Issue 9
Winter 2025

Core Quarterly

A publication of the
Michigan Geological Survey
at Western Michigan University

Watersmeet Gneiss:
The Oldest Exposed Rocks in the USA

by Nolan Gamet

Michigan's western Upper Peninsula (U.P.) is home to the oldest exposed rocks in the entire United States. In the latest edition of GSA Today, the authors reveal that the Watersmeet gneiss is estimated to be 3.62 billion years old! The Early Archean age date of this gneiss is geologically significant for many obvious reasons, especially when considering the age of the Earth. This gneiss forms the core of a dome that was uplifted during the Paleoproterozoic Penokean orogeny approximately 1.8 billion years ago and it represents the crystalline basement in northern Wisconsin and the Upper Peninsula of Michigan. The Watersmeet dome was once buried by the Penokean orogeny; however, it now extends 5 miles x 17 miles and exposes the deepest crustal level rocks in the orogeny (Frost and others, 2025).

For those unfamiliar with Michigan's geography, Watersmeet is a quaint town located in western Gogebic County at the intersection of Old U.S. 2 and U.S. Highway 45 (as shown in the bottom of Figure 1 on page 2). It is positioned partially within the Lac Vieux Desert Reservation and is surrounded by the Ottawa National Forest. The area is full of beautiful lakes, streams, and trails that are ready to be explored by any outdoor enthusiast. Whether you are fishing on one of the many lakes, hiking next to a waterfall, or driving down an ORV trail, take a moment to ponder how 3.62 billion years of geologic history have shaped the landscape around you.

MGS provides numerous opportunities for student involvement, allowing them to gain hands-on experience in data collection, preservation, analysis, and research. These projects not only enhance students' skills but also position them as strong candidates for the workforce upon graduation.

The Watersmeet gneiss can be observed roughly 4 miles north of Watersmeet alongside State Highway M45 (Figure 1 on the following page). These roadside outcrops are generally discontinuous; however, they are abundant and can be seen for over 100 feet moving northwards along the

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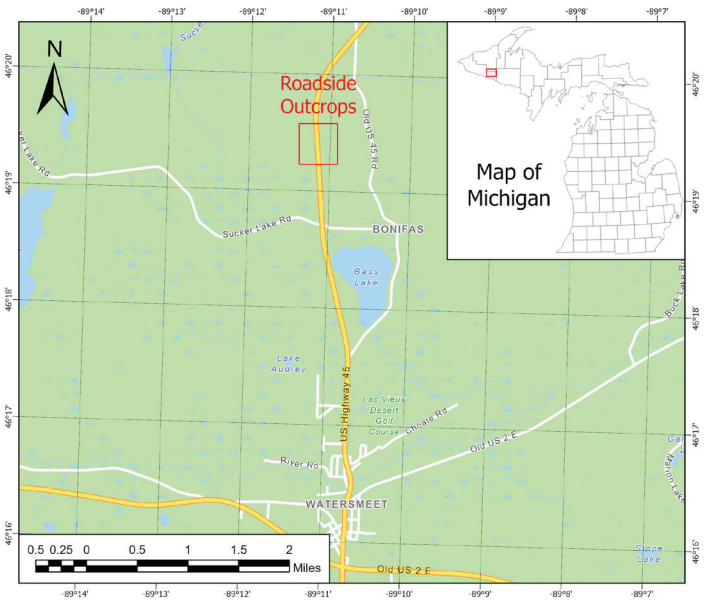

Figure 1. *The red box denotes the approximate location of the Archean gneiss outcrops along the roadside north of Watersmeet, MI.*

highway. They are made up of a tonalitic augen gneiss that is occasionally cross cut by smaller, coarser grain felsic to intermediate composition dikes. The gneiss is characterized by its augens, or metamorphic shear indicators, that define the felsic component of the quasi-planar foliation bands (Figure 2). These rock fabrics help to explain the complex geological story of the area. The tonalitic gneiss's major mineral components listed in order of abundance include quartz, biotite, and plagioclase feldspar. There are additional outcrop exposures of gneiss further to the north along M45, but the rock changes from a tonalitic augen gneiss to a biotite gneiss that is more fractured and weathered. Other outcrops located away from the road are hidden by the forest canopy and drastically vary in size (Figure 3).

There have been multiple bedrock geology maps published since the late 1960s that show different interpretations of the Watersmeet dome. A common consensus amongst geologists that hasn't changed since the 1960s is that the rocks of the Watersmeet dome have experienced a very complex geological history. These rocks were subjected to extreme pressures that metamorphosed them to an amphibolite facies. These rocks were mylonitized, folded, and sheared throughout the doming process and then later eroded down by glaciers. A blanket of Quaternary glacial sediments now covers much of the landscape which explains why the outcrops are constrained to the northern part of the dome (Figure 4).

The dome's current ellipsoid shape and geologic unit contacts were based heavily on aeromagnetic and gravity data from the early 1980s (Klasner and Sims, 1984). This

Figure 2. *Early Archean gneiss exposures. A) Tonalitic augen gneiss; B) Biotite gneiss.*

Figure 3. *Early Archean gneiss exposures. A) Tonalitic augen gneiss; B) Biotite gneiss.*

geophysical data combined with field observations, geochemistry, and geochronology helped the USGS construct Map I-2093 (Sims, 1990). Map I-2093 shows the Early Proterozoic Michigamme Formation unconformably overlying unexposed magnetic units, Early Proterozoic schist and amphibolite, and Archean gneisses.

Geologic interest in the Watersmeet dome increased during the latter half of the Cold War when companies were in search of possible Uranium deposits. Since the 1980s, anomalous rare earth elements (REE), fluorite, Mo, U, Th, Hf, Ta and other elements potentially related to critical mineral systems have been documented in the Watersmeet gneiss dome (Sims and others, 1984 and Barovich and others, 1991). To further investigate previous findings, the MGS received an Earth Mapping Resource Initiative grant to assess the critical mineral potential of the Watersmeet dome.

The U.P. team spent the 2024 field season mapping bed-

rock exposures along the northern margin of the dome. Over 120 rock samples were collected and sent to the USGS for geochemical analyses. With the analytical data now in hand, the UP team has started to make preliminary interpretations. The team will ultimately produce a 1:24,000 geologic map with accompanying cross sections, a final report stating our findings, a compilation of new geochemical and geochronology data, and a high-resolution aeromagnetic survey across the project area.

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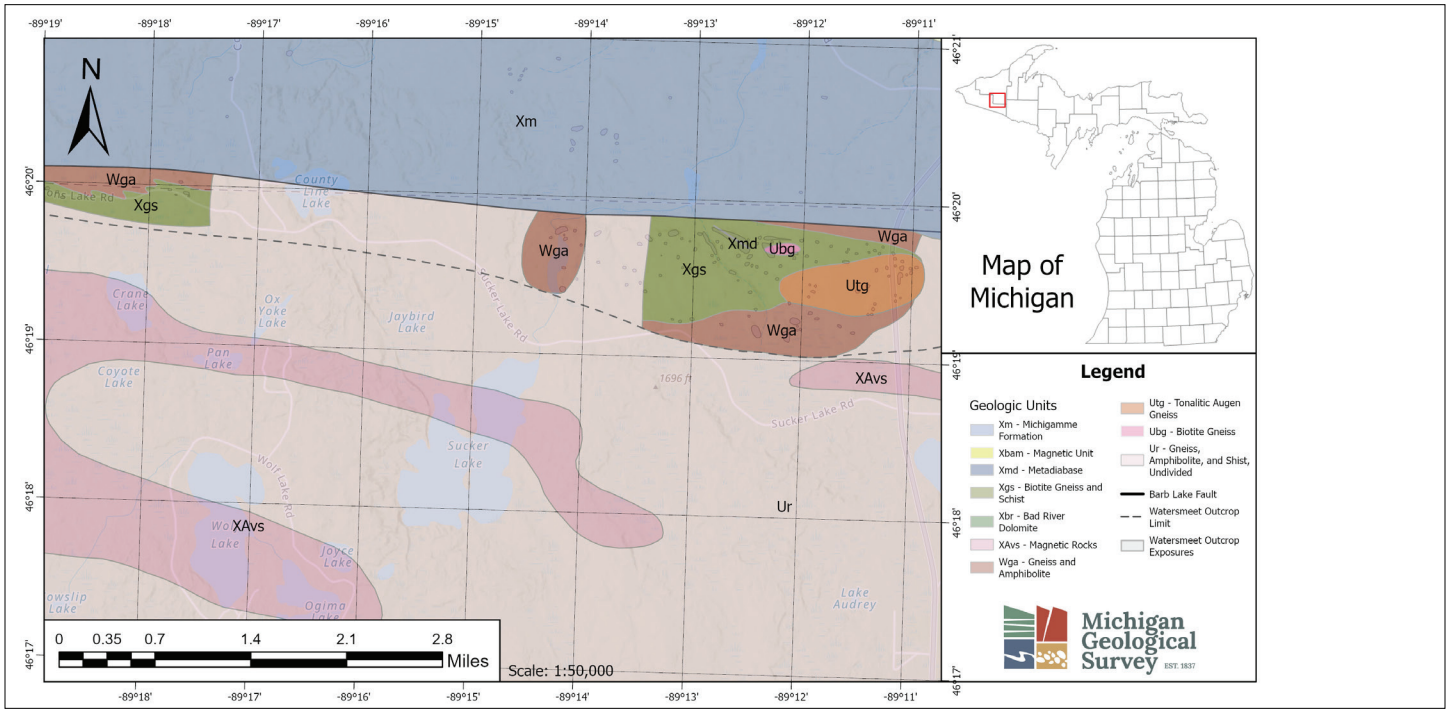


Figure 4. *A modified version USGS Map-I 2093 (Sims, 1990) shows the different Precambrian aged geologic units. The corresponding bedrock outcrops found since 1910 (Fritz, 1969) have been digitized and shown as grey polygons.*

MGS Shines at GSA

by Autumn Haagsma, PhD

In late March, several MGS team members attended and presented at the joint Northeastern and North-Central Section Meeting of the Geological Society of America. Our presentations covered the tremendous work MGS is leading including surficial mapping, GIS tool development, 3D modeling and printing, and aggregates. The presentations were:

A Peek into the Subsurface with Computers: Michigan Geological Survey Cross-Section Tools, Matthew Bell and Garrett Ringle

- Surficial Geological Mapping in Muskegon County Michigan USA: Late Wisconsin Landforms and Stratigraphy of the Lake Michigan Lobe, Nathan Erber,

Continued, page 8.

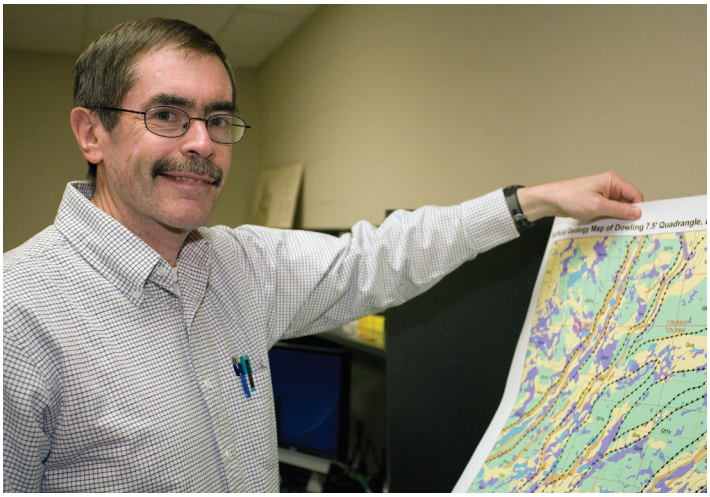
Time Well Spent:
Reviewing the Legacy of Alan Kehew's Field Work

by Linda Zabik

When I joined the staff at the MGS , I, a former WMU geology student, was assigned an important project: reviewing and organizing decades of field data collected by Dr. Alan Kehew. Now part of the MGS aggregate group, I have been carefully analyzing Dr. Kehew's extensive field notes, boring logs, and gamma ray data with an eye toward how this data could be used to meet the future goals of MGS. My work is intended to honor Dr. Kehew's legacy while bringing new life to the data he and his students gathered over the years.

Dr. Alan Kehew served on the faculty at Western Michigan University (WMU) for more than three decades, making significant contributions to the fields of glacial geology and hydrogeology. His research focused on the formation and evolution of glacial landscapes, groundwater flow in glacial deposits, and the processes that shape surficial geology. Throughout his career, Dr. Kehew led extensive field studies across Michigan and beyond, mentoring numerous graduate and undergraduate students in hands-on geological research. His work laid a foundation for modern interpretations of Michigan's glacial history and continues to influence geological mapping and resource management efforts today.

Linda Zabik is identifying information and data within Dr. Kehew's files that will be essential for the next generation of research.



Dr. Alan Kehew with a map that changed our view of southwest Michigan's water resources.

Hundreds of boring and gamma ray logs from six southwestern Michigan counties—Branch, Calhoun, Cass, Kalamazoo, St. Joseph, and Van Buren—are in the process of being cataloged and incorporated into ArcGIS. These records are now part of a growing database that will serve multiple purposes, most notably updating surficial geology maps for these counties and identifying aggregate resources such as sand and gravel deposits.

In addition to compiling and cataloging geologic logs, I am reviewing raw data and field notes captured in the many papers authored by Dr. Kehew. These materials are being scanned and archived for future use, preserving valuable insights for researchers. Moving forward, student research projects and theses prepared under Dr. Kehew's direction will also be reviewed and integrated into comprehensive geologic databases to support diverse mapping products and resource evaluations across the region.

Dr. Kehew's data has already been instrumental in completing glacial geology maps for these counties. Now, with the addition of high-resolution LiDAR data—Light Detection and Ranging, a remote sensing method that uses laser light to precisely measure surface elevations—these maps are being fine-tuned to achieve even greater accuracy. The use of LiDAR reveals subtle surface features in remarkable detail, allowing geologists to better interpret glacial landforms and sediment patterns critical to understanding Michigan's surficial geology.

This effort enhances our understanding of Michigan's glacial history, supports smarter land-use planning, and informs the management of important resources like aggregates and groundwater. From geological mapping and hazard assessments to water resource studies and mineral resource evaluations, the integration of this historic data underscores MGS's ongoing commitment to providing high-quality geoscientific information for the benefit of Michigan's communities and environment.

Dr. Kehew's legacy of field research continues to shape and strengthen Michigan's geological knowledge. This has been, truly, time well spent.

Mapping the Edge:
MGS UAV Study Reveals Insights on Lake Michigan Bluff Erosion

by Sara Pearson, CPG

For decades, the erosion of Lake Michigan's majestic bluffs has been a well-documented concern, with foundational research between 1996 and 2008 establishing a clear, troubling pattern. Early studies led by Drs. Ronald Chase and Alan Kehew showed that bluff failures were not just a high-water problem; they occurred even during periods of low lake levels. After a pause in this work, the MGS led by then Director John Yellich, CPG, in partnership with the U.S. Geological Survey's (USGS) Dr. Monica Palaseanu-Lovejoy and the University of Toledo's Dr. Richard Becker, revived the effort by launching a seven-year study from 2017 to 2023 utilizing advanced Unmanned Aerial Vehicle (UAV) technology to monitor three distinct shoreline sites: a mostly natural, unpopulated area near Pentwater; the rural, developed subdivisions of Miami Park; and the populated, engineered coast of St. Joseph. The goal was to build on the historical data and create the most detailed picture yet of the forces reshaping our coast.

The study's findings challenge the prevailing narrative that high lake levels and crashing waves are the singular cause. While rising water certainly exacerbates the problem by attacking the base of the bluffs, the report concludes they are "not the cause of many major bluff failures." The research uncovered a critical paradox in our attempts to fight back: man-made interventions can be unexpectedly destructive. The installation of armored barriers and seawalls, intended to protect property, were identified as "major contributors to bluff recession." The study documented "catastrophic bluff changes" that occurred right after these structures were built in localized areas, suggesting our solutions can unintentionally accelerate the very damage we seek to prevent.

By deploying UAVs to generate precise 3D models and using model building techniques like Structure-from-Motion (SfM) photogrammetry that overlaps a series of images, the study provides clear, data-driven evidence that the primary driver of catastrophic failure is groundwater. The research confirms that water from intense rainfall and snowmelt coupled with irrigation water and storm water discharges seep into permeable

2019

2021

2022

Time series aerial photos of bluff in St. Joseph focused on the Lake wall reinforced section show that the toe remains stable, but the top of the wall is beginning to creep outward potentially related to water buildup behind the wall

sand layers and become trapped atop impermeable layers of clay, forming “perched aquifers.” This trapped water builds immense internal pressure that weakens the soil from within, leading to sudden, large-scale collapses. This understanding shifts the focus from the lake’s edge to the land itself, highlighting the immense value of proper water management. For example, the Mount Pleasant subdivision, which has maintained stormwater controls and is heavily vegetated, experienced only minimal erosion throughout the study. This success underscores the importance of land-use choices, such as replacing irrigated turf with deep-rooted native grasses that absorb more water and stabilize the soil, a strategy specifically suggested for the Miami Park area. The conclusion is clear: bluff stability is a complex interplay of natural geology, human activity, and hidden groundwater dynamics. This research provides a crucial roadmap for developing more holistic and effective strategies to protect our invaluable coastline. All data from the study is publicly available for review.

Dig Deeper and See for Yourself:

The Michigan Geological Survey is committed to making this vital data accessible to the public. You can explore the full report, along with the UAV imagery and detailed geologic assessments, on their website. The USGS has also created a compelling visual summary of the erosion at the Miami Park bluffs.

Explore the Full MGS Report and Data:
https://mgs.wmich.edu/uav_bluff_erosion/

View the USGS StoryMap on the Miami Park Bluffs:
https://storymaps.arcgis.com/stories/5983930d-2737419c93290e7f9ef3984d

CoreKids Blasts into 2025

by Marie Solum

Our K-12 Outreach Program (known as CoreKids) had a great start to 2025 where we attended events with over 10,000 students participating in various outreach programs. Two of our events this quarter involved a new relationship with the Grand Rapids Public Museum. On February 6th, Shelby Hurst and Cristian Valle took part in the museum’s Engineering Day, an event attended by 899 Grand Rapids-area school children in 4th through 8th grades. Students participated in all types of hands-on STEAM activities provided by many local companies and organizations.

CoreKids staff Matt Bell, Marie Solum, Cristian Valle and Astronaut John Herrington.

On February 15th, Marie Solum, Matt Bell and Cristian Valle participated in another museum event, Roger That!, a space exploration-themed event named after Roger Chaffee, Apollo astronaut and Grand Rapids native. This Saturday event drew over 1,200 children and parents with fun hands-on activities. Corekids provided educational content about meteorites, planetary landforms and the geology of the moon. The highlight of Roger That! was meeting retired Navy Commander and NASA Astronaut John Herrington. In 2002, Astronaut Herrington flew on the 16th shuttle mission to the International Space Station on the Endeavor where he completed three extravehicular activities before delivering home the ISS Expedition Five crew from their six-month stay on the ISS.

We look forward to partnering more with the Grand Rapids Public Museum on many future events.

Ron Budros Legacy Collection Donated to MGRRE

by Linda K. Harrison

Ron Budros
1950-2023

We remember Ron Budros' dedicated work as a geologist in the Michigan oil and gas industry. As the founder and chief geoscientist at Innova Exploration, Inc., he was an avid data collector. He visited MGRRE often to examine cores and cuttings and talk about his latest work with Bill Harrison.

His primary targets for exploration were the Niagaran Reef trend and hydrothermal dolomite reservoirs in the Dundee and Trenton/Black River formations.

He was actively pursuing those targets when he died suddenly in his sleep on May 13, 2023. Ron was a generous donor to MGRRE in his lifetime and now through his estate. At his request, his family donated his collection of geological samples and photographs to MGRRE in September, 2024.

That collection includes drill cuttings, core chips, oil samples, and core photographs. The cuttings collection alone represents 81 wells, largely from the Trenton/Black River formations.

We didn't have cuttings from many of those wells before, and they will fill a data gap for us.

We will use those cuttings in our current carbon storage research to better characterize the Trenton and Black River formations.

We have always known that data has more than one life. Ron knew this as well—that's why he left this collection to MGRRE. This data will be used here in our research, education, and outreach, in ways that we cannot even imagine now. We are honored to archive this legacy collection.

Jen Trout inventorying cuttings donated to MGRRE by Ron Budros.

Each vial label shows the well name and depth.

Rock material in each vial holds direct data.

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Patrick Colgan, and Garrett Ringle
- Visualizing Michigan Geology using 3D models and printing, John Esch and Ricky Haagsma
- Surficial Geology of Cass County, Michigan: John Esch
- Aggregates Data: Creating a Michigan State-wide aggregate resources map with limited historic geologic mapping, Thomas Valachovics, Libby Ives, and Trent Adams

Additionally, MGS participated in the exhibition by hosting a booth full of interactive displays, generating high traffic and interest in our work.

MGS's 3D scanning/printing expert Ricky Haagsma shows off the new 3D prints of the Michigan Basin.

It was great bringing Michigan geology to the GSA meeting in Erie and connecting with so many colleagues.