MBMG

Montana Bureau of Mines and Geology

Biennial Report of Activities and Programs

July 1, 2014 to June 30, 2016

All cover photos by Jesse Mosolf, MBMG

A department of Montana Tech of The University of Montana

DIRECTOR'S INTRODUCTION

Photo by Lisa Wareham

The Montana Bureau of Mines and Geology's biennial report is our opportunity to reflect on the many and varied achievements of a unique group of scientists, engineers, staff, and students.

Our mission is to provide information for the sound use of Montana's geological and water resources.

Our vision is to be Montana's lead source of geologic and water information.

As a non-regulatory State agency within the Montana University System, we serve as Montana's geologic survey, addressing topics ranging from earthquake monitoring and geologic mapping to energy development and groundwater. We are housed on the Montana Tech campus and maintain a fully staffed office in Billings.

In 2015, the MBMG released a new 1:100,000-scale seamless geodatabase, which seamlessly combines 79 individual maps. This database provides geologic map data for use by geologists and others for exploration, planning, and economic development. The geodatabase currently covers approximately 80 percent of Montana and we are well advanced on the remaining 13 30' x 60' maps to complete the effort. The MBMG also released the very popular "Geologic Road Map of Montana," a handy travel-friendly map of our State's geology. More than 800 copies have been sold since its release in mid-2015.

Our Ground Water Information Center (GWIC) database remains very active and has become the flagship for several other online datasets, including earthquakes, proppant sources, abandoned mines, and historic data related to oil and gas and mining. The newest addition is our surface-water mapper, a cooperative effort with the Montana Department of Natural Resources and Conservation to provide real-time and historic stream flow data throughout Montana. As of the end of 2016 we present data for 176 locations, 29 of which are updated hourly.

The MBMG has several new members replacing retirees in geology; a complete list of MBMG members is included in this report. Susan Vuke, geologist, retired with 34 years of service; Clay Schwartz, a hydrologist in our Billings Office, retired after 15 years; and Debbie Smith, a geologist in our Earthquake Studies Office, retired after 9 years of service.

In Memoriam

Kenneth Lane Sandau passed away January 2, 2015, at his residence, of natural causes.

He was born in Missoula June 16, 1955, to George and Phyllis (Sticht) Sandau and attended Missoula schools, including Hellgate High School and Missoula Vo-Tech. He worked at the White Pine Mill for over 20 years until its closure. In 1996 Ken moved to Butte to work as a GIS specialist for the MBMG, where he participated in many publications over his 20-year career. He co-authored six publications, including the popular map of Lewis & Clark campsites in Montana.

He and his wife Sharon were married in Coeur D'Alene, Idaho, on November 5, 2004, and together they made their home in Butte. Ken enjoyed fishing, camping, and boating at Georgetown Lake and loved to golf.

He is survived by his wife Sharon Sandau and son Donny Sandau, both of Butte; daughter and son-in-law Stori and Matt Gray and son and daughter-in-law Ryan and Amanda Ahlquist, all of Belgrade; his parents, George and Phyllis Sandau of Missoula; grandchildren Kailey and Aubree Gray and Kaden Ahlquist; brothers Gary Sandau of Opportunity, Rod Sandau and his partner Alex of Opportunity, and Brad Sandau and his wife Sue of Missoula.

Ken will be fondly remembered by his many friends and colleagues here at the MBMG, as well as the dozens of geology and GIS students who learned their skills under his watchful eye.

UUNO SAHINEN AWARD

The Silver Medallion Award is given annually by the Montana Bureau of Mines and Geology in memory of Mr. Uuno Sahinen, the first full-time Director and State Geologist of the MBMG. The award is presented to those who have achieved long-term significant contributions to the understanding and development of the geologic and groundwater resources of Montana.

The 2015 Uuno Sahinen Silver Medallion Award was presented to Don Winston, Ph. D. on May 16, 2015, at the 114th commencement ceremony of Montana Tech. Originally from Washington DC, Don grew up in Minneapolis, Minnesota and graduated from high school in 1949. He received his B.A. in Geology from Williams College in 1953, and received his M.A. and Doctorate from the University of Texas at Austin in 1963.

In the fall of 1961, Don accepted a position at the University of Montana Geology Department, where he taught Petrology, Biostratigraphy, Paleoecology, and various field geology courses. In addition to teaching, he dedicated decades of research to the stratigraphy and sedimentology of the Precambrian Belt Supergroup, an immensely thick and complex package of rocks in western Montana and northern Idaho.

Don's attention to the stratigraphy and sedimentology of the Belt Supergroup provided many of his students with the knowledge and tools to explore economic deposits of silver, lead, zinc, copper, and gold. Many of his students became experts in Belt mineral exploration, while others followed in his footsteps as Montana geology professors. Don's former students who are geologists at the Montana Bureau of Mines and Geology and Idaho Geological Survey produce geologic maps of Belt Supergroup rocks that would not be possible without Don's mentoring. One of Don's former graduate students edited a classic MBMG Special Publication on the Belt Supergroup that is primarily a collection of research papers, maps, and correlated stratigraphic sections by Don and his former students.

Another of Don's former graduate students, whose research in Montana launched a career studying similar geologic formations throughout the world, is now Chief Scientist for NASA's Curiosity Rover Mission to Mars. Although Don retired in 2004, his passion for research and teaching has not diminished. As an emeritus professor at the University of Montana, he continues to collect new field data, give talks, attend professional meetings, publish papers, lead field trips, mentor students and colleagues, and share his knowledge of Belt rocks with anyone who is interested. He is a long-time active member of the Belt Association, Tobacco Root Geological Society, Geological Society of America, and the Society of Sedimentary Geology. The 2014 Rocky Mountain Section of the Geologic Society of America, held a special session in honor of Don's career accomplishments.

The 2016 Uuno Sahinen Silver Medallion Award was presented to Betty Ann Lindberg Skipp, Ph.D. on May 14, 2016 at the 115th commencement ceremony of Montana Tech. Betty was born in Chicago, IL on May 7, 1928. She graduated from Maine Township High School in 1945 and from Northwestern University in 1949 with a B.A. in Mathematics and Geology. She received her M.S. in Geology from the University of Colorado in 1956 and her Doctorate in 1985 also from the University of Colorado. She was elected to Phi Beta Kappa in 1948. At Northwestern, she majored in mathematics with a minor in geology, but soon came to realize that geology was her real interest. This came about because Robert M. Garrels was her freshman advisor, and the faculty hosted an outstanding array of professors including Lawrence L. Sloss, and W. C. Krumbein. Betty applied for and received a graduate scholarship from the University of Colorado. In 1951 she married James M. Skipp and she has one son, Gary Lindberg Skipp, also a geologist with the USGS. She received an M.S. in 1956 and a Ph.D. much later in 1985.

She began work for the U.S. Geological Survey in 1952 as an assistant to Clyde Polhemus "Hoss" Ross. Betty had her first field "lessons" working with Clyde in south-central Idaho. Clyde became a quiet champion and Betty was assigned to map the Maudlow Quadrangle in southwestern Montana on her own—by default. The project originally was assigned to four women geologists whom James Gilluly had on his roster and didn't know what to do with. After Maudlow, she was fortunate to be able to follow that assignment with additional geologic quadrangle mapping in southwestern Montana, and then on to the Paleotectonic map project and south-central Idaho. Her career has also included work on the Carboniferous Paleotectonic map project (Great Basin), the landslide map of the U.S., and the Enewetak Drilling Program. She proposed a zonation for mid-Carboniferous smaller calcareous foraminifers in the Redwall Limestone of Arizona, and was a member of the international committee that established the type section for the mid-Carboniferous boundary in Nevada. She has a foramineral genus, Skippella, named for her.

She has more than 80 publications with the U.S. Geologic Survey, the Montana Bureau of Mines and Geology, and several professional journals spanning from 1956 to 2004, well after her retirement. She is emerita with the USGS, a member of the Tobacco Root Geological Society, the Colorado Scientific Society, and a senior Fellow with the Geological Society of America.

OUTREACH

One of our primary missions at the MBMG is to disseminate Montana's geologic and water information to the citizens of Montana. During this biennium, our staff have been busy, as we always are, talking to and sharing our research with Montanans.

GROUND WATER ASSESSMENT

The Legislature established the Ground Water Assessment Program (85-2-901 et seq.) in 1991 to improve the understanding of Montana's groundwater resources by collecting, interpreting, and disseminating essential groundwater information. This information is vital for making science-based management decisions.

There are three Program components:

Groundwater Monitoring—to produce and maintain long-term water-level and water-quality records,

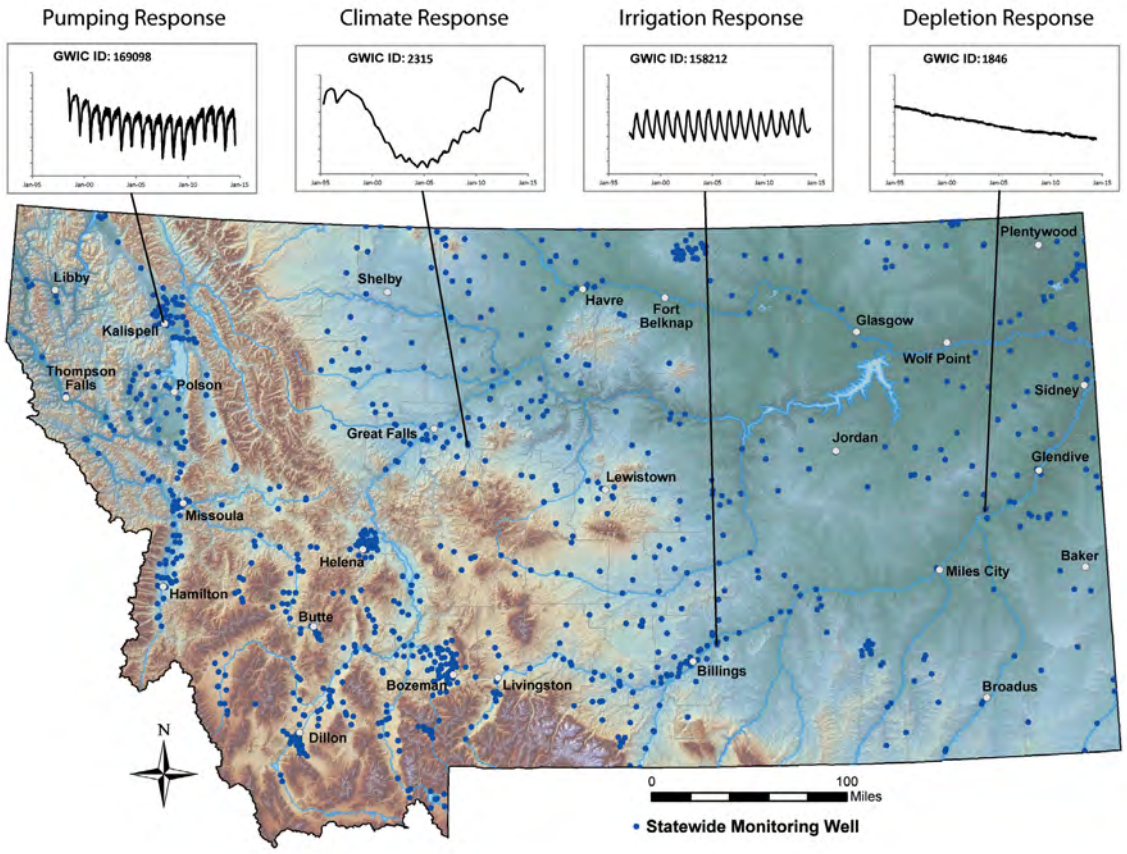
Groundwater Characterization—to systematically assess and document the hydrogeology and quality of the State's major aquifers, and

Groundwater Information Center (GWIC) database—to make groundwater information widely available.

An interagency Steering Committee selects study areas, coordinates groundwater research among State, Federal, and local government units, and oversees Assessment Program progress.

Ground Water Monitoring

The Ground Water Monitoring Program collects quarterly water-level measurements from strategically located wells across the State. Long-term groundwater-level records are the only direct measure of how Montana's aquifers respond to seasonal, climatic, developmental, or land-use factors. Long-term groundwater hydrographs are similar to long-term records of stream flow and precipitation, and must be evaluated at decadal scales.

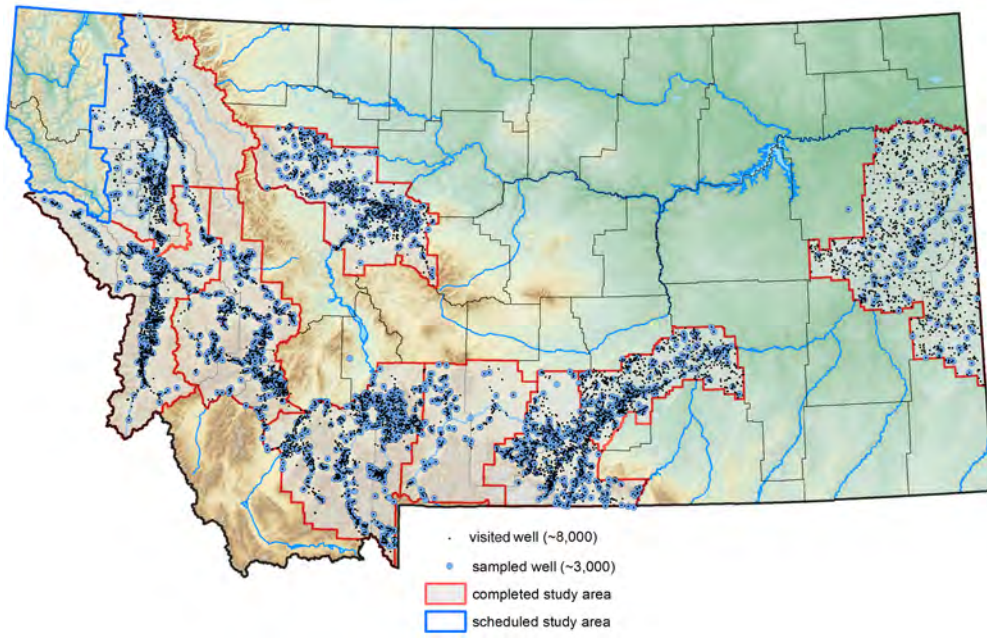


Since 1993, the MBMG has been collecting systematic groundwater-level data from a 900+ well statewide network; some wells have been regularly monitored since the 1950s. The network covers the State's major aquifers and includes wells that range from <10 feet to >3,600 feet in depth.

Water levels in many Montana aquifers follow natural seasonal patterns, typically rising each spring and early summer, and declining during the late summer and fall. In addition to the seasonal response, water levels respond to other stresses such as pumping (response may occur in hours or days), climate variability or drought (response may occur in years to decades), and widespread development (response occurs at varying time scales). Montana's long-term network is beginning to show where and which aquifers are impacted by these different stresses, highlighting the value of long-term, decadal-length records. Without continued monitoring, Montanans would have no data about these important issues.

Ground Water Characterization Program

The Characterization Program provides basic information about aquifers within specific areas as prioritized by the Ground Water Assessment Steering Committee. Completed and scheduled study areas are shown on the map at right.



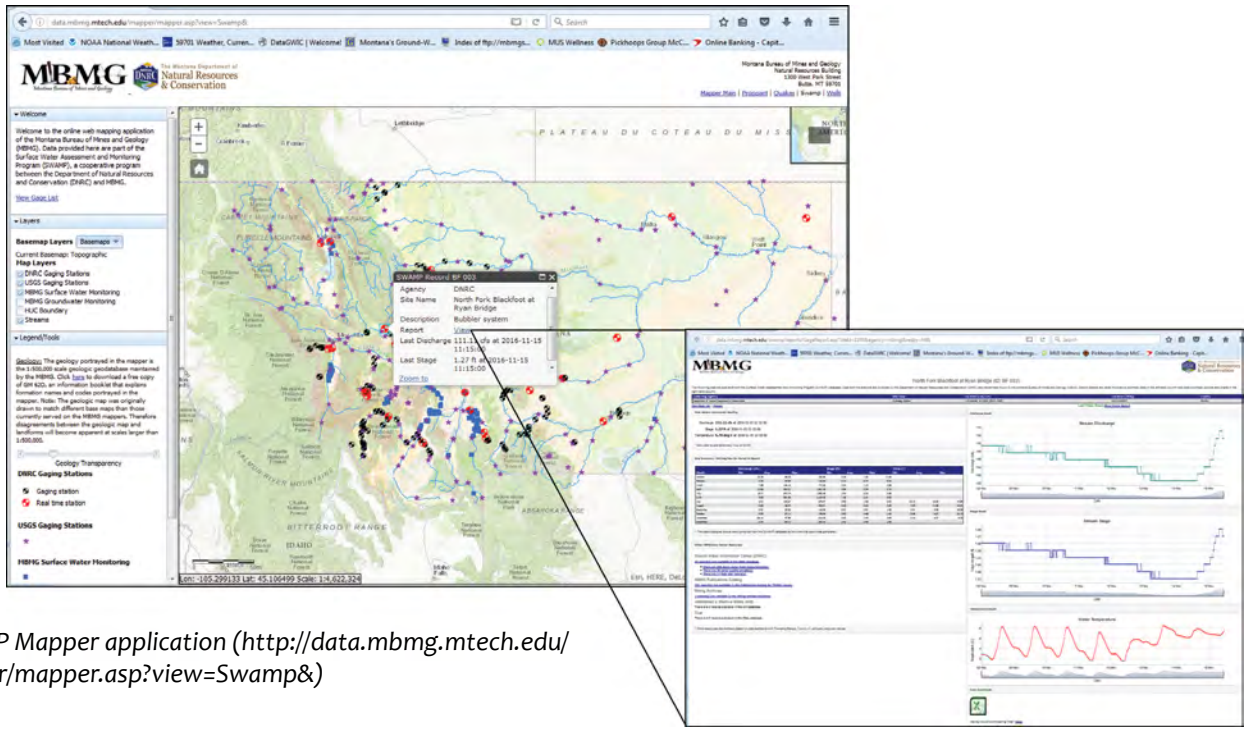
Characterization field staff have completed work in Park and Sweet Grass Counties, including a collaborative investigation with the Shields Valley Watershed group and the Park County Conservation District to establish baseline water-quality monitoring in areas of potential natural gas development. The Steering Committee has selected Lincoln and Sanders Counties as the next Characterization field area.

To date, more than 8,000 wells have been visited and about 3,000 groundwater samples have been collected. These data have been used to compile 64 maps and reports that describe specific aspects of Montana's aquifers, groundwater flow systems, and groundwater quality.

Ground Water Information Center (GWIC)

The Ground Water Information Center (GWIC) is the repository for the state's groundwater information. The website (http://mbmggwic.mtech.edu/) provides online access to water-well logs, hydrographs that track water levels in the State's major aquifers, maps of groundwater flow systems, and water-quality reports describing groundwater conditions across the State, as well as a variety of field, chemical and physical data.

As part of the evolving Data Center at the MBMG, GWIC provides interactive web mapping applications that allow online data visualization and facilitate map-based data retrievals for water wells, seismic activity, and native proppants. The newest application is the Surface Water Assessment and Monitoring Program (SWAMP) mapper. Surface water collected by the Department of Natural Resources and Conservation (real-time and manually downloaded gauges) and the MBMG are available for display and download. All new data for the real-time gauges are available at the top of every hour. The stream gauges monitored and maintained by the USGS are also included for viewing. Currently there are 176 locations; 29 sites provide real-time discharge, stage, and temperature data.



SWAMP Mapper application (http://data.mbmg.mtech.edu/mapper/mapper.asp?view=Swamp&)

GROUND WATER INVESTIGATION PROGRAM

The Ground Water Investigation Program (GWIP) answers locally identified, site-specific questions prioritized by the Ground Water Steering Committee (MCA 85-2-525). As mandated by the Legislature, GWIP conducts research on the most urgent water issues in the State.

Future water management will reflect the increasing value of Montana's water resources and will require a well-founded understanding of the groundwater systems. In Montana, groundwater is essential for safe drinking water supplies and for economic growth. On average, approximately 272,000,000 gallons (835 acre-feet) are extracted from Montana's aquifers every day. In many areas of the State, groundwater is the only reliable year-round source of water for household use and for livestock. Groundwater is also widely used for irrigated agriculture and for lawns and gardens, and it provides baseflow to streams and rivers. Changing land use and demographics can alter groundwater withdrawals, which could directly affect senior water rights holders, stream flows, the availability of irrigation water, and the health of aquatic ecosystems.

As the State's concern over water resources increases, the importance of investigating groundwater and surface water as a single resource has become more evident. The interaction of ground water and surface water has been shown to be a significant concern in issues related to water supply, water quality, and aquatic environments.

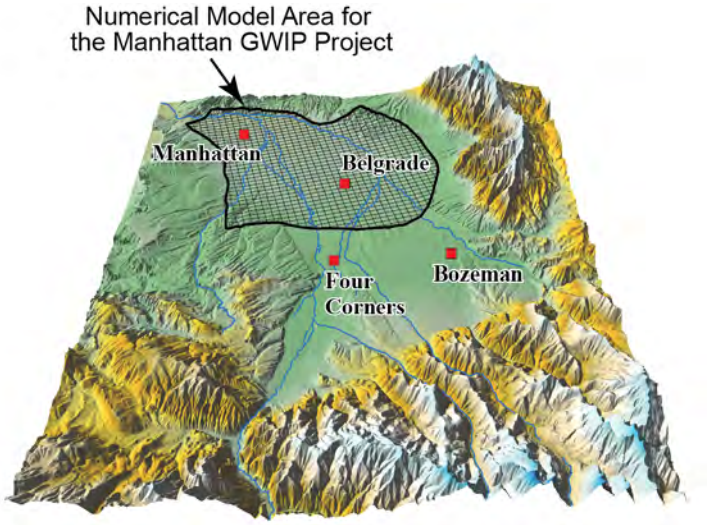
Current topics of investigation include:

- Effects of changing irrigation methods on groundwater recharge and surface-water baseflow (i.e., converting from flood to pivot irrigation).
- Identifying natural and man-made influences on stream dewatering.
- Aquifer and stream response to changing land use from irrigated agriculture to residential development.
- Hydrogeologic viability of replacing surface-water diversion points with irrigation wells.
- Groundwater sustainability in response to increasing residential and commercial demands.
- Changes in water quality due to increasing subdivisions.
- Aquifer sustainability in response to increasing numbers of irrigation wells.
- Viability of developing buried river channel aquifers.
- Impact on stream flow of increasing groundwater withdrawals.

Program Products

GWIP products are designed to provide a detailed understanding of the groundwater and surface-water systems. The information and tools such as numerical models can then be used by regulators, senior water rights holders, new water rights applicants, and other stakeholders to make informed water management decisions and to help anticipate hydrogeologic effects from changes in land use.

- ◊ Every GWIP investigation produces a detailed published report on the hydrogeologic system and responses to current and anticipated stresses.
- ◊ Most projects include a computer model that simulates specific hydrogeologic features and stress responses, and is available online for future test scenarios.
- ◊ A comprehensive set of hydrogeologic data are compiled for each site and are permanently available online through the Ground Water Information Center (http://mbmggwic.mtech.edu/).



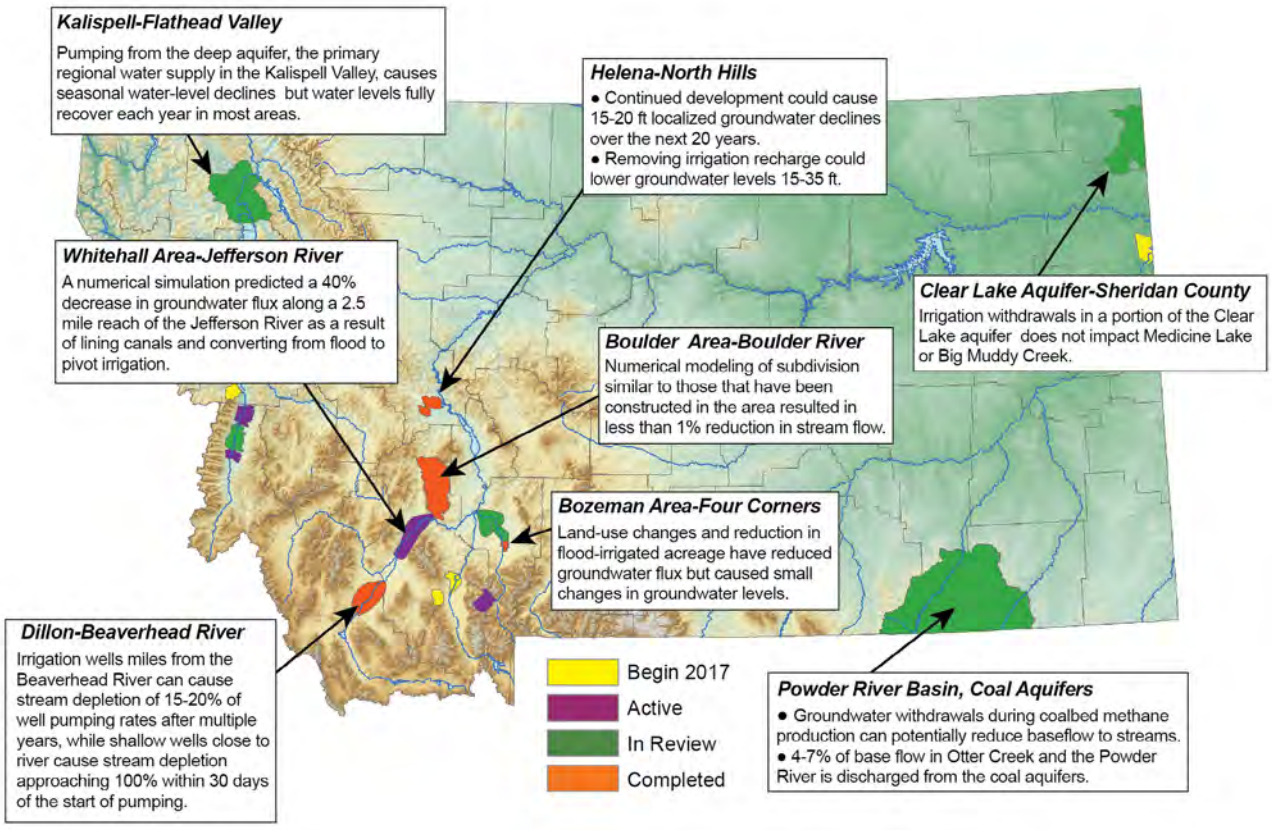
Detailed hydrogeologic data and land features are represented in a 3-D numerical simulation of the GWIP study area near Bozeman. The model will demonstrate how surface and groundwater respond to large-scale groundwater pumping under various conditions.

Program Status

To date, over 60 projects have been nominated and prioritized by the Ground Water Steering Committee. Results are presented in public forums, question and answer opportunities, conferences and published reports. Results of GWIP projects have been used in water rights permit decisions, water resource development, and county planning.

New GWIP Projects (start up 2016-2017):

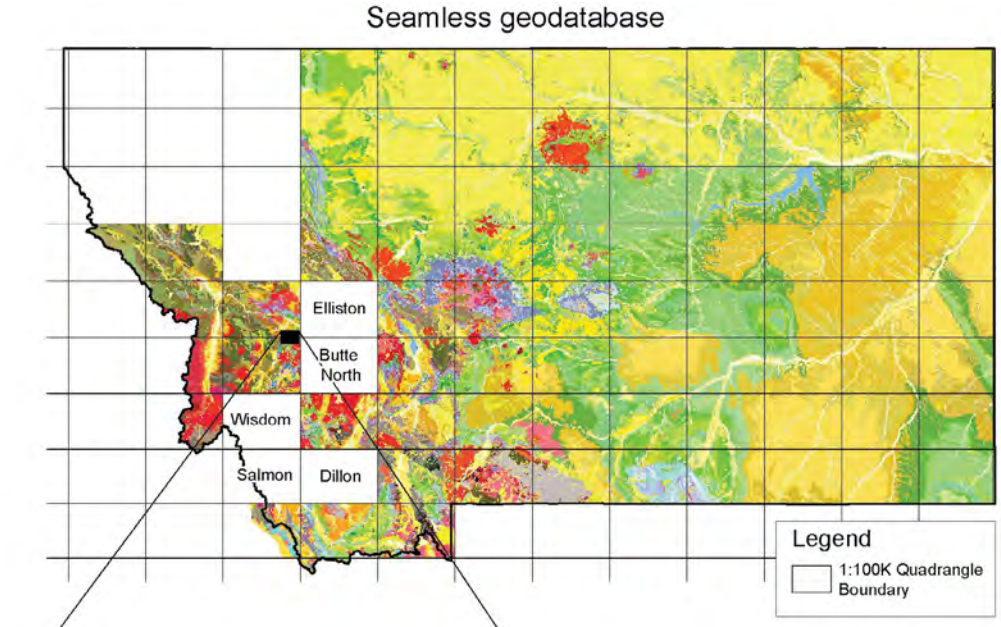
- Lolo Creek, Bitterroot Valley—Evaluate impacts to Lolo Creek that result in a dry creek bed
- Virginia City, Madison County—Public water supply and groundwater availability
- Sidney, Eastern, Montana—Groundwater availability for community and industrial growth
- Madison Valley, Ennis Area—Groundwater availability and quality to support residential growth

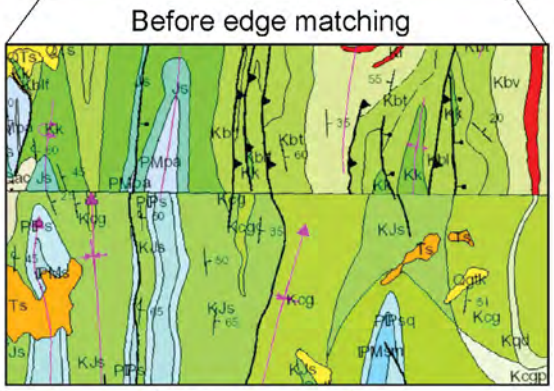


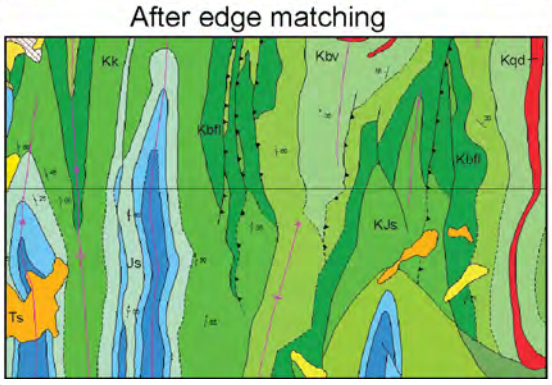
STATEMAP GEOLOGIC MAPPING

Detailed geologic maps provide information that is essential for better management of Montana's water, land, mineral, and energy resources. During the past biennium, the Montana Bureau of Mines and Geology published 11 new geologic maps based on field work conducted through the STATEMAP Program, a component of the National Cooperative Geologic Mapping Program. Funding for STATEMAP is awarded by the U.S. Geological Survey through a competitive grant process that requires matching dollars from the State and completion of all funded maps within 1 year. Map areas are prioritized by a STATEMAP Advisory Committee that represents Montana industries, universities, and Federal, State, and Tribal agencies.

The Advisory Committee's main priority is to complete geologic maps of all 30' x 60' quadrangles in Montana. The MBMG finished mapping in eastern and central Montana in 2014 and has focused on southwestern Montana since 2015. During the past biennium, the MBMG completed geologic maps of the Salmon and Elliston 30' x 60' quadrangles that are soon to be published. Mapping in the Butte North quadrangle will be completed in 2017. Mapping continues in the Wisdom and Dillon 30' x 60' quadrangles, and is expected to finished by 2021.



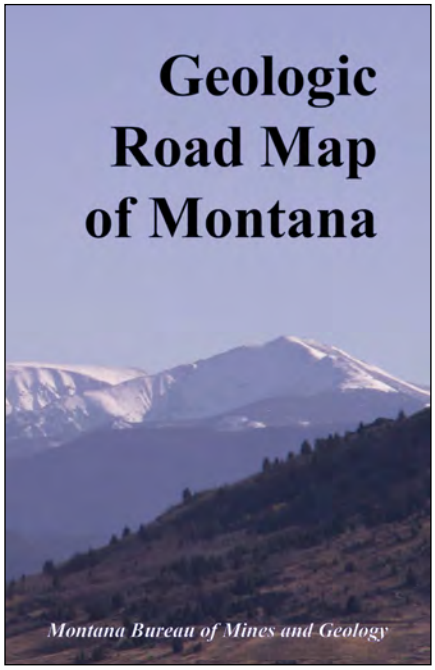


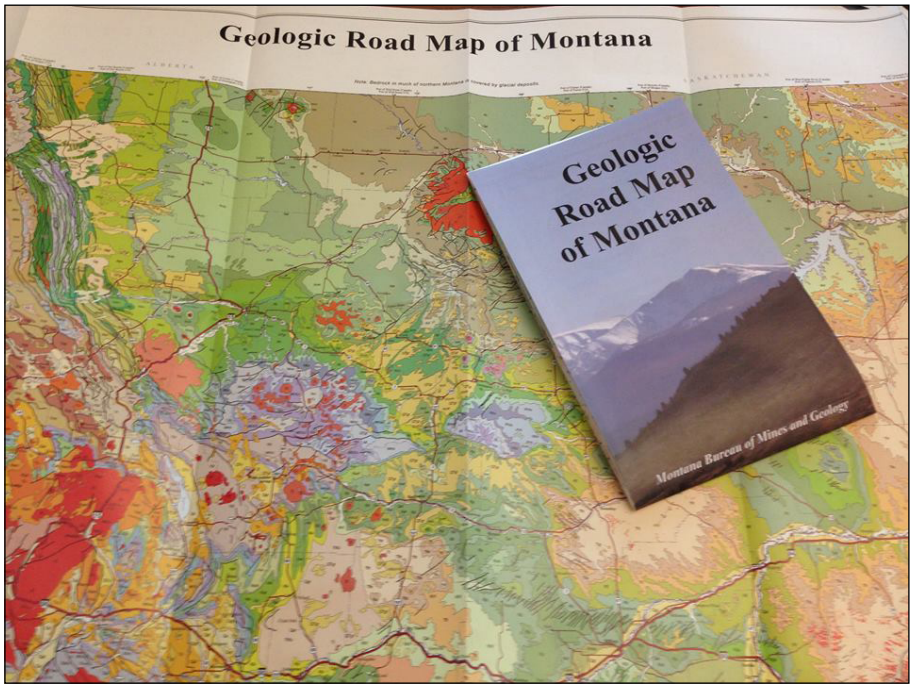


The Advisory Committee's second priority is production of more detailed maps that focus on particular geologic issues, transportation corridors, or areas where development is occurring or anticipated. Eleven geologic maps of this type were published during the past biennium. They include several geologic maps in the Elliston area, along with maps near Butte. Preparation of many other large-scale maps is underway.

All published STATEMAP products are available for free download from the MBMG website http://www.mbmg.mtech.edu/. In 2015, the MBMG released a new 1:100,000-scale geodatabase that seamlessly combines 79 existing 1:100,000-scale maps, including five published by the United States Geological Survey. The seamless geodatabase currently covers approximately 80 percent of Montana (figure at right), and coverage will increase as each of the 13 remaining 30' x 60' geologic maps are completed. The MBMG created the geodatabase in response to requests from geologic map users who need geologic coverage that seamlessly crosses quadrangle boundaries. The database can be downloaded at no cost from the MBMG website at http://mbmg.mtech.edu/gis/gis-server.asp.

In addition to traditional geologic maps, in 2015 MBMG published the "Geologic Road Map of Montana" that provides basic information on Montana's interesting and diverse geology. More than 800 copies of this popular map have been sold.





New MBMG geologist Petr Yakovlev, in the field with company. Long Peak, Anaconda Range, Anaconda Pintler Wilderness.

ENVIRONMENTAL HYDROGEOLOGY: TECHNICAL ASSISTANCE PROGRAMS

The MBMG works with State and Federal agencies, conservation districts, water-quality districts, and local communities to monitor, identify, and propose solutions to groundwater problems. Current projects run the spectrum from environmental problems associated with historic mining practices to water-quality issues related to organic waste-water chemicals in groundwater and waste-water-system effluent.

Montana has a rich history of natural resource development and corresponding environmental problems associated with those practices. Many of these problems are the result of mining practices dating to the late 1800s and early 1900s, which predate environmental and mining regulations. Mineral extraction in Butte and the surrounding area dates to the 1860s and continues today. Over the course of the past 150 years mining methods have changed to include large-scale open pit mines. The Berkeley Pit and associated underground workings are part of the larger Clark Fork Basin Federal Superfund Complex, and semi-annual sampling is required as part of a long-term monitoring program for the site. Due to a series of small to moderate slope failures (landslides) in the southeast portion of the pit, safety concerns have prevented sample collection in the Berkeley Pit since the fall of 2012. The regulatory and mine operational needs for sampling data from the Berkeley Pit have led the MBMG to partner with the Electrical Engineering Program at Montana Tech to develop a remote-controlled monitoring/sampling system. Funding was provided by Montana Resources and Atlantic Richfield in cooperation with the U.S. EPA and MT DEQ.

Figure 1.

Due to the physical size (1 mile by 1.25 miles), the low pH and elevated metal concentrations of the pit water, the monitoring/sampling systems had to be designed to operate at relatively long distances and under harsh conditions. The systems have been mounted on a typical drift boat (figure 1) controlled from the safety of the Berkeley Pit rim. The boat is powered by two electric trolling motors that can be either preprogrammed for a specific location on the pit water surface or maneuvered manually to a location on the water surface.

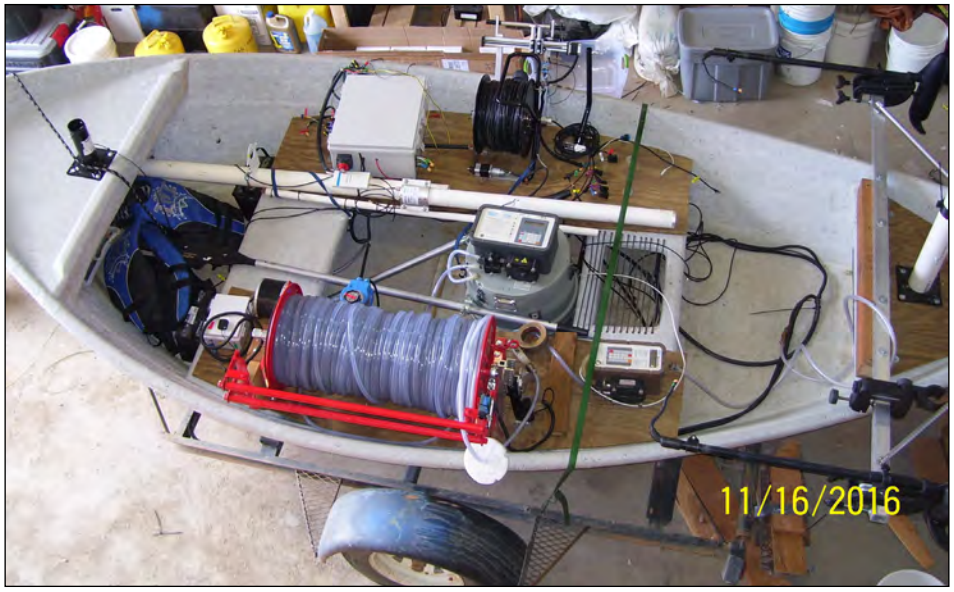


Figure 2.

The sample/monitoring system consists of the following components (figure 2):

1. Automatically controlled water sampler capable of collecting up to 24 500 ml bottles of water at various depths and equipped with 700 ft of sample tubing.

2. Multiparameter sonde that records various physical parameters of the water at depths up to 600 ft. Parameters consist of pH, water temperature, specific conductance, oxidation-reduction potential, dissolved oxygen, turbidity, and depth.

3. Two on-board cameras to view operation of the various components and help in guiding the boat.

4. Telemetry system for communication and transfer of collected data.

Real-time data are sent from the monitoring system to the communication center on the rim for use in selecting depths to collect water-quality samples.

Use of this system will allow collection of water-quality samples and physical-parameter data while limiting the safety hazards for sampling personnel. The system being developed has applicability for use at other pit lakes or similarly hazardous water bodies. Figure 3 shows the boat being tested on Silver Lake, west of Anaconda, MT.

Figure 3.

Topics Currently Being Investigated

- Acid mine-drainage mitigation through land-use changes and source control at an abandoned underground coal mine, Belt
- Inventory of placer mining operations in western Montana
- Groundwater monitoring of flooding underground mines and the Berkeley Pit
- Long-term monitoring of groundwater associated with the Anaconda Smelter Superfund site
- Assisting with evaluation of restoration options in the Upper Clark Fork River Basin
- Long-term monitoring of chromium concentrations in groundwater at the Mouat chromium repository, Columbus, MT
- Groundwater monitoring at the former Rocker Timber Treating site and review of controlled groundwater area boundary
- Evaluation of arsenic sources in groundwater, Upper Deer Lodge Valley, MT
- Metal concentrations in storm-water runoff, Mill Creek drainage, Anaconda, MT
- Groundwater issues relating to Butte Priority Soils Superfund site
- Crystal and Bullion mine adit discharge monitoring, Jefferson County, MT
- Geothermal resource inventory of Montana
- Superior, MT, Flat Creek Drainage groundwater/surface water inventory
- Development of an autonomous sampling system for use in the Berkeley Pit

ENERGY RESOURCES

Coal Assessment and Availability Studies

Montana leads the nation with 120 billion tons of demonstrated coal reserves. Montana ranks 6th in annual coal production with five surface mines and one underground mine producing 40–45 million short tons per year.

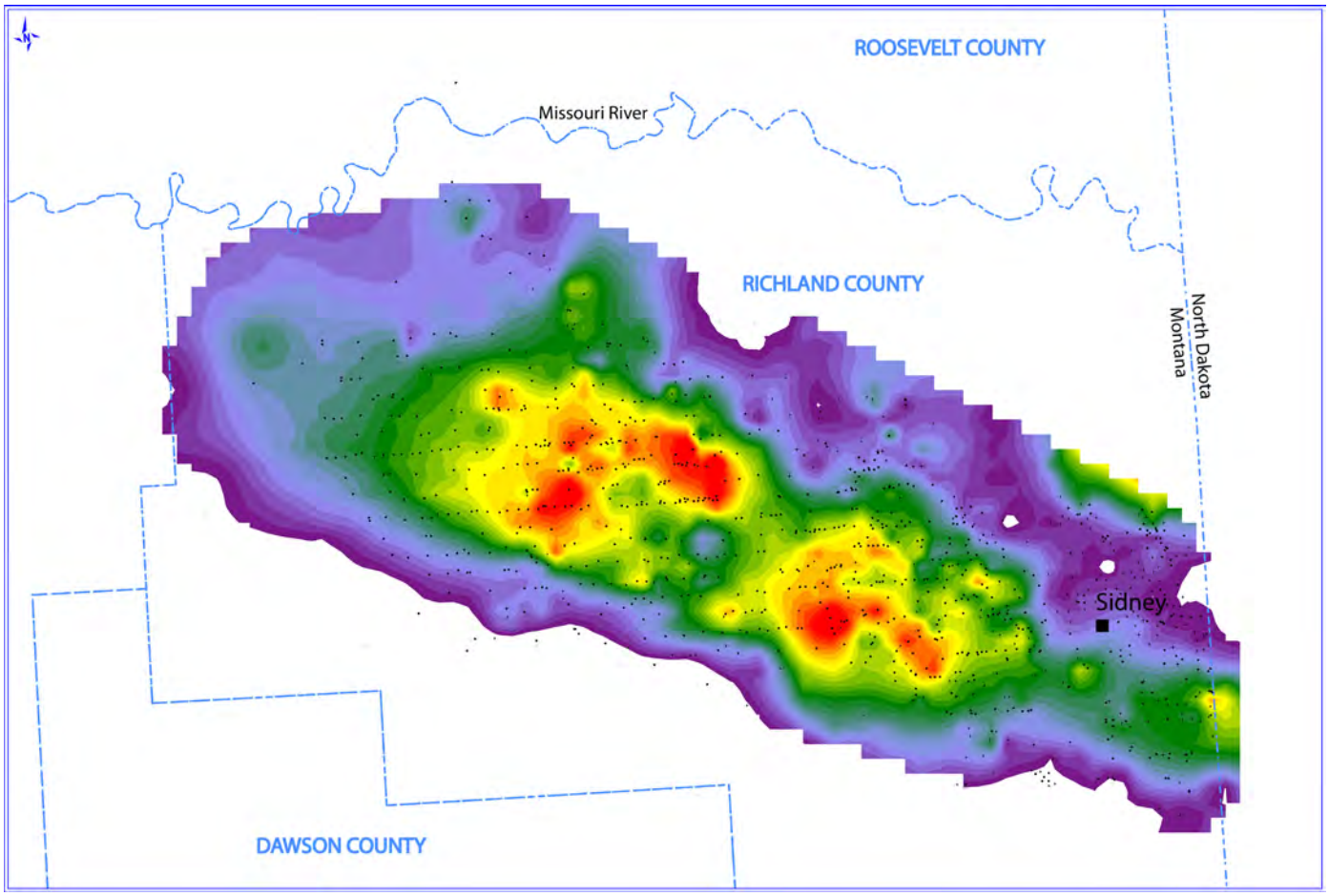
From the 1960s through today, the MBMG has conducted state-wide coal resource assessments and coal availability studies to determine the distribution, quantity, and quality of mineable reserves. Our most recent coal assessment in north-central Montana adds nearly 20 billion tons of newly identified subsurface coal resources to Montana's demonstrated reserve base. The MBMG also maintains the publicly available coal stratigraphic and coal chemistry databases. As the coal industry continues to move toward "clean coal" solutions, these data and research are vital to those developing and testing new coal power technologies and to those who make energy and land-use policy decisions.

Elm Coulee Field (Bakken) Reservoir Model

(funded by the Montana Board of Oil and Gas Conservation)

Elm Coulee field in Richland County has produced about 200 million barrels of oil from the Bakken Formation since the early 2000s, yet each well can only produce about 10% of the oil in place. We must use enhanced oil recovery (EOR) processes that inject gas or fluids into the reservoir to mobilize and produce additional oil. Bakken geology is complex, so it is not clear how these secondary recovery techniques will perform in an unconventional reservoir like Elm Coulee.

The MBMG and Montana Tech partnered to create a geologic/reservoir model of Elm Coulee field and use it to simulate the field's behavior and performance under varying EOR conditions. Reservoir simulations performed by Montana Tech suggest that an additional 20% of original oil in place may be recoverable using natural gas flooding at Elm Coulee. Understanding reservoir behavior prior to the onset of EOR will improve reservoir management, increase ultimate oil recovery, and extend the life of Elm Coulee field.



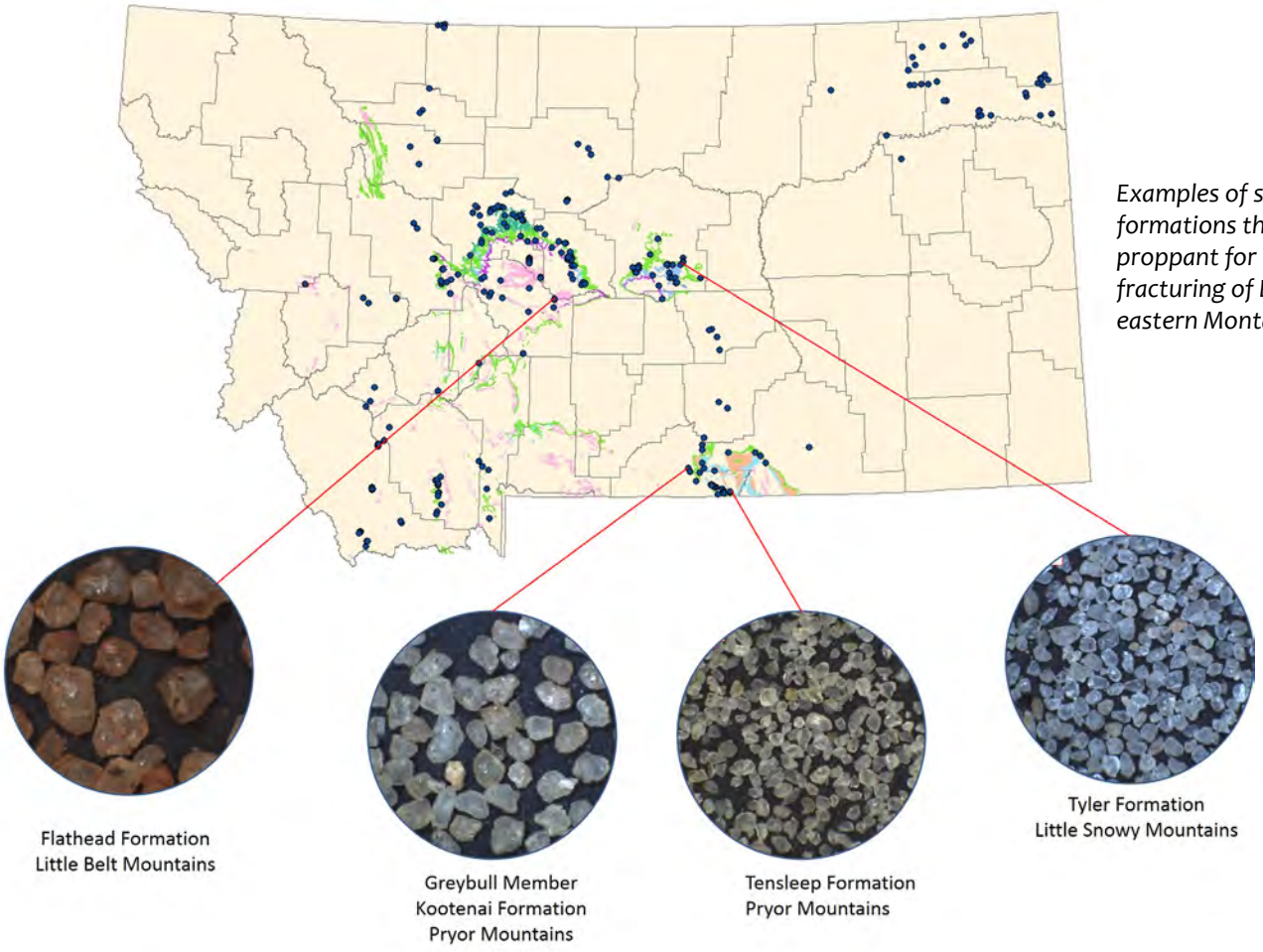
This map of "original oil in place" shows the variation in the Bakken properties across Elm Coulee field. Hotter colors (red, orange, yellow) indicate greater volumes of oil in place.

Survey of Natural Proppants

(funded by the Montana Board of Oil and Gas Conservation)

Hydraulic fracturing ("fracking") is a critical component of drilling and completing wells in shale oil reservoirs such as the Bakken Formation in eastern Montana. The fracking process uses high-pressure fluids to crack the rocks deep in the subsurface to improve oil and gas recovery. The cracks are held open by proppants—or "frac sand"—that is pumped into the wellbore.

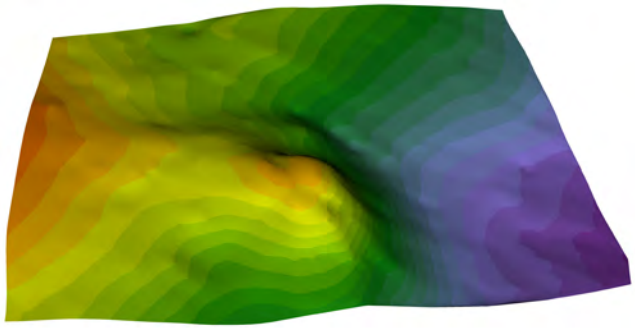
The MBMG and Montana Tech were funded by the Montana Board of Oil and Gas Conservation to identify, sample, and test potential sources of naturally occurring proppants in Montana. MBMG geologists surveyed dozens of geologic formations and collected over 300 samples for analysis. Montana Tech owns and operates one of the only labs in academia with full-range testing for proppant suitability. About 25% of the samples passed the standard minimum testing criteria, indicating that several of Montana's sandstone formations could serve as sources of frac sand. The geologic and engineering data are available to the public on the MBMG website.



Examples of sandstone formations that could supply proppant for hydraulic fracturing of Bakken oil wells in eastern Montana.

Subsurface Geologic Mapping

The geology below ground can be just as important as surface geology. Subsurface geologic maps are critical for understanding geologic hazards such as faults, managing and protecting groundwater aquifers, and exploring for petroleum and other resources. The MBMG is working on a long-term project to generate digital maps depicting structure (spatial positioning) and properties (e.g., thickness, porosity) of subsurface geologic units. Digital maps are easily imported into a wide range of software applications for visualization, grid manipulation, and constructing 3D models.

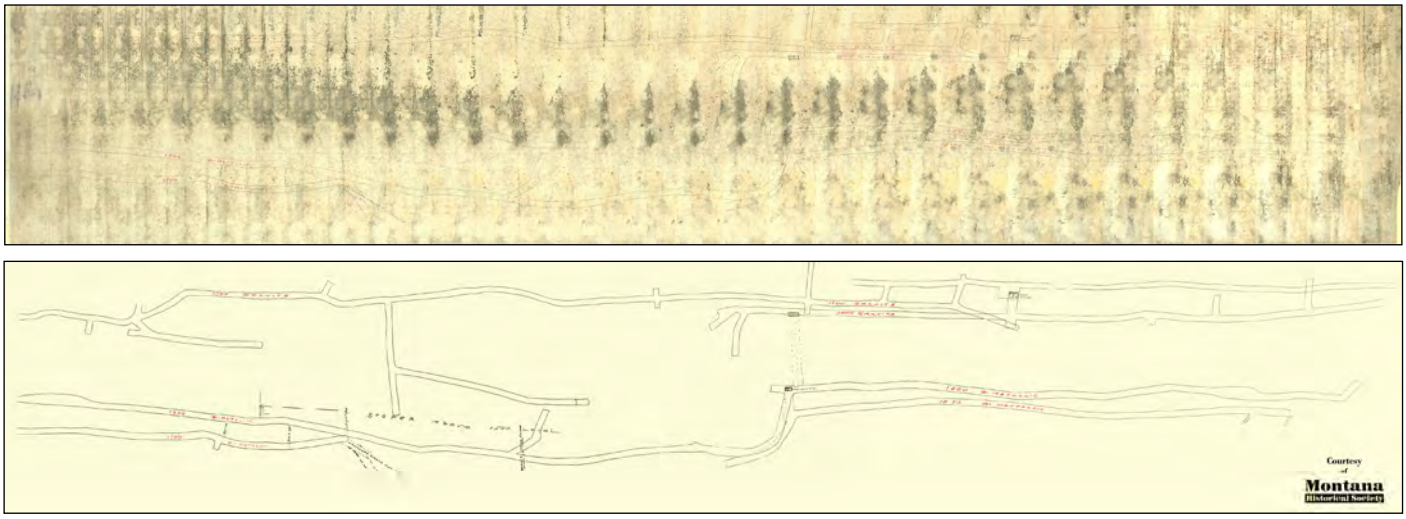


3D visualization of Eagle Formation structure, Wolf Creek 100K quadrangle.

DATA PRESERVATION AND MINING ARCHIVES

Montana's historic development of its natural resources generated a tremendous amount of geologic, geophysical, and engineering data that represent substantial investments of time, money, and manpower. Over the years, much of the information has been lost, destroyed, or forgotten. For decades, the MBMG solicited and received donations of historical mining information, which it organized into an archives. The Mining Archives' holdings are an irreplaceable information source for the general public.

Since 2005, the MBMG has participated in the USGS' National Geological and Geophysical Data Preservation Program (NGGDPP), which provides funds to identify, rescue, and preserve mining-related information in danger of being lost or destroyed. The program also provides funding to digitally preserve and restore compromised paper documents, retrieve data from obsolete digital media and preserve it on current technology, and expand user access to the data via the Internet.



Top: Digital original image of mold-ridden map that had been rolled up when stored. Bottom: Digitally restored version of the same map, revealing long-hidden mine workings information.

Recent NGGDPP-funded projects include acquisition and preservation of the New World Project collection (FY 2014–2015) and the Richard B. Berg collection (FY 2015–2016).

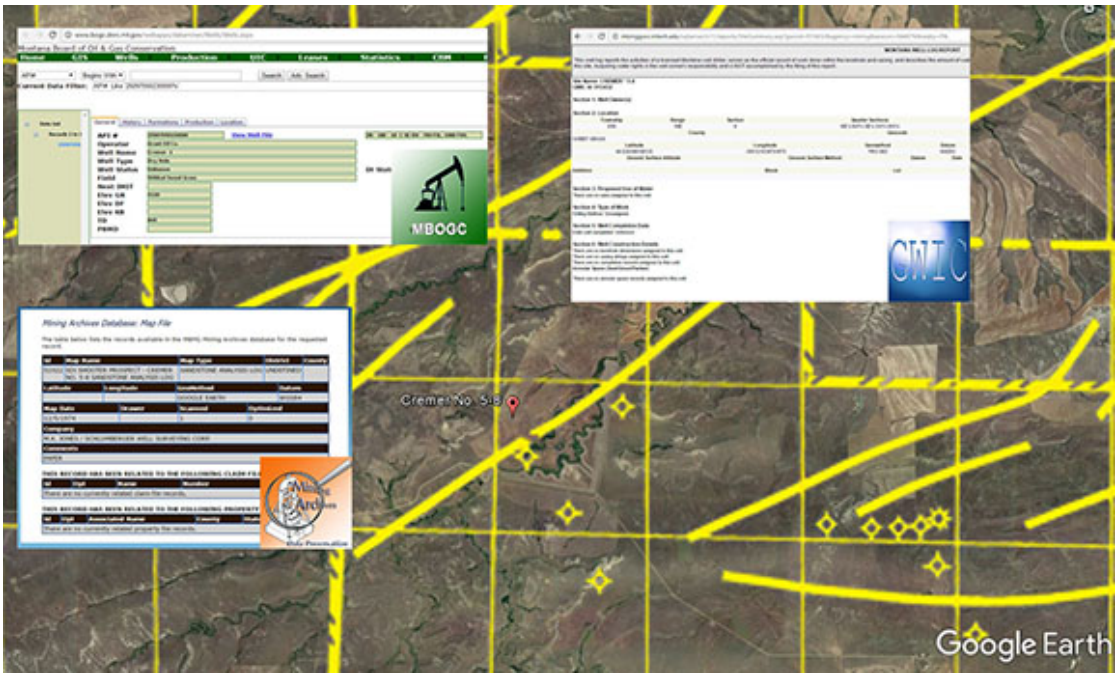
The New World Mine collection contains information related to the proposed New World mine in Park County, Montana, located adjacent to the northeast corner of Yellowstone Park. Because of the close proximity to Yellowstone Park, site ownership was transferred to private interests and withdrawn from mine permitting review. The collection's contents represent the most comprehensive extant data set related to the site's world-class Eocene epithermal gold deposit. Because of the site's now protected status, access to update geologic and historical mining data will not likely be gained. For the past 2 years, the Archives department organized, scanned, and digitally restored over 52,000 document pages and 1,034 mining-related maps.

The Richard B. Berg Collection includes 3,819 rock specimens and thin sections, field and lab notebooks, and 3,385 sample photos (support data) created by Dr. Richard B. Berg during his 50-year career with the Montana Bureau of Mines and Geology. The MBMG located, consolidated, inventoried, preserved, and created metadata for support data related to major research projects resulting in 14 MBMG publications authored by Dr. Berg. The collection's digital inventory and photos will be available online and its physical data housed in a secured space and available to researchers for further analysis.

In September 2016, we began the inventory, preservation, and digitization of the John W. Taber Collection. The collection is an intact repository containing geologic, engineering, development, production information, and 186 trays of mine core samples for the Crystal Mountain fluorite mine located in Ravalli County, Montana. Mr. Taber directed the mine's mineral potential evaluation, development, production, and closure. The collection is significant because the Crystal Mountain Mine was one of only two producing fluorspar mines in Montana and a major fluorite producer for the industry during its operations. Archival processing of the collection will be completed by September 2017.

Funding from the Montana State Legislature substantially expanded the MBMG's ability to secure new collections and organize, digitize, and restore them. Efforts to identify and secure collections related to coal, oil, and gas information resulted in the donation of two collections, the Charles Hauptman Collection and the Marion K. Jones Collection. Both men had long consulting careers and worked primarily in eastern Montana evaluating coal, oil, and gas properties. The collections are housed in temporary, secure storage and will be the basis for the next NGGDDP application process, if available.

Data Preservation also began developing overlays of historical oil and gas wells and mining map representations on Google topography embedded with hotlinks to MBMG and other agency sources for supplemental information.

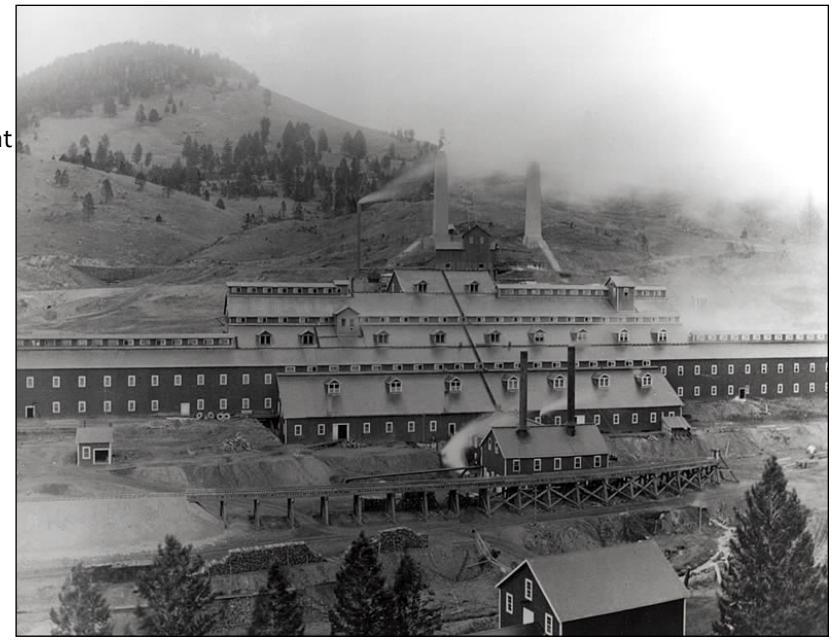


An interactive Google overlay of an oil and gas well location map with linked results from secondary information sources a selected well.

In addition to the major projects listed above, Mining Archives continues to digitize and restore its original archival holdings, assess possible new collections, publish document and map information on its website, and fulfill the numerous information requests from geologists, engineers, students, educators, legislators, and consultants. Examples include:

- Provided digitized field notes to the USGS related to properties included in its Sagebrush Mineral Resource Assessment (SAMIRA) project.
- Assessed a collection of a retired geologist, that included Atomic Energy Commission-related research and samples of properties outside of Montana. The collection was referred to a more appropriate federal repository.
- Digitized the hard copy file contents for 143 properties (4,761 pages) and 110 maps related to a substantial proposed mining property valuation and sale.
- Supplied a consulting geologist with nearly 1,000 pages of historical information pertaining to the historic Confederate Gulch mining district in Broadwater County, Montana, for engineering evaluations of the area and possible development permitting.
- Responded to grade school student requests (both hard copy and online) for mining and geology related information.
- Provide historical underground coal working maps to the Musselshell County Public Works Department in its evaluation of a site as a potential recreational area.

As interest in preserving our mining and geologic history increases, Mining Archives will continue to rescue geologic and mining-related information, reveal information long hidden by stains, mold, and discoloration, preserve Montana's natural resource development history, and



An 1892 photo of the historic Bi-Metallic Mill, a 100-stamp mill once located near Philipsburg, Montana. (Photo courtesy of Western Mining History)

EASTERN MONTANA PROJECTS

from our Billings Office

Groundwater and Energy

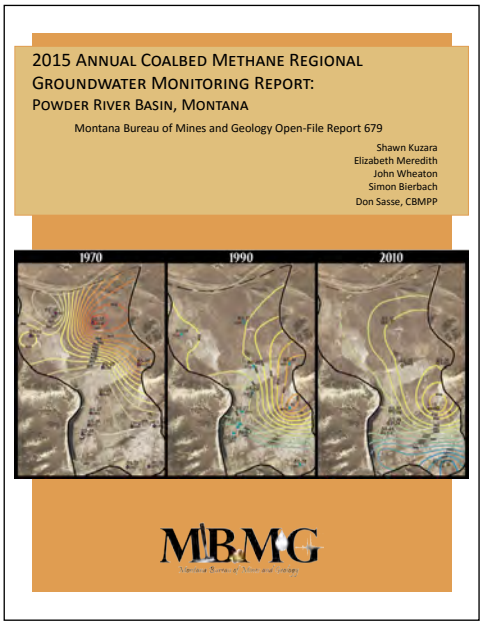
Oil and Gas

In response to concerns over new, enhanced petroleum recovery methods, the MBMG collected more than 160 groundwater samples in Eastern and Central Montana in areas undergoing oil and gas development. The samples were analyzed for organic and inorganic constituents. Levels of organic constituents were overall very low, non-detectable to just over the detection limit. Methane was prevalent at low levels throughout the area; it is naturally present in some eastern Montana aquifers and has both shallow and deep sources. The source of methane can be distinguished through isotopic analysis, which will indicate whether excursions of deep sources of methane have entered the shallow aquifers. This effort complements ongoing groundwater level monitoring and modeling of the Fox Hills aquifer in Eastern Montana. *This work is supported by the Montana Department of Natural Resources, the Montana Department of Environmental Quality, the U.S. Fish and Wildlife Service, the CBM Protection Program, and the Conservation Districts of Carbon, Stillwater, Sheridan, Roosevelt, Richland, Dawson, Wibaux, and Fallon Counties.*

Coal

The MBMG has studied effects on groundwater from coal mine activities in southeast Montana since the 1970s. The water-level records and historical sampling allow regulators and landowners to better project future trends. Water quality in coal-mine spoil aquifers show a slow but steady improvement and is trending toward steady-state after 40 years. This long-term monitoring network is one of the most comprehensive in the U.S. and is used as a model for other, similar networks being developed in Australia and Canada. *This work is supported by the U.S. Bureau of Land Management.*

In the north-central Montana coal fields, the MBMG initiated an isotope tracing of acid mine drainage in the Stockett–Sand Coulee area that will conclude at the end of 2018. Samples from groundwater in the Great Falls to Stockett corridor will be analyzed for isotopes of sulfur, carbon, oxygen, and hydrogen to trace the infiltration pathways. *This work is supported by the U.S. Office of Surface Mining Reclamation and Enforcement.*



Coalbed Methane

Mapping potential development areas and monitoring of groundwater around coalbed methane development began in 2001 and results are presented annually in an interpretive report. This long history of water-level trends and groundwater chemistry provide a platform for specific, issue-based studies such as quantification of coal aquifer baseflow and is the basis of work being done by university research groups on nutrient and microbial enhancement of CBM generation. *This work is supported by the U.S. Bureau of Land Management.*

Focus on the Billings Office

Irrigation

Irrigation plays an important role in recharging shallow groundwater in alluvial valleys; however, quantifying the amount of recharge as it varies by space and time requires considerable data. Recent work in Big Horn, Carbon, and Stillwater Counties has demonstrated the importance of local hydrogeologic characteristics that control how much application of irrigation water, locations of ditches, and unconsolidated stratigraphy influence groundwater recharge. For example, water budgets based on groundwater and surface-water measurements in irrigated fields indicate that groundwater recharge from flood irrigation varied from 90% on a site in Stillwater County to less than 10% on a site in Big Horn County. Work is ongoing to define the most important valley characteristics that influence the importance of irrigation as a source of recharge. Once a site has been evaluated, irrigators can weigh the effects of changing irrigation practices.

Regional Water Resource Investigations

Three watershed-scale groundwater assessments in Big Horn, Carbon, and Stillwater Counties will be concluded this year. Funded through the Montana Department of Natural Resources and Conservation, these studies looked at the role of irrigation, groundwater/surface water interaction, and bedrock aquifers. The MBMG works closely with Conservation Districts to ensure local water concerns are being addressed and results are directly applicable.

Pivot irrigation in the Big Horn Valley north of Hardin

Gated pipe irrigation of sugar beets in the Big Horn Valley

ECONOMIC GEOLOGY

In 2014 the MBMG's Economic Geology program began to reevaluate the potential of metallic mineral deposits in historic mining districts for future exploration. Currently, the MBMG is focusing on mining districts associated with the Boulder Batholith.

- Analytical results for the Emery district near Deer Lodge show exploration potential for a deep-seated porphyry system containing copper and/or molybdenum.
- Fieldwork is ongoing in the Big Foot district north of Whitehall and the Lowland district in the Lowland Creek drainage.
- A Montana Tech seed grant has funded a lead isotope study on all Boulder Batholith and Elkhorn Mountain Volcanics mining districts and will determine the geologic sources of the metallic mineral deposits. The results will be used to identify mining districts with possible future exploration potential.

The MBMG's work in mining districts has renewed interest in the Boulder Batholith and its mineralization. Specifically, mining groups are interested in the Emery district and the MBMG has been approached by Paget Minerals Corporation, which is seeking potential exploration projects.

Current Mining Operations

Golden Sunlight Mine, Whitehall, Jefferson County, MT

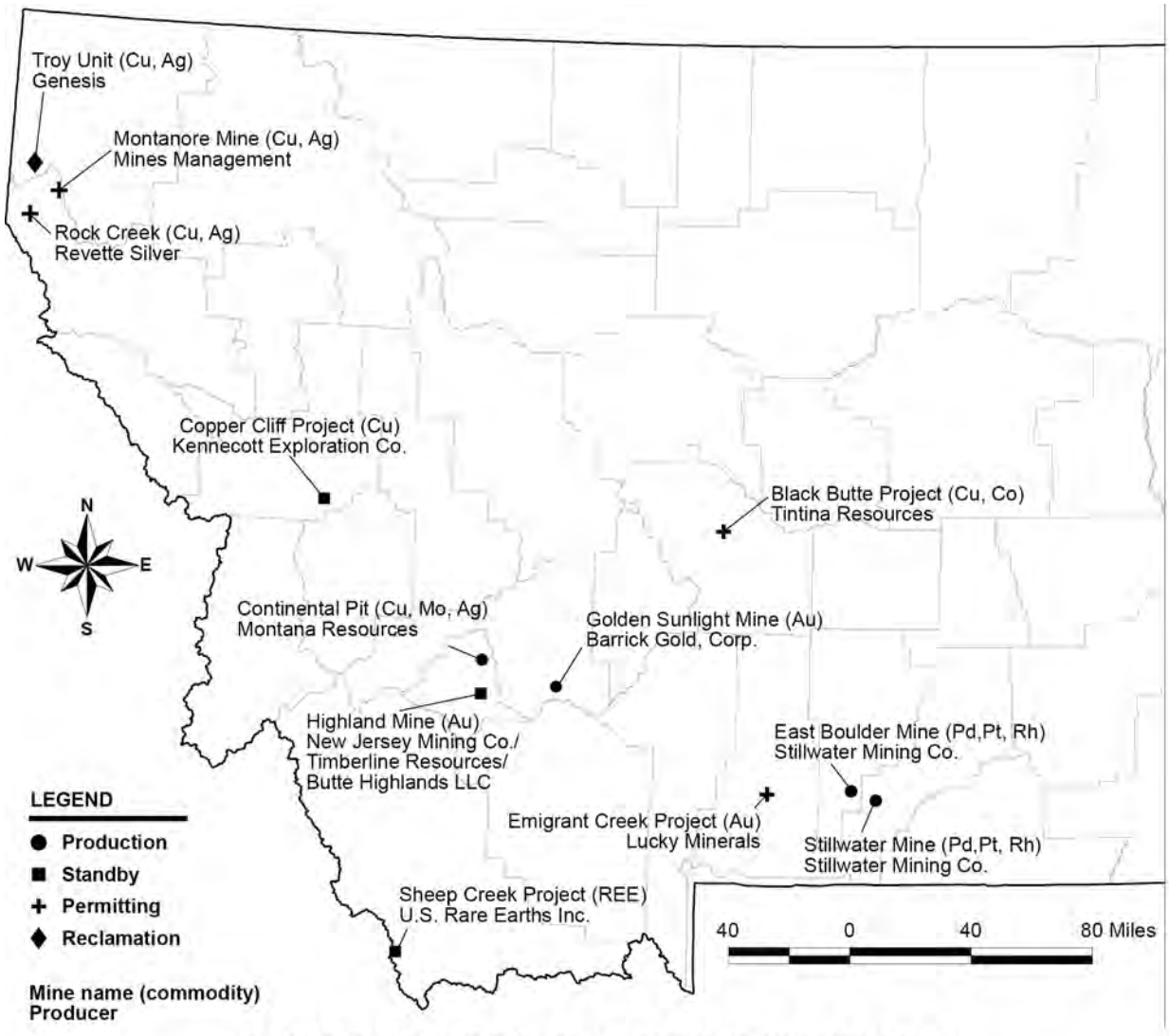
Even though metal prices are depressed, mines operated by Stillwater Mining, Montana Resources, and Barrick Gold Corporation are in production.

- Stillwater Mining operates the Stillwater and East Boulder mines near Columbus for platinum group elements (PGE). The company is driving a new decline (the Blitz Growth Project) that by 2021 will add 270,000–300,000 ounces of PGE annually to their production.
- Montana Resources operates the Continental Mine in Butte for copper and molybdenum. Plans to keep operating until 2040 required Department of Environmental Quality (DEQ) approval for an operating permit amendment to raise the altitude of the tailings embankment to 6,500 ft above mean sea level. Work on the tailings embankment will finish in 2018.
- Barrick Gold Corporation operates the Golden Sunlight mine near Whitehall for gold. In 2016 Barrick converted this mine from open pit to underground. Drilling results have suggested another mineralized zone 0.75 miles north of the current mine, and in 2015 the company filed a permit application with the DEQ to develop a new gold mine.

Exploration

Metal prices have remained depressed since 2012, but in 2016 prices for gold and some base metals have slowly increased. Increased prices help keep existing metals mines open and may encourage past-producing mines to reopen. Despite the depressed prices, there are several ongoing Montana exploration projects.

- Lucky Minerals is exploring for gold in the Emigrant mining district south of Emigrant, Montana, where the DEQ has permitted drilling 46 holes on patented mining claims. There are many public concerns about exploration in this remote area, and even if new deposits are found, much additional work and full permitting would be required before a mine could be developed.
- In 2015 Kennecott Exploration Company continued drilling in the historic Copper Cliff mining district in Missoula County. Two drill holes defined the western limits of the porphyry system. Accumulative drilling results define a copper porphyry deposit at 5,000 feet below surface. The project was suspended in 2016 due to depressed copper prices and changing company priorities.
- Hecla Mining acquired the Troy Mine and Rock Creek projects in 2015. Hecla permanently closed the Troy Mine in Lincoln County and is proceeding with environmental remediation. Hecla has started the permitting process for the Rock Creek project in Sanders County, but does not have plans to reopen the mine soon because of depressed silver prices.



CURRENT OPERATING METALS MINES AND ACTIVE EXPLORATION PROJECTS

Hecla Mining also acquired the Montanore project 23 miles south of Libby in Lincoln and Sanders County. This mine is in permitting, but will require additional exploration before opening.

- Tintina Resources Inc. submitted a mine operating permit application to the DEQ for the Black Butte Copper Mine in Meagher County. There is considerable public concern about opening a mine in the Smith River drainage and the DEQ is currently reviewing the permit application. Mine construction could begin in 2018.
- The Butte Highlands Gold project in Silver Bow County is jointly owned by the New Jersey Mining Company and Timberline Resources Corporation. The mining project is fully permitted and would open should sufficient financial backing be acquired.

Future exploration for rare earth elements in Montana and the United States does not appear promising because of depressed prices. China controls the rare earth market and lowered the prices to suppress competition. In 2013 U.S. Rare Earths Inc. explored their Sheep Creek project in the Lemhi Pass Thorium district, but the project is not currently active.

Golden Sunlight mill, Whitehall, Jefferson County, MT

MINERAL MUSEUM

The Mineral Museum on the Montana Tech campus began with the purchase of 177 specimens within 6 months of the founding of the Montana School of Mines, in 1901. Today, the MBMG curates over 12,000 specimens from all over the world, with new acquisitions every year.

This biennium the Museum hosted approximately 15,000 visitors, including 81 tour groups with both students and adults.

The Mineral Museum received 93 new specimens from 18 individual donors.

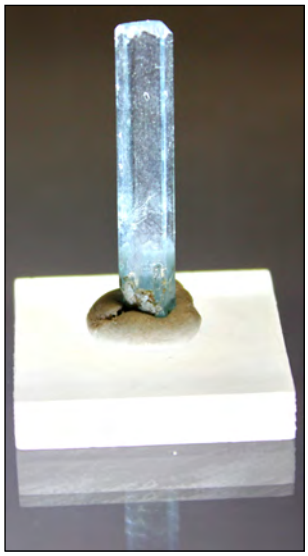
Significant donations include:

- A variety of mineral and fossil specimens from Raymond Buell, courtesy of his daughter Kathleen Woods.
- From Marlen Tweeten, a fine assortment of smoky quartz and feldspar specimens from the Lolo Pass area of Montana and a number of choice dripstone specimens from Granite County, MT.
- Bryant and Joan Harris donated two rare specimens of phenakite from the Boulder Batholith.
- Freeport McMoRan mining company donated a malachite specimen from the Democratic Republic of the Congo.
- Clarence Schwartz, a retired Montana Bureau of Mines and Geology employee, donated several rock and fossil specimens from his personal collection.

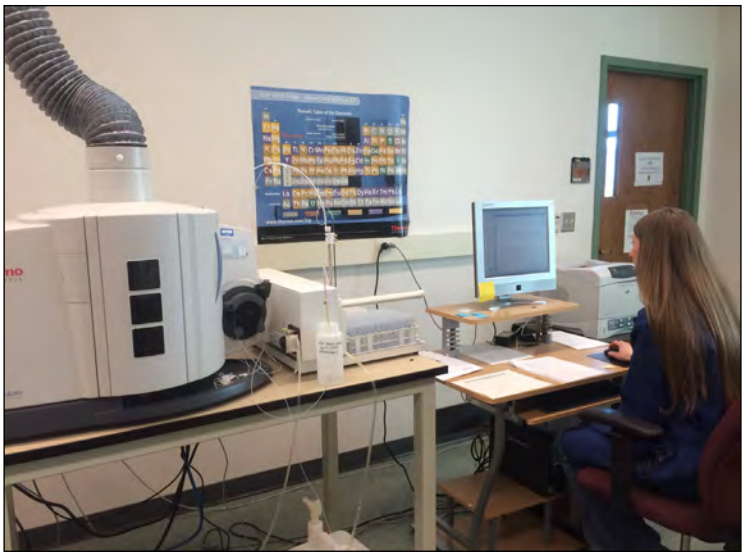
Loans include:

- A Russian Cave Bear fossil specimen from Elvis Gray.
- A collection of colorful sapphires the Rock Creek Sapphire District, Philipsburg, MT from Katie McDonald, a Montana Bureau of Mines and Geology employee.

The Mineral Museum hosted the Montana Mineral Collectors meeting for 2016. In addition, the Mineral Museum hosted a number of public lectures during the biennium.



ANALYTICAL LABORATORY



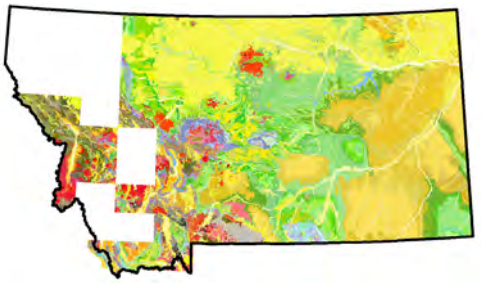
The MBMG Analytical Laboratory conducts analytical method development and sample analyses in support of research being done by MBMG programs. The lab is licensed by the State of Montana–Department of Health and Human Services to analyze drinking water supplies, and its QA/QC program meets criteria established by the U.S. Environmental Protection Agency (EPA) and the U.S. Geological Survey (USGS). The inorganic lab routinely determines major cations, anions, trace metals, selected isotopes, alkalinity, pH, and radon. The primary focus of the organic lab is the determination of acidic compounds, polynuclear aromatic compounds, and extractable petroleum hydrocarbons in waters and soils. All groundwater data obtained by the lab are reported in the GWIC database.

In addition to supporting MBMG research programs, the Analytical Lab works closely with several departments of Montana Tech to provide analyses to both graduate and undergraduate research.

Available instrumentation includes:

- Thermo Scientific iCAP Q inductively coupled plasma/mass spectrometer (ICP/MS) for trace metal analyses
- Thermo Scientific iCAP 6000 Series inductively coupled plasma emission spectrometer (ICPOES) for determining major cations
- Two Metrohm Compact IC Plus instruments for anion analyses
- Metrohm Robotic Titrator for measuring pH, conductivity, and alkalinity
- Picarro Isotopic Water Analyzer, L2130-i for water isotope analysis
- Picarro $\delta^{13}C$ High-Precision Isotopic carbon dioxide (CO_2) analyzer, G2131-i for ^{13}C isotopic analysis of CO_2 in water
- A Costech Combustion Module was added to the Picarro G1231-i to allow for ^{13}C isotopic analyses of solid samples
- Aurora 1030 Wet Oxidation TOC Analyzer for analyzing organic and inorganic carbon in water samples
- Agilent gas chromatograph with mass spectrometer detector (GC/MS) for organic compounds
- Agilent gas chromatograph with electron capture detector (ECD) for extractable hydrocarbons
- Beckman LS6000SC Scintillation counter for determination of radon in water
- ELISA testing in magnetic particle and 96 well plate formats for determining endocrine disrupting compounds in surface and ground waters

GIS LAB



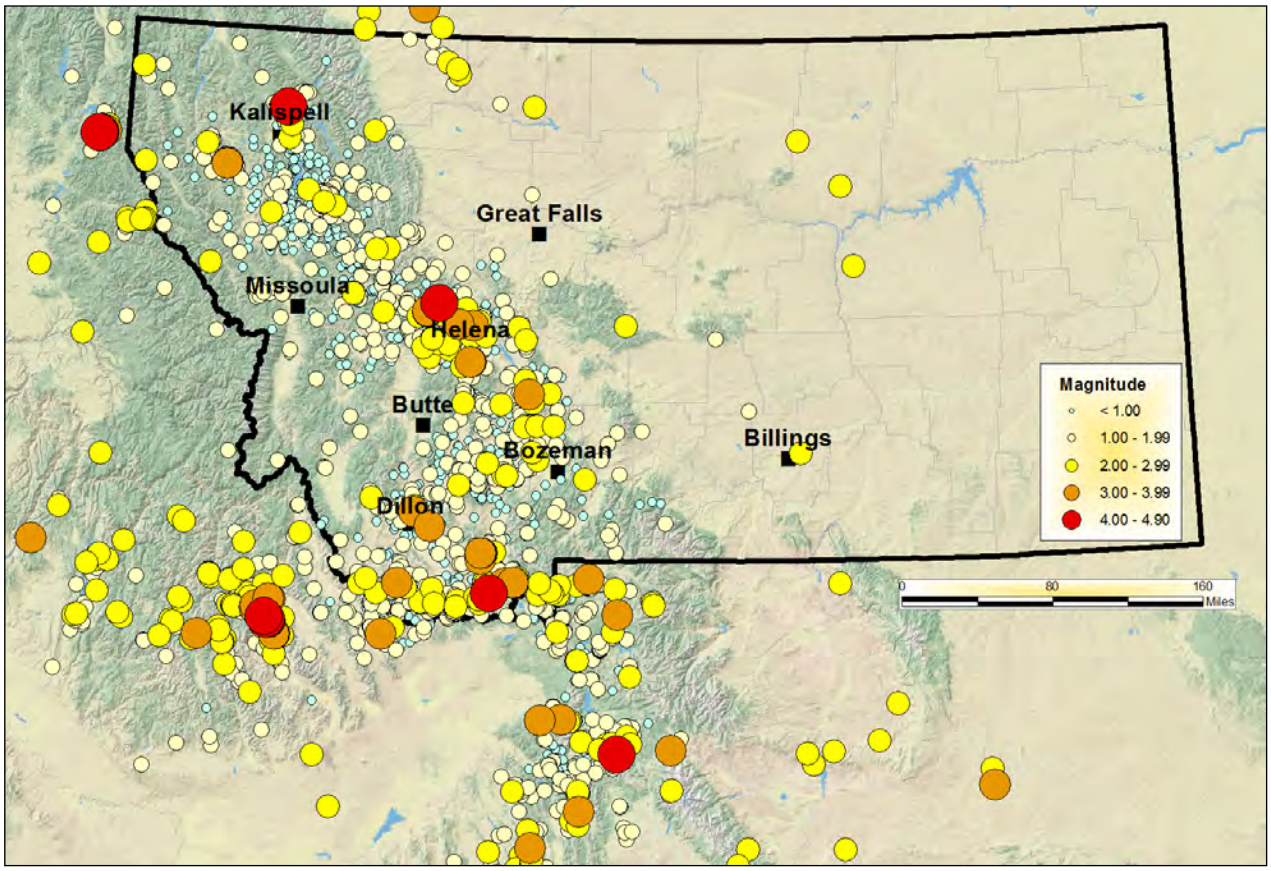
The GIS Lab has continued to move forward with data development and dissemination. A few significant projects have either been completed or have moved closer to completion over the past 2 years. The MBMG has adopted a new data standard for digital geologic maps. We have continued to produce products as part of our geologic mapping program. Some recent projects either completed or in progress are our seamless 1:100,000 geology data, the "legacy" 1:100,000 data, the 1:1,000,000 scale road map, & the State Geologic Map (GM 62).

The seamless geology data set is an effort to assemble all of our existing 100k data into an integrated (seamless) whole. The integration of maps across quadrangle boundaries was an effort that brought together geologists and GIS staff to refine data developed over many years. We still have work to complete as part of this process involving QA/QC and other tasks. New mapping at the 1:100k scale will be integrated into the seamless geology data. Two other data layers have been recently released. A data set was developed from existing map data (developed at the 100k scale) without any effort to integrate or assemble the various map data. This has been released as the legacy data. A 1:1,000,000 scale geologic map has also been released, known as the Geologic Road Map. The 1:500,000 State Geologic Map (GM 62) is another project available as an ESRI map service. This geologic map is a digital representation of the 2007 publication. Users of these map services can also download the data for use in ESRI software. The MBMG has published a number of different map services through its ESRI ArcGIS Server. MBMG staff and the public are increasingly searching for online spatial data in a ready to use format. Map services provide this capability.

Staff in the GIS Lab provide support to MBMG staff, Montana Tech campus staff, and students with various projects and training. The GIS Lab has one or two Montana Tech student employees dependent upon workload. Our students are valuable members of the GIS team and an asset to all of the MBMG.

EARTHQUAKE STUDIES

Western Montana has a history of large, damaging earthquakes and remains seismically active. Most of these earthquakes (including the 1925 magnitude 6.6 Clarkston earthquake centered north of Three Forks, and the magnitude 6.3 and 6.0 Helena earthquakes in 1935) occur 3 to 10 miles deep along faults that do not extend to the Earth's surface. The seismic hazards associated with these "blind" faults cannot be evaluated with traditional surficial fault mapping and are best studied with data from a permanent network of seismograph stations. As the population and infrastructure of earthquake-prone western Montana continues to grow, the exposure to seismic hazards—the risk—increases.

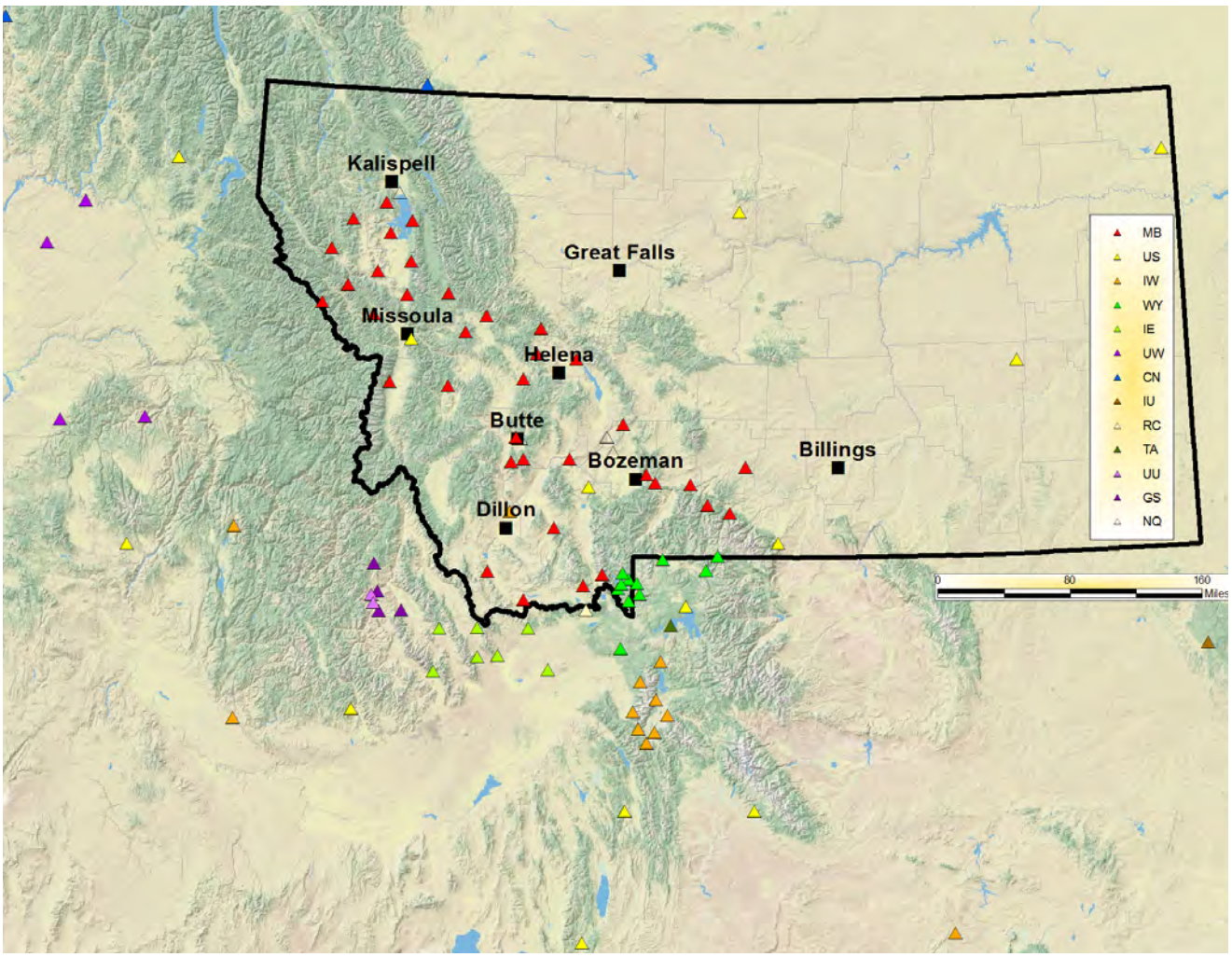


Epicenter locations for 4,899 earthquakes located by the MBMG from July 1, 2014 to June 30, 2016.

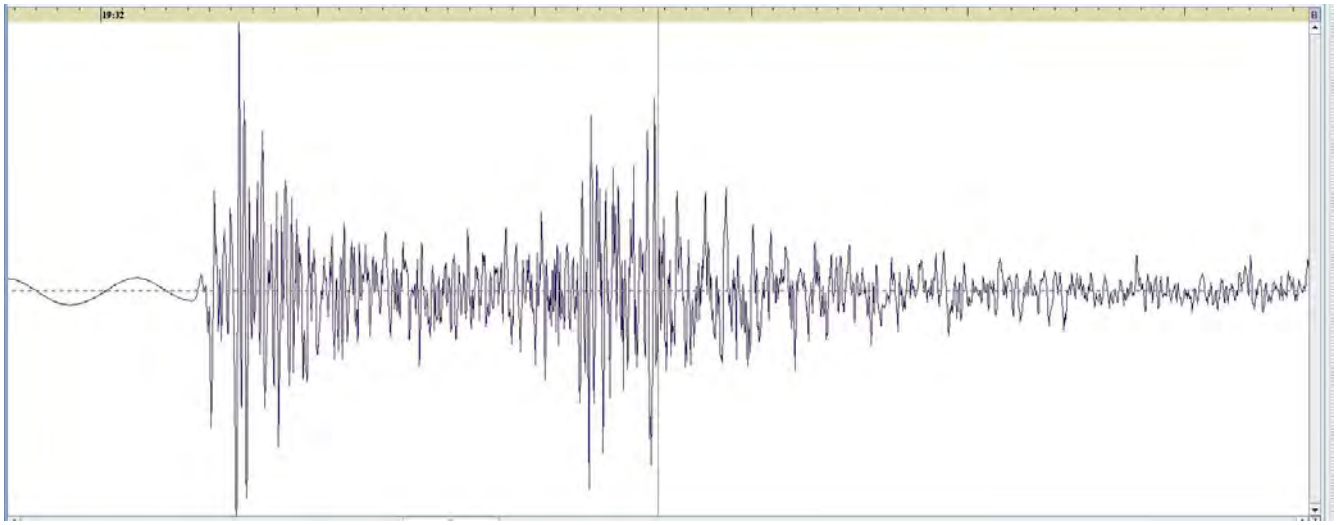
The MBMG operates a network of 40 seismic monitoring stations throughout western Montana, the most seismically active region of the State. The MBMG receives seismic data from seven USGS stations in Montana, including four stations in eastern Montana. Other regional seismic monitoring centers in Yellowstone National Park, central Idaho, and southern Canada exchange seismic data with the MBMG and provide additional monitoring coverage near Montana's borders. The MBMG has installed NetQuakes seismographs at four homes or fire stations in western Montana. These small instruments detect significant ground motions at urban locations and send the data to a central server via the internet. Upgrades to the seismic monitoring network in 2015 include reopening a long-abandoned seismic vault near Libby Dam, where continuous data streams from modern digital seismometers are sent back to the MBMG via a satellite link. In September 2015, the MBMG Earthquake Studies Office switched to state-of-the-art software that greatly improved seismic analysis and reporting capabilities and efficiency.

The MBMG records a total of 170 channels of seismic data from 102 local and regional stations in 13 different networks. These seismic data are used to detect and report earthquake locations and magnitudes to the National Earthquake Information Center. State and Federal agencies (Montana Disaster and Emergency Services, Montana Dam Safety Program, Confederated Salish and Kootenai Tribes Safety of Dams Program, and the U.S. Geological Survey), the media, and the public use this information. As part of its routine earthquake cataloging procedure, the MBMG determined times, locations, and magnitudes for 4,899 earthquakes with magnitudes ranging from -0.9 to 4.9 from July 1, 2014 to June 30, 2016.

Real-time views of seismograms from the MBMG network are available on the MBMG Earthquake Studies Office website (http://www.mbmg.mtech.edu/quakes/quake.asp), along with a listing of recent earthquakes and other information about seismic hazards in Montana. Information about Montana seismicity, faults, and earthquake hazards is available at: http://data.mbmg.mtech.edu/mapper/.



Seismograph stations connected in real time to the Earthquake Studies Office and used to locate earthquakes during 2016. Network codes are: MB, MBMG; US,USGS National; IW, USGS Intermountain West; WY, University of Utah Yellowstone; IE, Idaho National Labs; UW, University of Washington; CN, Canadian national; IU, Global Seismograph Network; RC, BYU Idaho; TA, Transportable Array, UU, University of Utah temporary stations; GS, USGS temporary stations; and NQ, NetQuakes strong motion stations.



Recording of a magnitude 4.3 earthquake that occurred 12 miles east of Lincoln on January 30, 2016.

INFORMATION SERVICES

The Information Services Division is responsible for creating, editing, and distributing MBMG publications and reports to the public, both through our Publication Sales office and the MBMG's website.

Visit the MBMG site, http://www.mbmg.mtech.edu, or come see us in the Natural Resources Building.

New publications in this biennium:

EDMAP

EDMAP 10, Geologic map of the Ratio Mountain 7.5' quadrangle, southwest Montana, Olson, N.H., Dilles, J.H., Kallio, I.M., Horton, T. R., and Scarberry, K.C., 2016

Geologic Maps

GM 65, Geologic Road Map of Montana, Vuke, Susan M., 2015

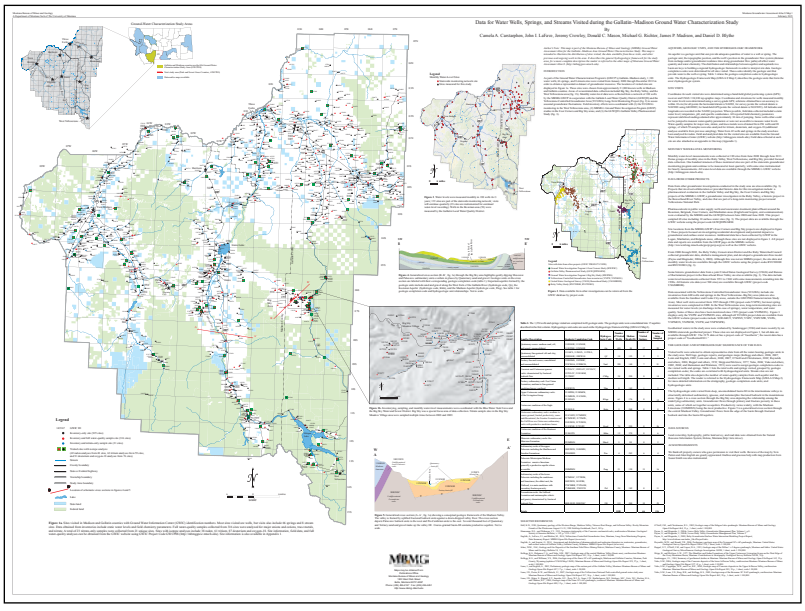
GM 66, Geologic map of the Wilson Park 7.5' quadrangle, southwestern Montana, Scarberry, K.C., 2016

Ground-Water Atlas Series

GWAA 6-03, Shallow groundwater altitude in bedrock units of the Carbon–Stillwater Study, Carbon and Stillwater Counties, Montana, Blythe, D.D., and Reiten, J.C., 2015

GWAA 7-04, Potentiometric surface in the Madison Group Aquifer, Cascade County, north-central Montana, Madison, J.P., 2016

GWAA 8-01, Data for water wells, springs, and streams visited during the Gallatin–Madison Ground Water Characterization Study, 40 p., Carstarphen, C.A., LaFave, J.I., Crowley, J., Mason, D.C., Richter, M.G., Madison, J.P., and Blythe, D.D., 2015



Ground-Water Open File Report

GWOF 23, Baseline water-quality investigation, Emigrant Creek watershed, south-central Montana, 24 p., LaFave, J.I., 2016

Open-File Reports

MBMG 619 A, Miles City—top of the Bearpaw shale/Pierre shale, Bergantino, R.N., 2014

MBMG 619 B, Miles City—thickness of the Bearpaw shale/Pierre shale, Bergantino, R.N., 2014

MBMG 619 C, Miles City—top of the Judith River Formation, Bergantino, R.N., 2014

MBMG 619 D, Miles City—thickness of the Judith River Formation, Bergantino, R.N., 2014

MBMG 619 E, Miles City—top of the Claggett shale, Bergantino, R. N., 2014

MBMG 619 F, Miles City—top of the Eagle Formation/gammon shale, Bergantino, R.N., 2014

MBMG 619 G, Miles City—top of the Kootenai Formation, Bergantino, R.N., 2014

MBMG 619 H, Miles City—thickness of the Kootenai Formation, Bergantino, R.N., 2014

MBMG 649, Preliminary geologic map of the Dearborn River 30' x 60' quadrangle, west-central Montana, 9 p., Vuke, S.M., 2014

MBMG 651, 2013 Annual coalbed-methane regional groundwater monitoring report: Powder River Basin, Montana, 89 p., Meredith, E., and Kuzara, S., 2014

MBMG 652, Hydrogeologic investigation of the Four Corners study area, Gallatin County, Montana, Groundwater Modeling Report, 76 p., Sutherland, M., Michalek, T., and Wheaton, J., 2014

MBMG 654, Hydrogeologic investigation of the North Hills study area, Lewis and Clark County, Montana, Technical Report, 376 p., Bobst, A., Waren, K., Swierc, J., and Madison, J., 2014

MBMG 655, A MODFLOW tool to define boundaries of a stream depletion zone, 24 p., Bobst, A., and Fleener, S., 2014

MBMG 657, Geologic map of the Maurice Mountain 7.5' quadrangle, southwestern Montana, Lonn, J.D., 2015

MBMG 658, 2014 Annual coalbed-methane regional groundwater monitoring report: Powder River Basin, Montana, 84 p., Meredith, E., and Kuzara, S., 2015

MBMG 660, Asteroid fossils from the upper Jurassic of south-central Montana, 12 p., Gunderson, J.A., 2015

MBMG 661, Butte Mine Flooding Operable Unit water-level monitoring and water-quality sampling 2014 Consent Decree Update Butte, Montana 1982–2014, 175 p., Duaime, T.E., Lorenzo, M.B., and Tucci, N.J., 2016

MBMG 663, Geologic map of the Mitchell Mountain 7.5' quadrangle, west-central Montana, Bregman, M.L., 2015

MBMG 664, Geologic map of the Lower Seymour Lake 7.5' quadrangle, southwestern Montana, 11 p. , Elliott, C.G., 2015

MBMG 665, Geologic map of the Nevada Mountain and Granite Butte 7.5' quadrangles, west-central Montana, McDonald, C., and Lonn, J.D., 2015

MBMG 666, Geologic map of the Ophir Creek 7.5' quadrangle, Lewis and Clark, and Powell counties, Montana, Lonn, J.D., and Vuke, S.M., 2015

MBMG 667, Digital coal outcrop patterns for the Powder River Basin of Montana, 21 p., Gunderson, J.A., 2015

MBMG 669, Proceedings of the 2015 Mining and Mineral Symposium, 69 p., Metesh, J., and Korzeb, S., 2015

MBMG 670, Synoptic groundwater sampling on the Ashland Ranger District, 52 p., Meredith, E., and Schwartz, C., 2016

MBMG 671, Butte mine flooding operable unit water-level monitoring and water-quality sampling 2011 consent decree update, Butte, Montana 1982–2011, 160 p., Duaime, T.E., and Tucci, N.J., 2016

MBMG 672, Geologic map of the Finn 7.5' quadrangle, Lewis and Clark and Powell Counties, Montana, McDonald, C., Mosolf, J.G., and Vuke, S.M, 2016

MBMG 673, Geologic map of the Nevada Lake 7.5' quadrangle, Lewis and Clark and Powell Counties, Montana, McDonald, C., and Mosolf, J.G., 2016

MBMG 674, Geologic map of the Sugarloaf Mountain 7.5' quadrangle, Deer Lodge, Powell, and Jefferson Counties, Montana, Scarberry, K.C., 2016

MBMG 675, Geologic map of the Windy Rock 7.5' quadrangle, Powell County, Montana, Mosolf, J., 2016

MBMG 676, Butte Mine Flooding Operable Unit water-level monitoring and water-quality sampling 2015 Consent Decree update, Butte, Montana 1982–2015, 175 p., Duaime, T.E., Icopini, G.A., McGrath, S. F., and Thale, P.R., 2016

MBMG 677, Survey of selected geothermal springs and wells in southwestern Montana, 44 p., Smith, M.G., and Icopini, G.A, 2016

MBMG 678, Geologic map of the Tash Peak 7.5' quadrangle, southwest Montana, Elliott, C.G., and Lonn, J. D., 2016

MBMG 679, 2015 Annual coalbed methane regional groundwater monitoring report, Powder River Basin, Montana, 96 p., Kuzara, S., Meredith, E., Wheaton, J., Bierbach, S., and Sasse, D., 2016

p., Vuke, S.M., and Stickney, M.C.

MBMG 643, Hydrogeologic Investigations of the Scratch-gravel Hills study area, Lewis and Clark County, Montana, Groundwater Modeling Report, 68 p., Butler, J.A., Bobst, A.L., and Waren, K.B.

MBMG 645, Geologic map of the Stillwater Complex within the Beartooth Mountains Front Laramide Triangle Zone, south-central Montana, 21 p., Geraghty, E.

MBMG 646, Hydrogeologic investigation of the Scratch-gravel Hills study area, Lewis and Clark County, Montana—Technical Report, 234 p., Bobst, A.L., Waren, K.B., Butler, J.A., Swierc, J.A., and Madison, J.D.

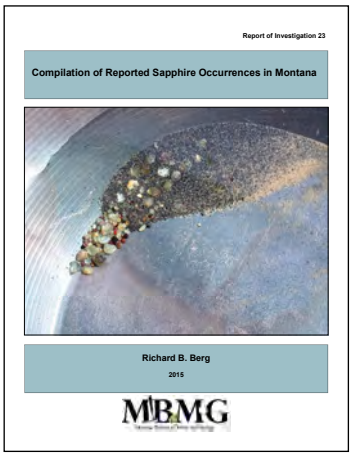
MBMG 648, Geologic map of the Bozeman 30' x 60' quadrangle, southwestern Montana, 44 p., Vuke, S.M., Lonn, J.D., Berg, R.B., and Schmidt, C.J.

Miscellaneous Publications

MISC 57, MBMG 2016 Wall Calendar featuring Lewis and Clark Caverns, 2015

Reports of Investigation

RI 23, Compilation of reported sapphire occurrences in Montana, 84 p., Berg, R.B., 2015



Information Services Statistics for this Biennium

Publication Sales:

- 1,019 titles
- 8,069 items sold
- 49 items published/released

Data downloaded:

- 949 titles
- 254,877 files

MBMG GRANTS AND CONTRACTS

in effect during this biennium

Bobst, A., Boulder River Valley Groundwater, Jefferson County
Bobst, A., Upper Jefferson River Valley Groundwater, Madison County
Buckley, L., GIN-Stack Geothermal Database for Montana, Arizona Geological Survey
Chandler, K., Stillwater County Groundwater, Stillwater County Conservation District
Chandler, K., West Crane Aquifer, Richland County Conservation District
Chandler, K., Clear Lake Aquifer, Sheridan County Conservation District
Delaney, M., National Geological & Geophysical Data Preservation Program; US Geological Survey
Duaime, T., Butte Mine Flooding Consent Decree Monitoring, MT Dept. of Environmental Quality
Duaime, T., Natural Resource Damage, Upper Clark Fork River, MT Dept. of Justice
Duaime, T., and Icopini, G., Rocker Timber Framing, MT Dept. of Environmental Quality
Duaime, T., and Berzel, M., Crystal & Bullion Mines Water Quality and Adit Discharge Monitoring, MT Department of Environmental Quality; US Environmental Protection Agency
Duaime, T., and Icopini, G., Long-Term Groundwater Monitoring at the Mouat (Columbus, MT) Superfund Site, MT Dept. of Environmental Quality
Duaime, T., Ground Water Assessment, US Forest Service
English, A., Yellowstone Controlled Ground Water Area Monitoring Program, National Park Service
English, A., Yellowstone National Park Database Administration, National Park Service
Gunderson, J., National Coal Resource Data System, Compilation, Collection and Correction of Coal Resource, US Geological Survey
Kuzara, S., Groundwater and Surface Water Interaction in the Rock Creek Watershed, Carbon County Conservation District
Kuzara, S., Groundwater quality sampling for areas near oil/gas development, Coal Bed Methane Protection Program.
LaFave, J., National Ground Water Monitoring Network Montana, U.S. Geological Survey
LaFave, J., Ground Water Assessment in Immigrant Creek, US Forest Service.
McDonald, C., and Vuke, S., STATEMAP FY15—Funded through the National Cooperative Geologic Mapping Program, US Geological Survey
McDonald, C., STATEMAP FY16—Funded through the National Cooperative Geologic Mapping Program, US Geological Survey
Meredith, E., Coalbed Methane Investigation, Treasure County CD
Meredith, E., Eastern Montana Coal Lands Ground Water Evaluation, US Bureau of Land Management
Meredith, E., and Wheaton, J., Montana Regional Coalbed Methane Groundwater Monitoring Program, Big Horn CD; MT Dept. of Natural Resource Conservation
Patton, T., and Blythe, D., Natural Resources Conservation Service Technical Services: Stock Water Supply Location and Flowing Well Rehabilitation Reports, US Natural Resource Conservation Service
Reiten, J., Eastern Roosevelt County; Eastern Roosevelt County CD; MT Dept. of Natural Resource Conservation
Reiten, J., Remediation of Hailstone Reservoir on Hailstone National Wildlife Refuge, US Fish & Wildlife Service
Reiten, J., Results of Water Quality Assessment, Clear Lake Aquifer, Sheridan County CD; MT Dept. of Natural Resource Conservation
Reiten, J., and Chandler, K., Inventory of Flowing Wells Richland County, MT Dept. of Natural Resource Conservation
Stickney, M., Flathead Seismic Monitoring System, Confederated Salish Kootenai Tribes
Stickney, M., Montana Regional Seismograph Network, US Geological Survey
Stickney, M., Operation of the Montana Regional Seismograph Network, US Geological Survey
Stickney, M., Western Montana Seismic Network Support, National Institution for Safety and Health
Timmer, J., Montana Pole Analytical Support, MT Dept. of Environmental Quality

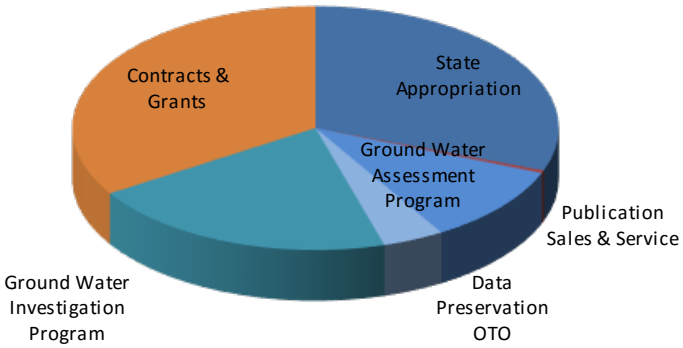
FINANCES

The Montana Bureau of Mines and Geology was established in 1919 to collect, interpret, and publish information on the geology of Montana. The main office is on the campus of Montana Tech in Butte and a second office is in Billings at 101 Grand Avenue. Our staff is composed of about 65 permanent employees in Butte and Billings, and about 30 students from Montana Tech, University of Montana, Montana State University, and MSU-Billings.

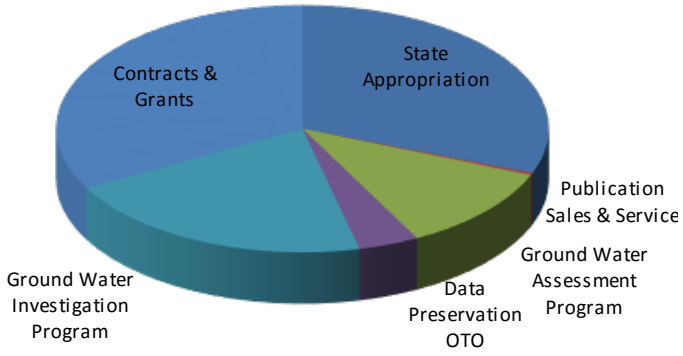
Funding for the past biennium came from six categories: (1) a biennial appropriation from the State's general fund to maintain core programs; (2) a biennial appropriation from the State's general fund for the Ground Water Investigation Program; (3) biennial appropriations from the State's special accounts for the Ground Water Assessment Program; (4) contracts and grants derived through agreements with variety of Federal, State, and local organizations to address specific issues of mutual interest to the sponsoring organization and the MBMG; (5) income from sales of MBMG publications; and (6) a special one-time-only appropriation for Data Preservation provided by the 2015 Legislature.

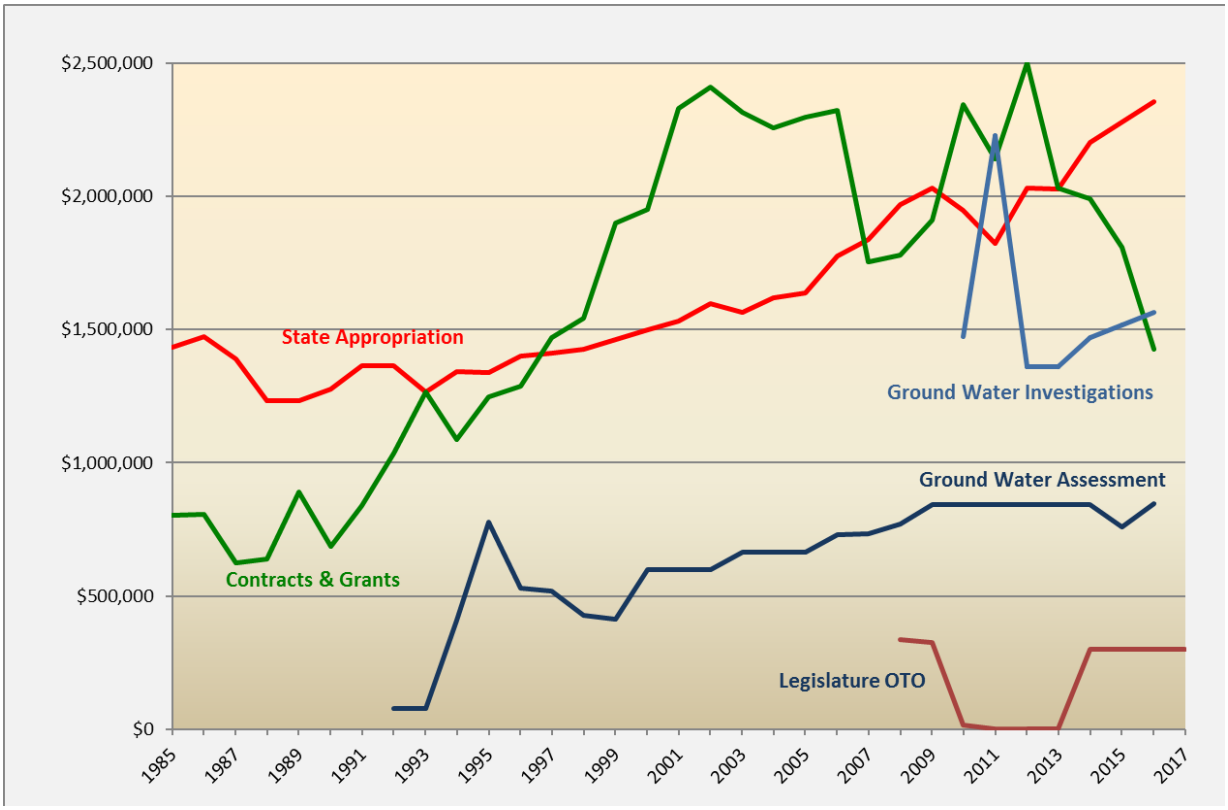
The long-term trend for the four major sources of funding continues upward at a modest rate; the generosity of the Montana Legislature and Governor is reflected in the steady growth of the core geologic programs as well as the recent addition of the new groundwater program. Many of the projects under contracts and grants rely on partial state support (matching funds); the decline in "soft money" reflects reduction of funds from Federal sources as well as a reduction in activities related to local Superfund projects.

FY 2015



FY 2016





MBMG STAFF

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Sara Richards, Accounting Associate III

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Susan Smith, Geologic Cartographer
Bette Wasik, Publication Sales, Administrative Associate III

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Clarence Schwartz, Groundwater Specialist
Deborah Smith, Seismic Analyst

COMMITTEES

The Montana Bureau of Mines and Geology endeavors to provide sound scientific maps and reports for use by many segments of society. An important component of our activities is the decision process to determine topics and geographic areas of our research; advisory groups and steering committees are critical to that process. The MBMG gratefully acknowledges the many individuals and agencies who participate on these committees.

Advisory Committees

Ground Water Assessment Program and Ground Water Investigation Program Steering Committee

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Mr. Chris Boe, Department of Environmental Quality
Mr. Christopher Kelley, Department of Agriculture
Mr. Troy Blanford, Montana State Library, Natural Resources Information System

EX OFFICIO MEMBERS

Governor Appointees

Mr. Walt Sales, Association of Gallatin Agricultural Irrigators, Bozeman—Agricultural water users
Mr. Mark Thompson, Montana Resources Inc., Butte—Industrial water users
Ms. Jane Holzer, MT Salinity Control Assn., Conrad—Conservation or ecological protection organization
Mr. Scott Cooney, Developer, Missoula—Development community

OTHER

Mr. Steve White, Montana Association of Counties Appointee
Mr. Steve Custer, Montana University System, appointed by the Board of Regents
Mr. Tom Patton, Montana Bureau of Mines and Geology
Mr. Joe Kolman, Legislative Services Division
Mr. James Halvorson, Board of Oil and Gas Conservation
Mr. Alden Shallcross, Bureau of Land Management
Mr. John Kilpatrick, U.S. Geological Survey
Mr. Jeff Baumberger, U.S. Bureau of Reclamation
Mr. Thor Burbach, USDA Forest Service
Mr. Jason Gildea, U.S. Environmental Protection Agency
Vacant—There is currently no appointee from an organization of Montana cities and towns.

State Map Advisory Committee

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Mr. Steven J. Czehura, Montana Resources
Mr. Michael Garverich, Natural Resources Conservation Service
Mr. James W. Halvorson, MT Board of Oil and Gas Conservation
Dr. Marc Hendrix, The University of Montana
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Mr. Chad Lee, MT Dept. of Agriculture
Ms. Bonnie Lovelace, MT Dept. of Environmental Quality
Mr. Seth Makepeace, Confederated Salish and Kootenai Tribes
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Mr. Ted Antonioli, Consultant Geologist

The MBMG thrives on its interaction with citizens and agencies throughout Montana. Serving on various advisory committees and boards gives us an opportunity to learn about many issues facing the state and provide information on quite a range of topics. Committees on which MBMG members have served:

Anaconda RWWS Operable Unit: Groundwater Technical Review Committee
Association of American State Geologists Executive Committee
State Water Plan Basin Advisory Committees
Board of Environmental Review
Butte Mine Flooding Public Education (Pit Watch)
Butte Silver Bow Pre-Disaster Mitigation Plan Committee
Butte-Silver Bow Superfund Advisory and Redevelopment Trust Authority
Clark Fork Watershed Education Program
Coalbed Methane Protection Program
DNRC Technical Advisory Council on Coalbed Methane
Future Fisheries
Governor's Drought and Water Supply Advisory Committee's Monitoring Sub-committee
Montana Board of Water Well Contractors
Montana Geologic Society
Montana Mining Association
Montana Resources - Groundwater Modeling Working Group
Montana Section of the American Water Resources Association
Montana Water Center
National Geologic and Geophysical Data Preservation Committee
National Ground Water Monitoring Network
Science Mine
Sheridan County Water Reservation Technical Advisory Committee
Subcommittee on Groundwater to the Advisory Committee on Water Information (DOI)
Tobacco Root Geological Society
Watershed Coordination Council
Western States Seismic Policy Council
Williston Area Aquifer Models Consortium
Yellowstone TOC

Photo by Ashley Huft, MBMG

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MBMG
Montana Bureau of Mines and Geology

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