geological Survey's STATEMAP program. During the fiscal year, the section's mappers completed 4 new surficial geologic maps and delivered them to the USGS program. With support from the Geologic Information Management Section, the mappers continued using digital technology such as the ESRI Collector app and ESRI ArcGIS products to more efficiently collect, compile and analyze their field data.

Mapping staff continued cooperative work with the Clean Indoor Air Partnership at the University of Kentucky College of Nursing to apply geologic map information to improve public health and communication of health issues. The focus of the project includes assessing geology-influenced radon potential to help communicate the need for home radon testing. Fifteen county maps depicting radon potential have been created for use in public education and awareness campaigns.

Geologic Hazards

China scholarly exchange and cooperative research— This was the 12th year for the exchange program between KGS and the Lanzhou Institute of Seismology and other organizations in the China Earthquake Administration. Geologic Hazards researchers visited Lanzhou to give lectures and conduct research on earthquake-induced landslides in loess areas and to give lectures in the Institute of Crustal Dynamics in Beijing and Fujian Earthquake Administration in Fuzhou. Three visiting scholars came to KGS to participate in research projects and exchanges, resulting in a papers published in the *Journal of Soil Dynamics and Earthquake Engineering* as well as the *Bulletin of Seismological Society of America*. The visiting scholars also contributed to two abstracts and posters for the 2016 Seismological Society of America annual meeting in Reno, Nev., in April 2016.

The Kentucky Seismic and Strong-Motion Network — The Kentucky Seismic and Strong-Motion Network continued to grow this fiscal year with three additional stations installed in eastern Kentucky. KGS maintained a real-time data share with the neighboring seismic network operated by the University of Memphis and also with IRIS Data Management Center for archiving. Data from networks operating in Kentucky and surrounding states, including EarthScope USArray stations were acquired in tandem with real-time data from the network and used to detect seismic events in Kentucky with unprecedented sensitivity.

Eighteen earthquakes occurred in the state during the fiscal year, with magnitudes ranging from 1.2 to 3.5. Seven of these events, including the largest, happened in the Mississippi Embayment, five occurred in the Blue Grass, five occurred in eastern Kentucky, and one was located south of Henderson. Eleven of the earthquakes

were reported felt by local residents. Notably, the May 1, 2016 magnitude 3.5 earthquake in northern Ballard County was the largest earthquake to occur in Kentucky since the November 10, 2012 Perry County magnitude 4.2 earthquake and was reported to have been felt in four states, and as far away as St. Louis, Missouri.

Temporary seismic network to monitor induced seismicity — KGS began setting up temporary network in the previous year in eastern Kentucky with State support and in partnership with the University of Kentucky and private companies to monitor very small earthquakes (microseismicity), both natural events and those that could have been induced by fluid injection and hydraulic fracturing (fracking). It is a proactive measure to establish background levels of microseismicity and to monitor any induced events in response to increasing interest in producing the unconventional Rogersville Shale play. Detailed analyses of the earthquakes recorded this year, including determination of faulting style for two events, was possible due to the temporary network. By the end of the 2016 fiscal year, thirteen of these temporary stations were operating. The data arrive at KGS in real-time using wireless communication for processing and archiving.

Landslide inventory — New entries were added to the KGS landslide inventory database, bringing the total number to 2,468 by the end of the fiscal year. The sources of the landslide locations include State agencies, field investigations, published maps, LiDAR mapping, and reports from the public. These records are documented as point data that represent a larger landslide area. In addition to the landslide inventory point data, landslide features digitized from Landslide and Related Features Maps published by the U.S. Geological Survey were added to the inventory. From these maps, staff digitized over 13,000 landslide areas derived from aerial photography and over 60,000 areas susceptible to debris flows derived from aerial photography, topography, and historical records. Both the documented point data and digitized landslide features can be viewed and queried in the KGS online Geologic Map Information Service http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp?layoutid=25. The landslides create a large data set that serves as a foundation for improving our understanding of landslide occurrence and provides information to assist mitigation efforts by land-use planners, transportation officials, emergency managers, and the public.

Site-specific monitoring continued for three shallow colluvial landslides in Kenton, Lewis, and Pulaski Counties. Slope hydrogeology, precipitation, landslide material and strength properties, landslide movement, and surface electrical resistivity data are being collected and analyzed. Hydrologic sensors capture the transient moisture conditions (volumetric water content and water potential) within the slope, which is compared to rainfall. Electrical-resistivity measurements have shown resistivity contrasts that correlate to lithologic differences, failure zone depth, shape of the landslide body, and groundwater conditions.

Figure 2. KGS students and staff conduct an electrical resistivity survey for landslide characterization at a site in northern Kentucky.

TECHNOLOGY TRANSFER AND PUBLIC OUTREACH

Web services

The KGS website (www.uky.edu/KGS) serves a diverse and international audience. More than 288,000 users from 220 countries accessed information about KGS, Kentucky's resources, and geoscience education from the website. Overall, the site experienced about 1.2 million hits during the fiscal year. The most-visited pages, besides the home page, were the fossil identification pages, followed by the coal information, rock and mineral identification, and the mining methods web pages. Among the improvements and additions during the year: A major project to convert the over 600,000 web-accessible oil and gas documents from DJVU-format into PDF-format was completed in December. PDF format should make these documents more accessible to users on all computer platforms including mobile devices. E-logs and strip logs from wells were also converted into JPEG-format images for faster viewing on the web and mobile devices. With grant support from the Watershed Watch Kentucky organization, a web application was

developed for viewing results from the volunteer water sampling events. Through this data portal (http://kgs.uky.edu/wwky/), users can view and download surface water quality data from sampled sites along creeks and rivers throughout Kentucky.

Earth Science Week

The largest educational event offered by KGS for the general public each year is the Earth Science Week open house, held each October. KGS invites students and families to browse earth science-related displays and demonstrations at our building on the University of Kentucky campus. They range from displays of rocks, minerals, fossils, gems and meteorites to demonstrations of volcanoes, earthquake recordings, and geologic carbon storage. The 2015 open house drew about 190 people, with the participation of partner organizations and departments.

Distinguished lectures

KGS helps bring scientific lecturers to the UK campus several times each year. On April 28, 2016, UK graduate John Holbrook, now with the Department of Geology and the Energy Institute at Texas Christian University, gave an AAPG Distinguished Lecture, "A tale of earthquakes past and yet to come: A cautionary account of New Madrid Faulting from the Mississippi River."

Annual Seminar

The 2016 KGS annual seminar focused on "Navigating the New Energy Landscape in Kentucky." KGS and state-agency presenters talked about Kentucky's coal, oil, gas, and renewable energy resources and utilization, as well as KGS research on the environmental effects of energy development. The timely topic drew about 130 people

Figure 3. The KGS annual seminar is the largest annual gathering of geologists in the state, drawing 130 people in 2016.

to the Well Sample and Core Library on May 13 for the seminar, poster sessions, and afternoon workshops.

Major Publications

Twelve new titles were published by KGS researchers or students who worked at KGS. They include three new publications related to heavy oils resources in the tar sands of western Kentucky: *Rocks to roads to ruin: A brief history of western Kentucky's rock asphalt industry, 1888 to 1957*; *Heavy oil and bitumen resources of the Big Clifty Sandstone, northeastern Grayson County and adjacent Hardin County, Kentucky*; and *Heavy oil and bitumen resources of the western Kentucky tar sands*. *The Geologic Context of Landslide and Rockfall Maintenance Costs in Kentucky—2002 to 2009* matched Kentucky highway maintenance costs with geologic units to assess the most costly and frequently repaired pavement sections according to geologic formation.

In addition, four new surficial maps of 7.5-minute quadrangles were completed by Geologic Mapping Section staff with funding from the USGS STATEMAP program. All of these publications are available for download from the KGS publications site.

LOUISIANA

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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 preform 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 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, production of geologic maps etc.

Continuing budget cuts for the last five years have resulted in the reduction of the LGS state budget by approximately 58% 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 2 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 the Louisiana Geological Survey (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 (USGS).

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 FY 2013, 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 53 sheets. Forty-three were prepared with STATEMAP support, and the other ten were prepared for the U.S. Army Corps of Engineers within the Fort Polk region, southcentral Louisiana.

State map 2015-2016 deliverables completed and submitted included geological maps and pamphlets covering four 7.5 minute quadrangles in two study areas (Poverty Point area in northeastern Louisiana and the Amite River Valley north-northeast of Denham Springs).

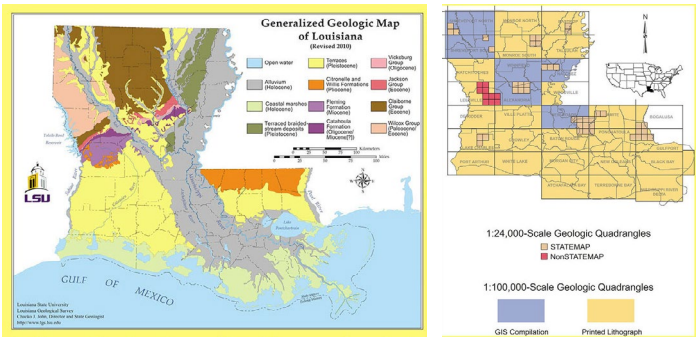

Figure 1. Generalized geology of Louisiana, and geologic map coverage generated at 1:100,000 and 1:24,000 scales since the advent of the STATEMAP program in 1993.

GIS Development of the Buried Holocene-Pleistocene Surface in the Louisiana Coastal Plain

This project was funded by the Water Institute of the Gulf on behalf of the Coastal Protection and Restoration Authority (CPRA) of Louisiana to investigate and develop

a three-dimensional GIS dataset of the buried Holocene-Pleistocene regional unconformity known as the "Base of the Holocene" for coastal Louisiana. This research was undertaken because of a lack of a single comprehensive map of the Holocene-Pleistocene surface that covers the entire coastal plain and adjacent continental shelf. Instead, the available data consisted of maps created by various authors at different times in different study areas using different criteria. As a result, many gaps existed in the coverage of these maps as well as conflicts in their interpretations.

The technical work conducted for this project consisted of (1) an investigation and compilation of existing published and unpublished boring data; (2) an analysis of collected data points; (3) the development of the GIS dataset of the Holocene-Pleistocene surface within the study area; (4) an assessment of the accuracy of the source data and (5) the preparation of deliverable GIS data sets, digital maps and a final report with an interpretation of the data. It is intended that this Holocene-Pleistocene surface model of this study area will offer improvement in understanding geologic variables in engineering design of coastal restoration projects, reduce uncertainties in for accessing future geo-environmental conditions, support coastal project planning and decision making and improve

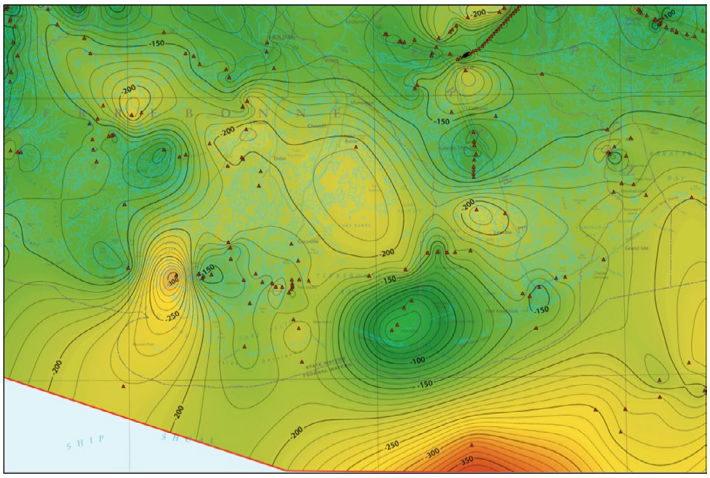

Figure 2. Barataria – Structure map of the H-P surface within the Barataria/Terrebonne area. Red triangles show location of boring data.

data and assumptions used in predictive subsidence modeling.

Preservation Potential of Prehistoric Cultural and Sand Resources

This study, started last fiscal year, was to investigate how the paleo-landscape of the late glacial continental shelf responded to the erosive effects of the late Pleistocene-Holocene transgression and was funded by the Bureau of Ocean Energy Management (BOEM). During this period of sea-level rise, wave and tidal movement preferentially eroded the coastal plain interfluves and often spared the valley fills and paleo-valleys that progressively accumulated. As part of this report, these erosive effects of the late Pleistocene-Holocene transgression on preservation of paleo-landscapes and associated features were evaluated using data provided by BOEM. In addition, a final GIS compilation of all these data sets were finalized along with other data collected and evaluated as part of the final report submitted to BOEM.

Continuation and Completion of the Stream Gaging and Rating Curve Study

This ongoing investigation from the last two fiscal years, funded by the Louisiana Department of Natural Resources, was continued for the 2015-2016 fiscal year. This involved collection of stream discharge data using a River Surveyor for measurements for large streams/rivers and a Flow Tracker for measurements of small streams. After collection of stream discharge results, they were included as part of a series of 50 stream rating curves relating discharge to gage level of a stream. Lake level data for four sites (False River, Pointe Coupee Parish; Lake Providence, East Carroll Parish; Black Lake, Natchitoches; Lake Bruin, Tensas Parish) were also monitored and recorded during this period. All data collected were transmitted to DNR. The final report also contained data sets on dams and reservoirs in Louisiana compiled from publicly available sources.

Baseline Determination of Groundwater Quality in South Central St. Tammany Parish

This parish funded project involved sending letters to owners of private water wells requesting permission to sample the wells which ultimately resulted in sampling of 97 domestic water wells and 3 public supply water wells to determine baseline values for 42 different analytes. This included: aluminum, arsenic, barium, benzene, boron, bromide, butane, cadmium, calcium, chloride, chromium, cobalt, copper, diesel range organics (DRO), electrical conductivity, ethane, ethylbenzene, fluoride, gasoline range organics (GRO), iron, lead, magnesium, manganese, methane, nickel, nitrate, nitrite, oil range organics (ORO), pentane, phosphate, phosphorous, potassium, propane, silicon, sodium, strontium, sulfate, toluene, total dissolved solids, vanadium, xylene(s) and zinc. Sampling was completed between December 2015 and June 2016 and analytical analysis of samples was completed by August of 2016 after which a final report was submitted to the parish.

Evaluation of Water Permit Requests

This three year project funded by DNR, now in its second year, requires LGS to provide DNR with unbiased recommendations for water permit requests. Such applications are mostly for withdrawal of water from running surface water resources submitted to the DNR Secretary pursuant to Act 955 of 2010. Applications are generally received by DNR from other state agencies, parish governments, etc. and are evaluated mainly to determine environmental consequences resulting from the action proposed in the concerned application.

Energy Projects

1. Update and Revision of the 2015 Oil & Gas Map
   LGS is currently working on updating the 2015 oil and gas map and is expected to be available in digital format by the end of the fiscal year 2015-2016.
2. Parish Atlas Series
   Work on the Parish Atlas Series which started last fiscal year is on hold at present mainly due to the lack of sufficient staff.

Geologic Review

This is a continuing environmental geology program which started in 1982 and is funded by DNR and the US Army Corps of Engineers which provides regulatory technical assistance to the Office of Coastal Management of the Louisiana Department of Natural Resources and to three districts of the U.S. Army Corps of Engineers. It assists in the implementation of section 404 of The Clean Water Act and the Louisiana Coastal Resources Program regulations, both of which impact oil and gas operations by mandating that only the least damaging feasible alternative shall be permitted. Oil and gas permit applications made to these two agencies which involve significant environmental impact to vegetated wetlands or other environmentally sensitive areas have their geology, engineering, lease, and site-specific data reviewed and evaluated to determine if any less-damaging feasible alternatives are available. Such alternatives may include reducing the size of ring levees and slips, reducing the length of board roads and canals, the use of directional drilling, and the use of alternate and less-damaging access routes, the goal being to avoid or minimize any environmental damage. The long-term effect of Geologic Review has been an overall approximate 75% reduction in the average length of canals and board roads built in the Louisiana Coastal Zone.

Geophysical Projects

LGS continues development of geophysical techniques, electrical resistivity and magnetometry, for shallow depth features of interest to geology, archaeology, and civil engineering. In studies thus far, the techniques have successfully resolved unmarked cemetery burials, prehistoric human habitations, modern buried pipelines, and lithostratigraphic relationships in the shallow subsurface. Pilot studies investigated anecdotal suggestions of burials and structural features of defunct plantations and military installations as well as the extent of economically important quarry resources. Two additional pilot studies in Texas identified locations of potential archeological significance at a future dam site and layout features of Antelope Creek (1200-1450 AD) structures. A funded comprehensive geological and geophysical study successfully identified subsurface burials in a neglected historic cemetery, providing the sponsor a reliable guide for future renovations and interments. More recently, these methods have been applied to resolve the internal structure of 5 ka Indian mounds widely distributed in southern Louisiana.

Digital Infrastructure and Data Rescue of Historic Geological Publications

This USGS funded project under the National Geological and Geophysical Data Preservation Program (NGGDPP) enabled LGS to digitize and scan a large number of historical LGS publications and maps. These were made available in digital (pdf) format and metadata pertaining to each scanned publication were uploaded to the USGS digital catalog.

Outreach Activities

Earth Science Week

Sponsored Nationwide by the American Geoscience Institute (AGI), this week was celebrated from October 11 – 17, 2015 with the theme of "Visualizing Earth Systems". As in previous years, LGS received 50 educational kits from AGI which were distributed to K-12 school earth science teachers with the assistance of the Louisiana Department of Natural Resources Office of the Public Information Director.

Tenth Annual Groundwater Symposium

The Louisiana Geological Survey and the Louisiana Water Research Institute (LSU) organized and hosted the "Groundwater, Surface Water and Water Resources" Symposium on March 24-25, 2016. It was a very well

attended symposium (100+) and many LGS staff members were involved in various aspects of the program. Attendees also received educational credits towards the registration requirements of the Louisiana Board of Professional Geoscientists (LBOPG).

Earth As Art (exhibit)

LGS was cosponsor of this exhibit along with the LA-RS-GIS Institute, Global Geospatial Solutions LLC and Louisiana View which was displayed at the Manship Gallery from April 21- July 12, 2016. The exhibit featured stunning images of the surface of Planet Earth captured by the Landsat Satellite jointly operated by USGS and NASA. The exhibit which was free and open to the public was a major success and was viewed by a large number of people.

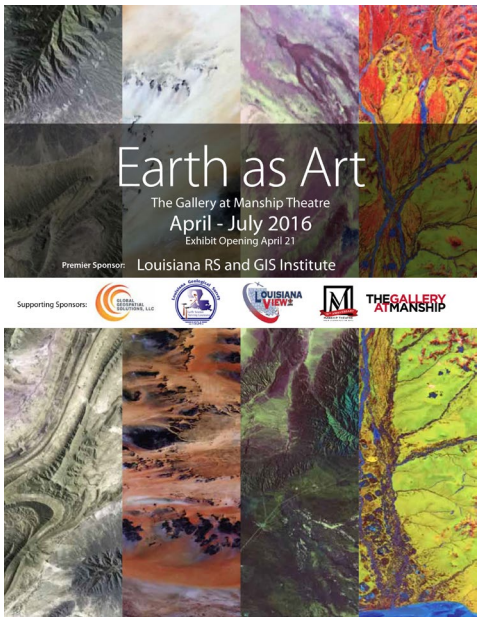

Figure 3. Earth as Art.

LGS Resource Center

The LGS Resource Center consists of a core repository and log library. It is located behind the old 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 feet of core from wells mostly in Louisiana. The well log library contains over 50,000 well logs from various parishes in the state. The Core Lab is equipped with climate controlled layout area, microscopes, and a small trim saw. The core and log collections are included as part of the LSU Museum of Natural History as defined by the Louisiana Legislature and is the only one of its kind in Louisiana. The LGS Resource Center is available for use by industry, academia and government agencies, and others who may be interested. Viewing and sampling of cores can be arranged by calling Patrick O'Neill at 225-578-8590 or by email at poneil2@lsu.edu. Please arrange visits two weeks in advance. A list of available cores can be found at the LGS web site (www.lgs.lsu.edu).

Figure 4. Tools found in the LGS core lab.

LGS publications 2015-'16

This years publications include:

Paleoenvironments, Depositional History, and Alternate Reference Sections for the Wilcox Group (Paleocene-Eocene) of Northwest Louisiana-East Texas by L.N. Glawe and D.E. Bell, 2016

Tunica Hills Wildlife Management Area and Angola State Penitentiary by Rick McCulloh, 2016

Soda Lake Wildlife Management Area by Rick McCulloh, 2016

Columnar Section of Differentiated Wilcox Group Strata Exposed in Northwest Louisiana
by Richard P. McCulloh, 2016

Geologic Mapping Of Natchitoches At 1:100,000 Scale (Paul Heinrich, Marty Horn, Richard McCulloh, and John Snead)

MAINE

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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 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 in1885 emphasized these critical mineral resources and their geologic settings.

Since those early days, the significance of geology to society has broadened. Programs of the Maine Geological Survey 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. This 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, the MGS has produced surficial geologic maps for about 170. Preliminary surficial maps at a more generalized scale cover much of the rest of the state. With regard to bedrock maps, there are about 60 completed at the 1:24,000 scale with another 20 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 the Figure 1.

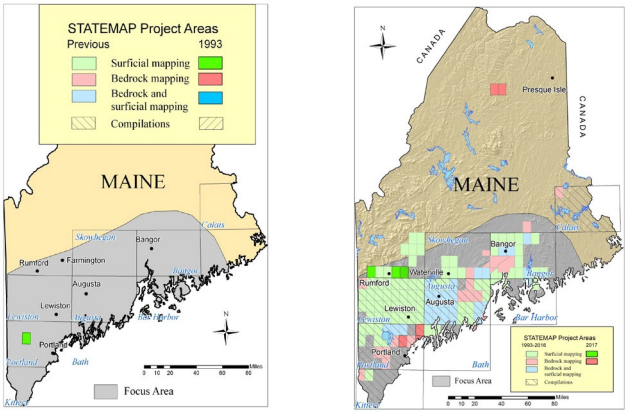

Figure 1. (Left) Status of STATEMAP mapping in 1993. (Right) Status of STATEMAP mapping through 2016. 1:100,000-scale quadrangles named in blue. Penobscot Bay is the large embayment at the western edge of the Bar Harbor quadrangle.

Our STATEMAP program shifted from the Augusta 1:100,000 quadrangle to neighboring areas where our experienced team of staff geologists and contractors could test the veracity of the geological models

developed through the Augusta mapping effort. We completed bedrock geologic mapping in the northwestern Penobscot Bay area. This area includes portions of the Norumbega fault zone, a major dextral strike-slip zone that was active in the late Paleozoic and early Mesozoic, and is analogous to the present-day San Andreas. Our earlier mapping in the Augusta area identified localities along the fault zone with both ductile (mylonite) and brittle (pseudotachylyte) features, suggesting the current exposure is in the critical ductile/brittle transition zone that is inaccessible in active fault zones. As a spin-off from our work, this zone is the focus of more detailed study by UMaine researchers through an NSF grant.

Our surficial mapping projects have been focused along the Kennebec River from Augusta to Waterville. This area is one of active development and high aggregate demand. Much of the area is underlain with glacial-marine mud which is highly susceptible to landslides. The revolution in surficial mapping facilitated by lidar has tremendously improved the identification of geomorphological features. In Figure 2, De Geer moraines that are hidden by the heavily vegetated landscape are starkly revealed in the bare-earth lidar elevation datasets. These features likely represent annual recession positions of the retreating ice margin.

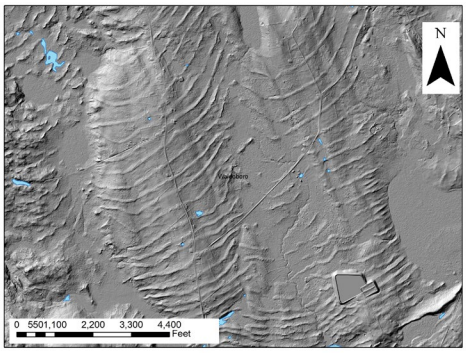

Figure 2. Dramatic De Geer moraines revealed in bare-earth lidar elevation data, mid-coast Maine. Moraines probably represent annual recession positions of the ice margin.

Our surficial mapping shifted in early 2016 to the Rumford area of western Maine where the only surficial map coverage currently available is at a scale of 1:500,000. This is a busy industrial area, with paper mills, a working forest, four-season recreational opportunities, a modest population, and a significant east-west transportation route.

Hydrogeology

Groundwater modeling, Popham Beach State Park: We continued an effort to model groundwater at this coastal state park as part of a vulnerability assessment (see Marine Geology section of this report). Coastal state parks are among the most popular in the state, with the number of visitors measured in the hundreds of thousands annually. Many of these parks are far from municipal infrastructure and must rely on local wells for their water supply. We are studying the water supply at Popham Beach State Park, at the mouth of the Kennebec River in Maine's mid-coast because the water supply there is particularly vulnerable. The Park's 529 acres of mostly dune and back dune physiographic environments are constrained by a dynamic ocean environment and a significant public road (Figures 3 and 4).

Figure 3. Popham Beach State Park location map, mid-coast Maine.

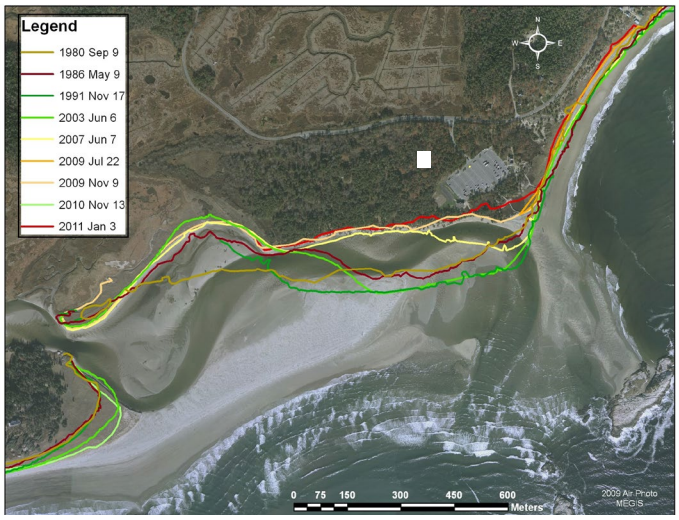

Figure 4. Dynamics of the shoreline at Popham Beach. In 2003 the shoreline was located at the most seaward green line. However, the outlet of the Morse River (lower left) has been particularly dynamic in the last decade. By 2011 the shore had shifted about 300 feet inland to the bright red line, threatening the parking lot (gray area), nearby bath house and leach field. Water supply well located at white box.

The parking lot, bath houses, and water supply infrastructure for the Park are located on top of a thick (>80 ft) unconfined aquifer of unconsolidated fine-to-medium sand that overlies regional bedrock. The water supply for the park is a gravel-pack well of about 28 ft in depth, installed in 2008 in an area of forested back dune, which draws water from the aquifer for public showers, flush toilets, and drinking water. Used water is disposed of in septic system and grey-water leach fields adjacent to the parking lot and bath house. The static free groundwater surface in the vicinity of the supply well is

about three feet above mean sea level, low enough to cause concern about the potential for salt-water intrusion into the well as sea levels rise. The lowest chamber of the septic system is about 4 ft above the estimated seasonal high water table, which is close enough to cause concern that rising sea levels and increasing precipitation rates will cause the water table to rise and flood the septic system.

MGS installed monitoring wells, performed water and terrain conductivity measurements, and constructed models of the saltwater interface and steady-state groundwater flow at the site. Continuing work focuses on using the groundwater model to predict the position of the saltwater interface under transient conditions and a variety of sea-level rise scenarios.

Groundwater modeling, Limestone Water District: In the past year, staff hydrogeologists have worked on a groundwater model for the Limestone Water District in northern Maine. This district is in a productive agricultural area and experiences seasonal problems with nitrate levels. MGS constructed a model to evaluate potential nitrate sources and transport times to the water district wells. Our preliminary results suggest that the water produced at the wells is decades old and that the nitrate is not related to current agricultural practices.

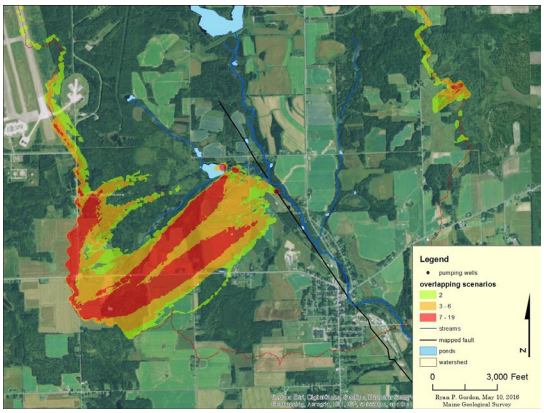

Figure 5. Aggregate of multiple model scenarios for the Limestone Water District showing most likely recharge areas in red.

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 and is accessible through an interactive web mapping app: http://www.maine.gov/dacf/mgs/pubs/digital/well.htm

Water use: MGS received a grant from the USGS National Water Census Program to improve water use information in Maine. In this first year, we worked with a stakeholder group to develop a five-year plan to collect water information in twelve categories and across three tiers of increasing detail. This effort will expand on a more generalized effort by the MGS over the past decade to collect information from the largest water users. As part of the first year project, we are accessing large databases from public water systems in order to better estimate domestic water use. Coefficients for domestic use developed through this effort will be applied to the 50% of the population that draws domestic water from private wells. In future years of this project, we will focus on agricultural irrigation, and commercial and industrial uses. Our current database has already proved invaluable to the discussions of water use versus availability. While for the most part there are few conflicts in water use, several watersheds have potential for conflict between in-stream and out-of-stream uses. Our data collection effort is helping focus scarce state resources on the areas with the greatest need.

Soil-Water-Balance Recharge Project: In the past year, MGS began working with the USGS New England Water Science Center Maine Office on a multi-year effort to develop 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 this first year and will be calibrated to surface water base flows in select watersheds over subsequent years.

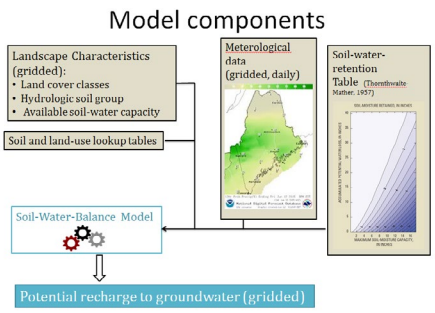

Figure 6. Schematic of primary inputs to the SWB model. When completed, the model will estimate recharge in any user-defined area.

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 UMaine 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 economically important beaches of the state. The results of several years of profiling are posted at http://www.geology.um.maine.edu/beach/. 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 (Nor'easters, southwesters, tropical storms) affect various beaches in southern Maine. Information will be compiled in the biennial State of Maine Beaches report that assesses the long-term accretion/erosion trends of the beaches and will be presented at the biennial Maine Beaches Conference in July 2017.

Coastal State Park vulnerability assessments: Through a cooperative program with the Maine Coastal Program and the Maine Bureau of Parks and Lands, and funded by a NOAA project of special merit, in the past year the MGS completed an assessment of vulnerability of coastal parks to storms and sea-level rise. This assessment used the new coastal lidar elevation datasets and reasonable scenarios for storm surge and sea-level rise at various tidal stages to identify park infrastructure most at risk. As the Parks revise management plans, these analyses will be useful in setting work priorities. Examples of the output of this project are shown in Figures 7 and 8 for Reid State Park.

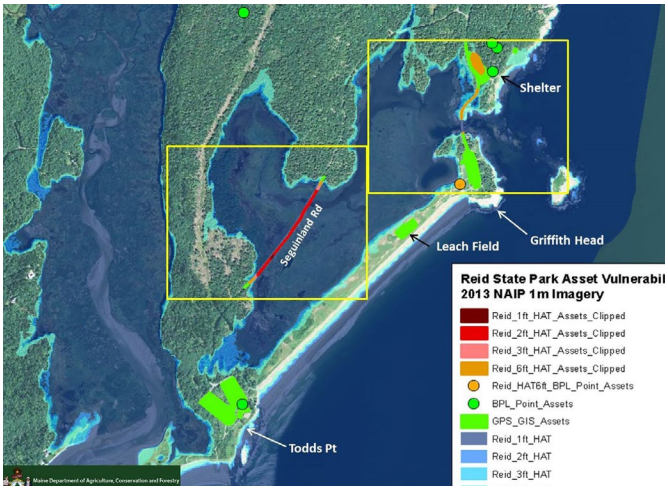

Figure 7. Reid State Park map with infrastructure features in green. Red through tan colors correspond to the vulnerability of features to storm surge and/or sea-level rise: Red – vulnerable in all scenarios; Tan – only at the highest estimate of sea-level rise.

Reid State Park Vulnerability Assessment								
Property	Asset	Mean Elevation (ft NAVD)	Source	Sea Level Rise/Storm Surge				
				HAT (6.3ft)	HAT+1 (7.3ft)	HAT+2 (8.3 ft)	HAT+3.3 (9.6 ft)	HAT+6 (12.3 ft)
Reid	Seguinland Road	7.3	LiDAR		0.1	0.4	1.4	4.3
Reid	Griffiths Head Road North	11.1	LiDAR					1.3
Reid	Pump Station 1	11.0	LiDAR					1.5
Reid	Pump Station 2	10.5	LiDAR					1.6
Reid	Griffith Head Sewage Sump	14.0	BPL					1.3
Reid	Griffiths Head Road South	17.3	LiDAR					1.5
Reid	Maintenance Parking Lot	12.1	LiDAR					0.4
Reid	East Beach Sewage Sump	13.0	BPL					
Reid	Shelter	12.9	LiDAR					
Reid	Leach Field	17.0	LiDAR					
Reid	Parking Lots Todds Point	27.0	LiDAR					
Reid	Parking Lot Reid	23.1	LiDAR					
Reid	Concession Building	19.7	LiDAR					
Reid	Bath House Reid	25.3	LiDAR					
Reid	Bath House Todds Point	18.2	LiDAR					
Reid	Griffith Head Wellhead 1	30.0	BPL					
Reid	Griffith Head Wellhead 2	27.0	BPL					
Reid	Todd's Point Wellhead	55.0	BPL					
Reid	Todd's Point Sewage Sump	19.0	BPL					

Figure 8. Vulnerability matrix for infrastructure at Reid State Park. While many Park facilities are well above the highest estimates for sea-level rise, others will be affected by slight to modest sea-level rise. This information will help Park managers prioritize remediation efforts.

Offshore surveys: Created by the Maine Coastal Program in 2013, the Maine Coastal Mapping Initiative (MCMI) is acquiring critical data about the terrain of the seafloor that will be used by regulatory and planning agencies to maintain marine ecosystems, expand offshore economic opportunities, improve maritime safety and prepare for anticipated environmental changes. The MCMI is a collaboration among state, federal, and non-profit partners, including the Maine Department of Marine Resources, the Maine Department of Transportation, the Maine Coastal Program, the Maine Geological Survey, the University of Maine, the University of New Hampshire, the U.S. Department of the Interior's Bureau of Ocean Energy Management, the National Oceanic and Atmospheric Administration, and the Biodiversity Research Institute. During summer 2015, high-resolution bathymetric data were collected in state and federal waters near the mouth of the Kennebec River, mid-coastal Maine. Part of the effort involves ground-truthing with grab samples for sediment and infauna analysis (Figure 9). Large swaths of the mid-coastal state waters (to 3 miles off shore) have now been completed.

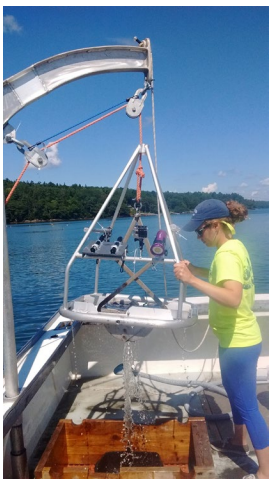

Figure 9. Benthic grab sampling near the mouth of the Kennebec River provides ground truth for sediment types imaged by the multibeam sonar system.

Hazards

Bluff erosion and landslides: Approximately 40% percent (1,400 miles) 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 miles of bluff, of which 34 were classified as either unstable or highly unstable (e.g. Figure 10). Bluff shorelines are present on year-round populated islands in Casco Bay as well as the bay's mainland. Using new coast-wide LiDAR, MGS identified more than 250 previously unrecognized landslide features in Casco Bay.

Through a NOAA Project of Special Merit, MGS is working with the Maine Coastal Program and the Cumberland

Figure 10. 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.

County Soil and Water Conservation district on an effort to address these coastal hazards. Specifically this project will:

1. Develop and apply a transferable, predictive bluff erosion model using sound, scientifically proven methodologies and existing and newly available Maine datasets.

2. Assess model efficacy for use locally and bay-wide in Casco Bay.

3. Evaluate "living shoreline" approaches to bluff stabilization.

4. Disseminate project results via technical assistance to municipalities, regional workshops, webinars, conferences and publications.

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 2016 and throughout the snowmelt period.

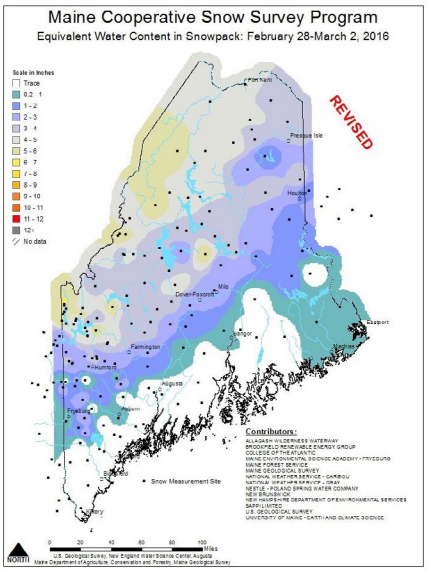

Figure 11. Snow survey map from March 2, 2016 showing water equivalent content of the snowpack (inches of water). This map and others were used by the River Flow Advisory Commission to assess the threat for spring flooding.

Our information helped forecasters refine the timing and extent of possible flooding from the snowpack.

Landslide studies: MGS began working with the Maine Emergency Management Agency (MEMA) to increase the emphasis on landslide hazards through the update Maine's State Hazard Mitigation Plan, which will occur over the next few years. As part of this effort, MGS has been reviewing newly available lidar for landslide features. The number of previously unrecognized landslide features in even a small area along the Saco River in southern Maine (Figure 12) is sobering! The primary question we seek to answer with this project is whether the landslides occurred during a relatively narrow window of time shortly after deglaciation or if they have been happening sporadically since then. The latter has broad implications for landslide risk assessment. We are working with MEMA to seek funding from the Federal Emergency Management Agency to

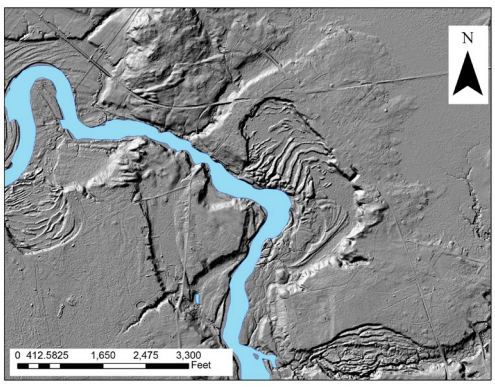

Figure 12. Three landslide features are starkly exposed in this bare-earth shaded relief lidar image along the Saco River near Steep Falls, southern Maine. These features had been erroneously identified previously as old meander scrolls along the river.

further investigate these features.

GIS AND PUBLICATIONS

Web pages: Our web pages continue to be very popular. Anchored by our publications search application and our "Geologic Site of the Month," usage continues to grow. The pages include a searchable bibliography of Maine geology with over 7,200 references.

http://www.maine.gov/dacf/mgs/pubs/publications_search.shtml#mapsearch

Users continue to download more than 6,000 geologic maps and reports each month, eclipsing our hardcopy publication distribution by ten-fold.

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 2016 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

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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
- 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 was incorporated into 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 ground water studies, the Survey conducts studies in support of the Maryland Department of the Environment's regulatory control over ground water quality and quantity and for improving understanding the quality of the state's ground water resources.

Currently, staffing levels are 17 professional, 1 professional contractual, 1 full time support, and 1 part time support. One full time support position was vacated during the year and the position is currently being recruited. Two professional staff were hired over the year. Mrs. Tiffany Vanderwerker comes to the Survey from Virginia Tech with experience in groundwater and groundwater contamination. Christopher Cannallon who once served as a contractual employee was hired to work in the Coastal program. Christopher is focusing on remote sensing, offshore sand resources, and laboratory operations. Hiring new professional staff has injected some youth and enthusiasm into the Survey's ranks, and being permitted to fill the vacant positions during difficult fiscal times indicates the degree of support for the Survey's activities within the larger Department.

In 2008, The Advisory Committee on the Management and Protection of the State's Water Resources identified the need for a comprehensive assessment of groundwater resources throughout the state. Rapid population growth and the attendant water demands are putting increasing stress on water resources which had previously been largely taken for granted in a state with relatively high rainfall rates. In cooperation with the Maryland Department of the Environment and the U.S. Geological Survey Maryland-Delaware-DC Water Science Center, MGS has benefitted from the renewed focus on water supply and groundwater studies. Work is continuing on developing a regional groundwater flow model of the Coastal Plain aquifers located south and east of the Baltimore-Washington Corridor, and on gaining understanding of groundwater hydrogeology in the fractured rock areas of the state to the west.

Groundwater studies in the Appalachian Plateau were a focus this year with the generation of several reports focusing on availability and quality. MGS developed an extensive database of groundwater conditions utilizing current Survey investigations and the studies from other Federal, State, and Local government studies to develop a more robust and comprehensive assessment of the groundwater throughout the region. This technique is now being utilized in three other counties in the State.

The United States Fish and Wildlife Service contracted with the Survey to evaluate springs around Rock Creek State Park. An analysis of these springs and the impact on endangered species developed a collaboration between biologists and geologists. Working together, different geologic investigation techniques were evaluated and utilized to investigate the shallow groundwater systems in the environment.

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.

The Maryland Ground Water Quality Monitoring Network is an ongoing effort intended to document the chemical quality conditions of Maryland aquifers. In 2012, 2013, 2014, and 2015, the Survey conducted a study of methane concentrations in drinking-water wells in the Appalachian Plateau province of Maryland, which includes all of Garrett County and the western edge of Allegany County. This area is considered prospective for development of the Marcellus Shale. This investigation is

intended to provide information on the range of methane concentrations in well water, and also on regional patterns of distribution (wells located in coal versus non-coal areas, and valley versus upland wells).

New funding from a USGS StateMap grant was secured to continue mapping of the natural gas-bearing areas in Garrett County. Initial work was started in the Accident gas storage field with the goal of defining subtle geologic structures which control the movement of gas and groundwater in western Maryland. Additional studies were performed in Sang Run and McHenry. New interpretation of faults in this area have generated further investigations in the area.

Utilizing DOE/Battelle funding, the Survey has started a Triassic basin study to understand the structural geology of our exposed and buried basins. An understanding of these basins will allow further development of carbon dioxide sequestration plans within the State.

The management of sand resources along the Atlantic Coast surged with a collaboration with the Bureau of Ocean Energy Management (BOEM). The conclusion of a two year study resulted in the centralization and integration of over 40 years of studies in the near shore of Maryland. The collaboration with BOEM has been extended for two additional years. This study will result in a thorough understanding and knowledge of sand resources along the Atlantic Coast.

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 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.

MGS continued studies for dam removal projects through the investigation of geomorphological changes in the Patapsco River. Facies mapping, transects, remote sensing of facies, structure from motion, and various other techniques were utilized to document preremoval conditions on riverine systems. It is anticipated that postremoval conditions will be documented in 2017.

Maintaining the shipping channels leading to the Port of Baltimore generates approximately 3.5 million cubic yards 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 the 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.

With funding from Chesapeake and Coastal Service, MGS is updating tidewater shoreline change maps and data. Currently available data are over 20 years old and no longer reflect current conditions and trends. The new mapping will employ the most up-to-date available shorelines from NOAA and other sources, and calculate change rates at user-selected intervals and areas. Maps for Harford, Baltimore, and Prince Georges Counties were produced in 2016.

The Survey continues to participate in the National Geological and Geophysical Data Preservation Program and is currently completing the scanning and metadata of aerial imagery over many decades. Additionally, the NGGDP program is now funding the development of the geologic core database. In addition to data preservation activities tied to NGGDPP grants, MGS has been collaborating with the Maryland State Archives (MGS) and the Johns Hopkins University (JHU) library to scan collections of MGS-produced historical maps. The collaborative effort grew out of the formation of the data preservation advisory panel specified in the NGGDPP request for proposals, and has generated significant interest among the involved parties and other libraries throughout the state.

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. The state geologist is the only state-funded position. Currently, we have one benefited senior research fellow who is the lead for our geologic mapping program, and a post-doctoral fellow who is funded 75% for the next year and will work on several projects.

We have reorganized the Survey's business model and diversified our funding portfolio by establishing a Massachusetts Geological Services cost center. 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 contract office. We have developed approved billing rates and have four product categories: Geologic Reports, Map Suites, Field and Site Services and Lab Services. We believe this will provide another important avenue of funding along with our normal federal and state grants and contracts.

Geologic Mapping

Approximately 35% of all grant funding secured by MGS is for geologic mapping, most of which comes from the NCGMP. We continue to work through STATEMAP to update older 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, 4 FEDMAP quadrangles and 7 EDMAP products (Figure 1).

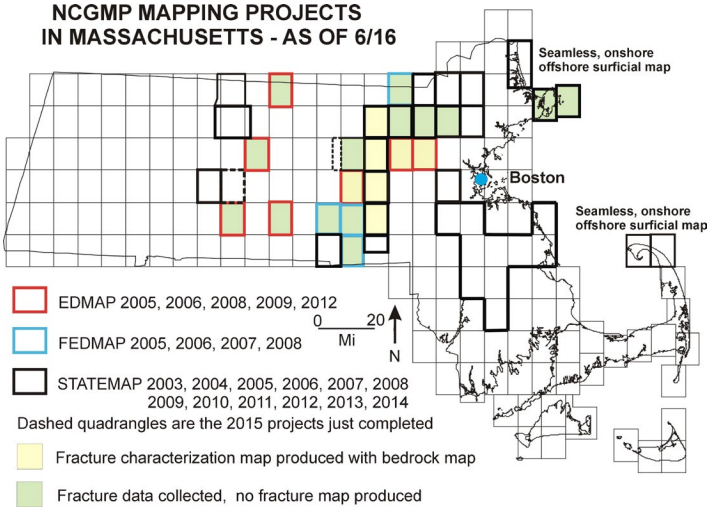

Figure 1. Map showing all NCGMP projects in Massachusetts since survey was established at the University in 2002.

MGS is also cooperating with the USGS on completing publication of surficial geologic maps for all 189 quadrangles in the state. This has been a major effort by the USGS under the FEDMAP program and will culminate with the production of a statewide Quaternary geologic map of Massachusetts on or about 2020. MGS continues to collaborate with other retired faculty on legacy mapping and acknowledges Drs. Peter Robinson and Chris Hepburn for their assistance.

Last year the MGS completed two maps as part of STATEMAP: "Preliminary Bedrock Geologic Map of the Sterling 7.5' Quadrangle, Worcester County, Massachusetts" and "Bedrock Geologic Map of the Winsor Dam and a portion of the Ware 7.5' Quadrangles, Hampshire, Franklin and Worcester Counties, Massachusetts". One mapping project is currently underway with FY16 STATEMAP funding.

Environmental Geology and Hazards

MGS continues to be involved in three major projects funded through FEMA's Hazard Mitigation Grant Program (HMGP), the Bureau of Ocean Energy Management (BOEM) and Massachusetts Department of Transportation (MassDOT).

The MGS is nearing completion of 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 is to see if the combination of expert analysis afforded by new surficial geologic mapping and shear wave velocity data produces significantly different earthquake loss estimates when compared with other methods such as Wald and Allen (2007) or assuming all soils as NEHRP category D. Analysis of the results is underway.

The MGS just completed the first two year of a four year beach nourishment project with funding from the Bureau of Ocean Energy Management. The first two years involved surveying summer and winter beach profiles at 18 public beaches across Massachusetts that are threatened by erosion or have important infrastructure that is at risk (Figure 2).

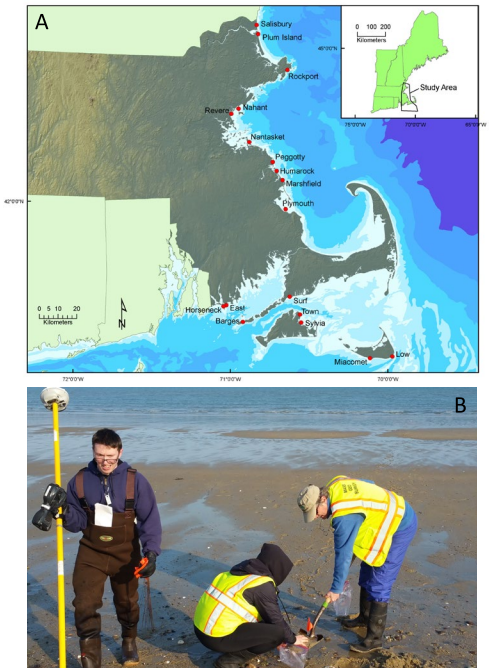

Figure 2. Beach nourishment study with BOEM funding. A) Location of beaches studied. B) Collection of beach profile data and sediment samples.

In addition, beach samples were collected for grain size analysis and characterization (Figure 3).

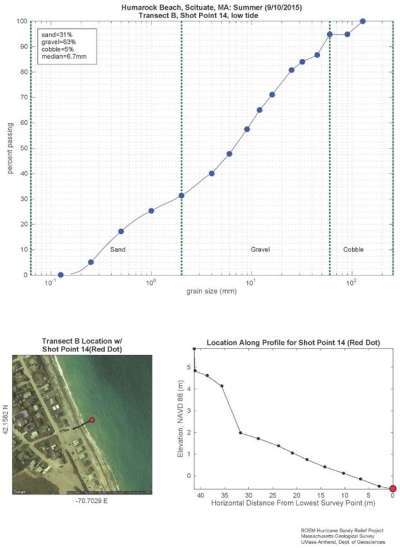

Figure 3. Example of grain size and beach profile data products to communities

Beach nourishment cannot proceed without an understanding of the beach profile and sediment characteristics. The second two-years of the project will involve analysis of vibracore, grab samples, bathymetry, side scan sonar and seismic data collected at 5 potential offshore borrow areas. The goal is to match the characteristics of the beaches with those of the offshore resources. Collaborators include the University of Massachusetts Department of Geosciences and the Massachusetts Office of Coastal Zone Management.

The MGS is in the middle of 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 focuses 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 an 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 (Figure 4).

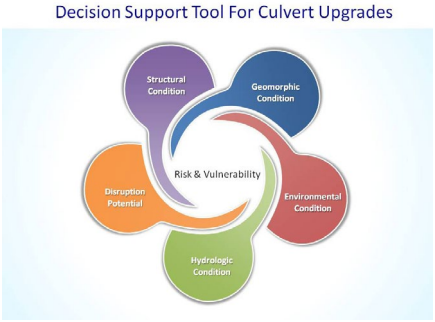

Figure 4. Elements evaluated to determine culvert vulnerability.

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.

Water Resources

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

The MGS also assists Dr. David Boutt, hydrogeologist in the UMass Department of Geosciences, with the collection

of surface and ground water 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.

Energy

Recent funding received from the Massachusetts Department of Energy Resources will be used to explore 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. This new funding will used to go back to these five areas and collect more samples for XRF analysis and to acquire temperature gradient data from deep wells to improve estimates of heat flow.

Data preservation

Two data preservations have just been completed. The first project inventoried and assessed the scope, type, quantity and condition of geologic map and field data on Massachusetts geology contained in the collections of two retired (one is deceased) University of Massachusetts geology professors. The second project will include scanning 58 maps. This includes 42 paper, 1:24,000 scale topographic maps with all the original line work on them that was used to construct the 1:250,000-scale statewide bedrock geologic map of Massachusetts in 1983 for the central part of the state. This is the only such set in existence showing the line work at this scale for this part of Massachusetts. The maps are invaluable as the basis for more detailed geologic mapping in the future at 1:24,000 scale. This work also includes scanning and digitizing 16 vellum, 1:48,000 scale hand drawn Bouguer gravity anomaly maps for central Massachusetts. These were produced by Jack Kick, a Ph.D. student at the University of Massachusetts in the 1970's, from data collected at hundreds of surveyed ground stations with a Lacoste-Romberg gravimeter. These maps have never been published and are much more detailed than any existing published gravity maps for the region.

MICHIGAN

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Introduction

The Michigan Geological Survey (MGS) in 2016 has been functioning at Western Michigan University, Geosciences Department for five years. The base functions of the Survey at this time include mapping and geologic investigation of regional areas of the State and the collection and archival of samples, cores, cuttings, and recording the documentation of geological investigations in the state. We are currently conducting shallow geological and geophysical surveys to map the glaciated terrain in local areas of the Lower Peninsula to identify potential buried water resources. The MGS mission is to serve the people of the State and the governmental entities, the Client.

The MGS announced, June 6, near the end of our fiscal year, June 30, that the Michigan Legislature has provided a one-time appropriation of $500,000 to the MGS to develop a program for assessing the natural resources of the State. MGS is extremely grateful to the three local legislators who supported this funding allocation. This is the first funding by the Legislature in more than 30 years and this will provide the opportunity for MGS to present near and long term programs that are woefully needed by the State to identify, assess, maintain, protect and develop our natural resources in an environmentally protective manner. The MGS has already completed a survey (Survey Monkey) of over 600 potential stakeholders requesting their assessment of need of why, where and when. These same questions were presented at four professional and public forums, at this time, and most of the responses have been consistent with the confidential survey. MGS is proceeding with the natural resource review with all the stakeholders (State regulatory departments and organizations and associations).

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

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. In doing this for the last three years, MGS has completed over 120 presentations of "What a Survey is" and "what we should be doing for the citizens, public and legislature of the State?" This includes meetings with the Directors and chiefs in the Governor's Quality of Life departments of Environment (DEQ), Natural Resources (DNR, Agriculture (MDARD) and Great Lakes (OGL) and with local and regional economic development managers, business and municipal regulatory 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, which includes natural resource identification, assessment, protection and development and the data management to support the overall management some of the critical natural resources i.e. water and aggregate resources in populated areas. Concurrently, Outreach has included formal presentations and formal and informal meetings and discussions and presentations of facts in a number of areas of the State for all stakeholders, which includes, professionals, academics, associations, citizen scientists, general public, legislators and the K-12 science education requirements.

Michigan has not been active in geological research for over 30 years. However, MGS discussions during past year with the USGS Mineral Resources group in both Reston, VA. and Denver, CO. These discussions have resulted in a plan to support a USGS demonstration airborne geophysical survey in the Upper Peninsula. Quality airborne data is something that is desperately needed to create an understanding of the buried subsurface Precambrian geology of the area. This will also provide a greater geologic picture of the potential for mapping the geology and identifying the structural setting that may allow identification and protection of water resources in the crystalline rock units and also those geologic systems which may be similar to those in Minnesota and Wisconsin, areas having geology that has been favorable to base and sulfide mineral deposits previously identified through airborne surveys. The Aeromagnetic survey was initiated but has been pre-maturely terminated and the USGS is working on getting this program re-started in the

future.

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 core 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 CO_2. 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 (7) million barrels of entrained oil, providing millions of dollars in additional revenue for the Michigan economy. MGS and MGRRE is continuing to work on the CO_2 sequestration through a DOE grant that has two years remaining which will continue our research and studies of CO_2 sequestration being done in Michigan. MGRRE continues to receive some donations from industry, when we have made specific requests for funding for special core and data storage.

Michigan is the number one provider of natural gas storage facilities in the geologic environment of the Michigan Basin, where the geologic samples of many of these storage systems is in the core samples retained at the MGRRE facility. MGRRE is the data resource for the energy industry and the State.

MGRRE is also recognized as the model geologic repository by the USGS in the National Geologic and Geophysical Data Preservation Program (NGGDPP), and again this year, and for the last 10 years, has received incremental grant support to secure and preserve geologic data. The MGRRE history is being touted by the USGS as an example of saving critical data and core that has provided the potential for identifying a new potash resource valued at an estimated $65 billion, that appears to be economically viable for production, by an independent company, in the Lower Peninsula, all because the data was retained at MGRRE.

MGRRE - Oil and Gas

The 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. There were two Conferences in 2016. The first had a total of 120 attendees, many from outside Michigan, at a multi session lecture and technical session held in March to more formally present the results of the multi-year research project by USGS researcher, Dr. Christopher Swezey. Chris used large segments of data from MGRRE in preparing this publication on oil maturation of Michigan formations and their potential for additional energy resources.

A second energy research program was held in September in Kalamazoo at MGRRE, lead by Michigan research engineers, looking at the natural gas reservoirs and gas storage systems in Michigan. The State of Michigan is the largest Gas Storage State in the region and the the Michigan Basin geologic formations are candidates for effective gas storage systems, again using rock core suites from the MGRRE collection. Geologists and production engineers from Texas, Oklahoma, Illinois and Colorado attended this workshop

Geologic Mapping

MGS participates in both the USGS STATEMAP and Great Lakes Geologic Mapping Coalition projects under the direction of John Yellich and Dr. Alan Kehew. Emphasis in the two USGS mapping programs is now concentrated in areas of limited geologic information that could support identifying and quantifying water resources and aquifer characteristics in the Lower Peninsula (LP). This data will also provide strong geologic evidence on aggregate locations and extent. The LP studies are being done with a refined 3-D approach which includes a combination of surface geologic mapping, utilizing new LiDAR that is available in some areas of the LP, a limited Rotosonic, wireline and 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 the stratigraphic formations and section. This also increases the quality of the data set in assessing the water bearing strata and resource availability for high production users, primarily the agricultural community as well as identifying the glacial units that have a high probability of producing aggregate resources. 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 they may be identified and not be excluded from development by changing land use.

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 the groundwater in certain areas of the State, but many of the requests do not have funding associated with any proposed study at this time.

Economic Minerals

The Western Michigan University (WMU) hard rock economic mineral geologist/petrologist, Dr. Joyashish Thakurta, has focused on the rock suites of the Upper Peninsula of Michigan. His efforts will be integrated into the MGS's role as a mapping and sample collector and analyzer of specific geologic data in little known exploration areas. He has written proposals to conduct studies with mining companies which will utilize students to sample and analyze the data for their respective thesis, the educational component of the MGS/University synergy.

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 believes and continues to search for what may be many other 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 compiled and published the first compilation of all publications on Michigan geology from the 1830's to present prepared though Michigan sources or universities, however, there was no attempt to reach out to all Universities, unless that publication could be found associated with a Michigan researcher or University. This effort by Dr. Peter Voice involved contacting all the libraries in Michigan, including universities to collect what appeared to be undocumented reports and Theses for a number of years, which was then verified by the respective geosciences departments. This research has resulted in over 6,000 references on Michigan geology now available on through 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 the elementary students but has greater emphasis of 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 general public at presentations or sessions, has continued to increase during the last three and half years and the Coordinator and staff have made over 13,000 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. Outreach also includes all the Michigan population and through this formal and informal process, the MGS is now reaching a greater audience of professionals, non- professionals and citizen scientists, which can be anyone having an interest in the geosciences.

MINNESOTA

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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 Geology and Geophysics.

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 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 50% 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.

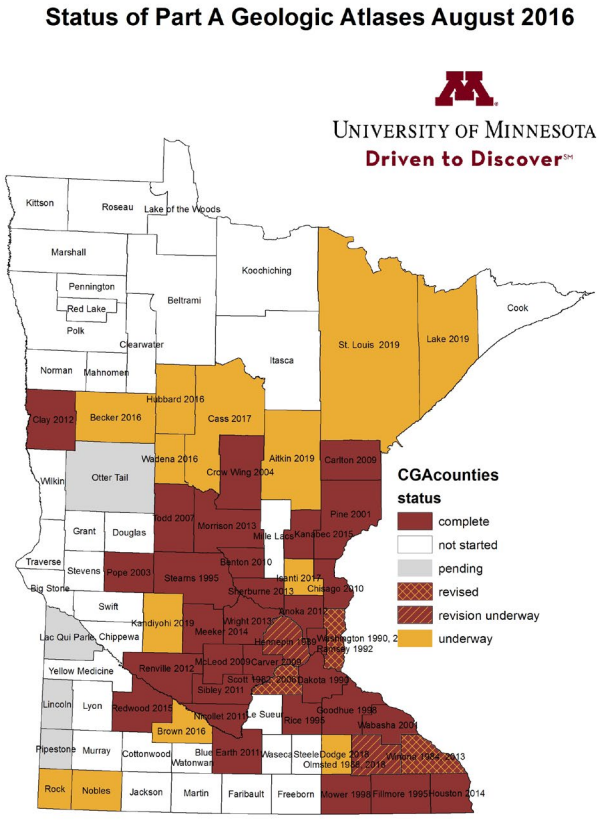

Figure 1. Status of the County Geologic Atlas Program in 2016

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 6,955 holes spanning more than 2.3 million feet of strata. We have recently created and updated the digital infrastructure of these logs, focused currently on gamma-ray data, for preservation and accessibility, using funds awarded from the National Geological and Geophysical Data Preservation Program (NGGDPP). Data from about 5,050 logs were converted from proprietary Century Geophysical Corporation format into Log ASCII Standard (LAS) format, as well as converted to PDF documents for efficient dissemination. Nearly 2,600 logs previously existed only on paper and have now been scanned to PDF images. A select number of these scanned logs deemed most important based on areas of low data density, deep drill holes and active mapping projects were digitized using the automated digitizing software available in NeuraLog (www.neuralog.com). This process extracts the x,y data from static log images, allowing conversion to digital data in the LAS file format. The data is available on Science Base Catalog (Collection of Borehole Geophysical logs from MN) and by request. Future web access on our web site is currently being evaluated.

Geodatabase development

The County Well Index (CWI), a database of water-well records and geologic interpretations of them, now contains more than 510,000 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, and the effects of geologic setting and ground water discharge on brook trout populations.

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Introduction

During Fiscal Year 2016 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 (MDEQ), 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.

Geological Data Collection Activities

The Surface Geology Division's geologic mapping program for FY2016 was funded in part by a federal STATEMAP 2015 grant of $69,990. Deliverables for the STATEMAP grant include the Pascagoula North, Three Rivers, and Harleston 7.5-minute quadrangles in southeastern Mississippi. These maps were published in color at a scale of 1:24,000 as Open-File Reports OF 276-278. The 2015 STATEMAP deliverables were delivered by the due date at the end of July 2016. Geologic units mapped, and correlated in the subsurface on the map cross section, include the Miocene age Pascagoula Formation, the Pliocene-age Graham Ferry Formation, Pleistocene-age coastal terraces, and Holocene age alluvium. Geologic mapping in FY2017 will be funded in part by the 2016 STATEMAP grant, which was awarded funding of $61,327. Mapping work in FY2017 includes the Ramsey Springs, Benndale, and Basin 7.5-minute quadrangles in southeastern Mississippi.

Two test holes were drilled to core the Eocene-Oligocene boundary in Wayne County and for geologic mapping in the Vicksburg National Military Park: the #1 LSU Hiwannee, Wayne County, core hole to a depth of 214 feet, and the #1 Patrick Vinzant, Warren County, to a depth of 430 feet. Thirty papers/books were published, including *The Geology of Mississippi* by University Press of Mississippi and Mississippi Department of Environmental Quality in April 2016 with 751 pages and 1099 figures, 10 articles in *Environmental News*, nine articles in the *Mississippi Geological Society Bulletin*, three abstracts in the *Journal of the Mississippi Academy of Sciences*, two articles in the *Mississippi Archaeological Society Newsletter*, two abstracts in the Geological Society of America, Southeastern Division, *2016 Abstracts with Programs*, and three geologic quadrangle maps as Open-File Reports OF 276-278.

The Environmental Geology Division gathers, studies, and archives subsurface geological and geophysical data for ongoing projects and other studies within MDEQ. Focused research is being done with regard to groundwater and other environmental issues. The division also provides support to other state agencies and academia. The Environmental Geology Division's geologist answers requests for information on groundwater availability, depth of wells, and potential yield of wells. These requests come from water well contractors, engineering firms, consultants, and private individuals.

MDEQ staff continue to be involved in the eight CUSEC states' work in disaster planning regarding the New Madrid Earthquake Zone (NMEZ). Northwestern Mississippi is at risk of significant damage to roads, bridges, utility systems, power grids, and other infrastructure along this active fault zone. Geologists from the Office of Geology are in contact with and involved in meetings regarding future projects and studies over the next few years.

Environmental Geology's geologists wireline logged a total of 32 test holes and water wells in 23 Mississippi counties in FY2016. Total footage logged was 16,840 feet. Eight water well contractors and two state agencies took advantage of this essential program. The Mississippi Office of Geology drilled the shallowest test hole wireline logged for the Office of Land and Water Resources. This was part of the ongoing Delta water resources project in Leflore County. Total depth of this hole was 130 feet. The deepest test hole wireline logged was sited in Chickasaw County. This test was drilled to a total depth of 1,168 feet for the City of Houston, Mississippi. Parks and Parks Water Well Service located in Houston handled the contract. Private wells comprised almost half of those logged while Industrial/Commercial wells came in second.

The Environmental Geology Division's technicians pulled, shipped and refiled samples for six geoscientists during FY2016. These visitors to the Core and Sample Library looked at approximately 210 boxes of cores and cuttings. Staff re-boxed 314 boxes of cores. Fifteen boxes of whole cores were slabbed and archived. Sample splits were

done on eight wells amounting to approximately 1,185 feet.

Numerous requests were made for digital copies of wireline data. Technicians scanned 75 new wells into the system, copied eight DVD's of wireline data and copied a number of DVD's of data from our oil and gas log files.

The Geospatial Resources Division focused its emphasis on remote sensing (RS) and geographic information systems (GIS) activities. The division manages the Mississippi Flood Map Modernization Initiative (MFMMI) and the Mississippi Risk MAP Program. This program develops and updates digital flood insurance rate maps (DFIRMs) for the 82 counties under funding by the Federal Emergency Management Agency (FEMA).

MDEQ is involved with the Mississippi Coordinating Council for Remote Sensing and Geographic Information Systems (Council) that 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. The division is responsible for the management and monitoring of MDEM data development contracts and the QA 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 FY2016, MDEQ continued monitoring and managing contractors completing work on MDEM data sets. These data included hydrography and elevation / topography Lidar data in different areas of the state. All data developed are of MDEM quality and will be made available for distribution through the Mississippi Geospatial Clearinghouse web site at: www.gis.ms.gov/Portal. During FY2017, projects continue that include development of MDEM data, including large-scale hydrography for several Hydrologic Unit Code 8 (HUC 8) river sub-basins in east-central Mississippi, and Lidar development covering the six coastal counties and the Hattiesburg/Camp Shelby area of the state.

FEMA began its new Risk MAP (Risk Mapping, Assessment and Planning) program in 2010. The program has shifted to HUC 8 sub-basin flood studies and added flood risk assessment and flood hazard mitigation and planning activities and products. As of mid-2015, there are nine HUC 8 Risk MAP projects and one LAMP (Levee Analysis and Mapping Procedure) project on the Tennessee-Tombigbee Waterway in northeastern Mississippi. This project is one of 25 pilot LAMP projects for mapping de-accredited levee systems chosen by FEMA from across the nation.

For an information-rich site for oil and gas related information, access: www.library.geology.deq.state.ms.us. A wealth of coastal data from twelve years of active research can be found at: www.geology.deq.state.ms.us/coastal. A web site for the Mississippi Flood Map Modernization Initiative (MFMMI) is available at: www.geology.deq.ms.gov/floodmaps. By visiting this site the public and local government officials are able to learn the current status of their county's DFIRM mapping project. Also, 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.

SURFACE MINING AND RECLAMATION OF SURFACE-MINED LANDS

MDEQ continued to regulate 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 inspecting complaints, overseeing the reclamation done by operators, and enforcing the law as per the promulgated Rules and Regulations and Commission orders. 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. The coal and non-coal regulations were renumbered recently to meet the style mandated by the Administrative Procedures Act.

In FY2016, the Mining and Reclamation Division performed 687 inspections (of which 73 were bond release inspections), recommended to the Permit Board the issuance of 33 initial and 5 amended permits, and received 71 Notices of Exempt Operations (operations less than four acres in size). A total of 1,938 exempts are on file, covering approximately 7,752 acres, and 1,246 acres were completely reclaimed as a result of the division's efforts to oversee reclamation. The state currently has 683 permits covering 34,063 acres. The Office of Geology's Mining and Reclamation Division

continued to update the mining database that provides valuable mining information in a GIS format so that mining sites can be located and viewed by anyone using the online Mining Viewer.

The Mining and Reclamation Division continued to provide the required Mine Safety and Health Administration (MSHA) training for mining operations in the state. MSHA regulations require an eight hour refresher training course be taught to all mine workers. In FY2016, division staff provided training to 18 miners and 71 contractors working in the mining industry.

The Coal Mining Division was established during FY2007 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 2013 for its fourth five-year term. The planned life of the permit is 30 years.

The Liberty Fuels, LLC mine permit in southwestern Kemper County was issued in December 2011, for 2,299 acres. The Liberty Mine will 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 mine. The life of mine area is planned to be approximately 18,200 acres, in Kemper and Lauderdale counties. The adjacent Integrated Gasification Combined Cycle power plant under construction is designed to produce 550 MW of electricity and be fueled by gas produced on-site from the lignite; construction is nearing completion.

Staff inspections of both mines are conducted at least monthly. One or more joint inspections of each mine are conducted annually with the federal Office of Surface Mining. One permit revision was finalized during FY2016. It is anticipated at least three permit revisions will be submitted during FY2017. One bond release was processed and approved during FY2016. One permit renewal is anticipated in FY2017, which should take approximately one year to review.

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-late 1800s to the late 1920s. The landowners of the two sites in Choctaw County do not wish to have reclamation work done on the sites. The landowners of the Lauderdale and Winston counties sites do want reclamation work done. These two sites have been determined to be a physical threat to public safety and well-being, but not to have any acid mine drainage or to be an environmental hazard. Design of the appropriate reclamation work at each site was completed in FY2015 and one site was reclaimed at the end of FY2016.

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The Missouri Geological Survey (MGS) continued to advance initiatives to increase core science by finalizing a 5-year strategic plan and taking steps to implement efficiency and effectiveness measures. The goals included better coordination and collaboration of critical natural resource issues; providing better service; and balancing financial, scientific and strategic coordination. These forward thinking efforts to better position the state for safe and timely resource assessment, protection, and development, economic viability, and natural hazards planning are being successful through realignment implementation. Functions of the survey include geologic resource assessment, environmental protection, groundwater protection through well construction, groundwater level monitoring, major water use monitoring, surface water observation and planning including interstate waters, dam and reservoir safety, and mine land reclamation, and administrative support. The survey is supported by 117 FTE and a budget of $13 million.

Primary survey responsibilities included assessment of mineral, energy and water resources. State water resource planning resumed, and oversight of oil and gas production and water well construction continue. The state hosts over 800 active industrial mineral mines yielding over $650 million in mineral value. Oil and gas production and construction of new wells over last year has remained nearly stagnant with only one company producing. MGS staff members have again been called upon to provide geologic support to many Missouri citizens impacted by recent geologic collapse, dam safety and landslide incidents. The survey finalized a publication detailing recharge areas of the state's large magnitude springs located in the south entitled, "An Update on the Recharge Areas of Selected Large Springs in the Big Four Region of the Ozarks." Missouri and Mississippi River flooding required support at multiple times during the year considering the state and surrounding area received more than average rainfall over the summer.

MGS continues to reside in the Buehler Building in the city of Rolla. Added land reclamation and water resources functions and staff that 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 the Buehler Building in Rolla. That facility accepted 60,978 additional feet of core and cuttings in 2016, an increase of 89% compared to 2015.

Administration Program

The Missouri Geological Survey's administration program 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 the survey on several councils, boards and commissions including the State Oil and Gas Council, Board of Geologist Registration, Well Installation Board, and Missouri Mining Commission. The State Geologist represents the state through the Central United States Earthquake Consortium (CUSEC) and is currently serving as president of AASG. 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 state-wide initiatives. Summer Young fulfilled functions of executive administrator, overseeing planning efforts for the 2017 annual meeting to be hosted by MGS in Branson, legislative review, and strategic planning efforts, among other duties.

Geological Survey Program

The Geological Survey Program is represented by three groups each with different disciplines:

1. The Geologic Resources Section 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. The section 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. Staff supported activities of the State Oil and Gas Council, Industrial Minerals Advisory Council, and the Geologic Mapping Advisory Committee.

2. The Environmental Geology Section provides geologic and hydrologic support for solid and liquid waste disposal,

and remediation of hazardous waste sites where aquifers have been impacted. The section evaluated the geologic characteristics of 153 proposed animal and domestic wastewater treatment systems and 32 proposed solid waste disposal sites for potential groundwater impacts. The section also investigated petroleum contaminated sites to locate the source of the contamination where aquifers have been degraded. The section evaluated the geologic aspects of 139 sites where hazardous wastes are present or suspected, including Superfund, RCRA, Federal Facility and Voluntary Cleanup Program sites. In addition, 75 non-earthquake geologic hazards assessments involving karst features or mine collapse were conducted.

3. The Wellhead Protection Section 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. Fees charged for well installation support this section.

Land Reclamation Program

The Land Reclamation Program ensures proper stewardship of the environment during and after surface mining of coal and industrial minerals, the reclamation of coal mine lands on which bonds were forfeited, and administers the reclamation of coal mine lands which were abandoned prior to 1977, and restores abandoned mine lands to productive use by:

- Issuing permits
- Conducting inspections and respond to complaints
- Overseeing the construction of restoration projects for surface coal mined lands
- Overseeing construction of the permanent sealing of dangerous mine shaft openings for both coal and metallic mining activities.

The Land Reclamation Program is represented by three overarching disciplines:

1. The Missouri Geological Survey provides support and oversight to more than 800 industrial mineral operations that mine aggregates 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.) to ensure that all exploration and surface mining operations are conducted in a manner that will not be detrimental to public health or safety, or cause environmental pollution.

2. The program 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.

3. The Missouri Geological Survey provides oversight services to coal companies through permits to comply with department of interior SMACRA requirement. Coal is a $15 million industry in Missouri.

Water Resources Center

The Water Resources Center's mission is represented by the following overarching disciplines:

1. Big River Basins: The Center protects the interests of Missouri citizens as it relates to the planning, operation, and use of the Mississippi and Missouri Rivers. The Center engages 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 represents the State as a member of the Missouri River Recovery Implementation Committee and actively works to provide citizens security regarding adequate flood control and navigation flows on the Missouri River.

2. Comprehensive State-wide Water Planning: The Center has recently begun work on a comprehensive update to the Missouri Water Plan, to take place over a 24-month period, concluding in fall of 2018. The Missouri Water Plan is a comprehensive program that takes an inventory of water use and availability, projects future water needs, and gathers stakeholder input to develop water resource development priorities. This update to the plan will work to ensure that the quality and quantity of water resources meet the future needs of Missouri's citizens, businesses, industries, and environment. Once completed, the Missouri Water 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 10 years.

3. Water Supply: The Center provides financial, technical, and planning support toward 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 3 years more than one million dollars in assistance has been provided to the development of the East Locust Creek and Little Otter Reservoir projects, Great Northwest Wholesale Water Commission water transmission pipeline project, and in planning studies for Tri-State Water Resources Coalition.

4. Groundwater: The Center provides real-time data regarding groundwater levels through one of the largest groundwater observation networks in the nation, with 171 wells

5. Dam Safety: The Center protects public safety through oversight of dam and reservoir infrastructure construction, operation and maintenance. It provides critical information to emergency responders and field staff in preparation for and during flood events. The Center 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.

Missouri State Rock: Mozarkite

Missouri State Mineral: Galena

Missouri State Fossil: Crinoid

MONTANA

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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. 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. MBMG also responds to thousands of informal queries for information and assistance.

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. Staff numbers and budget are generally stable, but have increased with the initiation of the Ground Water Investigations Program and the Geologic Data Preservation Program (OTO).

MBMG conducts research into all aspects of the geology of Montana, but groundwater dominates our work. Information for many of these projects can be found at http://www.mbmg.mtech.edu/grw/grw-main.asp. Major groundwater efforts include:

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 state-wide 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://mbmggwic.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 field work in 8 areas (22 counties) and released 60 maps and reports; 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 5 project areas. Both groundwater programs, GWAP and GWIP, were strongly supported in recent meetings of basin advisory councils throughout Montana and are integral to the new Montana State Water Plan.

OTHER GROUNDWATER PROJECTS

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

Longer term, the MBMG performs monitoring and local specific investigations in the Butte-Anaconda area through contracts with regulatory agencies and the Montana Department of Justice. This area has been subjected to releases from mining, milling, and other

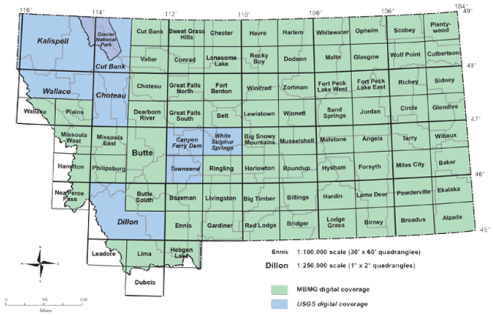
industrial sources over many decades that resulted in designation of upper Clark Fork River basin as the largest superfund site in the U.S.

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

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 ninety-four 30'x60' 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



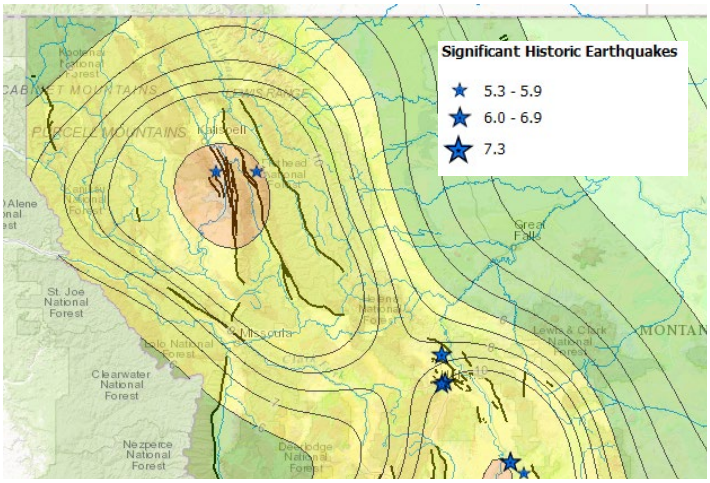
Status of Geologic Mapping as of March 2015

1:100,000-scale coverage or (2) to provide more detailed mapping in valleys and urban areas that are experiencing high growth rates and land-use pressures. The inevitable encroachment of development on mountainsides is commonly accompanied by severe problems with water resources and slope stability. PDF versions of our digital maps are viewable and downloadable from MBMG's website http://www.mbmg.mtech.edu/gmr/gmr-statemap.asp.

In addition to 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 five projects are conducted in most years.

Earthquake Studies

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



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 last decade questions related to coalbed methane have renewed impetus to the coal program and associated monitoring. 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.

Coalbed methane (CBM) is a separate, yet integral, aspect of coal resources in the Powder River Basin. With support from BLM, USFS, and other agencies, MBMG staff have provided technical hydrogeologic support and maps showing CBM potential, wells, springs, selected geology, and other data pertinent to CBM in the Montana portion of the Powder River Basin.

Mineral resources and data preservation

MBMG provides technical information on mineral resources through our mapping, our archival records as well as personal communications, mineralogical determinations, petrographic analyses, and information on recent developments in industry. 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 U.S. Geological Survey (USGS) and EPA protocols. Most of the work is related to groundwater, and the resulting data are entered directly into the GWIC database. Besides 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 δ18O/16O 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 MBMG's effort to provide digital data, databases, and web-based information. They develop and maintain the computer infrastructure, capture and convert data into an electronic format, identify methods by which researchers can analyze and interpret data using GIS technology, and assist 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

MBMG's Publication Division oversees release of research results as reports, bulletins, maps, or other publications. MBMG's website provides general information about the Bureau, its activities and projects, and various searchable databases on various topics including publications, groundwater data, abandoned/inactive mines, coal, and a soon-to-be launched database of historical mining files. Additionally, MBMG staff provide information through talks, personal contacts, and responses to thousands of informal requests. Through an agreement with the USGS, MBMG maintains an Earth Science Information Center for 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 1500 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 may request tours and special workshops.

Data center

MBMG hosts 9 online databases that includes surface water (real time and archival), ground water, coal, proppant, and mines data – many available through our new interactive mapper at http://www.mbmg.mtech.edu/datacenter/datacenter.asp

NEBRASKA

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Staff Developments

CSD added two faculty members in the past year and a part-time staff member.

Research Activities

During the previous year, the Conservation and Survey Division carried out research in stratigraphy, sedimentology, hydrogeology, geomorphology and landscape evolution, geochemistry, and geochronology.

CSD continues its cooperation in the Eastern Nebraska Water Resources Assessment (ENWRA). In 2015 and 2016 CSD drilled and logged approximately 3,800 feet of test holes aligned with the 2014-2015 ENWRA Airborne Electromagnetic Survey (AEM) reconnaissance lines to increase our understanding of the relationship between subsurface resistivity values and corresponding lithologies in eastern Nebraska. Five test holes focusing on the Cretaceous Dakota Formation (depths ranging from 380 to 734 feet) were advanced in the Lower Platte North Natural Resources District (NRD) and six test holes focusing on paleochannel deposits eroded into the Paleozoic were advanced in the Nemaha NRD. Additionally, CSD logged and provided monitoring well design services for approximately 2,000 feet of test-hole drilling along AEM lines in the Papio-Missouri River NRD in 2015-2016. A total of 15 new test holes, for all purposes, were drilled by CSD in 2016. CSD personnel are also involved efforts to improve LiDAR coverage of Nebraska and in the incorporation of metadata in USGS NGGDPP database (National Geological and Geophysical Data Preservation Program).

CSD personnel presented talks at meetings of the Geological Society of America, the Nebraska Well Drillers Association, Nebraska Water Leaders Academy, various Nebraska NRDs, and other organizations. CSD personnel also answered dozens of service calls, coordinated geologic investigations with Nebraska's Natural Resources Districts, and conducted field trips for the Nebrraska water Leaders Academy, Nebraska Geological Society, and for staff of National Geographic magazine. At least three CSD faculty are regularly involved in teaching undergraduate courses at the University of Nebraska-Lincoln.

In addition to receiving funding from the StateMap Cooperative Geologic Mapping Program, CSD also received grants from the U.S. Geological Survey, the National Parks Service, and the Daugherty Water for Food Institute

Digital Geologic Maps and Geologic Cross-Sections

(available at http://snr.unl.edu/data/geologysoils/STATEMAP/index.aspx)

Dillon, J.S., Hanson, P.R., Larsen, A., Raymond, C., Howard, L., 2016. Surficial geology of the Kearney SW 7.5-minute quadrangle.

Joeckel, R.M., Scofield, N.I., Howard, L.M., Olafsen-Lackey,S. Tucker, S.T., 2016. Surficial Geology of the Sparks 7.5 Minute Quadrangle, Nebraska Portion.

Young, A. R., Korus, J.T., Howard, L.M., Waszgis, M.M., 2016. Surficial Geology of the Raymond 7.5 Minute Quadrangle.

Published Peer-Reviewed Journal Articles with CSD Personnel as Authors or Coauthors

Gilmore, T. E., Genereux, D. P., Solomon, D. K., Solder, J.E., 2016. Groundwater transit time distribution and mean from streambed sampling in an agricultural coastal plain watershed, North Carolina, USA. Water Resources Research 52, 2025–2044, doi:10.1002/2015WR017600.

Gilmore, T. E., D. P. Genereux, D. P., Solomon, D. K., Solder, J.E., Kimball, B.A., Mitasova, H., Birgand, F. 2016. Quantifying the fate of agricultural nitrogen in an unconfined aquifer: Stream-based observations at three measurement scales, Water Resources Research 52, 1961–1983, doi:10.1002/2015WR017599.

Joeckel, R.M., Tucker, S.T., McMullin, J.D., 2016. Morphosedimentary features from a major flood on a small, lower-sinuosity, single-thread river: The unknown quantity of overbank deposition, historical-change context, and comparisons with a multichannel river. Sedimentary Geology 343, 18-37, http://dx.doi.org/10.1016/j.sedgeo.2016.07.010.

Sweeney, M..R., Zlotnik, V.A., Joeckel, R.M., Stout, J.E., 2016. Geomorphic and hydrologic controls of dust emissions during drought from Yellow Lake playa, West Texas, USA. Journal of SArid Environments 133, 37-46, doi:10.1016/j.jaridenv.2016.05.007.

Korus, J.T., Joeckel, R.M., Divine, D.P., Abraham, J., in press. 3-D architecture and hydrostratigraphy of cross-cutting buried valleys using airborne electromagnetics, glaciated Central Lowlands, Nebraska, U.S.A. Sedimentology

Miao, X., Wang, H., Hanson, P.R., Mason, J.A., Liu, X., 2016. Using both OSL and radiocarbon dates to constrain the time of soil development. Geoderma 261, 93-100.

Published Bulletins By CSD Personnel

Divine, D.P., 2015. The Groundwater Atlas of Saunders County, Nebraska. Conservation and Survey Division, Resource Atlas 9. Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln.7 p.

Divine, D.P., Joeckel, R.M., Lackey, S.O., 2016. Aquifers of Nebraska I: The Codell aquifer in northeastern Nebraska. Conservation and Survey Division, Bulletin 7 (New Series), Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln. 21 p.

Young, A.R., Burbach, M.E., Howard, L.M., 2016. Nebraska Statewide Groundwater-Level monitoring Report 2014, Nebraska Water Survey Paper No. 83, Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln.

NEVADA

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The Nevada Bureau of Mines and Geology (NBMG) is a research and public service unit of the University of Nevada 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 and 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 the economic development, public safety, and quality of life in urban and rural areas of Nevada. These include reports on mineral and energy 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. 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, water-resource, 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, Geochemistry, and Basic Geology

Current NBMG activities include detailed geologic mapping and stratigraphic studies in Nevada; research on the origin of gold and other metal deposits; geochemical investigations of mining districts; resource assessments on public lands; investigations of geothermal resources in the Great Basin region; 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 2014, Nevada led the nation in the production of gold and barite, and was the only state that produced magnesite and lithium. In many of the recent years, Nevada has led the nation in overall nonfuel mineral production. Mining in Nevada helps place the United States 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. Nevada hosts one of the two FORGE sites under investigation for a national field laboratory in geothermal energy. The Nevada site is located in Fallon in west-central Nevada. FORGE stands for *frontier observatory for research in geothermal energy* and is a program sponsored by the Department of Energy for testing technologies and methodologies for engineering/enhancing geothermal systems.

Environmental, Engineering, and Urban Geology

Major projects include investigations of earthquake hazards, crustal strain, and related aspects of neotectonics; studies of land subsidence in Las Vegas Valley and near some of the mines and geothermal power plants; and investigations of flood hazards on alluvial fans, rivers, and major streams. The NBMG's Geodetic Laboratory has built a network of global positioning system (GPS) stations across the Great Basin and is at the forefront of global research in geodesy. Programs are underway to increase the public awareness of earthquakes in Nevada and to prepare for emergency response when a major earthquake occurs. Satellite-based interferometric synthetic aperture radar (InSAR) is also being used to evaluate geologic hazards.

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 on the World Wide Web (http://www.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 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 American Institute of Professional Geologists, 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 for natural hazard risk reduction and emergency response.

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 Information Office 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 24 geoscientists and support staff. This includes fifteen geoscientists, four professionals in support of publication production (cartographers and GIS specialists), 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 external grants and contracts. In addition, NBMG employs about 20 graduate student assistants and several undergraduate student assistants. Ten emeritus staff members are also engaged in various professional activities. More information about products, programs, and staff is available on the Web (www.nbmg.unr.edu).

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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 ground water level monitoring programs.

Geologic Mapping

Surficial geologic maps completed under the most recent STATEMAP scope of work included the Danbury, Jefferson, and Jackson 7.5-minute quadrangles. These new surficial quadrangle maps increase the total number of completed quadrangles to 123, representing 58% of the 213 7.5-minute quadrangles that comprise New Hampshire. Bedrock geologic mapping was completed for the northern half of the North Grantham 7.5-minute quadrangle and the southern half of the Jefferson 7.5-minute quadrangle.

The FEDMAP Northern Appalachian Bedrock Mapping Project continued to focus on the Connecticut River Valley, spanning the border between New Hampshire and Vermont.

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 69 geoscientists.

Flood and Geologic Hazards

The flood and geologic hazards program within NHGS has enjoyed another year of success, particularly related to stream crossing (culvert) assessments, which has become a core component of the program's portfolio. While stream crossings are being assessed in states throughout the country to support improved fish passage and aquatic connectivity, New Hampshire's efforts are primarily focused on the potential risks posed by flood-induced culvert failures. In collaboration with the NHDES Wetlands Bureau, NHGS hosted 4 interns during the summer of 2016, who collectively added an additional 481 crossings to the ever-expanding state database of 6,621 stream crossings as of fall 2016. Also this year, the state established a stream crossing steering team, comprised of NHDES, NH Department of Transportation, NH Fish & Game Department, and NH Division of Homeland Security and Emergency Management (NH HSEM), to collaboratively guide and manage the multiple data collection efforts and database management issues. NHGS chairs this team, and provides leadership to this collaborative statewide effort. The collected data are used by NH HSEM in the state Emergency Operations Center (EOC) during flood events, and in hazard mitigation plans to help towns prioritize culverts for replacement with properly sized structures, using hazard mitigation funds. In collaboration with the NHDES Wetlands Bureau, NHGS has hired a part-time staff member who is working on developing technical criteria for how to use the collected data to allow wetlands mitigation funds to also support the most critical replacements.

NHGS continues to chair and lead the New Hampshire Silver Jackets team, in collaboration with NH HSEM, the state National Flood Insurance Program coordinator, and the Army Corps of Engineers. In the summer of 2016, NHGS led a technical team of state and federal agencies in a geomorphic assessment of a brook of concern in the Town of Hinsdale, which has experienced flood and bank erosion issues in recent years, a project requested by the town. A final report will be provided to town officials in the near future. New Hampshire Silver Jackets put forward an application for a project in 2017, which was selected for Army Corps technical assistance that will focus on geomorphic and hydraulic examinations on the Gale River in the Franconia area. This project, of interest to the Town of Franconia, comes in the wake of an ice jam on this river in February 2016. NHGS flood and geologic hazards program staff assisted with a field assessment in the aftermath of the event to identify potential causes. The new project, which brings together 9 state and

federal agencies, will more closely examine factors that led to the ice jam formation, the first known occurrence at its location. The Army Corps Cold Regions Research and Engineering Laboratory will be a participant, and has expressed interest in the project.

In addition to these efforts, the flood and geologic hazards program continues its strong relationship with NH HSEM. There is increased interest in ensuring that flood and geologic hazards program staff expertise is available within the state EOC during predicted major flood events. Program personnel also work closely with NH HSEM staff relative to flood components of state hazard mitigation planning, and assist in serving as a liaison between NH HSEM and NHDES. The program continues to provide fluvial geomorphologic expertise to units throughout New Hampshire state government.

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. Another year of stream permanence monitoring was completed in headwater channels using state sensors at nine new 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 are nearing completion 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. Public and agency interest in the groundwater monitoring data has been heightened by drought conditions that began to develop throughout the southern and central portions of the state early last spring.

Quality Level 2 airborne LiDAR for a total of 5,200 square miles (56% of the state) was recently delivered by the contractor after being acquired during fall 2015. The State Geologist, with multi-agency support, was successful in obtaining a Capital Budget appropriation during the fiscal year 2016-2017 biennium as match for funding that was awarded under the USGS 3D Elevation Program. Additional funds from the Natural Resources Conservation Service and the Federal Emergency Management Agency enabled the project footprint to expand beyond the 3,600 square mile footprint that was originally proposed. FEMA has subsequently committed to funding acquisition for the remaining 14% of the state. NHGS geologic mapping and flood and geologic hazards programs have greatly benefited from the new dataset. Considerable interest in the acquired LiDAR has also been expressed by programs within NHDES, NH HSEM, USGS, the state flood insurance program coordinator in support of enhanced floodplain mapping, and the land surveyor community, among others. The State Geologist continues to promote the 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 summer, NHGS was fortunate in enlisting the help of 2 part time volunteers to enter and scan 3285 reports from the estimated backlog of approximately 5000 reports.

NHGS completed its deliverables as part of a 2-year project, "Assessment of Offshore Sources of Sand and Gravel for Beach Nourishment in New Hampshire," in partnership with the University of New Hampshire Center for Coastal and Ocean Mapping and funded by the Bureau of Ocean and Energy Management. Changes in shoreline positions have been mapped using a sequence of historical aerial photography and trends in erosion/accretion of New Hampshire beaches have been quantified based on repeat airborne LiDAR datasets. The results are available through the state's Coastal Viewer web mapping application. NHGS is now partnering with the NH Coastal Program to implement a long-term volunteer beach monitoring program wherein volunteers will conduct monthly surveys along established beach transects.

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 Lee Wilder, NHGS Public Outreach Coordinator at geology@des.nh.gov

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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. In 2016, we had a total of 59 full and part-time employees, supported on a mix of state appropriation as well as funds obtained from grants and contracts.

In late spring 2014, we moved into a beautiful new building (Figure 1). Prior to this move, our organization had been housed in 4 different buildings across the New Mexico Institute of Mining and Technology campus, and moving into a single, purpose-built space has been a major step forward for us. The two showpieces of the building are our Mineral Museum and Publications Bookstore, which are located to either side of the main entrance to the building. We expect both these important components of our organization, described below, to thrive in their new settings.

Mineral Museum

With over 15,000 visitors per year, the Mineral Museum (Figure 2a and 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 United States. Each year,

the museum staff hosts the New Mexico Mineral Symposium, one of the largest meetings of its kind in the United States, attracting participants from around the world. Funding for the symposium (approximately $15,000) 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 17 donations in 2015 with an aggregate value of $610,000. 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 fiscal year 2016, direct monetary donations and sales from the gift shop generated approximately $50,000.

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 2016, monetary goals were defined to fund two projects: an outdoor walking exhibit of petrified wood, 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.

Publications Bookstore

Our new building includes a large, inviting space for our Publications Bookstore (Figure 3), placed just inside the main entryway, opposite the Mineral Museum. As part of designing the new space, bookstore staff expanded the types of items that we sell to venture beyond our

traditional inventory of geology publications, while keeping to a general geoscience theme. Some of the addition items include 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.

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 on-line, via direct download of viewing in our new interactive web-based application.

During 2016, our mapping group completed ~540 square miles of mapping under STATEMAP program. Ten maps were completed, and 23 maps were digitized. We received $154,913 awarded through National Cooperative Geologic Mapping Program. We were successful in winning several additional awards, including $350,000 awarded through a grant from the New Mexico Environment Department, $26,314 for a Pajarito Fault Study grant from LCI and Associates, and a $20,530 Quaternary fault database grant from the USGS. Our geological mapping program web site received a large number of visits (538,952), representing 7% of the web traffic for our organization.

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 a core goal of this research work. Ongoing projects include focused research in a large number of New Mexico counties and municipalities.

The hydrogeology studies group received an important gift in 2016 from the Healy Foundation to benefit the New Mexico's water and natural resources. The funds will be used to support two new 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 the local hydrogeology and groundwater conditions, which 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 web site.

The second project focuses on the development of digital maps of aquifers. New Mexico is the fourth leading state in terms of dependency of 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% of our land surface covered with water, needs (but currently lacks) 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 being addressed by this group 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, which will help guide water planning; and producing a statewide groundwater recharge model.

Energy and Minerals

Energy and mineral resources, including petroleum, coal, uranium and geothermal, all contribute to New Mexico's economy. Our petroleum research group produces primary 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 borehole temperatures, which can be used to evaluate geothermal resources around the state.

Among many specific energy and mineral projects that have been active in the past year, one focuses specifically on helium. Despite its importance in a modern, technological society, helium gas deposits are rare, and helium is typically a trace component of natural gases being emitted at the Earth's surface. As established supplies have become stressed, the price of helium gas has increases from $18 per thousand ft^3 to more than $200 per thousand ft^3. Helium has been mined in New Mexico, and the location of helium resources has been mapped by Ron Broadhead, our principal senior petroleum geologist. The mapping was carried out by examining the helium content of gases as a function of rock type and stratigraphic position. Then, correlations are examined between the variations in the geologic setting of the gas reservoirs, and the helium content of the gases, which can be used to better understand why high helium gases are found where they are.

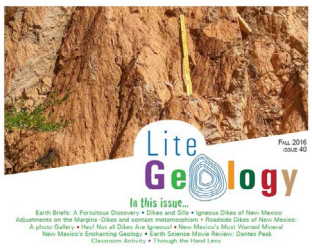
Laboratories

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 202 users, including 62 students from New Mexico Tech.

In the past two years, our laboratory capabilities have increased significantly. Through internal and external funding, a new Helix noble gas mass spectrometer (~$400,000), and a new microprobe spectrometer ($129,000) were acquired, and are contributing to analytical excellence. Also, an older ICP-MS was upgraded, and a new titrator was purchased, which has improved analytical speed and quality.

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 Matter* (Figure 4) and *Lite Geology* (Figure 5) as well as other, more technical publications, and other geological materials, can be purchased at our store or through our web site. 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 2016, in Las Vegas, New Mexico, at New Mexico Highlands University (Figure 6). There was full-capacity, K-12 teacher participation with 28 teachers from across the state. In order to help teachers and students better understand topographic maps, and geological processes, our staff built an "augmented reality sandbox" (Figure 7). This interactive sandbox allows users to create topography models by the sand. An elevation color map and topographic contour lines are then projected onto the sand surface. Rainfall and water-driven erosion processes can also be simulated. The system teaches users how to read a topography map, the meaning of contour lines, watersheds, catchment areas, as well to better understand geomorphic processes. The sandbox is very popular with teachers, students, and professional geologist, alike.

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 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 808,563 distinct visitors to our web site , and there were more than 7.9 million website page requests. A total of 19.45 TB of data were downloaded.

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

The New Mexico Bureau of Geology and Mineral Resources has received a number of honors in the past year. Dr. Ron Broadhead, Principal Senior Petroleum Geologist, received a lifetime service award from the New Mexico Oil and Gas Association. Peggy Johnson, hydrologist (ret) received a community service award from the Taos County Commissioners for 20 years of water science work in the county. A New Mexico Bureau of Geology and Mineral Resources Bulletin entitled "*Geology and Hydrology of Groundwater-Fed Springs and Wetlands at La Cienega , Santa Fe County, NM*", authored by Peggy Johnson, Daniel Koning, Stacy Timmons, and Brigitte Felix, received the John C. Frye Memorial Award for Environmental Geology, which was presented at the 2016 annual Geological Association of America meeting.

NORTH CAROLINA

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Introduction

The N.C. Geological Survey completed its 191st year of service to the State of North Carolina. A significant change occurred in late November 2015 when the Division of Energy, Mineral, and Land Resources (DEMLR) was broken up and the Energy Section and Geological Survey Section were moved into the Energy Group in the Office of the Department Secretary. We had a new Executive Director and this reorganization created a higher profile on our oil and gas research and our State's offshore oil and gas potential.

Geologic mapping

In July 2015 the NCGS started our STATEMAP 2016 with detailed mapping in all three of the Provinces. A geoprobe truck was acquired from the Division of Water Resources at no cost to support coastal coring for a 3-D perspective on coastal stratigraphy.

State Geologist served as a peer reviewer on the STATEMAP panel for year 2 of 3. NCGS hosted the STATEMAP Review panel in Asheville at the Mineral Research Laboratory and the NCGS's Asheville staff lead a fieldtrip to look at Blue Ridge and Inner Piedmont geology and geologic hazards.

Most of the NCGS staff were supported to attend and present at the GSA -- Southeastern Section Meeting in Chattanooga, Tennessee.

Energy research

Received new funding for oil and gas research from the General Assembly. Five hundred thousand dollars was allocated for the FY 15-16 year. New diamond coring was proposed at a new site in the Dan River Basin as well as analyses of last year's coring samples. The FY 15-16 funding was proceeded by $250K in FY 13-14, $300K in FY 14-15. There have been a number of presentations at oil and gas conferences on the results of our research. Most of our results are posted on AAPG Search and Discover web site.

NORTH DAKOTA

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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.

Activities of the NDGS

The Activities of the NDGS from July 1, 2015 to June 30, 2016 are summarized below:

Bakken and Three Forks Projects

We published articles on the Bakken Petroleum System including lower Lodgepole, Bakken, and Three Forks Formations (Mississippian and Devonian), including two core workshops. We also published a report on the Red River Formation (Ordovician).

Inyan Kara Formation

The vast majority of produced water in North Dakota is disposed of in the Inyan Kara Formation of the Dakota Group (Cretaceous). The Inyan Kara Formation primarily consists of sandstone, shale, and mudstone deposited in marine and nonmarine settings. The rapid increase in produced water volumes (around 1 million barrels per day) has drawn attention that some of the disposal wells are located in areas where shale is the more dominant lithology. For that reason, we began a mapping project to identify the optimal areas for saltwater disposal. We recently published two 100K sheets and will publish an additional four or five by June 30, 2017.

Temperature Project

A year ago we temperature logged 21 temporarily abandoned oil and gas wells between the depths of 3,000 and 13,000 feet in the North Dakota portion of the Williston Basin. This year we logged two additional wells and hope to continue logging two wells every year for the next four or five years. The results of the 23 temperature logs were recently published as NDGS Report of Investigation no. 115 (170 pages).

Rare Earth Project

We collected 180 lignite samples from the Fort Union Group (Paleocene) in western North Dakota for rare earth analysis. One hundred samples have been analyzed and the others will be sent to the lab this winter along with the 100 or so additional samples we collected this fall. Preliminary results will be reported in our January 2017

GeoNews (newsletter).

Geologic Mapping

We published 15 quadrangles (24K) this reporting year. One from the Minot area and the other 14 were from the Grafton 100k sheet in northeastern North Dakota. We also published landslide inventories for 21 quadrangles, identifying 701 landslides over an area of 14,440 acres. We recently accelerated the landslide mapping program to stay ahead of the wind farms that are being contemplated for North Dakota.

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 vertebrate fossils (Cretaceous dinosaurs, Tertiary mammals, Ice Age mammals, etc.). Our paleontologists supervised six public fossil digs during this time period (five in western ND and one in northeastern ND). The paleontologists collected 65 fossil field jackets during these digs and will be processing them this winter. We upgraded the graphics on our Cretescope (an interactive dinosaur display) this year and switched over from two IPads to a 55 inch flat screen panel. The ruggedized IPads were no match for the beating they took from the excited youngsters yanking them to and fro while they watched a Tyrannosaurus Rex and a Triceratops battle.

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 miles of core (150,000 three-foot core boxes) and 45,000 sample boxes. In addition to the cores and samples, we have approximately 21,000 thin sections made from these cores. We have photographed each thin section as well as 132,000 feet of core and placed the resulting 356,000 photos on the Oil and Gas Subscription site. In 2015, the North Dakota Legislature gave us $13.6 million for a core library expansion. We began construction on the new core facility in August 2015. We demolished the old core laboratory and office space and replaced it with a two story building that has six times the space and contains four core labs (one of which is dedicated for student usage), as well as a core photo lab, a core gamma ray lab, analytical lab, and a microscope lab. We removed the west wall of the original warehouse and attached a new warehouse that was double its size. The original warehouse filled to capacity in February so the expansion came just in the nick of time.

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 on state owned land. Over the past 12 months, we issued 81 permits under these programs. The majority of these permits were for residential, closed-loop geothermal systems.

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 69 presentations to 9,600 people and answered more than 2,900 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. For the last eleven years we have staffed a booth at the North American Prospect Expo (NAPE) in Houston, Texas. Hundreds of attendees typically stop by our booth during the two-day event to discuss the oil and gas posters we post for the event. In June we gave tours and spoke at the North Dakota Petroleum Council's annual teacher seminar.

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. We reviewed 109 projects including municipal and industrial solid waste permits, coal mine permits, infrastructure projects (roads, bridges, pipeline corridors, transmission line corridors, and wind farms). When requested, we assess the mineral potential (oil and gas, coal, sand and gravel, etc) on State lands.

Geologic Projects

We published 47 articles, maps, and reports on various aspects of North Dakota geology this past year.

OHIO

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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 with a satellite office at the Horace R. Collins Laboratory at Alum Creek State Park. The Division's staff of 26 provides technical expertise to citizens, industry, and other agencies of government concerning coal, oil and gas, minerals, and geologic hazards. During FY 2015 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 245 percent from June of 2014 to June of 2015.

The Division is organized into five groups: Administration, Energy Resources, Geologic Mapping & Industrial Minerals, HRC/Lake Erie Studies (HRCLES or "Hercules"), and Publications & Geologic Records Center.

Administration

The increased severance income associated with the Utica Shale play has allowed Chief Thomas Serenko to focus on two main needs of the Division: replacing retired staff (over a dozen retirees in four years) with enthusiastic new staff and obtaining badly needed field vehicles, laboratory and field equipment, software and hardware, furnishings, and displays. Chief Serenko has been with the Division for four years and has put an emphasis on rebuilding the data collection and research capabilities of the staff. He also has increased the Division's efforts in public outreach and partnering with other Divisions at ODNR. Chief Serenko has also noted the pressing need to systematically archive, preserve, and catalog the Division's significant paper and digital collections of maps, reports, files, records, and data. Assistant Chief Mike Angle handles many of the day-to-day operations, including budgetary, fiscal, contractual, and legal matters. He also helps review geologic reports, proposals, and oversees grants. He helps mentor newer employees and assists with numerous public outreach activities. Administrative Professional Renee Whitfield joined the Division in March and has been an immediate help to the Administration. She helps with fiscal and budget matters, oversees inventory and purchasing and helps oversee policy and rule changes. Her amiable personality is great for planning meetings and group activities. One of Chief Serenko and Renee's main projects has been to create a new meeting/conference room with modern projection, A/V, and audio capabilities J. D. Stucker and Chuck Salmons also have helped spearhead this major and badly-needed improvement. The room has been named the Poverty Run after a Pennsylvanian-age limestone in eastern Ohio.

Energy Resources Group

Dr. Mohammad Fakhari supervises the Energy Resources Group with great enthusiasm and serves as a good mentor to the younger staff geologists. Mohammad enjoys working on structural trends of shallow anticlines in northwestern Ohio as time allows. Senior Geologist Ron Riley retired in December of 2015 after completing Open-File Report 2016-3: *Mapping Source Rock and Thermal Maturity of the Devonian Shale Interval in Eastern Ohio.* Ron also continued to lead efforts with the Midwest Regional Carbon Sequestration Partnership (MRCSP) on suitable target formations for CO_2 sequestration. For the MRCSP project, Division staff conducted permeability analyses for select core samples from Ohio and surrounding member states. These analyses were performed at The Ohio State University, School of Earth Sciences SEMCAL Laboratory. Geologist Michael Solis has (1) worked on a report of investigations analyzing deep seismic lines in eastern Ohio, (2) delineated subsurface structural trends for an article in the AAPG Bulletin, and (3) been mapping salt deposits of the Silurian Salina Formation in eastern Ohio. The salt deposits reflect a resource, a potential barrier or cap rock for CO_2 sequestration, and a potential deep gas storage area in southeastern Ohio. Geologist Dominique Haneberg-Diggs has helped process, performs analysis, and interpret seismic profile lines and geophysical logs and is doing research on Silurian stratigraphy in southwestern Ohio. The goal of his Silurian study is to determine

how units change as they move from a near surface setting along the Cincinnati Arch eastwards into a deep subsurface setting within the Appalachian Basin. New geologists Kyle Metz and Chris Waid are following up on Ron Riley's research by working on the Devonian units as a potential source rock. Kyle is splitting out the various pay or organic-rich zones within this thick sequence. Kyle is also working on an ethane storage project for which we are collaborating with the Pennsylvania and West Virginia Surveys. Chris Waid has an extensive paleo background and is applying a sequence stratigraphic framework to the Devonian shale units. New geologist Julie Bloxson is working on mapping Silurian and Devonian units in northeastern Ohio and is noting how the facies change moving southward as she links with Dominique's study area. Julie is preparing to defend her dissertation on the mineralogy of the Utica Shale at Case Western Reserve University in Cleveland. 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 & Industrial Minerals Group

For the first time in over a decade, the Mapping Group conducted detailed bedrock mapping together with surficial mapping for the 2015–2016 USGS STATEMAP project. Senior geologist Frank Fugitt and geologist Audrey Blakeman performed detailed mapping of Mississippian rocks adjacent to the Scioto River valley near Portsmouth. Together, they mapped the bedrock geology of the Portsmouth, Friendship, West Portsmouth, and New Boston 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 adapted. Audrey is working on a report describing these changes in stratigraphic nomenclature. For the 2016–2017 STATEMAP project, Frank and Audrey will continue mapping Mississippian strata to the north and east, covering the Waverly and Lucasville, 7.5-minute maps. Frank also assisted intern Dreadnaught Stubbs, a M.S. candidate from Ohio University, with measuring numerous sections of Pennsylvanian-age rocks near Nelsonville, Ohio. Also as part of the 2015–2016 STATEMAP project, geologist Douglas Aden mapped the surficial geology of Portsmouth, Friendship, West Portsmouth, and New Boston 7.5 minute quadrangles at 1:24,000 scale. Senior Geologist Richard Pavey helped oversee this work before his retirement in October 2015.

The USGS-sponsored Great Lakes Geologic Mapping Coalition (GLGMC) is another long-term funding source for the Division. For 2015–2016, new geologist Nate Erber mapped the surficial geology of the Chillicothe East 7.5-minute quadrangle. During the mapping process, Nate discovered a recent excavation pit in the pre-Illinoian Minford Silts associated with the Teays Valley. Samples were sent to the University of Cincinnati for age dating. Nate is also helping to create a glacial till samples database and GIS layer that will geospatially locate thousands of samples with particle grain size and carbonate content analysis that should prove helpful for future mapping and research initiatives. Geologist Douglas Aden is leading the karst mapping component of the GLGMC project and recently produced Open-File Report OFR 2016-4: *Karst of the Belfast and Sugar Tree Ridge 7.5-Minute Quadrangles, Ohio*. Douglas is currently mapping karst in the Sinking Springs 7.5-minute quadrangle in southern Ohio. Douglas also serves as the Division's IT liaison and coordinator and helps manage the Division's extensive digital files and archives.

Senior Geologist Paul Spahr now serves as the supervisor of the Mapping Group, and he has begun an ambitious program of planning for future mapping and research projects. In November of 2015, geologist Lee Sorrell and Paul Spahr completed mapping and a resource estimate for the Pittsburgh (No. 8) and Lower Freeport (No. 6a) coal seams in eastern Ohio. Funding for this was provided by the Ohio Coal Development Office (OCDO). This work resulted in the publication of OFR 2016-1: *Evaluation of Available Resources of the Lower Freeport (No. 6a) Coal Bed in Ohio* and OFR 2016-2: *Evaluation of Available Resources of the Pittsburgh (No. 8) Coal Bed in Ohio.* A subsequent project has been proposed for the OCDO for mapping the Kittanning sequence (No. 5–No. 6) coals in eastern Ohio. New geologist Chris Wright and Shane Smallwood have been hired to replace Mr. Sorrel on the OCDO project.

Geologist J. D. Stucker compiled the 2014 *Report on Ohio Mineral Industries* which was released in November of 2015 and is finalizing the 2015 *Report on Ohio Mineral Industries* to be released in November of 2016. J. D. has worked hard to streamline and update this process. Along with Chief Serenko, J. D. represented the Division at the Forum on Industrial Minerals Conference in southern Indiana in August 2016.

Finally, 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 more than 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. Geologist technician Jeff Deisher serves as curator and oversees the collection, working with laying out core and collecting samples for visitors. Jeff has had some recent opportunities to obtain core from northeastern Ohio. Mark and Jeff are kept busy making necessary repairs and maintenance and are looking at some badly needed upgrades to lab equipment, classroom furniture, and modernizing the Ohio Seismic Network office.

Files and maps at the HRC are being organized and scanned to create a Lake Erie Data Center and a data archive for Division information. New records officer Lisa Long has been making good progress archiving and cataloging the vast number of maps, charts, files, and digital records associated with the former Lake Erie Geology Group. Ann Rogers, a M.L.S. student of Library Science completed a practicum during the summer of 2016 in which she helped archive and organize a large volume of side-scan sonar data. This effort is critical in helping the Division determine how much of the nearshore portion of the Lake has been analyzed with this technique. New geologist Amy Spaziani is conducting research on Lake Erie coastal processes including a NOAA-funded Textural GIS grant, where bluff composition was compared against transects depicting shoreline recession. The goal was to calculate the amount of sediment added to the sediment supply for the lake along the areas of eroding shorelines. This data will help predict formation or loss of beaches, effectiveness of shore protection, and other related factors along the coastline extending from Cleveland westward to the city of Huron. Amy is also doing an analysis of the data from this project and comparing it with historical sand and sediment supply data obtained from the U.S. Army Corps of Engineers. Mark Jones and Amy are also involved with another round of Coastal Erosion Area (CEA) mapping. This mandated program 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 Nate Erber and Douglas Aden are helping determine and digitize the shoreline recession. Erosion rates are factored 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 rolling the findings out in public meetings and addressing objections or concerns from the public.

The Ohio Seismic Network (OhioSeis), headquartered at the HRC, monitored earthquakes in the state using its network of 27 volunteer-run stations. Dr. Michael Hansen, founder of the OhioSeis network in 1999, retired at the end of 2015 after 40 years of service to the Division. Geophysicists Jeff Fox and Daniel Blake are now managing all the OhioSeis-related activities. The OhioSeis program has made great strides at implementing new IT developments, seismometers, data downloading, storage, and archiving. The OhioSeis staff visited a number of the network stations to troubleshoot current instrumentation and determine likely sites that can be upgraded to newer and more sensitive seismometers. The Division has obtained four modern seismometers, which were installed permanently in vaults in relatively "quiet" portions of the state to determine if there is any low-level seismic activity in these regions. The Division also purchased three (and has deployed two) NetQuake seismometer units that will be tied into the USGS national system. These units provide a trigger notification via e-mail if an event is recorded. The OhioSeis staff has also been working with data from the U.S. Transportable Array (TA)/EarthScope network, which has proven very valuable in locating seismic events. The Division has purchased three of the TA stations in eastern Ohio to help insure that this valuable monitoring continues. Senior geophysicist Jeff Fox has been working on a number of outreach-related activities, and Daniel Blake has been working with some shallow seismic data acquisition.

PUBLICATIONS & GEOLOGIC RECORDS 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, providing support for outreach activities, updating the website content, and taking care of printing and publishing tasks as well as editorial duties. Chuck has a particular interest in outreach activities geared towards children and has authored Educational Leaflet (EL)-21-*Your House Rocks* and an *Ohio Rocks ! Activity Book*. Chuck also serves as a liaison with 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 also 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 processed 215 web orders; assisted 200 counter customers; processed 370 miscellaneous sales transactions; taken over 500 phone calls; and distributed over 15,000 free handouts, such as leaflets, pamphlets, and 8½ x 11 geologic maps on various topics. Digital copies of downhole geophysical logs for oil-and-gas wells remain the largest selling item at the GRC. So far for calendar year 2016, income from the sales of maps, reports, and digital information was over $30,000. Madge also performs a myriad of behind-the-scenes tasks for the Division ranging from organizing all of our social and meeting events, such as our annual winter and summer picnics, to handling our petty cash account.

Archivist Cindi Flanagan left the Division in August 2015 and since has been replaced by Lisa Long who continues the relentless effort of going through Division files and records at both the Columbus office and the HRC. Lisa, along with Douglas Aden and Brittany Parrick, completed a USGS Data Preservation Grant project to curate the Division's extensive collection of 2" x 2" photographic slides and scan these into a more useable digital format. Over 2,500 slides were scanned. Metadata was created and embedded into the slides directly and into a master Excel spreadsheet, which was then converted to .xml format for upload to the USGS. Lisa also authored a very detailed final technical report for this project.

The group, along with the geological and administrative staff, has had a busy year of public outreach, participating in a number of major rock and mineral and fossil shows, including events held at Akron, Cincinnati, and Columbus in April; partnering with the Cleveland Museum of Natural History in October; participating in the Cincinnati Fossil Fest in November; and helping conduct a fossil and building stone tour at the Ohio State House. The Division also has a large presence during Earth Science Week in mid-October, including leading hikes at a number of state and metro parks and nature preserves, and hosting a number of presentations at universities and primary schools. The group also assists Ohio Aggregates and Industrial Minerals Association (OAIMA) with some of its educational outreach opportunities and at its annual conference in November. OAIMA also sponsors an annual legislative reception at the State House in which the Division participates.

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 College of Earth and Energy. The Survey is chartered in the Oklahoma Constitution and is charged with investigating the state's land, water, mineral, and energy resources and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources consistent with sound environmental practices. The OGS is not a regulatory authority. 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. OGSA employs 35 staff, including those working at the Oklahoma Petroleum Information Center, our core and oilfield data repository.

The dominant activity of 2015-2016 for the OGS centered on response to the rise in seismic activity. OGS took an official position in early 2015 that the earthquakes were triggered when saline formation water was injected into the Arbuckle Group. The very large volume of produced water came from high water cut wells in two limestone formations. Pressure transmitted from the Arbuckle into the underlying basement triggered earthquakes on faults, many of which were previously unrecognized. The earthquake frequency remained high through 2015, then began to decline in March 2016.

In the background of this sometimes frenetic activity, OGS completed a number of map projects, both for STATEMAP and in the energy area, as well as studies of underground injection of produced formation water. OGS staff continued to make presentations in a wide variety of locations in state and beyond, and on numerous topics in geology, hydrology, and geophysics. OGS also completed a long overdue update to its website (http://www.ou.edu/content/ogs.html), and began to develop an integrated data management system.

Geologic Mapping

Bedrock Mapping

From July, 2015 through June, 2016, the Oklahoma STATEMAP program focused on two main mapping programs: 1) detailed, 1:24,000-scale mapping of the Ada Quadrangle related to the Ada Project area, and 2) 1:100,000-scale, reconnaissance mapping of the Keystone Lake 1° sheet.

The Ada Project is a multiyear, detailed mapping program that was in its final year of investigation. Overall, the project represents the first detailed mapping of the area since the 1920's. The main impetus of the project is to aid reservoir engineers in determining bedrock characteristics for the proposed Scissortail Lake, west of Ada, Oklahoma. Along with bedrock characteristics, there have been considerable changes in the interpretation of the geology of the area, particularly stratigraphic, since the area was last mapped. As such, the secondary goal is to update the antiquated geologic characterization of the area. The current year centered on examination of the Ada 7.5' quadrangle proper. Mapping included both on and off road location and analysis of all rock exposures observed within the quadrangle.

Mapping of Keystone Lake is part of a longer-range plan to provide Oklahoma with full, 1° reconnaissance map coverage. Overall, the geology of Keystone sheet consists of gently westward dipping Permian and Pennsylvanian age sedimentary rocks. In the northern half of the quad, these strata are represented by marine carbonate and

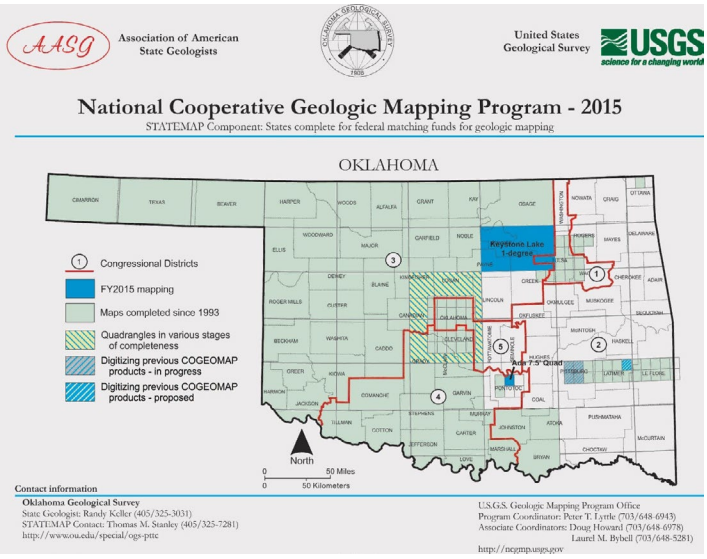

Figure 1. Map showing National cooperative Mapping Program activity in Oklahoma in 2015

clastic sedimentary rock with affinities closer to Kansas stratigraphy, whereas in parts of the southern half of the quad, sediment shed from the building Arbuckle

and Wichita highlands in southern Oklahoma is more prevalent. Much of the mapping of the Keystone Lake sheet was determining where the interfingering between Kansas stratigraphy from the north and Oklahoma stratigraphy from the south occur.

For both projects, actual mapping was performed from November, 2015 through to early April, 2016. After that, the remainder of the budget year was spent finalizing maps in the office. All deliverables were submitted on time at the end of August, 2016.

Energy research

OGS published a major revision of its Map of Oklahoma Oil and Gas Fields as Geologic Maps 39 (*Map of Oklahoma oil and gas fields: Distinguished by gas to oil ratio and gas vs. coalbed methane*) and 40 (*Map of Oklahoma oil and gas fields: Distinguished by coalbed methane and field boundaries*). This new version distinguishes coalbed methane fields as well as field boundaries. The maps were prepared by Brittany Pritchett of OGS with support from the OGS Cartography team, and updates an earlier map published in 2002.

Open File Report 4-2015: Preliminary Optimal Oklahoma Fault Orientations by Amberlee P. Darold and Austin A. Holland was also issued during this period. This map shows a compilation of recognized faults in Oklahoma compiled from literature and industry sources. It also identifies the risk level for seismic activity on fault segments within the present stress field of Oklahoma.

OGS also published *Open File Report 5-2015: Class II Saltwater Disposal for 2009–2014 at the Annual-, State-, and County- Scales by Geologic Zones of Completion, Oklahoma*, by Kyle E. Murray. This report summarized quantities of salt water co-produced with oil and gas disposed of in Underground Injection Control (UIC) Class II disposal wells in Oklahoma by county and disposal formation. It documents the large rise in injection of produced water that drives increased seismicity in part of Oklahoma.

The OGS initiated efforts to bring all of its legacy data, including publications and records stored at its Oklahoma Petroleum Information Center (OPIC) into a unified, geographically reference database system. Richard Andrews and David Brown continued work on the project *CO_2 Sequestration Project: Southwest Regional Partnership*. This is a multi-year project aimed at compiling and assessing data relevant to the study of possible sources of CO_2 storage in Oklahoma, particularly in the Anadarko Basin of western Oklahoma. David completed an Oklahoma Thermal Gradient map and an Arbuckle Apparent Thickness map for the project. Brian Cardott published six articles mainly on the organic geochemistry and petrology of Oklahoma shale and coal formations.

Induced seismicity

The OGS recorded and analyzed 5,070 earthquakes from July 1, 2015 through June 30, 2016. Of these 1348 were of magnitude greater than 2.8 (M2.8+). This represents a decrease from 2014-2015 in the total (from 6,745) and in the M2.8+ number from 1390. However, the number of M4.0+ earthquakes was the same both years at 20. These earthquakes are interpreted to have been induced by injection of produced water from oil and gas operations. Earthquakes are concentrated in fourteen counties where large volume injection of saline formation water from two major oil and gas plays into Arbuckle Group sedimentary rocks appears to have activated faults deep within the Precambrian basement of Oklahoma.

The OGS received $1.2 million in additional funding from the Secretary of Energy and Environment and from the Governor to enhance research on induced seismicity. Projects funded under this program included

Study of a 3D seismic reflection survey part of which was donated to the Survey by an White Star Petroleum, and Oklahoma City independent oil company

Enhancements to the seismic network in instrumentation, network, and software

Studies of basement and Arbuckle Group core and rock samples and geophysical logs to understand the stratigraphic architecture of the Arbuckle and the connection from it to the basement fracture and fault network

Bringing accelerometers to school classrooms across the state to teach students about earthquakes

Analysis of earthquake and produced water injection patterns in time and space to understand drivers for seismicity

During this period, the OGS lost both of its seismologists (Austin Holland and Amberlee Darold), who were hired away by the U. S. Geological Survey. Jefferson Chang served as Acting Lead Seismologist and Seismology Operations Manager during most of the year. OGS conducted a search for a Lead Seismologist during the year, and hired Jacob Walter from the University of Texas in the end of the period. The OGS hired three additional seismic analysts during the year, greatly expanding the capability to track seismicity in the state.

Part of the research on induced seismicity was funded

through a grant from the Research Partnership to Secure Energy for America (RPSEA), under the title: *4D Integrated Study Using Geology, Geophysics, Reservoir Modeling & Rock Mechanics to Develop Assessment Models for Potential Induced Seismicity Risk*. This project integrated efforts in seismology, gravity and magnetic fields, rock mechanics and reservoir characterization across the OGS and other departments in the Mewbourne College of Earth and Energy.

OREGON

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The 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. Our current funding ratio is 22 percent State general funds, 41 percent federal funds, and 37 percent other funds. Limited general fund support has led the Agency to seek partnerships with local, state and federal governances and organizations that need our services. Our 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 an ultimate 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 USFS. In 2016 DOGAMI also developed a partnership with FEMA, ODF and the USGS 3DEP program for a 1,000 square mile flight in early 2017. Over 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. Our interactive Lidar Data Viewer at www.oregongeology.org/dogamilidarviewer offers a look at bare earth DEMs, 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 2016, DOGAMI continued geologic mapping in the Wasco County area of Central Oregon, working in collaboration with USGS mappers and the Oregon Water Resources Department to help understand stratigraphic and structural controls on groundwater availability. This project is a high priority of the Oregon Geologic Map Advisory Committee, and work was supported in part by the U.S. Geological Survey STATEMAP component of the National Cooperative Geologic Mapping Program. DOGAMI also began a program to characterize the geologic controls on groundwater for the Harney Basin, with funding from the Oregon Water Resources Department.

The 2015 Oregon legislature passed HB 3089 which charged DOGAMI with making all mineral resource information available to the public online, and required the department to do a scoping study of the mineral resource potential of the southern and eastern parts of the state. The report was completed in September of 2016 and presented to the legislature and published online. This is the first mineral resource potential report the agency has published in nearly 30 years, and identified numerous counties with high potential for a variety of metals and industrial mineral commodities.

Coastal Processes and Hazards

With the completion of tsunami inundation maps and evacuation brochures for the entire Oregon coast, the state is now more tsunami-ready. DOGAMI developed a total of 131 new maps, including 89 new tsunami inundation maps and 42 new evacuation maps. Mapping was fully complete in August 2013. Inundation scenario data were released in October 2013, followed by release of model output files of maximum tsunami wave elevations, velocities, flow depths at specific locations over the course of the entire simulation, and other data in December 2014. In 2016, DOGAMI continued the development of "Beat the Wave" tsunami evacuation maps that show residents of coastal communities how fast they need to travel from any starting point in order to

reach safety ahead of the wave.

Oregon's coast has undergone major coastal erosion over the past century, and DOGAMI geologists are continuing to advance understanding of how the coast has and will continue to change. DOGAMI's Newport Coastal Field Office maintains the Oregon Beach and Shoreline Mapping Analysis Program (OBSMAP) to document the spatial variability of beach change, including seasonal, multi-year and long-term changes. DOGAMI continues to be a cooperative partner in the Northwest Association of Networked Ocean Observing Systems (NANOOS), a cooperative venture funded by NOAA to establish a northwest regional coastal ocean observatory for the estuaries and shores of Oregon and Washington. In 2015 DOGAMI published several new coastal flooding studies, funded by FEMA, for Oregon counties. These reports used state-of-the-art wave modelling and lidar topographic data to map areas at risk from ocean flooding during large storms.

Geologic Hazards Mapping and Data

DOGAMI continues to map landslide hazard 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. The most current version of the Statewide Landslide Database for Oregon (SLIDO) now includes locations and data for over 53,000 landslides, and an update in early 2016 includes a first-ever statewide landslide susceptibility map. 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 develop 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, is nearing completion in three northern coastal counties. These studies will be supplemented by a multi-hazard and risk analysis of numerous coastal communities that will used 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 M 9 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

Developing new ways for Oregonians to access information on our state's geology, natural hazards, mineral resources and more is an ongoing priority. The Agency's website at www.oregongeology.org is DOGAMI's online hub, and the primary way we make information widely available. The website saw a 66 percent increase in users from June 2014-July 2015 to July 2015-June 2016, with more than 290,000 users accessing the website. Spikes in user numbers occurred in July 2015, following publication of the New Yorker story on the Cascadia Subduction Zone, in December 2015, after free download of all DOGAMI publications was announced, and in February 2016, when a statewide landslide susceptibility map was published in PDF and interactive format.

Key accomplishments in 2016 include launch of an interactive geologic map of the state, based on our published digital geologic compilation database, in October 2016. In August 2016, new online collections of Oregon mining records went live. The records span decades, from the gold rush of the mid-1800s to modern-day aggregate mining operations. DOGAMI's entire collection of publications dating back to 1937, including lidar data, has been available since December 2015 for free download from our Publications Center at www.oregongeology.org/pubs.

Extensive community engagement—on topics from Oregon's mining history to earthquake preparedness—continues to be at the core of DOGAMI's outreach and education efforts. Creating partnerships to increase awareness of geologic hazards and opportunities is another agency priority. For example, we work with the National Weather Service and the Oregon Department of Transportation to highlight the potential for debris flows and landslides as part of flood watch warnings.

Mineral Land Regulation and Reclamation

DOGAMI's Mineral Land Regulation & Reclamation Program (MLRR) is the lead program for mine regulation in Oregon, and works with other state agencies, local governments, Oregon's federally recognized Indian tribes, industry and the public to minimize the impacts of mining and optimize the opportunities for reclamation. The fee-based, statewide program has the authority to regulate all upland and underground mining on lands within the State.

MLRR oversees nearly 900 permits covering 58,700

acres. To date, more than 7,800 acres of mined land have been reclaimed and put to secondary, beneficial use. The number one issue for the program is floodplain mining and its relationship to off-site resources, including natural habitats. The vast majority of mining sites in Oregon are aggregate mines. In addition to sand and gravel and quarry rock, there is significant diatomaceous earth production, an industrial mineral with a variety of commercial uses. Total annual aggregate production in Oregon is approximately 30 million tons. 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 mine sites.

Currently there are no active commercial metal or coal mines in the state. However, Calico Resources Inc. is engaged in the preliminary operating permit application process for an underground gold mine in eastern Oregon at Grassy Mountain. Exploration drilling and geologic work has also occurred in far southeastern Oregon for uranium resource potential. Exploration permits have also been issued for precious and base metals in several locations in southeastern Oregon. MLRR also regulates the exploration and development drilling for oil and gas, and geothermal. Rising interest in natural gas resources and Oregon's Renewable Energy Portfolio Standard for geothermal energy development has led to increased activity. For example, the US Geothermal Neal Hot Springs Geothermal Power Plant in Eastern Oregon now produces 149,000 MWh of power annually, enough to power almost 15,000 homes.

As part of the Agency's ongoing efforts to encourage best practices in mining, MLRR presents an annual awards program for operators that recognizes operation and reclamation above and beyond the requirements of regulation. Among the 2016 winners was Wildish Sand & Gravel of Eugene, for their commitment to reducing the potential impacts of their operation on neighbors and the environment through actions such as working with partners to develop a river bank stabilization plan, building a materials transport bridge to ensure safe boating access to the McKenzie River, and bringing in an archaeologist to document cultural and historic resources discovered on their properties. The late Robert Traverso of Canby Sand and Gravel was also recognized for his lifelong commitment to seeking out and implementing best practices for mining operations, as well as his dedication to exceed regulatory requirements in order to return mined land to thriving fish and wildlife habitat. Information all current and past award winners: www.oregongeology.org/mlrr/awards.htm.

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." BTGS consists of three divisions, with a total complement of 34 staff members: Geologic Mapping, Economic Geology, and Geologic and Geographic Information Services.

Geologic Mapping Division

The Geologic Mapping Division is responsible for bedrock and surficial geologic mapping, karst investigations, and groundwater studies. This year, all bedrock mapping was conducted under the auspices of the STATEMAP component of the National Cooperative Geologic Mapping Program. In August 2015, BTGS delivered draft bedrock geologic maps of four quadrangles to the USGS. These maps focused on parts of the stratigraphic section that are important both economically and in terms of tectonics and geologic history. Two maps in the north-central part of the Ridge and Valley Province concentrated on lower Paleozoic stratigraphy, particularly the Cambrian Gatesburg Formation, which includes the Sauk III transgression. The Gatesburg is the only high-yielding aquifer in the region that is free from contamination by nitrate and agricultural chemicals. The overlying Cambro-Ordovician carbonates are part of the Great American Carbonate Bank. They are mined for a wide variety of products, including aggregate and crushed stone, sand, and pharmaceutical-grade lime. Cores of complete sections of three gas-bearing shales were also recovered as part of this project. A third map in the south-central Ridge and Valley Province filled in some gaps remaining in a STATEMAP project from the previous year. The main objective of the project was to examine the relationship between the deep water clastic facies (Martinsburg Formation) and shallower water clastic facies (Reedsville Formation) of the Ordovician-age Taconic foreland basin. Part of this interval is correlative to the gas-bearing Utica Shale in the subsurface of western and northern Pennsylvania. A fourth map was undertaken to resolve stratigraphic and structural issues raised during a previous STATEMAP project in an area of active gas drilling in northeastern Pennsylvania. In July 2015, mapping began on the STATEMAP FY16 projects: one quadrangle in north-central Pennsylvania and four quadrangles in extreme northeastern Pennsylvania. These projects support stratigraphic studies and water quality concerns in areas of active or potential gas drilling.

Ongoing surficial mapping is part of a project to map the bedrock topography and drift thickness for the eight glaciated counties of northwestern Pennsylvania, using data from about 40,000 water well records. This work is conducted with funding through the Great Lakes Mapping Coalition. Bedrock topography and drift thickness maps for two quadrangles in Warren County were submitted to the USGS in November 2015. These maps are needed for 3-D surficial mapping, correcting apparent mismatches between bedrock maps and the modern topographic surface where surficial materials cover bedrock, and groundwater studies. Generally, the topography of the area is bedrock-controlled, with thin (generally less than 20 feet) upland drift and thick (up to 200 feet) drift in partially buried valleys. The exceptions are minor areas of local constructional glacial topography along the Kent Moraine and along valley walls. Two additional quadrangles in Warren County are underway, with anticipated completion in FY16.

In cooperation with the USGS Pennsylvania and New York Water Science Centers, Mapping Division staff analyzed the rock core, geophysical logs, water quality, and gas-isotope data from a 1,512-ft-deep test hole in the Cherry Flats quadrangle in north-central Pennsylvania. The hole was left from extraction of continuous core of the lower part of the Middle Pennsylvanian Allegheny Formation through the upper part of the Upper Devonian Catskill Formation, drilled for a STATEMAP project. The study characterizes the lithologies, fractures, water-bearing zones, groundwater quality, and isotopic signatures of hydrocarbons at the drilling location. Furthermore, the work helps to quantify the depth and character of the fresh and saline groundwater in an area of shale-gas exploration. Results were released in the Open-File

Miscellaneous Investigation 15-24.0: Geohydrologic and water-quality characterization of a fractured-bedrock test hole in an area of Marcellus shale gas development, Tioga County, Pennsylvania. The report consists of a text file and supplemental files pertaining to a complete core description, geophysical logs, and video logs.

Water Wells and Springs

In December 2015, BTGS completed entry of a batch of 55,000 water well records into our Pennsylvania Groundwater Information System (PaGWIS) under a grant from the National Geologic and Geophysical Data Preservation Program. The PaGWIS database is the Commonwealth's repository of water well information, containing more than 500,000 water well records and more than 1,600 spring records. A redesigned online interface was released in April 2016, making PaGWIS records more easily accessible to the public. The new interface includes a map search function along with new download packages that can be imported into most database and spreadsheet applications, and report formats for individual wells and springs. In addition to managing maintenance and upgrading of PaGWIS, staff of the Groundwater and Environmental Geology Section oversee the licensing of water-well drillers and submittal of water-well completion reports, and respond to numerous groundwater service requests from the public. They also document springs and collect basic spring data for entry into PaGWIS (Figure 1).

Figure 1. BTGS geologists measuring the discharge at Derry Spring, Dauphin County, Pennsylvania. Flow from the limestone spring was estimated at 519 gallons per minute. (June 2016)

Technical Assistance

Part of the mandate of BTGS is to provide technical assistance to our sister bureaus of State Parks and Forestry within DCNR, as well as to other state agencies. Mapping Division geologists assisted with siting new water wells for Cherry Springs, Hickory Run, and Oil Creek state parks, and for Elk, Delaware, and Gallitzin state forest district facilities. Largely through the efforts of a single staff geologist, with assistance from our GIS section, BTGS released five bathymetric maps of lakes in state parks and collected data for five additional maps. Staff also handled requests from the Department of Environmental Protection (DEP) for expertise on sinkholes near regulated quarry facilities.

Economic Geology Division

The Economic Geology Division gathers and interprets data related to oil and natural gas, coal, non-fuel mineral resources, and rock formations in the subsurface. One of the products of the Division completed within the past year is a revision of the Directory of Nonfuel-Mineral Resources in Pennsylvania, Open-File Mineral Resource Report 15–01.0. This was published online as a tabular-formatted PDF that contains detailed information from mining companies about the locations of their extraction operations, the rocks that are being mined, and the products that are derived from those rocks. The data in the directory can also be accessed through an interactive map. (Figure 2)

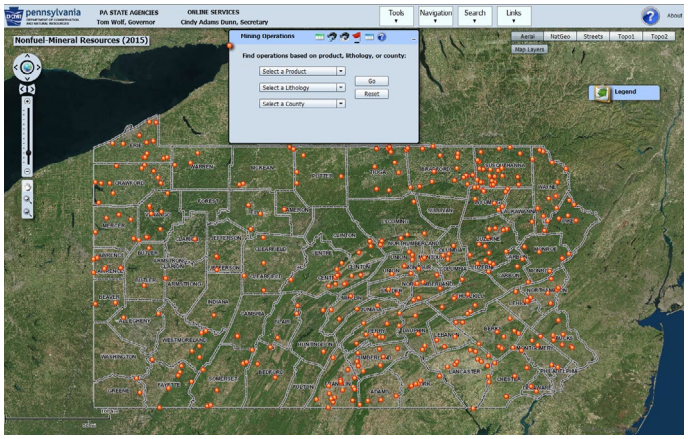

Figure 2. The Directory of Nonfuel-Mineral Resources in Pennsylvania allows the user to search for resources by product, lithology, and county using a scalable interactive map that can display the results using several map bases. The orange dots on this map represent the locations of all mine and quarries in the directory.

Also released this year was Open-File Oil and Gas Report 15-03.0: Using geophysical and remote sensing techniques to evaluate deep geologic formations in Indiana County, Pennsylvania – Well data. This is the fourth of seven planned reports on a reconnaissance-level evaluation of the suitability of a site in southwestern Indiana County for carbon dioxide sequestration. The area is one where coal-fired power plants, a major contributor to regional greenhouse gas emissions, are prevalent. The case study looks at the subsurface geology in the area and illustrates the use of geophysical and remote-sensing techniques to characterize deep geologic structure. This report includes the data from deep wells that were used in conjunction with seismic reflection data to generate the structure contour map of the Onondaga Limestone that was the focus of the first report in the series (OFOG 14-01.0). The report consists of a short text and appendices of well data in an Excel workbook. Appendix A includes basic information on 6,229 shallow and deep

wells—including their locations, operators, field and pool assignments, well type, and total measured depth. Appendix B includes geologic formation tops interpreted from the 149 deep wells in the county.

BTGS participates in several multi-state consortia to study energy and resource-related issues, including the Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment Project. This collaboration is a three-year project designed to assess potential carbon storage areas between the Georges Bank Basin and the Baltimore Canyon Trough. In the current phase of the project, BTGS geologists are using modern software capabilities to reprocess a variety of geophysical logs from the 1970s. These efforts will enable better geologic correlations and a more thorough evaluation of potential storage capabilities and geologic seals.

Geologic and Geographic Information Services Division

The Geologic and Geographic Information Services Division manages the BTGS databases, web applications, library, and other information technology. The GGIS Division also is responsible for organizing and preparing for publication geologic data, maps, and other products prepared by agency staff and cooperating scientists. A major project undertaken by the Division this year was development of the Pennsylvania Universal Bedrock Geologic Units Table (PUBGUT), a database of all the geologic units that have appeared in BTGS maps and publications since 1919. Any geologist can probably guess that such a database includes a number of contradictions, discrepancies, and general disagreements about stratigraphy, correlation, and nomenclature. In June 2016, the database was released to the staff for review and comments. The GGIS Division will collect all the comments, and with the help of appropriate staff from the rest of the Bureau, prepare a second cut of the database. Ultimately, PUBGUT will form the basis of a comprehensive system of stratigraphy and nomenclature across the state.

Seismic Network

In 2006, BTGS established its first seismic network of six permanent stations. The network grew steadily since that time with the addition of four more permanent stations and 25 temporary stations. While the network started as essentially a pure research tool, as in other natural-gas producing states, there is increasing concern in Pennsylvania about induced seismicity. During 2015 and 2016, DCNR converted many of the temporary stations to expand its 10-station permanent seismic network to 30 permanent stations. The network is operated by Penn State under a contract with DCNR. Beginning in June 2015, DEP executed a 3-year agreement with DCNR to pay half the cost of upgrading and maintaining the network. 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 (http://ds.iris.edu/mda/PE).

Education and Outreach

BTGS staff performed numerous education and outreach activities during the year including "Rocks4Kids," "Eco-Camp" and other programs at state parks, school programs, summer day camp programs, presentations at professional conferences, and invited talks to professional groups. Three staff members participated in the field trip for the 12th International Symposium on the Ordovician System, based in Harrisonburg, Virginia, providing on-the-ground assistance with trip logistics. Many BTGS staff are experts in running field trips from their experience with organizing the annual Field Conference of Pennsylvania Geologists. In October 2015, the 80th Annual FCOPG hosted about 170 professional geologists and students in Pottsville, Pennsylvania, to explore the stratigraphy, structure, and mining history of the Southern and Western Middle Anthracite fields.

General interest publications accessible to geologists and non-geologists alike are an important facet of our educational efforts. New editions of two Educational Series booklets – The Geological Story of Pennsylvania, and Sinkholes in Pennsylvania – were released this year. Staff added six more summaries of Outstanding Geologic Features of Pennsylvania, bringing the total to 91 sites that can be viewed through the State Parks, Forests and Geology Interactive Map (http://www.gis.dcnr.state.pa.us/maps/index.html). In 2017, the Outstanding Geologic Feature summaries will be made part of a new Trail of Geology publication series. Another publication released this year that will be moved into that series is open-file report OFMI 16-04.0 A guide for the geologic tourist to the Northern Extension of the York County Heritage Rail Trail.

SOUTH CAROLINA

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SCGS MISSION

The mission of the South Carolina Geological Survey is to provide reliable geologic information to decision makers as part of the Earth Science Group of the South Carolina Department of Natural Resources–Land, Water, and Conservation Division (DNR).

GEOLOGIC MAPPING

The SCGS continued to be the sole-source provider of geologic map information to the public in the state. Geologic mapping is partially supported by the federal STATEMAP program. Geologic mapping, which represents original research, and digitization of that geologic information are core competencies. Collection and distribution of geological information also continue to be long-term base-line measures in the operation plan.

Surficial Mapping

The SCGS continued to map in the both the Coastal Plain and Piedmont. Mapping in the Lower Coastal Plain focused on finishing the coast northeast to the North Carolina state line. The South Carolina parts of three quadrangles were mapped to finish the first pass of the coastal compilation. A quadrangle also was mapped in Sumter County in the Upper Coastal Plain. In the Piedmont, mapping was done in the Carolina terrane and in the Inner Piedmont. Compilation of outsourced maps covering parts of the Carolina terrane also began.

Offshore Mapping

Along the coast, offshore mapping of the Grand Strand has been outsourced to Coastal Carolina University and south of Charleston to College of Charleston. An offshore map extending northeast from Winyah Bay to Little River was completed, and a map offshore Folly Beach has been used by the USACE in a beach nourishment project (Figure 1). SCGS is now developing its own in-house expertise in offshore mapping techniques partially funded by BOEM.

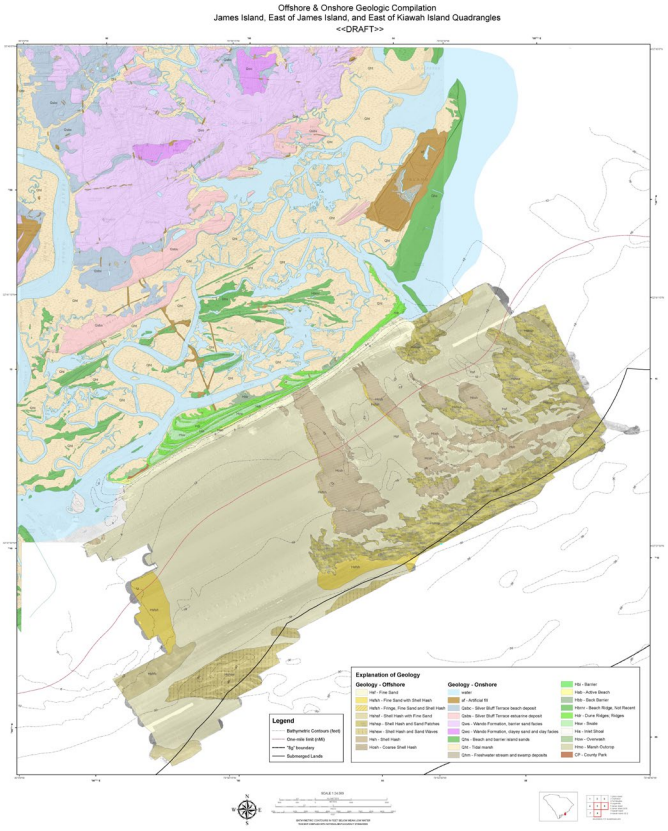

Figure 1. Offshore map Folly Beach, South Carolina.

GEOLOGIC INFORMATION AND DATA MANAGEMENT

SCGS has developed mapping standards and procedures for both Coastal Plain and Piedmont mapping projects. These procedures constantly are being updated and improved. Currently, Piedmont standards are being updated to include digital mapping procedures. Data is either developed or translated into a digital format for processing and analysis. Digital data is developed into GIS databases that can be transferred as digital files or exported as documents. Currently, we are trying to implement NCGMP'09 as a standard database design. GIS development is overseen by a GIS manager. Procedures used to process and analyze data are well known from the literature and are commonly discussed among the USGS-AASG Digital Mapping Techniques group.

SOUTH DAKOTA

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The South Dakota Geological Survey is a Program in the Division of Financial and Technical Assistance, Department of Environment and Natural Resources. Although the Geological Survey's main office is located on the University of South Dakota campus in Vermillion, the Geological Survey is part of the executive branch of state government. The mission of the Geological Survey 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

Three maps of surface geology at a scale of 1:24,000 were published for the Hill City, Mount Rushmore, and Rockerville 7.5 minute quadrangles in the Black Hills. The maps for the Hill City and Rockerville quadrangles were reissues of previously published maps with revisions. Mapping for publication at a scale of 1:24,000 also occurred in the Deadman Mountain, Fourmile, Nemo, Pringle, Rapid City East, and Signal Hill quadrangles. The mapping provides critical information for land-use decisions and provides the foundation for derivative maps of aquifer vulnerability.

Geologic mapping at a scale of 1:100,000 occurred for bedrock and surface geology in Sully County and was performed for bedrock geology in McCook County. The understanding of bedrock geology was also refined in an area of Bon Homme County as part of an investigation of glacial hydrology.

Aquifer Delineation

Work related to understanding and documenting ground-water resources in the glaciated part of South Dakota was again a primary emphasis. The Geological Survey's drilling resources were used to drill 59 test holes totaling 10,616 feet. Twenty two of those test holes were completed as monitoring wells. Additionally, 95 water samples were collected and analyzed to aid in the interpretation of aquifer extent and continuity. Much of this work was planned 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 water.

Of the 95 water samples collected for "aquifer delineation," 54 were collected and analyzed for some or all of the stable isotopes of oxygen-18, deuterium, carbon-14, and tritium. Results from these and prior analyses will be used to better understand recharge to buried glacial aquifers. This information is of importance to the management of the State's ground-water resources.

A project was conducted to aid the Lewis & Clark Regional Water System better understand the performance of their wellfield and the impact of ground-water withdrawal. This water system will ultimately serve parts of southeastern South Dakota, southwestern Minnesota, and northwest Iowa.

Statewide Ground Water 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 nonpoint-source pollution in many of the surficial aquifers across the state. An important difference between South Dakota's Statewide 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. Samples were collected and analyzed from 91 wells in the network in fiscal year 2016 for common inorganic constituents and pesticides.

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 will produce additional reports, maps, and cross sections pertaining to South Dakota's oil and gas resources.

Work performed in fiscal year 2016 resulted in the re-boxing of 825 feet of core related to oil and gas, the slabbing (cutting lengthwise) of 521 feet of core, and the photographing of 1,948 feet 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. Vetting and correcting historical information regarding the physical locations of 2,096 wells drilled for oil and gas was also performed.

Online Information

In an effort to continually provide more information and to make our information more accessible, additional data layers were added to an online, interactive map and the Geological Survey's website was rebuilt using responsive web design (mobile compatible) technology. Data layers added to the interactive map were (1) water quality analyses – allows viewing of sample locations and access to laboratory analytical results for each location, (2) earthquakes – shows locations, magnitudes, and dates, and (3) bedrock type and elevation in eastern South Dakota.

Public Outreach

Public outreach was again an important part of the Geological Survey's activities. In FY 2016, 47 presentations were given to various groups including students (elementary, high school, college, & older adults), state agency boards, tribal entities, and the general public. Some outreach activities were traditional presentations followed by a time for questions and answers while others were day-long events with continuous public interaction.

TENNESSEE

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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 $685,028 during fiscal year 2015-2016, of which $166,709 came from state appropriations. The remaining $518,319 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 performs 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 (1 inch=2,000 feet) since 1960. These maps cover about 60 square miles. 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 526 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 65.4 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 the 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 FY 2015-2016		
Quadrangle	County	Authors
Elverton (130 NW)	Roane and Morgan	Peter J. Lemiszki
Meadow (139 NW)	Loudon and Blount	Barry W. Miller, Robert T. Fetters, Jr., Donald J. Hathaway, and K. K. Kimball
Sharp Place (335 SE)	Fentress, Pickett and Scott	Albert B. Horton and Mike L. Hoyal
Sunnyhill (430 SW)	Haywood	Vince Antonacci, Mike L. Hoyal, and Albert B. Horton
Trenton (437 NW)	Gibson	Mike L. Hoyal, Vince Antonacci, and Albert B. Horton

Cooperative Projects

State Geologic Mapping Program

During fiscal year 2015-2016, TGS was approved for funding under a $76,177 cooperative agreement from the U.S. Geological Survey (USGS) under the State Geological Mapping Program element (STATEMAP) of the National Cooperative Geologic Mapping Program. Since 1994 the survey has received nearly $865,000, completing 45 new geologic maps and converting 23 previously completed geologic maps to digital coverages under this program. The TGS web site has a National Cooperative Geologic Mapping Program fact sheet updated through September of 2016 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 fiscal year 2015-2016 project was to map the geology of the Grimsley (115-SW), Maury City (429-SW) and Windrock (129-SE), Tennessee 7.5-minute quadrangles in Anderson, Crockett, Fentress, Haywood, Morgan, and Roane counties, and to complete digital compilation of the Big Ridge Park Geologic Map. Staff geologists Vince Antonacci, Albert Horton, and Assistant State Geologist Mike Hoyal from the survey's Nashville office worked on the Maury City and Grimsley quadrangles. Chief Geologist Dr. Peter Lemiszki and staff geologist Barry Miller from the survey's Knoxville office were responsible for Windrock, and Pete worked on Big Ridge Park.

National Park Service Geologic Resource Inventory

In addition, TGS completed work under a $174,500 contract from the National Park Service (NPS) to complete geologic mapping of the Barthell SW, Oneida North, Oneida South, and Sharp Place Tennessee 7.5-minute quadrangles in the Big South Fork National River and Recreation Area (BISO) in Fentress, Pickett, Scott counties and submitted the final map (Sharp Place) to NPS on November 30, 2015. The 1997 NPS Strategic plan prescribed a digital geologic map as one of twelve essential data sets for parks. To meet this goal, the Natural Resources Program Center undertook a Geologic Resource Inventory of 270 natural area parks. BISO was identified as one of those parks. This project was designed to accelerate completion of the BISO geologic map. In addition to other issues, this project addressed natural resource development and environmental impacts, including those associated with coal mining and oil and gas exploration. Coal data obtained during mapping of the area such as strip and underground mine extent, coal thickness and elevation, and exploratory drill hole information was utilized and also entered into the National Coal Resources Data System database. Staff geologist Albert Horton and Assistant State Geologist Mike Hoyal from the survey's Nashville office worked on the Sharp Place Geologic Map during fiscal year 2015-2016.

National Geological and Geophysical Data Preservation Program

TGS also worked under an $18,365.75 cooperative agreement for fiscal year 2014-2015 from the USGS under the National Geological and Geophysical Data Preservation Program (NGGDPP). Since 2007, the survey has received more than $106,000 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).

Four projects under the fiscal year 2014-2015 cooperative agreement were to compile metadata in a format suitable for input into the National Digital Catalog (NDC) and to convert paper/mylar documents into a digital format. The first project was to create the metadata records and convert to a digital format the remaining 500 documents

in the Coal Exploration Core Hole Logs Collection. The result of this project was that 507 core hole logs were digitally captured with associated metadata. The second project was to create the metadata records and convert to a digital format 500 documents in the Coal Mine Maps Collection. The outcome of the project was that 557 coal maps were digitally captured with associated metadata. The third project was to create the metadata records and convert to a digital format 1000 documents in the Mineral Resources Collection. The metadata file consisted of 690 records and represents nearly all of the documents in the Mineral Resources Collection located in the Knoxville Field Office. More than 1000 document scans were associated with the 690 records. The fourth project was to create the metadata records and convert to a digital format 100 field books and ancillary documents in the Field Notes and Maps Collection. The outcome of the project was that the metadata for 324 field books and ancillary documents were compiled and 294 field books were scanned under a contract with Dr. Michael Gibson and Department of Agriculture, Geosciences, and Natural Resources students at the University of Tennessee at Martin.

In addition to providing the metadata records for the Coal Exploration Core Hole Logs Collection, the following outcomes were realized as a result of completing this objective:

1. We continued to review and better organize the material in the Coal Exploration Core Hole Logs Collection
2. Our in-house Coal Exploration Core Hole Logs Collection Excel database includes additional information not included in the NDC to assist TGS staff with the searching and sorting of records, as well as the storage location of each document in the collection
3. The existing Excel database also feeds directly into a GIS (ArcMap) project to better visualize the geographic location and query the documents in the collection.

Geologist Barry Miller in TGS's Knoxville Field Office was responsible for scanning, image processing, and creating the metadata files for the Coal Exploration Core Logs Collection.

In addition to converting coal maps in the Coal Mine Map Collection into a digital format and creating metadata for the maps, the following results were realized by working on this objective:

1. We continued to assess and better organize the material in the Coal Mine Map Collection
2. The digital scan files can be reviewed for coal information without disturbing the original fragile coal maps. These digital scan files can be also be utilized in GIS software to create shapefiles, databases, and maps that display the characteristics of each coal seam
3. Our in-house Coal Mine Map Collection Excel database includes additional information not included in the NDC to assist TGS staff with the searching and sorting of records, as well as the storage location of each document in the collection
4. The existing Excel database also feeds directly into a GIS (ArcMap) project to better visualize the geographic location and query the documents in the collection.

Barry Miller was also responsible for scanning, image processing, and creating the metadata files for the Coal Mine Map Collection.

In addition to providing the metadata records for the Mineral Resources Collection, the following outcomes were realized as a result of completing this objective:

1. Our in-house Mineral Resources Collection Excel database includes additional information not included in the NDC to assist TGS staff with the searching and sorting of records, as well as the storage location of each document in the collection
2. The existing Excel database also feeds directly into a GIS (ArcMap) project to better visualize the geographic location and query the documents in the collection.

Chief Geologist Dr. Peter Lemiszki in TGS's Knoxville Field Office was responsible for reviewing, sorting, and organizing the documents in the Mineral Resources Collection. He completed the metadata file and supervised secretarial staff to assist him with document scanning. He was also responsible for completing the Final Technical Report and uploading all of this year's NGGDPP project datasets onto the USGS ScienceBase website.

There were four primary goals of the TGS Field Book Digitization Project. The outcome for each of the goals is listed below:

1. Digitally scan ~100 field books and loose field notes into PDF format at specified resolution. Digital scanning of all field books was completed with the final total being 294 field books and loose note packets.
2. Digitally scan large format maps into PDF format at specified resolution. There are 39 large format items within the collection that were not scanned; however, the information files were entered into the metadatabase. The large-format scanner necessary for this task is available at the TGS office in Nashville, but requires specialized covering to be used so as to not damage the maps. Once the necessary protective covers are obtained, it will take approximately 2 days to scan and update the information for the 39 maps in the metadatabase.

3. Enter pertinent data for each field book into metadata file. Each field book has been entered into a metadata spreadsheet. All available pertinent data for each field book and loose note packet were entered into the database resulting in 294 entries. Entry data include field book names, authors, dates, abstract of contents, coordinates of studies, and additional information about each book useful for later historical study (e.g., type of book, condition of book, etc.). Field books also were used to record laboratory analyses, but often the author did not include the necessary information to relate these numerical data to specific sample locations, etc.

4. Enter pertinent data for each large format map (> 11 x 7 inch) into metadata file. All available pertinent data for each large format map were entered into the metadatabase resulting in 39 entries. Entry data includes map names, authors, dates, abstract of contents, coordinates of map, and additional information about each map useful for later historical study (e.g., condition of map, etc.).

Peter Lemiszki was responsible for providing technical guidance to Dr. Gibson and his students. He also reviewed and made final revisions to the Field Books Collection metadatabase prior to uploading the file onto the USGS ScienceBase website.

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. Nearly all of TGS's coal mining and zinc mining maps and reports collections are unpublished and in paper/mylar form. As result, companies, government agencies, and the general public are unaware of the abundant site specific data available. TGS has not yet reached the point where it can provide the on-line presence needed for its collections. Therefore, preparing metadata records for uploading into the NDC is the first step towards providing the public with a method to search for, locate, and evaluate the type of information that is available in them. 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 for companies to evaluate potential areas for future exploration. 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 1966 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.

USGS Annual Mineral Industry Survey

Peter Lemiszki continued to provide an annual summary to the USGS Mineral Information Team for their annual Mineral Industry Survey of Tennessee.

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 drillers 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 fiscal year 2015-2016 the survey reprinted Bulletin 72, entitled *Gold Deposits of the Coker Creek District, Monroe County, TN,* by Robin C. Hale, and printed a publication by former survey geologist Robert A. Miller, entitled *The Geologic History of Nashville and the Surrounding Middle Tennessee Region*. All of the survey's publications are distributed through a maps and publications sales office in Nashville. Carolyn Patton oversees over 1450 inventory 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 http://www.tn.gov/assets/entities/environment/attachments/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 nearly $2,000 in fiscal year 2015-2016 accounted for only three percent of the survey's revenue. More than $1300 was from the sale of 106 bulletins, $400 was from the sale of 48 geologic and base maps, nearly $130 was from the sale of Tennessee related publications, and $96 was from the sale of 16 topographic maps. Sales tax collections totaled $60. A total of 68 customers were served.

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 19 lectures, led 3 field trips, and manned survey booths at the Knoxville Gem and Mineral Show, Long Hunter State Park, National Earth Day Festival at Centennial Park, National Wild Turkey Federation convention, and Murfreesboro Earth Day Celebration during FY 2015-16, involving nearly 4000 individuals. TGS's Nashville office also distributed 50 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 2015.

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 ground water 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 more than 300 geologic information requests, performed 20 environmental evaluations, and conducted 11 geohazard inspections, involving one seismic event, 8 sinkholes, and 2 subsidence problems during FY 2015-16. Knoxville office staff also performed geologic hazard evaluations for 4 East Tennessee Development District projects.

Publications List

Antonacci, Vince, and Horton, Albert B., 2015, Mineral resources summary of the Sunnyhill quadrangle, Tennessee: Tennessee Geological Survey MRS 430-SW, 8 p.

Antonacci, Vince, and Horton, Albert B., 2015, Mineral resources summary of the Trenton quadrangle, Tennessee: Tennessee Geological Survey MRS 437-NW, 7 p.

Antonacci, Vince, Hoyal, Mike, and Horton, Albert B., 2015, Digital geologic map of the Sunnyhill quadrangle, Tennessee: Tennessee Geological Survey DGM 430-SW, scale 1:24,000, 1 sheet.

Horton, Albert B., and Hoyal, Mike, 2015, Digital geologic map of the Sharp Place quadrangle, Tennessee: Tennessee Geological Survey DGM 335-SE, scale 1:24,000, 1 sheet.

Hoyal, Mike, Antonacci, Vince, and Horton, Albert B., 2015 Digital geologic map of the Trenton quadrangle, Tennessee: Tennessee Geological Survey DGM 437-NW, scale 1:24,000, 1 sheet.

Lemiszki, Peter J., 2015, Digital geologic map of the Elverton quadrangle, Tennessee: Tennessee Geological Survey DGM 130-NW, scale 1:24,000, 1 sheet.

Miller, Barry W., Fetters, Robert T., Jr., Hathaway, Donald J., and Kimball, K. K., 2015, Digital geologic map of the Meadow quadrangle, Tennessee: Tennessee Geological Survey DGM 139-NW, scale 1:24,000, 1 sheet.

TEXAS

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About the Bureau of Economic Geology

The Bureau of Economic Geology, part of the John A. and Katherine G. Jackson School of Geosciences at The University of Texas at Austin, functions as the state geological survey of Texas. The Bureau curates the largest volume of subsurface core and cuttings in the United States at three world-class centers located in Houston, Austin, and Midland and maintains a major wireline-log library with nearly 1.5 million Texas well records on file.

The Bureau conducts basic and applied research related to energy and environmental issues. Its mission is to provide research and advice related to these issues and to perform state geological survey functions as requested by the Texas State Legislature. Outreach efforts involve the public, State agencies, Federal agencies, private foundations, and various industries.

Energy Research

The Bureau's Energy Research group conducts approximately two-thirds of current Bureau research, focusing primarily on oil and natural-gas energy resources. The Fossil Energy component of the group includes fourteen Industrial Associates programs for basic research, as well as numerous sponsored-research projects funded by the State of Texas, the U.S. Department of Energy (DOE), and individual companies or groups of companies.

Main areas of focus include salt tectonics, carbonate and clastic reservoir characterization, fracture characterization and prediction, multicomponent seismic applications, shale systems, and nanotechnology. From outcrop studies to the evolving science of reservoir characterization, the Energy Research group is noted for its insight and innovation. In Texas, where 70 percent of in-place reserves typically remains in the ground at the time of oil-field abandonment, research on oil recovery has enduring economic and societal importance.

The Bureau has developed a world-class unconventional oil and gas program concentrating on increasing petroleum energy reserves, educating stakeholders on energy economics through the Center for Energy Economics, and conducting leading-edge research in subsurface applications of nanotechnology to enhance petroleum production through the Advanced Energy Consortium.

Environmental Research

The diverse Environmental Research group conducts a wide range of basic and applied research in groundwater resources, vadose-zone hydrology, coastal studies, near-surface geophysics, and geologic mapping. The group's Gulf Coast Carbon Center is a national leader in the study of geological sequestration of carbon. The Bureau is also developing additional programs that relate energy and the environment, including how water resources intersect fossil energy exploration/production and electricity generation from power plants. The group investigates characteristics and processes of shallow Earth systems and the impacts of human activities on those systems. Many of the projects address the needs of State and Federal agencies, although the group conducts research in other states and in Latin America, as well.

The Bureau owns and operates an advanced airborne laser terrain and bathymetric mapping system (lidar) and a ground-based mapping system, both of which provide unique opportunities for conducting research requiring information on the shape and structure of the Earth's surface. The Bureau's newest equipment also includes hyperspectral imaging capability. Each project is well supported by complementary hardware and advanced software for data analysis and modeling, and researchers routinely apply related technologies in GIS, GPS, and remote sensing to maintain the research-grade survey quality necessary for many earth-science applications.

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 2016, researchers Eddie Collins, Jeff Paine, and Chock Woodruff completed one Miscellaneous Map and three new STATEMAP open-file maps (OFMs) of the following areas: upper Lake Travis area, and the Port O'Connor, Saint Charles Bay, and Bee Cave 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) look at new venture studies where regional fairways for drilling exploration wells will be emphasized, and (3) utilize CO_2 sequestration studies to promote profitable sequestration of CO_2 in oil fields through CO_2-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 hazards mapping.

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; the TCEQ and RRC have, with technical support from the Bureau, 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 identify possible CO_2 plays and estimate capacity in the Miocene formations in Texas State waters, including 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 potential partner agencies include the Texas Department of Transportation, Texas Parks and Wildlife Department, TCEQ, and Texas Water Development Board.

In 2015, the governor of Texas signed legislation authorizing the establishment of the TexNet Seismic Monitoring Program. The initiative, led by the Bureau of Economic Geology, is a collaborative effort to place seismometers throughout the State to enhance the ability of researchers to gather information about subsurface seismic activity. TexNet will create a continuously operating, statewide seismic-monitoring and data-collection network capable of detecting and locating earthquakes with magnitudes of 2.0 and greater.

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

Bureau hydrologist and senior research scientist Bridget Scanlon has been elected a member of the National Academy of Engineering (NAE), one of the highest professional honors accorded to engineers and scientists. Scanlon leads the Bureau's Sustainable Water Resources Program, a research group that combines a variety of analysis methods—from local field measurements to data from NASA's GRACE satellite—to provide insight on water in the environment at a variety of scales. Recently, Scanlon led the most comprehensive study to date on the water supply of the Colorado River Basin, a water source for over 40 million people. Her work has improved

the understanding of groundwater depletion worldwide and has played an important part in informing U.S. water policy, particularly water management in California's Central Valley. Scanlon has also studied water use in energy production.

Bureau director Scott W. Tinker was presented with the AAPG Honorary Member Award, which is bestowed upon "persons who have distinguished themselves by their service and devotion to the science and profession of petroleum geology and to the Association."

Stephen Laubach was recognized by the Society of Petroleum Engineers (SPE) for his contributions as editor for the Society and its publications. Laubach has been designated as "A Peer Apart," a title honoring those who have reviewed 100 or more technical papers as a member of the SPE Editorial Review Committee. Laubach joins 8 other honorees this year and is one of only 143 in the history of the Society to have received the honor.

Published articles are the tangible products that the Bureau of Economic Geology can display as evidence of its scientists' research successes. The Bureau recognized first authors of papers published in 2015 with its First Author Publication Awards. Of the Bureau's approximately 140 external publications in 2015 (up from 120 the year before), 76 were written by 49 Bureau first authors. Tieyuan Zhu, a postdoc in Sergey Fomel's group, had the most first-author publications this year, with four articles. Bill Ambrose and Bob Loucks shared the distinction of being honored the most years for first-author publications: 8 times each since the award's inception in 2009.

The Tinker Family BEG Publication Award is presented each year to a Bureau researcher (or researchers) for the best peer-reviewed publication in the previous year. This year's recipients were Andras Fall and his co-authors (Peter Eichhubl, Robert Bodnar of Virginia Tech, Stephen E. Laubach, and Steve Davis of ExxonMobil) for "Natural Hydraulic Fracturing of Tight-Gas Sandstone Reservoirs, Piceance Basin, Colorado," which appeared in the Geological Society of America Bulletin (v. 127).

The Bureau of Economic Geology was well represented at the annual convention of the Gulf Coast Association of Geological Societies (GCAGS) and the Gulf Coast Section of SEPM held in Houston in late September. During its Opening Session and Awards Ceremony, Dallas Dunlap was honored with the 2015 GCAGS Distinguished Service Award for his "exemplary service" to GCAGS over the years. Bob Loucks and Robert Reed earned the President's Award for Outstanding Paper, 2014, for "Scanning-Electron-Microscope Petrographic Evidence for Distinguishing Organic-Matter Pores Associated with Depositional Organic Matter versus Migrated Organic Matter in Mudrock." A further honor bestowed on Bureau researchers that evening was second Place for the Gordon I. Atwater Best Poster Award, 2014, presented to the team of Dunlap, Ramón Treviño, Tip Meckel, and Jackson School Master's student Francis Mulcahy for "High-Resolution 3D Imaging of Quaternary Channelization: Offshore San Luis Pass, Texas."

Bureau Senior Research Scientist J. P. Nicot was honored for his election as a Geological Society of America (GSA) Fellow at the group's annual convention in Baltimore on November 1, 2015. The select membership recognizes distinguished contributions to the geosciences through such avenues as publications and applied research. Nicot was noted for his oft-cited and substantial body of published research on greenhouse gases and climate change, energy security, and sustainability of water resources, including "Evaluation of Large-Scale CO_2 Storage on Fresh-Water Sections of Aquifers: An Example from the Texas Gulf Coast Basin" and "Water Use for Shale-Gas Production in Texas, US."

Bureau associate director Eric Potter was honored in 2015 by the Jackson School of Geosciences (JSG) for his "outstanding service to a unit, the School, the University, or the profession." Said JSG dean Sharon Mosher of Potter: "His geologic insights and expertise are broadly sought across Texas and beyond by professional societies, industry, governments, and fellow academics. His administrative experience and counsel is a critical part of the Bureau's success.... For 15 years, Eric has served the Bureau and the School selflessly, consistently deflecting credit from himself to others, and being quick to recognize the best in others. He embodies the idea of service." Potter, who will retire this year, was also praised by Bureau director Scott W. Tinker: "For over 25 years now, I have had the great pleasure to work for and with Eric Potter, the Bureau's associate director of Energy Research."

Jake Covault, principal investigator of the Bureau's Quantitative Clastics Laboratory (QCL), was recently honored by the New Orleans Geological Society with its "2015 NOGS Best Paper Award" for his presentation in New Orleans last June of "Predictive Organization of Deep-Water Lobes."

Bill Ambrose, principal investigator of the Bureau's State of Texas Advanced Oil and Gas Resource Recovery (STARR) program, is the recipient of the American Association of Petroleum Geologists Southwest Section's "A. I. Levorsen Memorial Award" for his April 2015 presentation of "Tidal Depositional Systems in Pennsylvanian Strata in the Anadarko Basin, Northeast Texas Panhandle" at the Southwest Section Annual

Meeting held in Wichita Falls, Texas.

Lauren Redmond, a Master's candidate and graduate research assistant for the Bureau's STARR and MSRL programs, won Best Poster Award at the Houston Geological Society's Applied Geoscience Conference on March 8–9. Her presentation, "Tying Core Descriptions and Optical Petrography with XRF Geochemical Data for a Detailed Characterization of the Mississippian Barnett Formation in the Southern Fort Worth Basin of North-Central Texas," was coauthored by her Master's degree supervisors Bob Loucks and Harry Rowe.

Education and outreach

The Bureau of Economic Geology educates 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 2016, the Bureau partnered with the Texas Department of Transportation (TxDOT) to post geologic information signs at two TxDOT Safety Rest Areas. The work is part of a new initiative to engage the public and promote the understanding of geologic information.

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 United States. Taught by university faculty and research scientists, and mentored by professional geologists from industry partners, the trips engage and empower the students by exposing them to environments completely different from those of their homes and schools. 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. The Bureau has also developed a portable 3D-presentation system for outreach that includes 3D projectors, 3D glasses, and a variety of 3D interactive geologic modules about ongoing Bureau research.

Bookstore

With more than 2700 publications issued since 1909, the Bureau continued making enhancements to 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 drawn on a U.S. bank.

The Bureau issued one Miscellaneous Map and three new STATEMAP open-file maps (OFMs) in 2016, which are for sale at The Bureau Store:

Woodruff, C. M., Jr., and Collins, E. W., 2016, Geologic map of the upper Lake Travis Area, Texas: The University of Texas at Austin, Bureau of Economic Geology, Miscellaneous Map 52, scale 1:50,000.

Paine, J. G., and Collins, E. W., 2016, Geologic map of Port O'Connor quadrangle, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM 224, scale 1:24,000.

Paine, J. G., and Collins, E. W., 2016, Geologic map of the Saint Charles Bay quadrangle, Texas Gulf of Mexico Coast: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM 225, scale 1:24,000.

Collins, E. W., 2016, Geologic map of the Bee Cave quadrangle, Texas: The University of Texas at Austin, Bureau of Economic Geology, Open-File Map, OFM 226, scale 1:24,000.

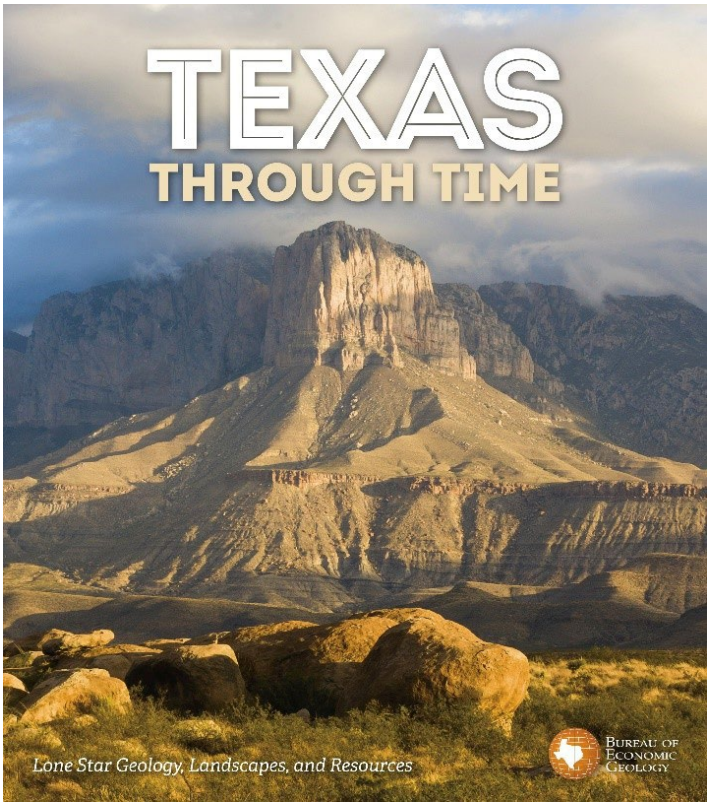
Downloadable (PDF) versions of these maps, and many other Bureau books and maps, were added to The Bureau Store in 2016.

The Bureau bookstore also promotes and sells GCAGS Transactions 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.

Notable new publications issued in 2015 were Volume 65 of the GCAGS Transactions and Volume 4 of the peer-reviewed GCAGS Journal.

In the fall of 2016, the Bureau will release a new publication, Texas Through Time. Available in both soft and hardback covers, the beautiful volume contains

striking images of the landscapes and geologic features of the Lone Star State, and its rich narrative outlines the deep history of Texas' geology and how it continues to shape and impact the state's culture and economy. Texas Through Time is the first truly comprehensive overview of Texas' geology to be published in the last 85 years.



Cover art: Texas Through Time: Lone Star Geology, Landscapes, and Resources, by T. E. Ewing, with contributions by Heather Christensen. 431 p., 2016. Udden Series No. 6.

UTAH

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As reported last year, the UGS has experienced a large decrease in funding ($2 million per year) due to the decline in oil prices and its effect on mineral lease revenue to the state that began in late 2014. Total staff numbers decreased from around 80 to around 66 by early 2016 due to a combination of retirements and layoffs. Fortunately, the 2016 legislature recognized that the UGS had suffered enough, and it appropriated an additional $1 million per year of ongoing state funds so that additional layoffs could be avoided. Staffing levels have stabilized, although the recent retirements have left some critical gaps in expertise that will take time to fill. The UGS budget of $8.2 million for FY17 is 52% state funds, 28% contract revenue, and 19% mineral lease revenue.

The UGS's Crawford Award went to Bob Biek in recognition of his work in mapping the geology of the Panguitch 30' x 60' quadrangle (UGS Map 270DM). 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 Map 270DM also received national recognition as the recipient of the AASG's 2016 Charles J. Mankin Memorial Award.

Another UGS publication receiving national recognition was UGS Special Study 150, *Investigation of Land Subsidence and Earth Fissures in Cedar Valley, Iron County, Utah*, by Tyler Knudsen, Paul Inkenbrandt, William Lund, Mike Lowe, and Steve Bowman. UGS Special Study 150, which was also the 2014 UGS Crawford Award winner, received the 2015 GSA/AASG John C. Frye Memorial Award in Environmental Geology.

The UGS/Utah Geological Association's 2015 Lehi Hintze Award—which recognizes outstanding contributions to the geology of Utah—went to UGS Senior Geologist Douglas A. Sprinkel, for his geologic contributions over a 40-year career including (1) petroleum exploration, (2) management and research with the UGS, (3) volunteer activities for numerous professional organizations, and (4) an extensive publication record including geologic maps and technical papers.

Energy and Minerals Program

The Energy and Minerals Program (E&MP) encourages prudent energy and mineral resource development through a variety of studies to 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 extractive industries, the general public, and other local, state, and federal agencies make decisions about managing and developing energy and mineral resources in Utah.

Some recent E&MP projects include (1) studying Utah's potential 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 a salt crust under the north arm of Great Salt Lake, (6) developing an extensive digital database on Uinta Basin wells with core and/or cuttings in the Utah Core Research Center, (7) studying microbialites in the modern environment (Great Salt Lake) and in the ancient environment (Eocene Green River Formation), (8) updating the Utah Mineral Occurrence System (UMOS) database and mining districts map for GIS, and (9) 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 a team competing for 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. In early 2016, the DOE announced that the Milford site and another site in Nevada near Fallon will advance to Phase 2 to determine the final site for this underground laboratory.

The E&MP maintains the Utah Core Research Center, which contains cuttings from more than 4,000 wells, cores from over 900 wells, and representative samples of oil, coal, minerals and rocks from various producing areas in Utah (geology.utah.gov/about-us/geologic-programs/energy-minerals-program/utah-core-research-center). Annually, the center hosts at least 20 core 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 as part of the Geologic Hazard Mapping Initiative, (2) is finalizing 44 geologic-based flood maps along the Wasatch Front and in Cache Valley with the U.S. Army Corps of Engineers, (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; inventorying, digitally scanning, and developing metadata for aerial photography and imagery (http://geology.utah.gov/resources/data-databases/aerial-photographs/); and cataloging, digitally scanning, and entering metadata for our engineering geology and geologic-hazard document and photograph collection (https://geodata.geology.utah.gov).

The Western States Seismic Policy Council awarded the UGS the 2016 National Award in Excellence for Educational Outreach to Business and Government for developing and hosting the Basin and Range Province Seismic Hazards Summit III.

Geologic Information and Outreach Program

The Geologic Information and Outreach Program (GI&OP) answers public inquiries; performs public, teacher, and media outreach; prepares translated publications for a nontechnical 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 GI&OP tracks UGS outreach statistics; this year the UGS responded to 3,800 public inquiries (telephone, email, and walk-in). The UGS Library, which maintains more than 14,000 publications, assisted nearly 600 patrons. The Natural Resources Map & Bookstore's inventory includes UGS publications, other DNR divisions' publications, USGS topographic maps and publications, Utah Geological Association guidebooks, and other related publications and maps. This year's bookstore sales totaled 25,000 geologic and related items.

Education outreach this year included loaning out 143 Earth Science teaching kits; providing more than 300 AGI Earth Science educational packets to schools; giving six presentations at public schools and three presentations to industry, professional society, and enthusiast groups; participating in the Dynamic Planet Science Olympiad, a teacher science expo, a university podcast, and a teacher training course; and providing hands-on activities for 702 students during Earth Science Week.

The GI&OP continued work on two nontechnical publications, one on Utah's hot springs and one on liquefaction. Also, GI&OP staff added numerous interactive maps and databases to the UGS website, including interactive maps of the Utah Mineral Occurrence System database, abandoned coal mines, and Utah's Quaternary faults; and a searchable database providing online access to our repository of over 2,300 UGS publications. The UGS website received 413,000 visitor sessions (average of more than 1,100 per day).

Geologic Mapping Program

The Geologic Mapping Program (GMP) produces printed and digital GIS geologic maps at popular intermediate and detailed scales. Program goals are to complete at least preliminary intermediate-scale (1:62,500–1:100,000) GIS map coverage of Utah's 30′ x 60′ quadrangles by 2025 and to map selected areas at more detailed 1:24,000 scale as priorities dictate. Maps are multi-purpose, and many include booklets that describe the bedrock and Quaternary deposits, structure, geologic hazards, economic geology, groundwater resources, and scenic geologic resources. The GMP provides these maps to geologists, government officials, industry, academia, and the general public to promote better understanding of Utah's geology, delineate resource potential, detect and assess geologic hazards, and aid in land-management decisions.

This year, in the 30′ x 60′ quadrangle series, the GMP completed another block of mapping on four ongoing, multi-year projects: the Duchesne, Loa, Salina, and Tooele quadrangles. We also supported outside work on the Beaver quadrangle, and USGS work on the Grouse Creek,

Tremonton, and Newfoundland Mountains quadrangles. We published a new geologic map of the eastern 2/3 of the Wildcat Mountains 30' x 60' quadrangle (a huge area encompassing the U.S. Army's Dugway Proving Grounds), and produced a new updated release of the eastern half of the Salina 30'x60' quadrangle that includes improved versions of the geology and GIS database. Currently about 75% of the state (34 of 46 quadrangles) now have geologic maps that meet most of our standards; the four listed above are nearing completion.

This year, the GMP published or open-filed nine 7.5' quadrangle geologic maps. The maps 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 with valuable geologic resources. This year, working with our SMAC, we developed a new program 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' quadrangle maps to our interactive geologic map website (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 four student-generated maps posted to our website, and is likely to continue in future years.

Groundwater and Paleontology Program

The Groundwater and Paleontology Program (GW&PP) evaluates the quality and quantity of Utah's groundwater and wetland resources, maintains and publishes records of Utah's fossil resources, provides paleontological recovery services to state and local governments, and conducts studies of paleontological resources to aid in land-use management.

GW&PP hydrogeologists evaluated groundwater conditions in the Malad River basin (Box Elder County), Goshen Valley (Utah County), Ogden Valley (Weber County), and Round Valley (Wasatch County) to help facilitate groundwater management; established Utah's portion of the National Ground-Water Monitoring Network (NGWMN) and linked Utah's data to the NGWMN data portal (http://cida.usgs.gov/ngwmn/index.jsp); continued building a water-quality clearinghouse from which the public will be able to download data; and continued to maintain and evaluate data collected from monitoring-well, shallow-piezometer, and spring-flow gauging networks in the Snake Valley area of Utah's west desert, and updated the networks' Groundwater Monitoring Data Portal (geology.utah.gov/resources/data-databases/groundwater-monitoring) to provide public access to the data.

GW&PP wetlands scientists assessed the status of wetlands in the Jordan River watershed to determine common stressors and overall wetland condition; compared attributes between wetlands with and without breeding populations of the boreal toad to help biologists understand population declines; developed an aquatic stress model that incorporated watershed-based metrics; completed wetland mapping projects in wetland complexes near Mona and Mills and in the Upper Bear River watershed, and worked on wetland mapping for Great Salt Lake and the Jordan River watershed.

GW&PP paleontologists continued the excavation, preparation, and scientific description of several new species of dinosaurs from sites in Grand County; completed a paleontological inventory in Grand and San Juan Counties; co-hosted the annual Society of Vertebrate Paleontology meeting; and maintained a digital paleontological locality database in partnership with the U.S. Bureau of Land Management.

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Introduction

The VGS, a Division in the Department of Environmental Conservation (DEC) in the Agency of Natural Resources, is guided by the Department mission to protect human health and safety. Our services, research, publications and educational outreach provide basic geologic information and emphasize the application of geology to issues of health, hazards and groundwater resources. Activities are guided by statute that designates the State Geologist as the Director of the Division of Geology and Mineral Resources. Statutory activities include providing aid and advice, providing geologic expertise to regulatory programs, conducting research related to geology and mineral resources, and publishing and disseminating geologic reports. Geologic research and mapping are used to address critical issues in Vermont.

Groundwater and Heatlth

The VGS and our partners develop geologic data and information for the public to inform decisions about groundwater use and protection related to public health concerns (arsenic, radioactivity, asbestos, radon, nitrates). Aquifer characterization studies have been conducted by town and by region. For example, arsenic levels above health-based standards in drinking water supplies were investigated by integrating mapping with water and bedrock geochemistry.

PFOA Project

Based on expertise developed in studies of naturally-occurring contamination, the VGS was asked to conduct a geologic and geochemical study of PFOA contamination of fractured bedrock in southern Vermont. Jon Kim (VGS) is leading the aquifer characterization project to map bedrock and structure, review water well logs, log selected wells in partnership with SUNY Plattsburgh, photograph and describe cores that were drilled on the Chemfab property, and map surficial deposits in coordination with DeSimone Geoscience. Middlebury College has also partnered with the VGS to collect and analyze water chemistry data. The USGS is conducting an isotopic age study based on analyses of 5-8 wells. The integrated data will give a 3-dimensional view of the subsurface in the plant vicinity and be used to interpret groundwater flow. The study has implications for future mitigation in the area.

Figure 1. Water sampling at a spring in North Bennington

Nitrates Project

In 2015-2016, the VGS and colleagues from the Vermont Agency of Agriculture and Middlebury College concluded a 10-year study of point and non-point source nitrate contamination of bedrock wells near a dairy farm in East Montpelier and the subsequent recovery of those wells. Their work showed that zones in the bedrock aquifer responded differently to both contamination and remediation during the 10-year time frame and it documented the physical and chemical methodologies and data needed to characterize a bedrock aquifer and groundwater chemistry in deformed metamorphic rocks. The data and methods defined potential flow paths, rates of groundwater flow in various directions, connectivity of wells to fractures, and potential mineral chemistry effects on the water chemistry. The bedrock aquifer characterization methods established are currently being applied to the evaluation of the PFOA contamination in the bedrock aquifer in North Bennington and a nitrate contamination issue in Sutton.

Reference: Kim, J., Comstock, J., Ryan, P., Heindel, C., and Koenigsberger, S., 2016, Denitification and dilution along fracture flowpaths influence the recovery of a bedrock aquifer from nitrate contamination: Science in the Total Environment 569-570, 450-468, http://dx.doi.org/10.1016/j.scitotenv.2016.06.091.

Other Groundwater Programs

The VGS, in coordination with others in DEC, received a US Geological Survey Water Use Data and Research program grant to assess and inventory the current state of water withdrawal and consumptive use data collected in Vermont and to investigate, based on priorities, how to develop collection efforts to produce better baseline

data. The VGS seeks better quality water withdrawal and consumptive use data to apply towards water budget analyses and towards identification of geographic areas in need of detailed groundwater and hydrogeological information.

The Vermont Rural Water Association (VWRA), EPA, Rodney Pingree (Drinking Water and Groundwater Protection Division) and the State Geologist conducted several seminars for groundwater protection and planning groups in Vermont. A case study of a local community "NoWaterTown, Vermont" and basic geology and groundwater information were presented as a framework for planning for future public water supplies, loans and outreach. Kira Jacobs of EPA discussed the Source Protection Collaborative and other Federal partnerships and Liz Royar of Vermont Rural Water Association addressed planning for source protection at the local level. The small focus groups were an ideal forum for productive discussions with planners.

Vermont's Regional Planning Commissions requested our assistance in defining areas at higher risk during drought and in understanding groundwater availability.

Mapping Program

Bedrock and surficial maps are used to address Vermont issues such as radioactivity and arsenic in groundwater, groundwater recharge potential and to mitigate landslide hazards. The VGS involves communities at a grassroots level and addresses issues specific to town and state needs while maintaining the quadrangle mapping structure. This year our town partners provided in-kind match (GIS services and field assistance) for the cooperative federal STATEMAP program. The funds were further leveraged through student interns who spent time in the field and later completed projects ranging from water chemistry to tectonics. Maps were posted on the VGS web site for easy access for Vermont communities.

Figure 2. Sandy till mapped in Woodbury, Vermont.

The following maps and Open File reports, funded in part by the STATEMAP program, were released in 2016:

Springston, G., Kim, J., Gale. M. and Thomas, E., 2016, Geology and hydrogeology of the Town of Calais, Vermont: VGS Open File Report VG2016-1, 8 color plates, scale 1:24,000.

Springston, George, 2016, Surficial geology and hydrogeology of the Cabot 7 1/2 minute quadrangle, Vermont: Vermont Geological Survey Open File Report VG2016-3, text plus 9 plates and GIS data.

VanHoesen, John, 2016, Surficial geology and hydrogeology of Monkton, Vermont: Vermont Geological Survey Open File Report VG2016, text plus 9 plates and GIS data.

Landslide Hazards

Landslide hazard mapping, first response to landslides, and monitoring of landslide and rockfall sites in order to reduce public exposure to hazards were major activities of this program. Outreach efforts were directed towards regional planning commissions and implementation of landslide mapping protocols. A Phase One landslide hazard map for Addison County, with heavy reliance on Lidar and some field verification, was completed.

A more detailed landslide hazard mapping project in Highgate, funded through the Local Hazard Mitigation Grant Program (LHMPG), was completed in 2016. The findings of the hazard assessment report will be used to identify potential mitigation projects and will be incorporated in the Town's Local Hazard Mitigation Plan (LMHP).

The VGS and our partners also responded to bank failures along several rivers, Lake Champlain and to a train derailment. The National Transportation Safety Board (NTSB) contacted the Geological Survey for geologic assistance at the train derailment site in Northfield, VT in the fall of 2015. The NTSB, an independent US Federal Agency, is charged with determining probable cause(s) of transportation accidents and making safety recommendations.

The following reports were released in 2016:

Springston, G., 2016, Final report on a landslide inventory of the Town of Highgate, Vermont: Vermont Geological Survey Open File Report VG2016-4, text plus 6 plates, scale 24,000.

Van Hoesen and others, 2016, Final Report summarizing the efficacy of GIS-based modeling of landslide susceptibility, Addison County, Vermont: Vermont Geological Survey Technical Report VGTR2016-1.

Seismic Hazards

The Vermont Division of Emergency Management and Homeland Security (VEMHS) held a statewide emergency exercise, Vigilant Guard, in 2016. The Vigilant Guard exercise included a postulated earthquake(s) which would have significant (devastating) impacts on the State. The State Geologist presented earthquake information to the planning group and highlighted less devastating

but more plausible earthquake scenarios. To meet the needs for this particular exercise, the exercise planners developed a worst-case scenario involving several epicenters in New England and Quebec.

A year-long study was conducted by Northeast States Emergency Consortium (NESEC) in association with the Vermont State Geologist, the Vermont National Guard and the VEMHS. Buildings were rated through ROVER (Rapid Observation of Vulnerability and Estimation of Risk) based on factors such as year built, type of building (unreinforced masonry, steel frame etc), number of occupants, and plan irregularities. The building rating was then applied to estimate damage during a seismic event in HAZUS-MH, a computer program for risk assessment and damage estimates. Based on the report, 85% of the critical facilities screened were recommended for detailed review based on safety ratings. The report is part of our effort to develop technical information applicable to earthquake mitigation in Vermont. Plans were made to develop projects with the UVM College of Engineering service learning class to conduct the on-site assessments of facilities.

Public Outreach

Survey staff is active in education and outreach through school visits, field trips for towns and local officials, lectures, and the web site. Presentations at professional meetings such as the National Groundwater Association and the Northeast Geological Society of America are also important venues for maintaining 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, university seminars and classes, conservation groups and a church congregation.

VIRGINIA

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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 nine full-time geoscientists, three hourly support staff, and several external contractors. In FY 2016, funding for DGMR came from state-appropriated recurring general funds (48%), federal grants (48%), and proceeds from publication sales (4%).

DGMR continues to expand the availability of its digital datasets by placing them in a web-based map viewer. Powered by the ArcGIS Viewer for Flex, the interactive map allows users to zoom, pan, and query layers depicting bedrock geology, geologic hazards, historical mine sites, available geologic publications, and many of our other holdings.

Economic Geology

In a project supported by the U.S. Department of Energy and the Southern States Energy Board, DGMR geoscientists are assisting in reservoir characterization of deep, unmineable coal seams in the Virginia portion of the Central Appalachian Basin for their potential to store carbon dioxide. In conjunction with the Virginia Tech Center for Coal and Energy Research and Cardno MMA, a Bluefield-based consulting firm, the project team is performing an injection test of 20,000 tonnes of carbon dioxide into coal seams in the Pennsylvanian Pocahontas and Lee formations. Nearby coalbed methane wells are being monitored to determine if the injection contributes to increased natural gas production and to assess the mobility of the injected gases in the reservoir.

In another carbon sequestration assessment project, DGMR is participating in the Southeast Offshore Storage Resource Assessment (SOSRA). This project aims to assess the carbon dioxide storage potential of offshore reservoirs in the southern Mid-Atlantic, the South Atlantic, and the eastern Gulf of Mexico. Partners include the Southern States Energy Board, Virginia Tech, the University of South Carolina, The South Carolina Geological Survey, the Geological Survey of Alabama, Oklahoma State University, and Advanced Resources International.

Under the USGS National Geological and Geophysical Data Preservation Program (NGGDPP), the division rescued nearly a thousand feet of core from an under-maintained storage facility at Virginia Tech. The core had been acquired during a geothermal energy resource assessment of the southeastern states during the 1980s. The project required acquisition and assembly of several new core racks in our onsite core storage facility. The NGGDPP also supported the cataloging and scanning of field maps, field notebooks, and pre-digital-era open-file reports.

With a grant from the Bureau of Ocean Energy Management, DGMR continued its long-standing commitment to assessing offshore sand resources needed for beach nourishment. The work involves acquisition of offshore sediment samples, grain size analysis, and analysis of heavy mineral concentrations.

The division continues to contribute data to the National Coal Resources Data System (NCRDS). With a grant from USGS, DGMR provided coal thickness and elevation data for several coal seams in the Southwest Virginia Coalfield. NCRDS continues to be an important source of data for characterizing remaining coal resources in the U.S. The Economic Geology Section is also supporting DMME's coal mine reclamation permitting and enforcement program with the compilation of watershed-specific geologic maps and narratives, which are incorporated into Cumulative Hydrologic Impact Assessments (CHIAs).

Geologic Mapping

Geologic mapping in Virginia is carried out under the STATEMAP program, funded under the USGS National Cooperative Geologic Mapping Program with a 50%-50% state-federal match. Projects are prioritized pursuant to the Division's long-range mapping plan and approved by the Geologic Mapping Advisory Committee, a panel

composed of representatives from the mining industry, academia, the consulting community, and state and federal 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 Callaway, Eagle Rock, McDonalds Mill, and Singers Glen quadrangles. In the Richmond MSA, geologic maps were completed for the Church Road, Petersburg, South Anna, Sutherland, and Zion Crossroads quadrangles. A portion of the mapping was carried out in collaboration with Virginia Tech, James Madison University, and the College of William and Mary. All maps were compiled in ArcGIS v.10.3 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. The entire area is within the Richmond MSA; therefore, the mapping will complement our STATEMAP project work.

Work on geologic hazards is managed under our Geologic Mapping section. DGMR initiated a statewide fault mapping project with our second grant under the FEMA Hazard Mitigation Grant Program. The project aims to investigate the link between earthquakes and known or unknown faults in Virginia's three defined seismic zones, and educate state and local government agencies in planning for earthquake hazards specific to their region.

The Virginia Geological Research Symposium

In April, the Division hosted its 8th Annual Geologic Research Symposium. 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 offshore sand resources, new evidence for Cretaceous dinosaur species in Virginia, sinkhole detection with LiDAR imagery, and regional tectonics of the Piedmont. The day also included a poster session and breakout sessions on groundwater, energy, and coastal resiliency. Nearly ninety people attended.

Five Year Anniversary of the August 2011 Virginia Earthquake

August 23 was the five year anniversary of the magnitude 5.8 earthquake that shook the east coast, shut down a nuclear power plant, and caused so much damage to the Washington Monument that it was closed for nearly three years. DGMR recognized the event with an afternoon seminar featuring a talk by Martin Chapman, Director of the Virginia Tech Seismological Observatory. After lunch, Dr. Chapman was joined by Mark Carter (USGS) and Matt Heller (DGMR) for a panel discussion on the science response to the earthquake. The Virginia Department of Forestry provided milk "shakes" for refreshments.

Looking Forward

During Fiscal Year 2016, DGMR requested and received state funding to hire two new geoscientists, one to focus on economic geology and one to focus on geologic hazards. Additional federal funding was received from the Bureau of Ocean Energy Management to hire one full-time geoscientist for two years to conduct studies on offshore sand resources for beach nourishment. As the fiscal year ended, DGMR began recruiting to fill these three positions. When this process is complete, our staff will consist of twelve full-time geoscientists, split evenly between state- and federally-funded positions.

WASHINGTON

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Introduction

Since 1890, the Geology and Earth Resources Division, as Washington's Geological Survey, has provided geological data and services that benefit the people of Washington. Information about our products and services is available on the Division's new website (http://www.dnr.wa.gov/geology).

Figure 1. Division staff on a recent field trip along south Puget Sound.

To carry out its responsibilities during the period of July 2015 to June 2016, the Division employed 35 full-time equivalent staff. The Division's office is located in the Natural Resources Building in Olympia, Washington, where there is an extensive geology library with over 80,000 items, mineral property files, and an oil/gas well log and sample archive for use by the public, government, and industry. Much of this information is now available online on both our web page and Geology Portal.

The Division has maintained a presence in geological hazards, environmental geology, geological mapping, and earth resources with the assistance of both Federal grants and State funding. The Division serves databases and publications on these and other topics through our website, the Portal, and our Library.

Geologic Hazards

The Hazards Group performs research, education, and outreach about landslide, earthquake, volcano, hazardous minerals, abandoned mine lands, and tsunami hazards. We completed tsunami inundation models for several areas of the coastal areas and held many workshops with local government and citizens to help better inform and prepare them for a geological hazard event. We also completed an evaluation of evacuation routes on the outer coast in the event of a Cascadia subduction earthquake event that affects slope stability and liquefaction of the routes. This study takes on even more meaning since the Japan–Tohoku earthquake and tsunami of 2011. New construction of the first vertical tsunami evacuation building in America began this year at an elementary school in Westport, WA. Other coastal communities are now following suit.

During the 2015 Washington State legislative session, new legislation was passed to enhance our authority concerning geological hazards and Lidar. With the legislation, we have established two new programs, the Landslide Hazard Program and the Lidar Program.

Landslide Hazard Program

The Landslide Hazard Program is a group of five landslide 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. Accurate landslide inventories are a key component for landslide susceptibility hazard, and risk assessment, and disaster emergency management. Thus far, the group has mapped shallow and deep-seated landslides, landslide susceptibility, and vulnerability in Pierce County.

Figure 2. Lidar imagery of landslides along the Cedar River, King County.

Lidar Program

The Lidar Program was established to collect lidar data statewide, with extra focus on areas prone to landslides.

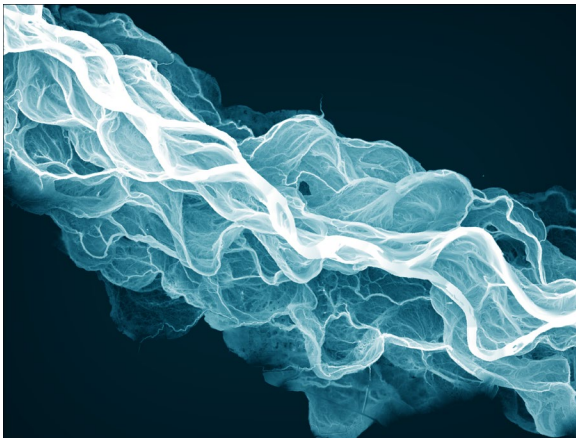

Figure 3. Lidar-based relative elevation model of the Sauk River floodplain.

This new program works to apply for federal grant funding for new lidar collection, establishes contracts and cooperative agreements with stakeholders, manages our current extensive lidar holdings, performs quality control of new lidar acquisitions, and provides the data and lidar derivatives to the public. To that end, we are developing a Lidar Portal so that the public can both view and download available lidar data across the state.

Figure 4. We recently worked in collaboration with the U.S. Geological Survey Cascades Volcano Observatory to develop a series of five posters to education and raise awareness during Volcano Preparedness Month. The Mount Rainier poster is shown above.

Geologic Mapping and Subsurface Geology

The state geologic map program continues to produce two 1:24,000 geologic maps per year. Recent detailed mapping has focused on the trend of fault zones near Seattle and faulting and glacial stratigraphy in the Hood Canal area. We are transitioning our focus southward to the northern Willapa Hills in order to investigate the potential seismic hazard posed by the Doty fault to the nearby communities of Chehalis and Centralia.

The Division maintains a state-wide database of many types of subsurface data. Division 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, and geothermal wells. The centralization of these data represents a significant effort that benefits the entire geologic and geophysical community in Washington. There are currently over 100,000 boreholes in the subsurface database with thousands added each year.

Geothermal Resources

Resource evaluations are focused on geothermal resources. We recently awarded funding in Phase 2 of a U.S. Department of Energy grant focused on geothermal play-fairway analysis. With this grant, we will collect and incorporate newly collected data into a refined geothermal model for three locations in the Cascade Range: (1) Mount St. Helens seismic zone, (2) the southeast flank of Mount Baker, and (3) the Wind River valley. These sites were chosen because we have more detailed data for these areas and they have fewer land-use restrictions. With our collaborative partners from industry, government, and academia, we conducted extensive field work this summer at the three plays consisting of ground-based gravity and magnetics, magnetotellurics, electrical resistivity, passive seismic surveys, and geologic mapping. Successful development of new methodologies to locate geothermal targets would benefit the renewable energy outlook for Washington State, and it has implications for geothermal exploration prospects elsewhere.

Mineral and Oil and Gas Regulation

There has been no drilling for oil and gas in Washington this past year. Activity in the surface mine reclamation program has made important contributions to reclaiming

mines in Washington. New mines and expansions of older properties are in the process of being permitted throughout Washington. The Buckhorn Mountain gold mine, which is the only operating gold mine in the state, has stopped their exploration program and the mine is scheduled for closure next year. One of the most significant improvements in mine regulation in Washington is the use of mobile devices to collect data efficiently and resolve issues with permit holders more quickly.

WASHINGTON GEOLOGIC INFORMATION PORTAL

The Division has created an interactive geology site known as the Washington State Geological Information Portal that is widely used and has proven to be an effective way of communication geology to professionals and the public. The Portal provides geologists and non-geologists alike a way to use and analyze GIS data without knowing ArcGIS.

We have begun an upgrade to our portal that will be complete in about a year. When finished, the Portal will have a clean and modern interface, and it will be 3D enabled, allowing the user to both view geologic data above elevated terrain, and to view subsurface data beneath the Earth's surface. Stay tuned! Entry to the Portal is at http://www.dnr.wa.gov/geologyportal

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Introduction

The West Virginia Geological and Economic Survey (WVGES) has a broad mandate to acquire and make publicly available a detailed knowledge of the geology, mineral, energy, and water resources of West Virginia, for the benefit of all citizens. Established in 1897, WVGES is an executive state agency within the Department of Commerce.

The mission of the Survey is to make publicly available timely, responsive, and credible geoscience information to promote wise public policy; to create wealth and general prosperity; and to maintain a high level of environmental quality, economic opportunity, and quality of life for all citizens of West Virginia.

Coal

The Coal Program investigates the quantity, quality, utility, location, mining, and geologic history of coal and coal-bearing rocks in West Virginia, producing databases, maps, reports, and providing consultation. On-going activities include 1) creating and maintaining the Geographic Information System-based coal maps for use by the West Virginia Department of Revenue in mineral land taxation as well as the public; 2) contributing to a national database of coal stratigraphic and quality information; and 3) maintaining a coal geochemical database detailing various chemical aspects of coal and coal-bearing rocks.

Coal Program staff have been engaged in a long-term effort to remap the Coal Measures of the state. Most of the state has been addressed, with small areas in the central and eastern parts of the state yet to be completed. Current efforts revolve around updating mined areas, addressing newly acquired industry data, extracting coal bed site-specific data from mine maps to fine tune coal thickness maps, and disseminating coal-chemistry data, especially rare earth elemental (REE) analyses. Maps for more than 80 individual coal beds and splits include structure contours, outcrops, general occurrence (study) area, total bed thickness, total coal thickness, total parting thickness, and mined areas by methodology.

In FY2016 staff began high-resolution scanning of older mine maps, most of which are on poor quality acid paper and are deteriorating. The Survey takes great pride and responsibility in the stewardship and preservation of these priceless resources. Creating digital images of these old maps will preserve the information they provide while enhancing their legibility and enabling their use in digital computing.

Much effort was spent integrating coal bed chemistry into the Oracle coal stratigraphic database this fiscal year. In addition to traditional coal chemistry data, rare earth element (REE) data were collated and analyzed as part of the increasing interest in producing REEs as a separate product stream from coal mines. The Survey provided samples for REE analyses from its large Coal Sample Library to Battelle Memorial Institute in Ohio and the US Department of Energy's National Energy Technology Laboratory (NETL) in Morgantown. The analyses provided by Battelle and NETL were added to the Survey's coal analytical database to enhance the understanding of the distribution of rare earth elements in the state's Coal Measures. Additional research opportunities involving REEs are being developed.

In addition to producing coal resource maps, Coal Program geologists conduct geologic mapping in areas adjacent to the coal fields. Cooperative work with various state, national and international geoscientists continues in the diverse fields of paleobotany, geochronography, Appalachian Basin stratigraphy, coal and overburden geochemistry, and coal bed methane resources. Development of a planned paleobotanical research facility is developing slowly, with a collection exceeding 20,000 specimens. Full-scale implementation of this facility will likely not occur prior to the completion of the State's coal resource mapping. Eventually these specimens will be sent to the Natural History Museum at the Smithsonian Institution for permanent curation.

Our Earth Science Information Center (ESIC) continued to provide expertise and products on aerial photographs, topographic features, geographic place names, various "corporate" boundaries, etc. ESIC maintains a large collection of legacy aerial photographs of several vintages and makes these photographs available to the public. These invaluable and irreplaceable photographs are being scanned at 1200 dpi and copies are available to all interested parties. Currently there is no plan to serve these scans online due to the very large size of the individual digital images.

Oil and Gas

The Oil and Gas Program compiles and distributes information on oil and gas resources in the state by maintaining a publicly-accessible database and interactive web-based mapping applications, conducting research, publishing maps and reports, consulting with the public and industry, and giving presentations. Available information includes the location of oil and gas wells and fields, pays/shows and production rates of wells, and subsurface geology.

Data-related accomplishments include: 1) scanning additional geophysical logs for an updated scanned log total for nearly 25,000 wells and digitizing log suites for 50 of those wells, with placement of these digital products on the agency's website for staff usage and public download; 2) continuing to input data from well plats and completion records into the Oracle-based database in support of research and information programs, with public access to the data provided via the agency's website; 3) on-going scanning of well records, with emphasis this year on digital preservation of the oldest well records in our collections; 4) maintaining a public library of 157 cores, with samples from more than 4,500 wells; 5) developing interactive mapping applications and services covering all wells, various tight gas plays, and the Marcellus and Utica shales; and 6) creating downloadable data and mapping files available on the agency website which summarize current permitting and drilling activity for the Devonian Marcellus Shale play, the Ordovician Utica Shale play, and other emerging conventional and unconventional targets. There is considerable public interest in our e-logs, and in sampling our cores and cuttings for analysis.

WVGES participated in a multi-state research consortium to study the Utica Shale and results of the study were released to the public in July of 2015. Accompanying this release was an update of two resource assessments conducted by WVGES geoscientists—a volumetric analysis of original-gas-in place and a probabilistic assessment of technically recoverable resources.

Research programs currently underway or recently completed include 1) a study of the stratigraphic framework of the Marcellus Shale across the state, with a volumetric resource assessment specifically for West Virginia; 2) participation in a regional Carbon Dioxide Sequestration program funded by the U.S. Department of Energy to characterize reservoirs that may be suitable for enhanced oil recovery (EOR) or enhanced gas recovery (EGR) via CO_2 floods; 3) the Wellbore Integrity project funded by the U.S. Department of Energy and administered by the Battelle Memorial Institute, researching the type, diameter, and installation characteristics of casing strings used in wells that inject or withdraw carbon dioxide; and 4) a RPSEA regional cooperative study to evaluate depleted reservoirs for their potential to store brine or water produced as a by-product of oil and gas drilling, completed in October 2015.

During the year we worked with the West Virginia Land Trust, a non-profit organization dedicated to preserving "special places" across the state via conservation easements. Mineral rights are commonly severed from many of the surface tracts the Land Trust considers for acquisition. The Oil and Gas Program provided reports detailing assessment of risk for future surface destruction from oil and gas drilling. One candidate tract assessed contains stands of virgin timber and horizontal legs from six Marcellus wells underlie the property. This relationship highlights just one way the decreased surface impact of horizontal drilling helps preserve natural landscapes across the state.

General Geosciences

Through fieldwork, research, service, and outreach, the Geoscience Program provides information and expertise on geologic mapping, environmental geology, geochemistry, hydrology, and resource assessment. Key activities include: 1) producing geologic maps through field work, resulting in maps for sale to the public in paper, PDF, or GIS format; 2) providing environmental geological expertise in categories including earthquakes, karst, landslides, and mine subsidence; 3) collecting data on the geochemistry of bedrock and sediments; 4) gathering and distributing information and providing expertise on issues relating to ground- and surface-water hydrology, water use, and water quality; 5) conducting advanced research on methods of resource assessment; and 6) evaluating geologic site characteristics for Underground Injection Control (UIC) permits for injection of fluids into subsurface rock formations .

Geologic Mapping at WVGES consists of the direct acquisition of new geological information through field reconnaissance and the conversion of new and existing geological information from hard copy (paper, mylar, etc.) to digital format.

Acquisition of new geological data is carried out under the auspices of the STATEMAP program funded jointly by the United States Geological Survey (USGS) and WVGES. During the summer and fall of 2015 and spring of 2016, field work was conducted on five 7.5-minute topographic quadrangles in central and eastern West Virginia (Alvon,

Bowden, Valley Point, Cuzzart, and Sang Run (WV portion)). Published as WVGES Open File Reports, the data are currently available as paper maps, PDF files, and geographic information system (GIS) geodatabases. In September 2015, the STATEMAP Advisory Committee, composed of individuals from industry, government, and academia, met to evaluate new potential map areas within WV for the upcoming 2016 field season. In November 2015, a multi-project proposal was successfully submitted to the USGS and mapping of the Parsons, Kingwood, Terra Alta, and Oakland (WV portion) quadrangles was partially funded.

Geographic Information Systems

This program is responsible for planning, organizing, coordinating, and delivering high level Geographic Information System (GIS) advice to agencies in state government, and is headed by the State GIS Coordinator. The program continues to make headway in a number of critical areas: promoting data sharing between agencies; providing technical assistance to state, county, and local governments and the public; and fostering efficient and effective use of the state's geospatial capabilities.

The Coordinator provided support to the Division of Homeland Security, Department of Environmental Protection, the West Virginia Water Development Authority , Infrastructure and Jobs Development Council (IJDC), the National Guard, the West Virginia Intelligence Fusion Center - Hazard Mitigation Section, and other state, regional and local agencies in their search for GIS contract services, funding, and GIS application development.

Data exchange protocols to enhance data sharing and exchange among state and local agencies established in the previous years have proven to be successful. The protocol began the inclusion of state and locally produced datasets in the GIS Clearinghouse maintained by the WV GIS Technical Center in Morgantown.

Information Services

The Information Services Program facilitates accumulation, documentation, and categorization of results and interpretations of agency mapping and research, and provides and maintains programming and geotechnical information support for agency staff. Within this program, the Survey: 1) produces high-quality, cost-effective publications and information products summarizing research and service activities; 2) provides editorial, cartographic, and production support for agency programs; 3) provides information technology support and development for agency programs and projects, including an integrated computing and networking infrastructure, an integrated mineral resources database, and administrative systems; and 4) develops Internet-based mapping services for public access.

During the past year the WVGES website received more than 18 million page views on 1,015,656 visits. The most accessed page was our "pipeline" access to well-specific oil and gas data; other very popular pages included the coal mine map information database, the core viewer, and geologic hazards. Among the most popular downloads were scanned geophysical logs and mine maps, the state geologic map, and several geoscience education pages. Updated interactive maps include geology of the Marcellus Shale, activity in the Utica Shale Play, and geographic distribution of broadband providers in the state. Web-based services updated during the fiscal year include a program to create a nearly dynamic daily update of Excel spreadsheets for Marcellus shale wells and horizontal wells in general.

WISCONSIN

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Introduction

The Wisconsin Geological and Natural History Survey (WGNHS) provides objective information about Wisconsin's geological, mineral, and water resources. WGNHS was created by the Wisconsin Legislature in 1897, with earlier state surveys in Wisconsin dating back to 1854. During 2016, the staff of the WGNHS consisted of 24 science and support staff. They were involved in a variety of mapping, research, and educational projects in the areas of geology, hydrogeology, and mineral resources.

During 2016 WGNHS worked on projects in all 72 of Wisconsin's counties, drilled over 2,000 feet of rock core and nearly 1,000 feet of geoprobe core, measured water levels in 153 monitoring wells, and geophysically logged 47 municipal wells.

Geologic Studies

Columbia County

Declining groundwater quality in Columbia County has driven the need for a bedrock map to help inventory and assess its groundwater resources. Additionally, understanding the geology and distribution of industrial sand and road materials will help local officials address land-use questions.

Dodge County

In 2016, we worked on the second year of a 4-year bedrock mapping project in Dodge County. Detailed knowledge of the bedrock is essential both for assessing groundwater resources and for pointing to the distribution of the county's mineral resources.

Driftless Area

Prior to this 8-year study, begun in 2012, the WGNHS had no geologic maps of the Quaternary geology of the Driftless Area. Among the research projects conducted during this project, we've been able to document the ancient reversal of the Wisconsin River, which bisects the Driftless Area.

Oneida County

We finished mapping Oneida County's glacial geology. This new map can be used to answer questions about natural resource management (sand and gravel, water) and improve understanding of the geologic history of Wisconsin's Ice Age.

St. Croix National Scenic Waterway

Geology is the foundation of park ecosystems and provides important information needed for park decision making. To meet this need, the National Park Service asked the WGNHS to create a geologic map of the St. Croix and Namekagon Rivers for their geologic resources inventory.

Water-Resources Studies

Western Wisconsin

Wells in western Wisconsin draw water from rock units with naturally occurring metals that could be potential health hazards. We are mapping the distribution and testing the composition of these rocks to better understand where these metals are present and how to avoid them in water supply wells.

Bayfield County

When a large-scale hog farm was proposed in Bayfield County, officials turned to the Survey for information about their groundwater and water supply wells. We analyzed data from over 660 wells and created a water-table map and cross-sections to help them make informed land-use decisions.

Columbia County

More than 20% 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.

Groundwater Models

WGNHS staff worked on groundwater studies in Chippewa County, for the Chequamegon-Nicolet National Forest, for Dane County, and for the Little Plover River watershed in the Central Sands region.

Springs

We are in the middle of a project inventorying all known springs in Wisconsin that discharge at least 110 gallons of water—the equivalent of filling two bathtubs—every minute. The database will strengthen our understanding

of springs and their vulnerability to changes in land use and climate.

WGNHS BY THE NUMBERS

Our numbers provide a snapshot of the work the WGNHS did in 2016 across the width and breadth of Wisconsin.

Core repository—*maintaining a rock and core repository*

- 600,000 feet of rock core
- 15,500 rock thin sections
- 11,000 water well cuttings

Geologic data—*making our data available*

- 31,000 thin section photographs
- 3,300 pages of field notes scanned
- 540 feet of geoprobe core photographed

Education and outreach—*answering questions from industry, regulators, government, and the public*

- 14,000 educational contacts
- 24,400 publications downloaded (http://wgnhs.uwex.edu)
- 2,300 Facebook likes (https://www.facebook.com/WGNHS)
- 1,400 Twitter followers (https://twitter.com/wgnhs)

WYOMING

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Introduction

For more than 80 years, the Wyoming State Geological Survey (WSGS) has performed the important and critical function of interpreting Wyoming's complex geology. Our mission is to promote the beneficial and environmentally sound use of Wyoming's vast geologic, mineral, and energy resources while helping protect the public from geologic hazards.

The WSGS is located on the University of Wyoming campus in Laramie, Wyoming, and has 23 full-time benefited staff positions. The WSGS works to (1) study, examine, and understand the geology, mineral resources, and physical features of the state; (2) prepare, publish, and distribute (free or for sale) 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.

Mapping

The WSGS, under its StateMap program, published three new geologic maps that are focused on the geology related to energy resources and geologic hazards in Wyoming: a 1:24,000-scale Geologic Map of the Rawlins Peak SW Quadrangle, Carbon County; a 1:24,000-scale Geologic Map of the Shamrock Hills Quadrangle, Carbon County; and a 1:100,000-scale Surficial Geology Map of the Afton Quadrangle (30' x 60'), Lincoln and Sublette counties. The WSGS additionally published a 1:100,000-scale Surficial Map of the Red Desert Basin.

Figure 1: WSGS geologist Jacob Carnes surveys for a map of the Dixon quadrangle in southern Wyoming.

Resources

State mineral resources

Wyoming's mineral resources were the topic of four reports published by the WSGS as requested and funded by the state legislature. One study examined zeolite resources in Wyoming. Geologists verified previously reported occurrences and explored additional favorable locations for natural zeolite deposits.

A rare earth elements report was a continuation of a previous study. Geologists collected more than 275 new samples from known and potential host rocks of rare earth elements and other minerals. Another 45 samples previously collected by the WSGS for other projects were analyzed as well.

The third report was on Wyoming's potential lithium resources. It was the first such comprehensive report and involved a review of geochemical data for nearly 68,000 Wyoming sediment, soil, rock, and water samples obtained from seven state and federal databases. Additionally, geologists collected 697 rock and soil samples.

Phosphate rock in Wyoming was the focus of a fourth investigation conducted by the WSGS. The study provides a geologic overview of phosphate occurrences in the state, and includes historical information, a compilation of previously published data and new data from samples collected in the field, and color location maps. Twenty samples from several known and potential deposits were collected for this study. Powder X-ray diffraction and whole-rock geochemical analysis of these samples were used to determine the amount and type of phosphates present.

The final report was on the state's iron resources and involved geologists sampling sites across Wyoming based on previous state and federal iron investigations, known iron sources, and historic iron mining locations. The report is the first comprehensive statewide study that includes historical research coupled with current field investigations.

Energy

Geologic Study on the Great Divide Basin

The WSGS published a geology study on the Great Divide Basin that involved creating a databased of more than 4,000 records of exploration wells with data provided by the Wyoming Oil and Gas Conservation Commission and the U.S. Geological Survey.

Water/Aquifer

Groundwater Salinity in the Denver-Julesburg Basin

The WSGS completed a groundwater salinity study in the Denver-Julesburg Basin of southeastern Wyoming. The report examines the salinity of groundwaters that occur at depths of 5,000 feet or less in the Denver-Julesburg structural basin where significant oil and gas activity has taken place in recent years.

Geologic Hazards

Sinkholes and Karst Features in the Southern Laramie Basin

The WSGS published a report on the occurrence of sinkholes and other evaporite related karst features in the southern Laramie Basin, including in and around the city of Laramie in southeastern Wyoming. For this study, geologists conducted field surveys, examined geophysical well logs, and reviewed historical records of gypsum karst occurrences in the basin.

Outreach

A Guide to Wyoming's Cultural Geology

The WSGS released an intelligent travel program, "The Origin of Landscape: A Guide to Wyoming's Cultural Geology." The Guide allows users to see and virtually explore the nexus between geological phenomena, landscape, and cultural beginnings. The project involved collaboration with the Wyoming Department of Transportation, Wyoming Office of Travel and Tourism, and the Alliance for Historic Wyoming.

New Geologic Signage Installed off Snowy Range Scenic Byway

The WSGS collaborated with the Medicine Bow-Routt National Forests and installed two new interpretive signs along the Snowy Range Scenic Byway in Wyoming. The WSGS designed the signs, which explain the area's geology.

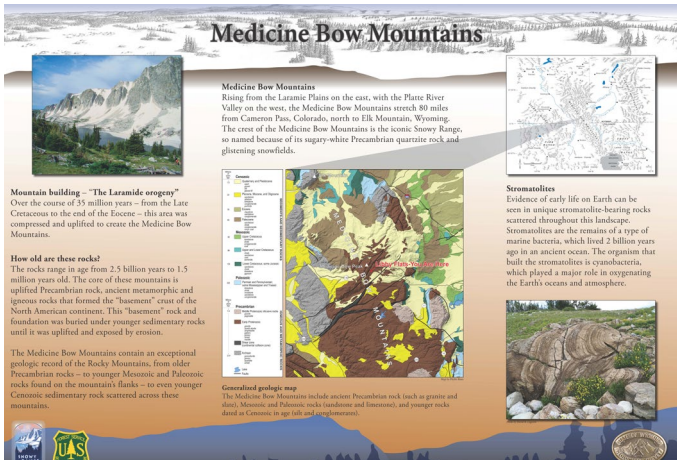

Figure 2. One of two interpretive signs along the Snowy Range Scenic Byway in Wyoming WSGS collaborated with the Medicine Bow-Routt National Forest in installing.

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 2016 recipients of this award are:

John Steinmetz, Honorary Member, Indiana State Geologist (retired)

Eric Potter, Texas Bureau of Economic Geology

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 2016 award winner is:

Peggy S. Johnson, Dan J. Koning, Stacy S. Timmons, and Brigitte Felix, 2016, Geology and Hydrology of Groundwater-fed Springs and Wetlands at La Cienega, Santa Fe County, New Mexico: New Mexico Bureau of Geology and Mineral Resources Bulletin 161, 92p.

An excerpt of the report summary notes: "La Cienega's springs and wetlands are important hydrologic, ecologic and cultural resources, and provide many beneficial water-related functions. The wetlands discharge groundwater from regional and local aquifers that provide the sole water source for the southern Santa Fe region. We investigate the wetland system by examining the hydrologic interactions manifested in the wetland water balance."

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.

Jon Arthur, State Geologist of Florida, and Past President of AASG, announced the winner of AASG's 2016 Charles J. Mankin Memorial Award:

Robert F. Biek, Peter D. Rowley, John J. Anderson, Florian Maldonado, David W. Moore, David B. Hacker, Jeffrey G. Eaton, Richard Hereford, Edward G. Sable, Harry F. Filkorn, and Basia Matyjasik, 2015, Geologic

Map of the Panguitch 30' x 60' Quadrangle, Garfield, Iron, and Kane Counties, Utah

"The Award is given each year to a nominated geological map, compilation, or report on regional, energy, or mineral resource geology published in one of the three preceding calendar years by a state geological survey. Please join me in thanking the nominators of five outstanding award candidates. Also join me in congratulating the nominators, winning author and co-authors at the Utah Geological Survey for producing a superb publication."

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 2016 Pick and Gavel Award to **Anne Castle** 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.

Anne J. Castle, Senior Fellow at the Getches-Wilkinson Center, University of Colorado School of Law and former Assistant Secretary of Water and Science at the Department of the Interior, is the 2016 Pick and Gavel Award recipient, recognizing her significant leadership and service to the geosciences through contributions at the Department of Interior and in other capacities throughout her career.

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 2016 recepient is **Berry H. (Nick) Tew**, State Geologist of Alabama.

The following is an excerpt from the AGI press release:

"The American Geosciences Institute (AGI) is pleased to recognize Berry H. "Nick" Tew, Jr., the State Geologist of Alabama, with the AGI Medal in Memory of Ian Campbell for Superlative Service to the Geosciences, its highest award. He is recognized for his roles, abilities and successes in bringing academia, government, industry and the public together to address major societal challenges in the geosciences.

Dr. Tew has served as State Geologist and Oil and Gas Supervisor of Alabama for 14 years and, in these capacities, he directs the Geological Survey of Alabama and the State Oil and Gas Board. He is a fellow at the Geological Society of America; a member of the National Petroleum Council; the National Academies of Sciences, Engineering, and Medicine's Unconventional Hydrocarbon Roundtable; the Executive Board of the Council of Scientific Society Presidents; and a Commissioner of the North American Commission on Stratigraphic Nomenclature. He has been deeply involved with the Interstate Oil and Gas Compact Commission and the Groundwater Protection Council and is a leader in the dialog surrounding the development of unconventional hydrocarbon resources, serving on the Board of the State Oil and Gas Regulatory Exchange. He also holds an appointment as a Research Professor in the Department of Geological Sciences at The University of Alabama, where he directs the Center for Sedimentary Basin Studies."

AASG Presidential Awards

AASG Presidential Awards are announced and presented at the Annual Meeting, at the discretion of the AASG President, to recognize extraordinary service to the objectives of AASG by one or more active member(s) of the AASG community, including friends of AASG, during the preceding year. The 2016 recepients are:

Simone Montayne, Alaska

Ken Woods, Alaska

Karen Berry, Colorado