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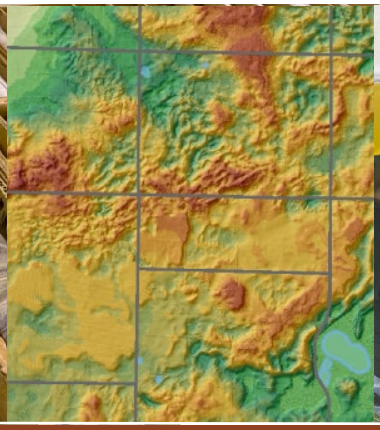
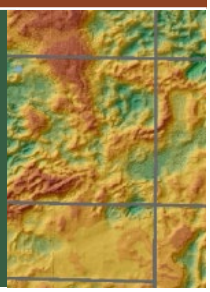


Issue 4
Fall '23

Quarterly Updates from the Michigan Geological Survey

MICHIGAN GEOLOGICAL SURVEY
EST. 1837

Core Quarterly



Highlights >>>

A Note from the Director

The Michigan Geological Survey (MGS) has completed the first year of functioning under an annual budget in over 30 years. A thank you to all that have supported our research efforts. MGS has grown, not just in staff, but is developing and producing more mapping and project deliverables in multiple geologic environments from grants and funding in both the Lower Peninsula and Upper Peninsula, all benefiting Michigan and our Natural Resources. MGS has also prepared or has produced a number of reports, maps and data summaries and is experimenting with videos to explain these projects and present Michigan's treasures. MGS is positioning our data programs for access by all, from citizens to the highest level of scientists. MGS continues to employ and train many entry level scientists in geological and other physical data methods. Please contact MGS if you have a need for data or how we can assist you in withdrawing data from our data sources.

~ John Yellich

For more information go to https://wmich.edu/geologysurvey

https://wmich.edu/michigangeologicalrepository

MGRRE Seeking New Home

Preserving the Past to Protect the Future

The Michigan Geological Repository for Research and Education (MGRRE) has served the state, industry, academia, and research realms for more than 40 years by preserving critical geologic data and information and providing access and resources for industry, research, and education.

The state recently recognized the importance of our contributions and the need we have for new facilities. In order to meet our growing collection and staff, we must at least double our current facilities. The state has awarded us $3M from the higher education budget and $2.9M from the EGLE budget to help us build new or expand our facilities!

However, our work isn't done yet. The generosity of the state has provided us the seed to begin our growth, with the overall goal of raising **$14M** to ensure we have the capacity for the next 50 years. Today, more than ever, natural resources are increasingly needed to fuel safe and sustainable economic growth, meet our energy and resources needs, and combat climate change. Reliable data and maps about our subsurface resources are essential to meet that need.

Our goals are to:

- Expand our research and purchase
- Continue to educate the next generation of earth scientists, and
- Increase MGS's work with members of industry and government to fulfill our legislative obligations to the citizens of Michigan

Read more about the new funding in the WMU news!
https://wmich.edu/news/2023/12/73664

MICHIGAN GEOLOGICAL SURVEY
Western Michigan University
Department of Geological and Environmental Sciences
Established 1837

WESTERN MICHIGAN UNIVERSITY

Key Updates >>>

Introducing New Staff

Amber Conner – Paleozoic Geologist

Amber Conner is a research geologist and geochemist with over a decade of experience working in carbon capture, utilization, and storage (CCUS), oil and gas, and critical minerals. Her critical mineral work focuses on analysis and identification of CM-enriched rocks and fluids to uncover geochemical and geological trends. Amber is passionate about political and community outreach opportunities and has created STEM learning activities focused on CCUS. She received her B.S. In Geology from Central Michigan University and M.S. in Geology from Ohio University.

Gregory Anderson – GIS Specialist

Greg has a long history of collaboration with the Geology department at WMU and over 30 years of GIS experience.

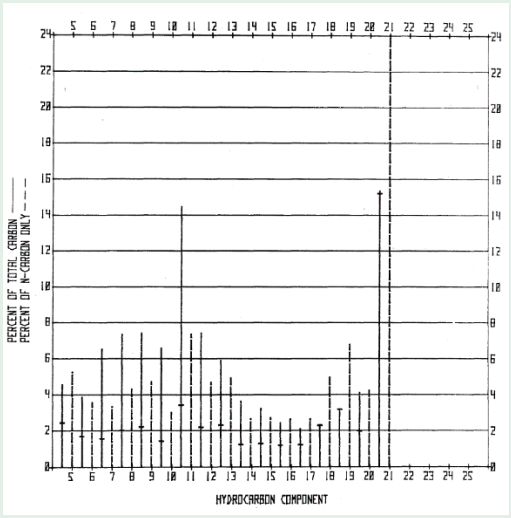
He earned his B.S. in Geography from WMU in 1992 and began his professional career in Barry County and assisted in establishing one of the first county mapping programs in the state. In 1994, he was hired by WMU to provide mapping services for the G.E.M. Regional Center (a collaboration between Geology and Geography) and the GIS Research Center (Geography). This was followed by assisting Dr. Alan Kehew of the WMU Geology department on multiple surficial geologic mapping projects and compilations in the mid-1990s and early 2000s. In 2005, a $4 million private gift allowed the formation of the W.E. Upjohn Center for the Study of Geographical Change where he served as project manager on multiple projects, including the award-winning Geochange and Authoritative Topo map series. The growing mapping needs of MGS led to Greg joining the mapping group as a full-time employee in October of 2023. In addition to providing GIS expertise to multiple mapping projects he serves as the lead on GeMS compliance for USGS mapping submissions.

Jessica Meskil – Administrative Assistant

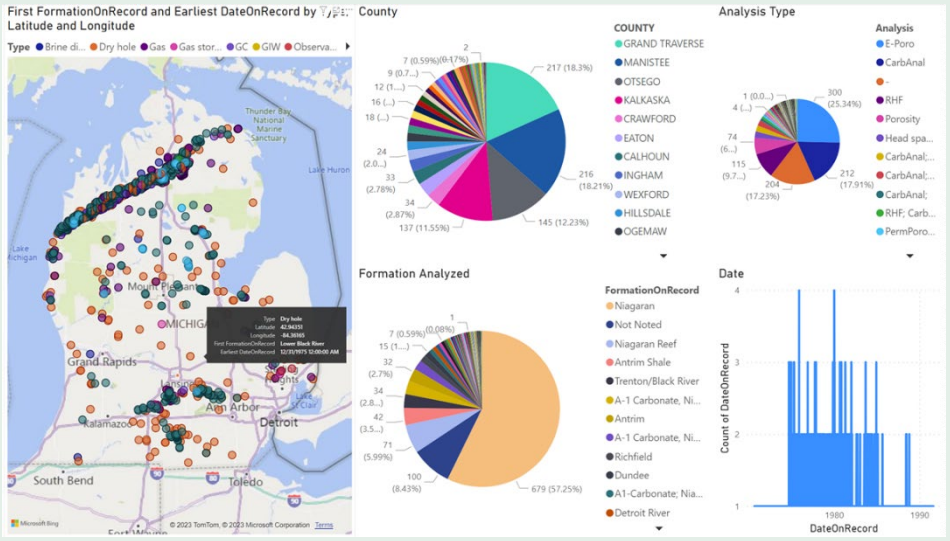
Jessica was hired in November of 2023 to assist with the day to day administrative and budgetary functions related to MGS, MGRRE, and related grants. She comes to us with a vast amount of diversified business experience including 10 years in banking, 18 years in the insurance industry, and the past 5 years of working for non-profit organizations managing various State and Federal grants. Jessica previously attended WMU and earned an Associate degree from Kalamazoo Valley Community College. She is currently taking classes at WMU to finish the remaining credits needed to complete her Bachelor's degree in General Studies with a concentration on Biology, Psychology, and Holistic Health.

Data Highlight – Gas Chromatographic Analyses

MGRRE has collected gas chromatographic analyses from more than 1,100 wells. These analyses include carbonate analyses, hydrocarbon composition, and carbon content. They provide clues about the hydrocarbon sources and are valuable to use for new exploration. We have scanned all of the paper copies. If you are interested in a copy of the data, contact us! If you are interested in having the data digitized and want to sponsor a student, contact us!



Example scanned hydrocarbon component analysis



Summary of gas chromatographic data including well location, formation analyzed, analysis type, and date.

Outreach and Education Activities

Full and Fun Fall season for CoreKids!

In October, Dr. Peter Voice and Marie Solum participated in the annual MiCareerQuest Southwest where 4,700 8th grade students from 43 middle schools in Kalamazoo, Calhoun, Allegan and Cass Counties explored a variety of STEM-related career paths from 54 local industries. Our hands-on booth displayed Michigan-area fossils and natural resources. Students were able to examine a fossiliferous limestone core and try out our popular core pumps showing porosity and permeability. This was a fun two-day experience that we look forward to participating in next year.

In November, CoreKids teamed with GeoClub members at the Department of Geological and Environmental Sciences in a university-wide STEM Day for Portage Northern Middle School. Approximately 180 8th graders rotated throughout numerous science

the university to learn about various STEM fields and future careers. The students were able to try the core pumps and also learn a little about the geology of Mars. The students planted seeds into simulated Mars soil and were able to take their plants back to their classrooms to see if they grew.

Also in November, Gabe Fox and Tori Brown from GeoClub were on-hand at the Air Zoo for a Webelo Scout event where they helped scouts earn a badge identifying rocks and minerals. Dr. Voice also hosted a teacher workshop at MGRRE sponsored by the Michigan Earth Science Teachers Association. Teachers gained knowledge and classroom activities about polar ice cores and climate science as well as taking a tour of the facility.

New YouTube Series in the Making

The outreach team has been hard at work developing the next series of YouTube videos! We will be walking through the stratigraphic column and showcasing different time periods in Michigan. Be sure to follow along!

http://www.youtube.com/@michigangeologicalsurvey

Follow MGS on Instagram!

Did you know MGS has an Instagram? We have been posting mini-videos, rock and mineral highlights, staff highlights, and job posts. Be sure to follow along!

https://www.instagram.com/michigangeologicalsurvey/

New Director of CoreKids- Marie Solum!

After a decade of running the CoreKids program, the joint outreach program of the Michigan Geological Survey and the Department of Geological and Environmental Sciences at Western Michigan University, I decided to step down as Director of the Outreach program. During my time heading the program, the CoreKids reached new heights – routinely interacting with more than 10,000 children, teachers, and parents each year. Unfortunately, the pandemic derailed the progress that we made and CoreKids essentially went into hibernation.

With state funding for the Survey starting last year, outreach became important. One of our first acts was to hire Marie Solum as outreach coordinator. A role that she has done ably and fantastically – developing new resources and activities that enhance our offerings, while developing new partnerships and engaging with new school groups. With Marie's support, CoreKids was able to return to a level of activity that we have not seen since 2019! I am thrilled to hand off the Directorship of the CoreKids program to Marie and look forward to seeing the program take off under her direction.

I will continue to be involved at the Survey – serving as a research associate and as the faculty oversight of the CoreKids program. I will also help Marie with larger outreach events.

~ Peter Voice

A Busy and Exciting Quarter at MGRRE!

Written By: Linda Harrison

Fall MGRRE Core Workshop

At our November 2nd core workshop, we welcomed 110 participants to MGRRE. They heard presentations from our research staff and students, members of industry, and government who shared insights and experiences. They enjoyed hands-on examination of hundreds of feet of core from the Traverse, Dundee, Richfield, Niagaran, Burnt Bluff, and the Trenton/Black River formations. As we reviewed the workshop evaluations, we were excited to read that they learned some new ideas, renewed partnerships and forged new alliances.

November 2 MGRRE Core Workshop

MDOT delivers cores to MGRRE

Geological samples received and preserved

We archived glacial and shallow bedrock cores received from MDOT and MGS drilling. MGS/MGRRE uses these to (1) map sand and gravel deposits to show their distribution and depth, and (2) to map bedrock surfaces and structures. Using data from these cores produces benefits by shedding light on resources and revealing potential risks for construction projects. The maps produced from that data also benefit home owners and farmers by showing where shallow groundwater sources are located.

MGRRE Provides Online Access to our Geological Samples and Data

Through funding by a USGS NGGDPP grant, Jen Trout and our students have been scanning paper records and photographing cores to upload these high-resolution images to Scholarworks. We are doing this to meet our goal of making our resources freely accessible and discoverable to all our stakeholders, both here and abroad. We can now document that our information is being used. Here are the download numbers for 2023:

Digital Collection	Number of Institutions	Number of Countries	Number of Referrers	Total number of downloads
Core Photos	33	43	205	3010
Lith Strips	8	21	16	1074
Pure Scout Records	40	48	44	9405
Thin Sections	18	36	91	5876

Ongoing Preservation Work

We continue to rebox cores that suffered from water and poor storage conditions before they were donated to us. Jen Trout recently reboxed cores from a geologic test well near the Wayne County airport. These cores preserve formations from the bedrock surface to the Salina Group. Now that these cores have been better preserved and footages better marked, we will be able to use these cores in our recently funded CCUS research.

Jen Trout reboxing core from a geologic test well near Wayne County Airport

Research Findings

USGS Earth Mapping Resources Initiative

Written and Interpreted by: Nolan Gamet

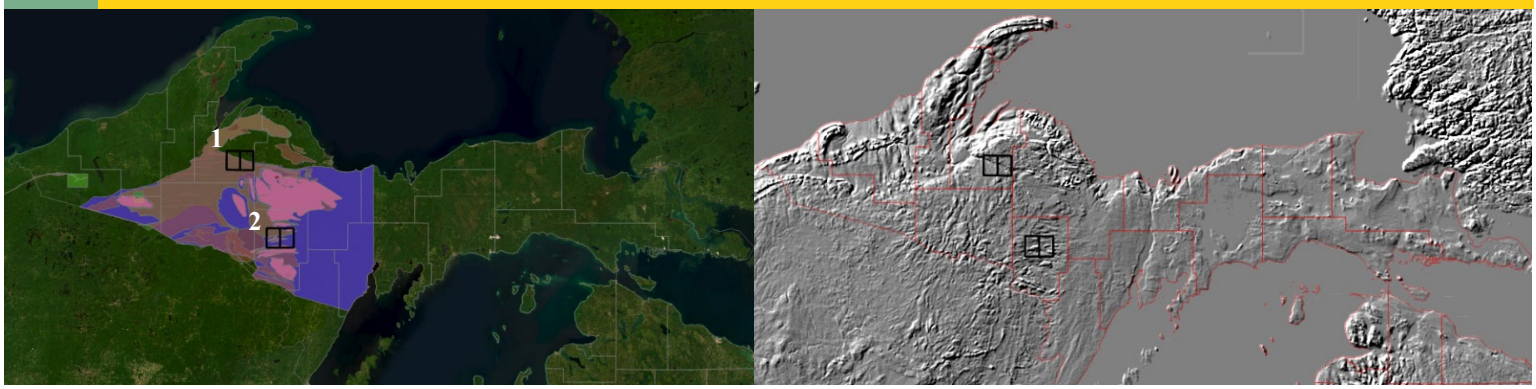


Figure 1. *Left - Map extent of Michigan's Upper Peninsula showing counties (grey polygons) and areas of interest separated by different mineral systems (multi-colored polygons). Right – Map extent of Michigan's Upper Peninsula showing counties (red polygons) with U.S.G.S 3DEP LiDAR hill shade layer added to signify topographic highs and lows. The black boxes represent the two Earth MRI mapping project areas: (**1**) Three Lakes in the north and (**2**) Central Dickinson in the south.*

The U.S.G.S-funded Earth Mapping Resources Initiative (Earth MRI) mapping project kicked off during the tail end of the 2023 field season. Geologists with the Michigan Geological Survey and Michigan Technological University faculty are currently working together to map the bedrock geology and related structural features of two quadrangles near Three Lakes and two quadrangles in central Dickinson County. The goal of this project is to update older published geologic maps of the area using new geophysical data and GPS technology, as well as old fashioned boots-on-the-ground methods. Outcrops are often hard to find in the field and not always obvious on orthophotos, so high-resolution LiDAR data provided by the U.S.G.S is a crucial asset for identifying possible exposures for mapping and sampling. The resulting state-of-the-art geological and geophysical maps will help us achieve a greater understanding of the local and regional geologic framework of Michigan's Upper Peninsula. The updated maps will also help to identify areas with the potential for critical mineral deposits in an effort to reduce our reliance on foreign sources of minerals that are crucial for our Nation's economy and security. The team of geologists will continue conducting field work and collecting samples for lab analyses in the upcoming 2024 field season.

Figure 2. *MTU professor James DeGraff and MGS geologist Nolan Gamet describing an outcrop of iron formation near Felch, MI. Photograph taken by Bob Mahin.*

With winter settling in, the MGS UP team is creating ArcGIS databases and compiling literature on critical mineral systems, logging drill core housed at the Upper Peninsula Geological Repository, and prepping field samples to be sent out for preliminary geochemistry analyses. Project updates will be available as more data are collected and analyzed.

Figure 3. *MGS Geologist, Nolan Gamet, thinking critically in the field while transcribing notes for the outcrop and surrounding area. This photo also depicts a ridge forming outcrop that is visible with the 3DEP LiDAR layer. Photograph taken by Bob Mahin.*

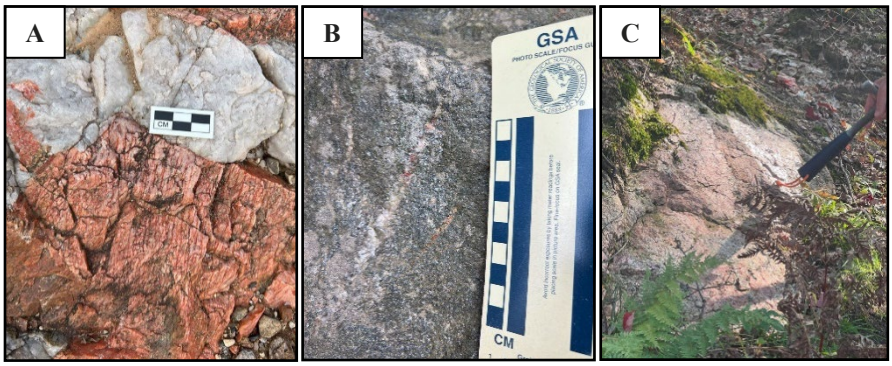


Figure 4. ***(A)*** *Pegmatite outcrop displaying centimeter-size feldspar and quartz crystals near Groveland Mine.* ***(B)*** *Sulfide mineralization within quartzite unit along State Highway M69, (C) Very large feldspar crystal reflecting light near North Branch Sturgeon River. Photographs taken by Nolan Gamet.*

Research Findings

Development of a Geologic Complexity Ranking System

CCUS Research Update by Autumn Haagsma

Autumn Haagsma successfully defended and completed her PhD dissertation in November, 2023. Her dissertation, titled "Development of a Geologic Complexity Ranking System for Carbon Dioxide Storage to Inform Site Selection," focused on assessing potential geologic storage sites by including qualitative and quantitative data, variability, and geologic complexity, to improve the site selection and comparison methodology. She evaluated multiple reservoirs to determine impactful geological variables, developed and tested a matrix based ranking system, and applied the ranking system to a local and regional scale (**Figure 1**).

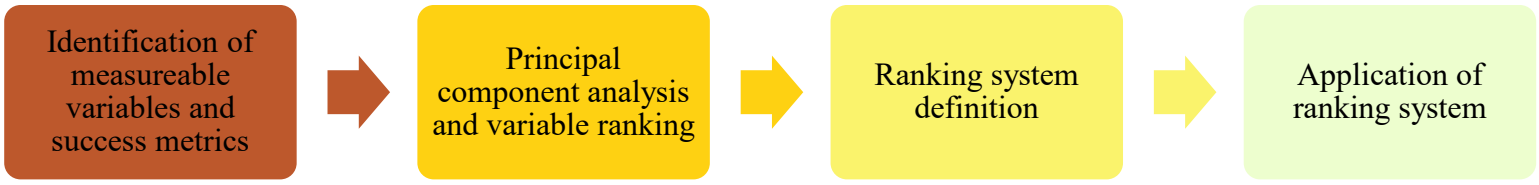


Figure 1. *Simplified workflow of developing and applying a geologic complexity ranking system*

Basic Requirements	Proven = 2X	Plausible = 1X	Unknown = .5X	Disproven = 0X

Category	Component	Score/Description			
		16	8	4	2
Regional Scale Geologic Complexity	Depositional Environment	Simple, uniform, single environment	Generally simple and predicable conditions single to few environments	Complex with some predictability and/or multiple environments	Highly complex, variable, and/or multiple environments
	Structure	None observed or expected	Limited, non extensive features	Extensive known features	Multiple structural components or unknown
	Diagenesis	Unlikely or not observed	Possible but not observed	Observed but not extensive	Observed and extensive
	Surface Changes	Uniform and predictable	Regular with some changes	Irregular over region	Highly irregular and/or not predictable
Reservoir Scale Variability	Continuity	Continuous across region/site	Depositional Pinch-out	Structural Pinch-out	Highly irregular and/or not predictable
	Thickness 2X Net 1X Gross	Variance <100	Variance <1000	Variance <10000	Variance>10000
	Lithology	Single lithology	Predictable lithology changes	Multiple lithology changes	Irregular lithology changes
	Facies	1-2 predictable facies	2-5 predictable facies	2-5 facies with some unpredictable	Irregular and unpredictable
	Porosity 2X Effective 1X Total	Variance <10	Variance <15	Variance<20	Variance>20
	Permeability	Variance <10	Variance <100	Variance <1000	Variance >1000
Data Confidence	Data Quality	Modern data with multiple data types	Modern data, single source	Vintage data with multiple sources	Vintage data, single source
	Data Proximity	Multiple points within defined area	Few points within defined area	Edge of defined area	Outside of defined area or analog

Figure 2. *Geologic Complexity Ranking System for Reservoirs*

The Niagaran Reefs in Northern Michigan and the Clinton Sandstone in Eastern Ohio were evaluated to determine which geologic variables had the best correlation with a successful outcome, such as produced oil, CO_2 stored, and brine stored. Based on those results, a multi-category ranking system was developed which included regional scale geologic complexity, reservoir scale geologic complexity, data confidence, and multipliers for confidence in meeting basic requirements for CO_2 storage (**Figure 2**).

The ranking system was applied to 10 reefs which have undergone CO_2 enhanced oil recovery. The reefs were ranked using multiple methods. The newly developed ranking system showed a high correlation to success (.78-.84), far outweighing traditional and other ranking methods (-.27 - .49).

Once the ranking system was finalized, it was applied to 11 sites across the Midwest United States to evaluate, compare, and rank the Mt. Simon Sandstone. The results showed that SW Michigan and Central to Northern Illinois were the best sites for CO_2 storage due to high reservoir quality, and relatively lower geologic complexity (**Figure 3**). The results were also used to demonstrate the regional variability in reservoir properties across the region and how it could impact CO_2 storage (**Figure 4**). The research was support by the Midwest Regional Carbon Initiative (MRCI) through Battelle.

The ranking system will be further applied and developed on our newly awarded DOE project – *"Advancing CCUS in Michigan"*. We plan on adapting the ranking system to include confining systems and other considerations.
https://netl.doe.gov/project-information?p=FE0032368

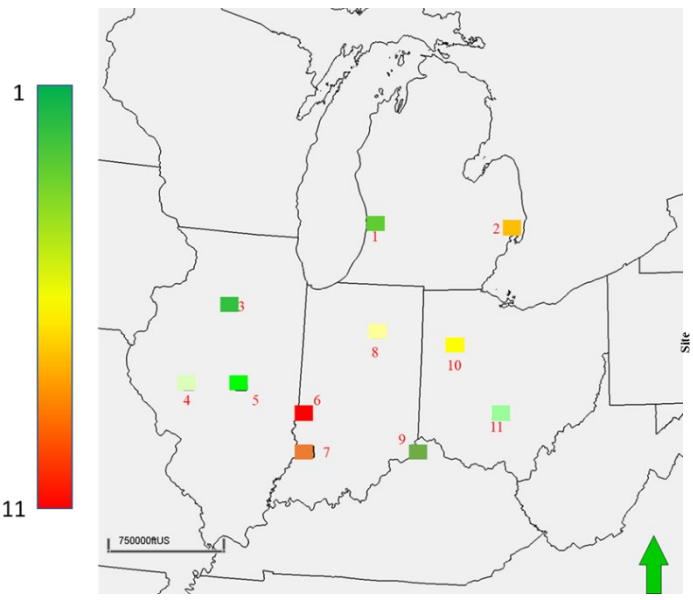


Figure 3. *Mt. Simon Sandstone site rankings*

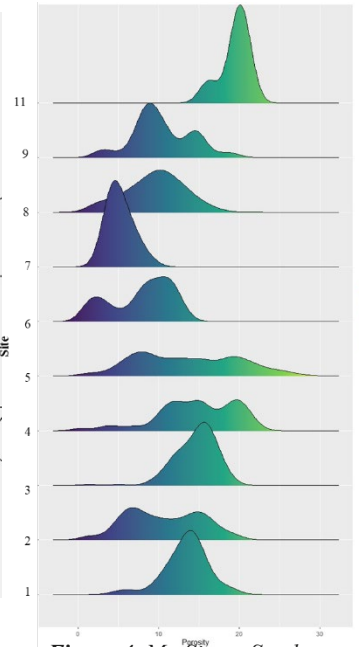


Figure 4. *Mt. Simon Sandstone porosity distribution by site.*

Core Stories

MGS and EGLE Rally Together to Save Core

Upper Peninsula Geological Repository

416 Avenue C, Gwinn MI 49841

Written and Interpreted by: Nolan Gamet, Ashley Quigley, and Bob Mahin

Staff from the Michigan Geological Survey (MGS) and the Oil, Gas, and Minerals Division (OGMD) of the Michigan Department of Environment, Great Lakes, and Energy (EGLE) rallied together at the Upper Peninsula Geological Repository (UPGR) this past November (**Fig.1**). The mission was to ensure the integrity of drill core samples in jeopardy of loss due to long-term and continued exposure from being stored outside for over ten years. The core was donated by Rio Tinto and was drilled as part of the company's magmatic Ni-Cu exploration program that took place in the 2000's and 2010's after the Eagle Mine was discovered. The drill holes are from Baraga and Houghton Counties. These diamond drill holes hold valuable information about the subsurface geology related to the Midcontinent Rift System (MRS).

Despite the weather, the incredible team, made up of over 20 geologists and other staff with positive attitudes, were determined to accomplish as much progress as possible over the course of 3 days (**Figs. 2 & 5**). The combined effort was an unqualified success. Drill core from 17 pallets was transferred from rotting and sometimes collapsing cardboard core boxes to approximately 1,000 new corrugated plastic boxes provided by the MGS (**Fig. 3**). Of course, all those had to be assembled first. With time running out, pallets representing about 35 holes were moved into the UPGR warehouse and await new boxes. An additional 22 pallets of core were successfully consolidated to the back of the UPGR warehouse and later tarped before the snows hit. These will receive new boxes and be re-palletized once the snow melts (**Fig. 4**). All in all, over 90 percent of the core was saved with only a few unsalvageable pallets that were later hauled away.

***Figure 1**. Shown here is the assembly of geologists and their methods used to re-box the core from the disintegrating core boxes while enjoying a rare glimpse of sunlight. Photograph taken by Nolan Gamet.*

***Figure 2.** The air pressure outside may have been low, but the team's morale was high. From left to right: Melanie Humphrey, Benjamin Hinks, and Garrett Ringle. Photograph by Nolan Gamet.*

***Figure 3**. Shown here are 2 of the 17 pallets that were reboxed and further organized based on depth intervals. This hole is 11-BIC-52. Photograph taken by Nolan Gamet.*

***Figure 4**. Tarped pallets waiting to be reboxed this Spring. Photograph by Nolan Gamet.*

Core Stories

MGS and EGLE Rally Together to Save Core

Upper Peninsula Geological Repository

416 Avenue C, Gwinn MI 49841

Written and Interpreted by: Nolan Gamet, Ashley Quigley, and Bob Mahin

Much of the saved core was drilled into relatively rare MRS igneous intrusions. While the MRS-related Keweenawan dikes, dozens of which crisscross the U.P. are common, vertical plugs and intrusions are not. The Bovine Igneous Complex (BIC) is one such intrusion. Located eight kilometers southeast of the town of L'anse, and unique to Michigan, it is an oval-shaped layered mafic/ultramafic intrusion 800 meters by 300 meters in size (**Fig. 6**). It was emplaced in the southwestern part of the Paleoproterozoic Baraga Basin approximately 1 billion years ago. BIC consists of sub-horizontal layering with an ultramafic, olivine-pyroxene cumulate base that progresses upward through classic magmatic differentiation phases. The upper unit is an oxide gabbro. BIC contains subeconomic, though locally high, grades of nickel and copper. Rio Tinto cored over 55 holes in and around BIC in an effort to find economic quantities of nickel and copper. Core from about 25 of those holes are now saved in the UPGR.

Two other, previously unknown MRS-related intrusions are located near the town of Kenton (**Fig. 6**). Known as the Haystack intrusions, they are very small intrusive gabbro plugs. Little else is known about them.

Figure 5*. Another small glimpse of sunshine drying off the stack of empty core boxes ready to be filled by the hard-working team. Photograph by Nolan Gamet.*

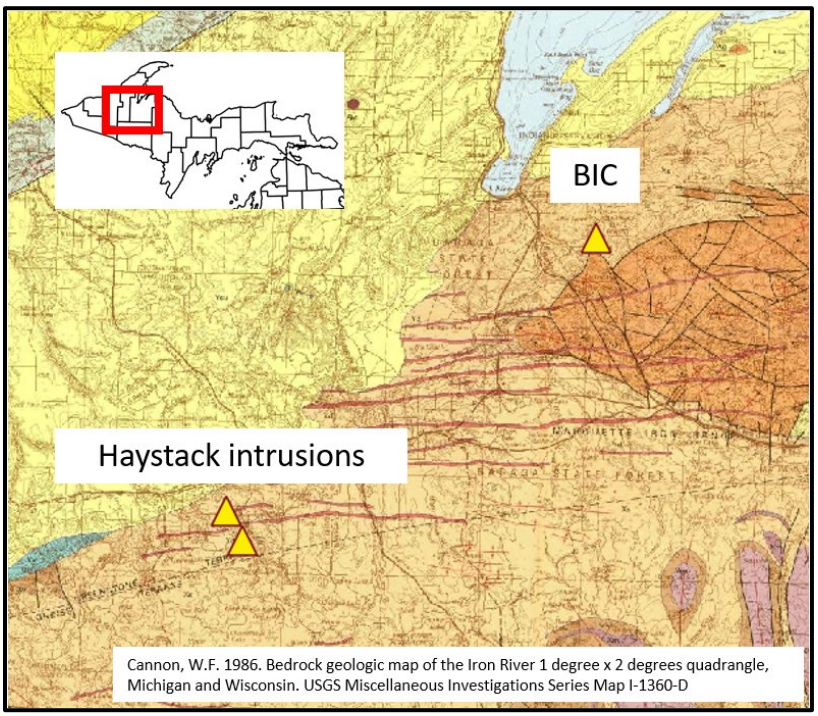


Figure 6*. General location of Midcontinent Rift intrusions depicted by yellow triangles with red outlines. Image originally from Cannon, W.F. (1986) and modified by Bob Mahin.*

Michigan's Upper Peninsula is ideal for anyone who is trying to better understand the MRS geology and related structures. The core recovered from this cooperative effort represents an excellent opportunity for students and researchers to study the internal complexities of these rare intrusions.

The planned effort to rebox the rest of the core will help to fill in geologic knowledge gaps that result from a lack of outcrops in foliage covered areas. This is just one example of the plethora of other drill core the UPGR holds within its inventory.

A big thank you goes out to everyone involved with this successful effort and we are looking forward to future projects with the UPGR, MGS, and OGMD staff from EGLE!

Also, check out the Oil, Gas, and Minerals Division's Data Explorer (Dataminer). This interactive application allows users to access oil, gas, mining, and water well related data across the entire state of Michigan through a search and map-based interface.
https://www.michigan.gov/egle/maps-data/dataminer

Field Stories

Geologic Mapping in Dickinson County

Written by: Nolan Gamet

The field season in Michigan's U.P, lasting from mid-May to late-October, is short compared to other locations in the Midwest. Toward the end of the 2023 field season, geologists from the Michigan Geological Survey and professors from Michigan Technological University (**Fig. 1**) started a 3-year Earth MRI project mapping bedrock geology to help assess the potential for critical minerals in Michigan's U.P. By implementing a boots-on-the-ground strategy coupled with a robust toolkit, a plethora of valuable data were collected which will be used for the current mapping projects as well as in other projects in future years.

***Figure 1**. Bob Mahin (left, MGS) and Dr. James DeGraff (right, MTU) excavating a beautiful Sturgeon Quartzite outcrop near Felch, MI. Photograph by Nolan Gamet.*

A typical field geologist's toolkit includes a Brunton compass, GPS device, paper maps, shovel, notebook, pencil, sharpie, backpack, ruler, magnet, scratch tester, safety glasses, high visibility vest, durable boots, gloves, hat, bug repellent, hand lens, brush, and most importantly, a rock hammer.

***Figure 2**. Dr. Jim DeGraff pictured with dispersed field gear on top of large red granite outcrop overlooking the East Branch Sturgeon River. Photograph taken by Nolan Gamet.*

Rock exposures in the U.P come in many varieties such as natural outcrops or roadcuts. Some outcrops are buried beneath the soil and moss that require some amount of excavation in order to be exposed for observation (**Fig. 3**). Unearthing outcrops can be exhausting and time-consuming, but often results in exciting surprises. It also can rekindle the childhood love for playing in the dirt!

***Figure 3**. Excavated amphibolite dike outcrop (left) and Randville dolomite outcrop previously hidden behind a thin layer of moss (right). Photographs by Nolan Gamet.*

Spending time in the field and coming face to face with actual rocks is important for fully understanding classroom descriptions of geologic rocks and systems. Observing geological field relationships brings to life what you learned in class, whether it was 30 days or 30 years ago. For example, good exposures of cross-cutting relationships are sometimes rare, especially in the U.P. which has limited continuous outcrops. Luckily, we were able to uncover a textbook example of cross cutting and terminated dikes (**Fig. 4**). Relative timing of the three rock units listed from oldest to youngest: banded red-grey gneiss (1) crosscut by granitic pegmatite dike (2), and grey amphibolite dike intruding both.

***Figure 4**. Mafic amphibolite dike terminating against granitic pegmatite that is cutting across banded grey gneiss, exposed in a gravel pit south of Groveland Mine. Photograph taken by Bob Mahin.*

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MICHIGAN GEOLOGICAL SURVEY

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DEPARTMENT OF GEOLOGICAL AND ENVIRONMENTAL SCIENCES

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Directory

John Yellich
MGS Director
CPG Geologist
269-387-8611
John.A.Yellich@wmich.edu

Autumn Haagsma
MGRRE Director
MGS Assistant Director
Geologist
269-387-8696
Autumn.Haagsma@wmich.edu

William B. Harrison, III
MGRRE Research Director
Geologist
269-387-8691
William.Harrison_III@wmich.edu

Nathan Erber
Senior Research Associate
Geomorphologist
269-387-8604
Nathan.R.Erber@wmich.edu

Evangelia Murgia
Research Associate
Hydrogeologist
269-387-8606
Evangelia.M.Murgia@wmich.edu

Jennifer Trout
Research Associate
Geologist
MGRRE Collections Manager
269-387-8633
Jennfier.L.Trout@wmich.edu

Linda Harrison
Administrator
Geologist
Industry Outreach Coordinator
269-387-8642
Linda.Harrison@wmich.edu

Peter Voice
Research Associate
Teaching Faculty Specialist
269-387-5486
Peter.Voice@wmich.edu

Marie Solum
Outreach Coordinator
Geologist/Teacher
269-387-8608
Marie.Solum@wmich.edu

Ashley Quigley
Senior Research Associate
Precambrian Geologist
269-387-8634
Ashley.Quigley@wmich.edu

Directory

Garrett Ringle
Research Assistant
Geologist
517-677-6367 (M)
Garrett.Ringle@wmich.edu

Nolan Gamet
Research Assistant
Geologist
969-412-0723 (M)
Nolan.Gamet@wmich.edu

Gregory Anderson
Research Associate
GIS Specialist
269-567-8742
Gregory.Anderson@wmich.edu

Sophia White
Triage Project Manager
Geologist
269-387-5486
Sophia.F.White@wmich.edu

Amber Conner
Senior Research Associate
Paleozoic Geologist
Amber.Conner@wmich.edu

Jessica Meskil
Administrative Assistant
Jessica.Meskil@wmich.edu

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