



THE GEOLOGICAL SOCIETY OF MINNESOTA

News

*Volunteer
opportunities,
field trips,
lectures, and
public service,
since 1938*

From the President's Desk...

As I write, I have just returned from a glorious but damp 2-week tour of both countries of the Emerald Isle. I learned history and saw historic sites, but the tour also covered geologically interesting areas including the Cliffs of Moher, the Burren, and Giant's Causeway. I plan to share words and photos of these in a future issue.

Summer means the State Fair, so Minnesota's Great Get-Together is coming up. This year is its earliest start, August 21. GSM started meeting with fairgoers in 1970 (55 years ago!), and we've only missed the pandemic years. As in the past few years, Patrick Pfundstein is organizing our presence in the Education Building, and you have received correspondence from him. We depend on our members to staff our booth; if you have not yet signed up for a shift or two, it's not too late. The Fair is one of the primary ways GSM reaches and educates the public, as well as how we attract new members. It is always fun interacting with visitors of all ages (often youngsters coax their parents over) and promoting GSM's lectures and field trips. And of course, it is fun to talk about our collection of rocks.

The approaching end of summer also means the resumption of GSM lectures. For Fall 2025, Steve Erickson has again put together a great array of topics and speakers. See the schedule in this Newsletter and on our website. As has become our practice, a couple lectures each semester are held online via Zoom, allowing us to tap expertise that would otherwise not be available. It also allows members who have difficulty getting to in-person lectures a chance to participate. In-person lectures will be on the U of Minnesota campus; we'll let you know the building and room in September.

Our first lecture is September 15. Usually, this is our Fall Banquet; however, with the closing of U Garden, we have not yet found an alternative venue. Regardless, we will conduct our Annual Meeting at the first lecture. The primary purpose of this meeting is to elect new members to our nine-person Board of Directors. As you know, we limit Board members to two consecutive terms (4 years), to encourage individuals with new perspectives to join. This year, we have three positions open (usually two). Non-officer positions on the Board do not involve a great time commitment – just four two-hour meetings per year, plus some prep time before each meeting. I encourage you to contact me (dewilhelm53@msn.com) if you might be interested.

In May, Randy Strobel & Joanie Furlong conducted a field trip to New Mexico. It was a great trip; reports and photos appear in this issue. Looking ahead, we are planning a "Soils Day" at nearby University of Wisconsin River Falls, conducted by Holly Dolliver and her students. Holly presented "Soils: The Most Undervalued and Overlooked Geologic Resource" to us on February 10th this year. This activity will likely occur on a Friday in late September or early October. Joe Newberg and I are always looking for new destinations for field trips; contact us with yours.

I want to give a special shout-out to Patrick Steury who joined GSM less than one year ago.



GSM President,
David Wilhelm

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GSM Field Trip to Red Wing, Minnesota. Barn Bluff 1940. Photo taken from Memorial Park.



In this short time, Patrick has shown tremendous enthusiasm and energy, especially regarding the GSM markers throughout our state. He surveyed pretty much our entire state to compile an inventory including exact locations and current conditions. A summary of his report appears in this issue. I want to congratulate Patrick on recently finding employment as an assistant geologist at Dakota Gold in the Black Hills. He reports: "I absolutely couldn't have done it without the help of the GSM; connecting me with Freshwater, the ILSG, and having [the marker] project to work on were all instrumental in getting the position. My sincere thanks to everyone! I'm sad to be leaving but will certainly visit home as often as I can." South Dakota's gain is our loss. Best wishes, Patrick. Fall means it is membership renewal time. Joanie Furlong will be accepting membership renewals at fall lectures or you can mail it in. See the renewal form in this issue.

As always, I thank Kate Clover, Mark Ryan, Harvey Thorleifson, and Rich Lively for their great job of compiling and editing the GSM News. But editors need content; this publication is by GSM members for GSM members, and it is a permanent record for our society. Consider submitting an article about something you read, a place you visited, a geological experience from your childhood, or whatever you think might interest your fellow enthusiasts. And thanks to all who have contributed articles to this issue.

Enjoy the next few months outdoors, with typically some of the best weather of the year. May your travels be rewarding and fun, wherever you venture. David Wilhelm

GSM

2025 Board of Directors:

- David Wilhelm, President
- Deborah Naffziger, Vice President
- Dave Kelso, Treasurer
- Stephen Willging, Secretary

Board Members: Roger Benepe; Dick Bottenberg; Kate Clover; Lowell Hill; Dan Japuntich

Field Trip Coordinator: Joe Newberg; David Wilhelm

Geological Markers: Dick Bottenberg (chair); Patrick Steury; Alan Smith; Rebecca Galkiewicz; Dan Japuntich

GSM Outreach: Open

Lecture Recording: Dick Bottenberg;

Lowell Hill; Joe Wright

Liaison Officer: Dave Wilhelm

Membership: Joanie Furlong

Newsletter: Kate Clover; Mark Ryan; Harvey Thorleifson; Rich Lively

Programs/Lectures/Labs: Steve Erickson

State Fair: Patrick Pfundstein

YouTube Administrators: Patrick Pfundstein

Video Library: David Wilhelm

Webmaster: Alan Smith

Web Site: gsmn.org

The Geological Society of Minnesota is a 501(c)3 nonprofit organization.

GSM Mail Address: Send all GSM membership dues, change of address cards, and renewals to: Joanie Furlong, GSM Membership Chair, P.O. Box 141065, Minneapolis, MN 55414-6065

Membership categories and dues:

Student (full time)	\$10
Individual	\$20
Family	\$30
Sustaining	\$50
Supporting	\$100
Guarantor	\$250

Individual and Family memberships can be renewed for 1, 2, or 3 years. Members donating at the Sustaining, Supporting or Guarantor levels will have their names highlighted in the GSM membership directory.

GSM News: The purpose of this newsletter is to inform members and friends of activities of interest to the Geological Society of Minnesota. GSM News is published four times a year during the months of February, May, August and November.

Newsletter contributions welcome:

GSM enthusiasts: Have you seen interesting geology while traveling? If so, please consider sharing your experiences with others through our GSM Newsletter. Write a short article, add a photo or two and send it in. Deadline for submission is the first of the month before the publication date. Send your story to newsletter editor: Kate Clover, kclover@fastmail.fm Thank you in advance.

GSM Board Membership:

The GSM Board consists of members who have a special interest in advancing the goals of the society, including lectures, field trips, and community outreach. The Board currently has ten members, and our bylaws

limit terms to four years to encourage turnover, and a change of perspectives and ideas.

The Board meets quarterly, on the second Thursdays of February, May, August, and November, or on a different date if conflicts arise. In-person and Zoom meetings are from 7 - 9 pm. Meeting location will be announced close to the meeting date. Board meetings are open to all GSM members. If you are a new or long-time member and Board membership is of interest to you, please consider attending a meeting. If you have a topic you would like the Board to consider, please contact David Wilhelm, dewilhelm53@msn.com

Welcome New Members!

No new members

Total GSM membership: 174

Notes from the Past

From the November 1971 edition of GSM News

SURVEY RESULTS GIVEN: The results of the survey sent to all GSM members by the Planning and Evaluation Committee are now tabulated. Forty-five people responded, about a third of the membership. This was the first time that the Committee and the Board had obtained tangible evidence of the members' feelings about Society activities. They want to thank those who responded. If you still have your questionnaire, it is not too late to send it in and make your opinions heard. Members generally seemed satisfied with the present system for lecture meetings, field trips, and social activities. They thought that the State Fair exhibit should continue, and that the Society should work with schools and environmental agencies. They favored low-cost geological materials, and low membership dues.

In Memory of Elfrieda Schaaf



Elfi passed away on July 18, 2025 due to respiratory problems. Elfi might be remembered by some GSM members. She participated in meetings and field trips in the early 2000s, but mobility issues prevented her from attending recent events. Her husband Vern is still active in the club. Elfi enjoyed collecting all sorts of

interesting rocks and minerals. Her son, David, noted that he has great memories of GSM field trips, some of which included the whole family: Vern, Elfi, brother Mark, and himself.

Fall Banquet – CANCELLED

The U Garden has closed, and we've not found a new location to host our banquets. Please send any suggestions to Dave Wilhelm.

Fall - Winter 2025 GSM Lecture Schedule

September 15, 2025: "Beautiful Ohio: Sedimentary Dreams: A Virtual Field Trip." *Deborah Naffziger*, Geological Society of Minnesota.

September 29, 2025: "Feathers, Flight, and Fossils: Current Perspectives on the Evolution of Birds from Dinosaurs." *Peter Makovicky*, Professor, University of Minnesota.

October 13, 2025: "Geomorphology of the Upper Mississippi." *Andrew Wickert*, Associate Professor, University of Minnesota.

October 27, 2025: "From Formations to Foundation, the Geology of Bridge Construction." *Jill Mickelson*, Braun Intertech.

November 10, 2025: "Lake Superior and its Gales." *Paul McKinney*, University of Minnesota.

November 24, 2025: Zoom Lecture. "Rock Elm Meteorite Crater." *Bill Cordua*, University of Wisconsin, River Falls.

December 8, 2025: "The Sudbury Impact Structure and Mining Area." *David Joyce*, Adjunct Professor, University of Toronto.

ILSG 2025 in Mountain Iron, MN

The Institute on Lake Superior Geology 2025 conference was held May 14 – 17 in Mountain Iron MN at the Mountain Iron Community Center. A total attendance of 132, from US and Canada, included academic, consulting, and industry geologists, and enthusiasts – all exchanging updates on the geology of the Lake Superior region. A handful of GSM people included Steve Erickson who recruited speakers to give GSM lectures. GSM donated funds to support the conference; our donation was acknowledged in the conference book.

The conference consisted of two days of technical presentations, and two days of field trips before and after the meeting. There also was time for discussion at posters. Books were for sale, and rocks were auctioned. GSM donated 35 copies of *Minnesota Fossils and Fossiliferous Rocks*, by Robert Sloan to the "free" table.

The Friday evening banquet speaker was Pete Kero P.E. of Barr Engineering, who spoke on "Mine to Mountain Bike Mecca: the story of Redhead Mountain Bike Park." He discussed the transformation of lands around ten idled open pit iron ore mines around Chisholm into world-class trails for mountain biking, hiking, fishing, and kayaking. The trailhead parking lot is located next to the Minnesota Discovery Center in Chisholm.

Eight field trips were scheduled, three or four on each of the field trip days. Forest fires caused some stops to be skipped, and one trip to be scrapped. But with so many significant exposures of rocks in the region, no one was denied an opportunity to visit sites of geological significance.

I attended the "Cu-Ni deposits of the Duluth Complex" trip led by Mark Severson, retired NRRI geologist. We started at the Twin Metals Minnesota office in Ely, with their Chief Geologist Kevin Boerst as host.

Twin Metals geologists have thoroughly assessed the

Maturi deposit over the past couple of decades. If opened, Twin would produce copper, nickel, cobalt, and platinum group metals (PGM) from the state's first underground mine since the closure of Ely's Pioneer Mine in 1967.



The facade of the Twin Metals office building in Ely integrates columns of the periodic table and highlights the platinum group elements (PGE) found in local ore deposits. Minnesota has the world's largest known undeveloped copper-nickel deposits in the world. Among Cu-Ni-PGE sulfide deposits worldwide, the Duluth Complex is 2nd largest in copper, 2nd largest in PGE and 3rd largest in nickel

In the office, we learned about project geology, and saw mineral-rich drill cores. We donned hard hats and safety vests and toured the drill core storage facility which houses over 1.5 million feet of core. Walking into the drill core building felt like entering an icebox as all the rock was still holding onto the winter's cold; however, on the 88° day, the chill felt good. Another stop that day was at the Soudan Mine in Soudan, MN; there we got on our hands and knees and closely looked at the laminae on the "most photographed" outcrop in Minnesota—the famous Soudan member banded iron formation (BIF), which displays two generations of tight folding with delicate laminae of chert (creamy white), chert-hematite jasper (red), and magnetite-chert (black to silver colored). The outcrop exhibits a variety of

Drill core shows a sulfide-rich ore. Copper, nickel, cobalt and platinum group metals are considered critical minerals because of their importance to the U.S. economy, national security and the emerging green economy. Copper is needed for electrical infrastructure. Nickel is needed for electric cars and medical devices, Cobalt is used in cell phones and batteries.



controlled, annual, or something else? There is agreement that the sediment deposition occurred below wave base by the precipitation of chemical sediments.



The drill core storage building at Twin Metals in Ely houses over 1.5 million core feet from the deposit and surrounding geology.

We did not tour the Soudan Mine. It was on one of the other field trip's planned stops, but sadly, due to flooding, the underground mine tour was closed.

The former Mary Ellen Mine, now the Biwabik Mary Ellen Stone Co. LLC, in Biwabik was another stop on the Wednesday field trip. This mine is well known as the source of the Mary Ellen Jasper, a world-

class type locality of 2 billion-year-old Precambrian stromatolites. The mine, once a source of high-grade hematite ore, is now closed and Mary Ellen stromatolite is now harvested from the waste rock piles, to be cut and polished into beautiful slabs for countertops, tabletops, monuments and markers as well as landscape stone.

The mine operated between 1924 and 1928, and again opened from 1948 to 1951. Ownership changed, and it operated again from 1952 - 1961. Cumulative output of natural ore was 4,574,973 long tons according to a mining directory. The Mary Ellen Jasper, which could be as much as 15 feet thick, was considered overburden and had to be removed before mining could begin. This rock was rejected because it didn't contain enough magnetite or hematite. Mammoth waste rock piles were everywhere we looked.

After seeing the sawing operation and the pallets of slabbed and polished rock, we poked around the rocks at one of the old pits. A few of us carried out specimens for our collection.

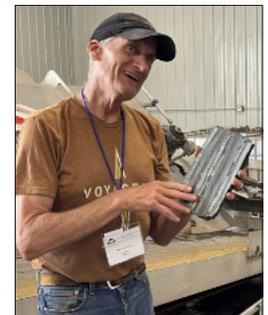
The Saturday Field trip included visiting more great outcrops, conversations, and learning opportunities. Yes, more stromatolites. These ILSG field trips are the best:

interested attendees, expert trip leaders, "secret" outcrops you'll only find with one who knows the area, not to mention entrance into places not generally open to the public. And lots more learning about our regional geology. After a full day, we returned to the community center around 5pm; we expressed our gratitude to the trip leaders and said goodbye to friends. I heard a few people say: See you next year.

Plan ahead: The 2026 ILSG conference will be held in Thunder Bay, Ontario. Tentative dates are May 19 - 23, 2026 (dates may change due to venue availability).



Minnesota's "most-photographed" geologic outcrop: Banded Iron Formation at the Soudan Mine. The creamy white is chert, the black is magnetite chert, the red is chert-hematite jasper



Mark Severson, trip leader, holds a piece of the Mary Ellen Jasper with layers of creamy chert and hematite rich chert.



This slab shows a cross-sectional cut through the Mary Ellen Jasper. The slab illustrates layers of sediments deposited 2 billion years ago in a tidal or beach environment: creamy chert (white), chert-hematite jasper (red) and magnetic-chert (black to silver colored). Specimens take an exceptionally brilliant polish.

Story and photos by Kate Clover

GSM Field Trip to northern New Mexico, May 14 – 20, 2025

This report chronicles the 7-day New Mexico field trip led by Randy Strobel and Joanie Furlong in May 2025. Several participants wrote about what they saw on one or two of the days. Except as noted, Dave Wilhelm shot the photos.

Day 1, May 14: Capulin Volcano and Folsom Museum by Mary Kay Arthur

By the end of the Archean, at 2.5 billion years ago (Ga), a continent named Laurentia had formed. In time it would grow to become North America. In the Proterozoic, a subduction zone existed on its southern edge. Between 1.8 and 1.7 Ga, an island arc (the Yavapai Terrane) riding on the southern ocean's plate collided with Laurentia. Between 1.7 and 1.6 Ga, the Mazatzal Terrane was similarly sutured to the growing continent. Where the two terranes meet is a zone of weakness, running southwest from present-day northeastern New Mexico. The Jemez Lineament is the source of recent volcanic activity that we visited in northern New Mexico.

Raton-Clayton Volcanic Field

As we drove across the 60-mile-wide Raton-Clayton Volcanic Field, the view was filled with volcanic features, flat topped mesas, little cinder cones, tumuli (little pop ups, many with trees growing out of their tops), a shield volcano, and extensive fields of lava. This is the transition from the High Plains grasslands to the Rocky Mountains, an "edge" terrane with great biodiversity. Humans arrived here 10,000 years ago. We traveled on the Santa Fe Trail along the huge cinder cone named Capulin, a 1300-foot-tall volcano with a base 4 miles across. Its crater is 415 feet tall with a diameter of 1450 feet.

The Jemez Lineament is a linear zone of volcanism mostly less than 9 million years (Ma) old. The gases within its rising magma expanded under the decreasing pressure and exploded as cinders. Towards the end of the eruption, the lava "spattered" hot enough to weld the cinders. As the magma supply was exhausted, the gas pressure released the remaining lava from weak points, creating huge lava fields. Cinder cones have a limited supply of magma, so eventually the lava seals the vent. Seen through the car's window as we approached, Capulin seemed to be leaning, a sign that the west wind carried material to the east, making that side a bit taller.

After watching a film at the visitor center, we drove to the volcano rim on a road that encircles Capulin. There were paths leading higher and paths descending to the bottom of the crater. A



Model of Capulin Volcano

ferocious wind persuaded many of us to descend into the volcanic throat. The "plug" was unusual, a rhyolite which is "stickier" and doesn't flow as well as the more usual viscous basalt.

Folsom

After a torrential rainstorm in 1908, a cowboy, George McJunkin, came across a site with massive bones.



Folsom Point Arrow

Recognizing that the bones were far larger than modern bison he tried to interest others. In 1928, the site was finally developed. Bones with embedded arrowheads were judged to be 10,500 years old. The museum in the town of Folsom, NM, displays these points which were more advanced than the points found at Clovis, NM. They had a shallow indentation which provided for the point to be more securely attached to the shaft with sinew. Also displayed was an atlatl, a tool used to throw spears with greater power and distance.

The museum is a proper old-timey museum displaying huge fossils from the Pierre Shale, a willow cane child's rocking chair, a dentist's chair, saddles, bolt cutters, mourning stationary, old canned goods, family scrap books, and the telephone switchboard where Sally Rooke lost her life alerting the town's people of a flood.

K-Pg boundary

In a city park high above Raton NM is a sign: Iridium. Under an overhanging bush, nestled in between the coal seams, is a thin white layer known to contain way too much iridium and shocked



K-Pg boundary

quartz. Below are bones from non-avian dinosaurs; above there are none. This is the remnant of an event at 66 Ma, marking the end of the Cretaceous and the beginning of the Paleogene (formally known as the Tertiary). The K-Pg is visible sporadically across the High Plains along the eastern flank of the Rocky Mountains.

Sugarite Canyon State Park

The Dry Cimarron River has cut a deep valley through the coal seams of what is now Sugarite Canyon State Park (pronounced "shug-ur-ee"). In 1894, railroads began to develop the water and coal to serve a line to Raton. A company town was founded in 1912, serving as many as 1000 people at its peak. Miners and their families came from Italy, Mexico, Japan and the middle of Europe. The company provided a school, theater, store, telephone, community center, and a ball field. When mining ended in 1944, the City of Raton maintained the old town as part of a city park. In 1985, the entire area became a state park. There are trails and signage among the old foundations. Upstream, remains of old mine adits protrude from the riverbanks. The old post office, the only remaining building, serves as the park museum and houses displays of old mining works, information on the area, and a very large poster book with pictures of every person who ever lived in Sugarite



Remnants of the store steps

Canyon. Lilacs were blooming amongst the old foundations. Many thanks to Randy and Joan, whose organizational skills and attention to detail kept us on track through a busy and informative day.

Days 2 & 3, May 15 & 16: Rio Grande River and Bandelier National Monument by Jack Matlock

May 15th started warm, clear and pretty. Our first stop was the Palisades Sill (36.5376, -105.1532), an amazing porphyry layer with very impressive columnar jointing. The sill was formed at about 40 Ma on top of 2.3 Ga Precambrian bedrock. The cliffs were subsequently cut by the Cimarron River due to uplift along the southern



Palisades Sill, northern New Mexico. Photo by Jack Matlock

Rocky Mountains. A breathtaking sight as it also allowed us to breathe the fresh air of northern New Mexico!

At about 9:30 AM, we made a spontaneous stop to see the view from Eagle Nest Pass.

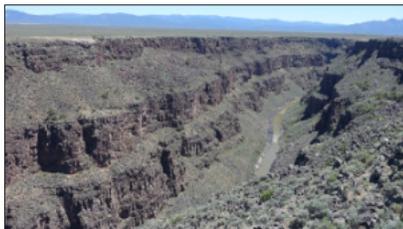
To the west was Eagle Nest Reservoir nestled in the Merino Valley (a graben in a part of the Rio Grande rift). Water at our feet could either flow west toward the Rio Grande River or east to the Cimarron River.

Around noon, we managed to find our way to the base of



View of Rio Grande River from the John Dunn Trestle Bridge. Hot springs come out at base of bank on right side of picture. Photo by Jack Matlock

a canyon where the old John Dunn Trestle Bridge crossed the Rio Grande River (36.5351, -105.7088). A short hike along the steep bank of the river took us to an area where warm springs were oozing out of the rock. Here water from the higher mountains to the east percolated through deep underground magma-heated areas and was subsequently heated; then, emerged at the base of the canyon as hot spring water.



Rio Grande Gorge taken from west bank looking south. Photo by Jack Matlock

As the day progressed, we arrived at the Rio Grande Gorge Bridge (36.4768, -105.7328) at about 1:30 PM. The bridge crosses the Rio Grande Rift Valley at

a point where the steep canyon walls show an impressive view of the layers of basalt that make up the canyon.

Most of the group walked across the bridge to experience the majesty of earth's geological spectacle.

At 3:15 pm, our last stop of the day found us at Earthship

Biotecture (36.4956, -105.7530) near Taos, NM. We had pre-arranged a guided tour for 5 PM, run by a local young man named "Knowledge." He indicated that the project was started in 1969 by an architect named Michael Reynolds who was inspired by the need to address the problem of trash and the lack of affordable housing. After much experimentation and hard work, he developed a form of "house-building" that uses waste materials to build living spaces he now calls "vessels" (i.e. not houses, per se). We noted the "vessels" were scattered about a 640 acre plot that formed the so-called Earthship Biotecture community. His lecture was very informative and gave us an idea of how and why the community exists today. The buildings incorporate natural and repurposed materials in their construction: used tires, glass bottles, cans, adobe mud, discarded household appliances and reclaimed materials from demolition sites, etc. Water is collected from rain and is conserved and reused through a thoughtful design



Earthship Biotecture "vessel" i.e. house made of reclaimed materials. Photo by Jack Matlock

incorporated into the building. Power comes from solar (active and passive) and wind. After touring a few of the buildings, we noted that the entire endeavor was impressive and apparently the community of about 150 is as socially diverse as the 115 vessels that make up the community. All in all, it was an interesting place and left us with a new perspective on how to live with a smaller eco-footprint.

At 9 AM on May 16th, we met at the head of the company road to the Harding Pegmatite Mine (36.1933, -105.7948). The mine opened in about 1900 and closed in 1975 and was subsequently



Another Earthship Biotecture "vessel." Photo by Jack Matlock

given to UNM. After driving 1½ miles on unimproved roads, we progressed on foot to the mine. The mine had been worked through a large pegmatite seam that contained relatively large quantities of lithium-bearing lepidolite and other rare earth minerals. It took discipline to refrain from loading the car with samples! This was a good place to see Precambrian rocks.

After lunch, we met and regrouped at Bandelier National Monument (35.7787, -106.2703). The site is in the canyon-and-mesa country and is part of the Pajarito Plateau formed by two violent eruptions of the Jemez Volcano over 1 Ma ago. Volcanic ash more than 1000 feet thick was subsequently deposited and ultimately became the amazing feature it is today. The part we visited was in a very deep valley called Frijoles Canyon, where evidence of past human activities dates back more than 10 thousand years (Ka). Early peoples migrated in and



Bandelier National Monument showing tuff cliffs where ancient people built homes. Photo by Jack Matlock



Archeological buildings. Photo by Jack Matlock

out of the area and later populations built pit houses, and dug-out cave-like homes in the volcanic tuff of the cliffs. Ceremonial structures called kivas, apparently for religious, education, and community purposes, were of particular interest to us.

The Taos High Road Scenic Byway led us (i.e. the Matlocks) back to our campsite for the evening.

Day 4, May 17: Valles Caldera and Cañon de San Diego by Janet Hopper

Volcanic History of the Valles Caldera

The Valles Caldera is a prominent feature within the Jemez Mountains, composed entirely of Cenozoic volcanic rocks. These mountains are situated on the west side of the Rio Grande Rift, where it intersects the Jemez Lineament—a zone of crustal weakness associated with volcanic activity that began at 14 to 15 Ma, shaping the landscape over millions of years.

A major geological event occurred 1.6 Ma ago with the formation of the Toledo Caldera. This eruption produced the Guaje Tephra during a Plinian eruption, followed by the lower member of the Bandelier Tuff, which formed as an ash flow from the collapse of the eruptive column. Around 1.25 Ma, the Valles Caldera formed, nearly obliterating the Toledo Caldera except for remnants in the Toledo Embayment. The ash from this event was hotter and exhibited better welding than the earlier eruption, although the chemical compositions of the two tuffs are remarkably similar. River deposits between the two tuff layers indicate that drainage systems were re-established during the interval between the eruptions.

The Valles Caldera eruption began at a single vent but evolved into multiple eruptions along the ring fault as the magma chamber emptied. As the chamber continued to deplete, the caldera's roof collapsed, causing dramatic elevation changes—the eastern side of the caldera dropped approximately 5,000 feet, while the western side sank about 1,000 feet. The eruption persisted in the western part of the caldera, depositing ash exclusively within its newly formed boundaries.

As the magma chamber refilled, it created a resurgent dome known as Redondo Peak, the highest point within the caldera. Around 1.2 Ma, volcanic activity resumed along the ring fault, beginning with Cerro del Medio on the eastern side and progressing counter-clockwise. The most recent eruption occurred approximately 400,000 years ago at San Diego Peak, producing rhyolitic lava flows that breached the caldera rim and extended southwest into the surrounding terrain.

Hydrological History of the Valles Caldera

Following the caldera's collapse and the cooling of the tuff, a lake reminiscent of Crater Lake in Oregon formed within the caldera. As Redondo Peak emerged and volcanic activity continued, the lake featured islands and reached its maximum depth about 800,000 years ago. Eventually, the caldera walls were breached, allowing water to carve the Cañon de San Diego.

The San Diego eruption later blocked this outlet as lava flowed through it, forming new lakes. The larger of these lakes contributed to the creation of the flat-lying Valle Grande, a striking feature commonly depicted in photographs of the Valles Caldera. A smaller lake formed on the northern side of the caldera. Over time, the East Fork of the Jemez River and Redondo Creek carved new outlets on either side of the lava flow, further altering the landscape.

Cultural History

The ancestral Puebloan peoples discovered that obsidian from Cerro del Medio was ideal for crafting tools and weapons. Over the centuries, this resource was extensively mined; today only small obsidian fragments can be found.

The caldera's lush former lake bottoms, maintained by slight dampness, created excellent grazing grounds for wildlife, making it an ideal location for hunting. After 1500, this heritage of hunting and grazing extended to livestock, with several ranches occupying the valleys over time. However, this history made the establishment of the Valles Caldera National Preserve a contentious issue, as it balanced conservation efforts with traditional uses of the land.

The preserve was finally established in 2000. Since then, the hunting and livestock grazing have stopped, but the existing buildings are being preserved. The area has also been used to film the TV series "Longmire" and several movies.

Cañon de San Diego

Cañon de San Diego provides an important window into the Proterozoic to Pleistocene geologic history of the Jemez Mountains region. Portions of oceanic shorelines and continental-scale river systems are preserved in the late Paleozoic to middle Mesozoic sedimentary rocks in the canyon. The course of the canyon is controlled by the Jemez fault system with the older rocks being on the north side of the canyon.

Trip Activities

May 17th began at the gate to the Valles Caldera



Redondo Peak and Valle Grande



Obsidian or volcanic glass. The included crystals probably made this chunk undesirable for tool making

National Preserve, where we joined a line of people waiting to get back-country permits. Fortunately, there were very few of us.

The first stop was Cerro del Medio where we searched for weapons-grade obsidian. We found a few cobbles in a small rivulet, but no outcrops. We continued following the ring fault and the small volcanoes until we could see the wave terraces of the smaller northern lake.

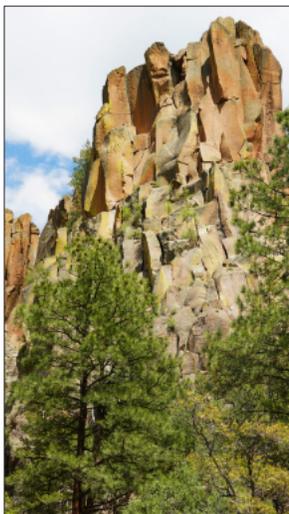
For lunch, we headed for a campground outside the preserve. We chose this because it was on the edge of the San Diego lava flow and we were told there was an explosion crater where the lava had run over water



Wave terrace. The prairie dogs like the soft soil; notice their burrows in the foreground



San Diego Canyon



Battleship Rock

where we could find obsidian. We found the crater, but it was deep and no one was anxious to climb down and back up.

After lunch, we went to the San Diego Canyon overlook where we could see where we were going next. The first stop in the canyon was Battleship Rock, an imposing cliff capped with Bandelier Tuff. This is where the two streams that drain the caldera merge to form the Jemez River.

The last stop of the day was the Jemez Soda Dam, a natural travertine dam formed by mineral-rich spring water. Heated underground by proximity to the magma chamber, the water used the fault system to reach the surface. Unfortunately, building the road cut the dam off from its supply of minerals. The warm spring still flows on the northwest side of the highway. However rather than overtopping the dam, the river has eroded its way through the edge of the dam and formed a waterfall that flows out of a tunnel.

Day 5, May 18: The San Diego Canyon and Jemez Pueblo by Janet Hopper

On May 18, we continued down the San Diego Canyon. We did some back-tracking so the stops are in chronological order, but not in geographic order. We started with a hike on the Red Rocks Trail that begins at

the Walatowa Visitor Center of the Jemez Pueblo. The name "Walatowa" means "this is the place" and is the name of the surrounding village.

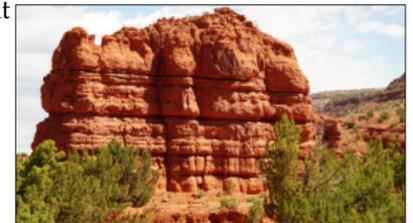


Jemez River flowing through a tunnel in the travertine dam

We were out of the volcanic rocks of the Jemez Mountains and into the rocks of the Colorado Plateau. The red rocks we hiked through are part of the Entrada Formation which was deposited in the Jurassic Period sometime between 180 and 140 Ma. In this area they seem to be mostly river deposits. Wind erosion has since sculpted fantastic shapes.

The area is full of wildflowers; we only saw a few blooming lace hedgehog cactus, bluets and yucca. The only wildlife we saw was a small lizard, likely a Southwestern Fence Lizard. One trailside sign read: "Respect rattlesnakes' rights to privacy." We were glad we didn't see any!

After the hike, we went back north to Jemez Springs and the ruins of the San José de los Jemez Mission and Gúsewa Pueblo Site. "Gúsewa" is a Towa word that in English means "place at boiling water," because the pueblo is located near a thermal spring. There were definitely whiffs of hydrogen sulfide on the breeze.



The Red Rocks of the Entrada Formation are mostly river deposits

The site has been occupied since the late 13th century. The Spanish arrived and built the mission around 1621, but it was abandoned in 1639. In 1680, the Pueblo Revolt drove the Spanish from New Mexico. The Spanish returned and recolonized New Mexico 12 years later, but the Jemez continued to war with the Spanish until 1696. After suffering a heavy defeat, the Jemez survivors left their villages to join other Pueblos. By 1706, the Spanish moved the remaining Jemez to Walatowa.



Mary Kay walking the trail

Most of the ruins are part of the San José de los Jemez Mission and were built of local limestone. The most impressive are the remains of the church including an octagonal bell tower. The traces of the pueblo are subtler since they were made of adobe. However, there is a reconstructed kiva. Then it was time for lunch. We went back to



Ruins of the church



Randy & Joanie preparing to explore a kiva



At the visitor center, check out the lava flow art work by the bathroom near the back door

Walatowa Visitor Center because they had a courtyard with shaded picnic tables. Across the highway, the locals had set up a food stand where they made fresh fry-bread and served some of the favorite foods of New Mexico. I was getting tired of gas-station sandwiches for lunch, so this was a welcome change. We continued down the Jemez River as the canyon widened out to a plain and farmland. We were

crossing increasingly younger rocks.



Lunch in the courtyard of Walatowa Visitor Center. Clockwise from lower left: Jeanne Matlock, Joanie Furlong, Kevin Miller, Randy Strobel and Jack Matlock

The final stop of the day was at the White Mesa and the Tierra Amarilla Anticline.



View of the eroded Tierra Amarilla Anticline

The White Mesa is named for the gypsum deposits that are being mined nearby – we had made a wrong turn onto mining property. From the rim of the anticline you could see all the rock strata laid out in front of you with the red rocks of the Entrada formation at the bottom. The domes at the bottom of the anticline may be travertine deposits from springs. This is a popular area for geological field camps. There was a group of students



Cabazon Mesa

coming back from a day of field work. We may have spilled the beans as we made comments about what we were seeing.

The view from the top also reminded us we were still in the Jemez lineament with a view of Cabazon Mesa – a volcanic plug that has eroded out of the surrounding rock.

Another interesting aspect of the area was highlighted by a warning to stay on the trails. The desert soils in the area are a fragile ecosystem of cryptobiotic crust, a community of tiny organisms that form a distinct crust on the top of soil in arid landscapes. These organisms include cyanobacteria, lichens, mosses, green algae, micro-fungi, and bacteria; they play a vital role in holding loose soil together and preventing erosion.

The day was supposed to end with a scenic tram ride to the top of Sandia Peak near Albuquerque to see the sun set. Unfortunately, due to strong winds, the tram was closed.

Day 6, May 19: Petroglyph National Monument and the Mining Museum by Kevin Miller

We started day 6 in Albuquerque at the Petroglyph National Monument visitor center. There we watched a short video on the efforts to protect the area from further development and learned how the national monument was established in 1990. In the video, an indigenous person is asked how to interpret the meanings of the petroglyphs. He replies that modern people could give them any meaning they wanted since no matter what meaning they gave them—it would probably be wrong. I took this to mean that their true meanings remain a mystery, lost to time and specific to the creators.



This petroglyph is dominated by a possible lizard and a human figure

At the visitor center, we talked to a volunteer about the various trails. She suggested the Piedras Marcadas Canyon trail and gave us a map. After a short drive, we arrived at the trailhead and started off. We quickly started seeing fascinating petroglyphs. However, it shortly began to rain and sleet so we headed back to the cars. We returned to the visitor center to regroup and have lunch and decided on our next hike: the Boca Negra Canyon Trail.



This glyph possibly depicts a lizard holding a rattle

We started on the Boca Negra Canyon Trail and soon found petroglyphs on most surfaces that were covered with desert varnish. The glyphs are interesting to look at and try to interpret. They could be



A Macaw is depicted here. These are non-native birds introduced by the Spaniards in the 1500s and 1600s



A collection of human-like glyphs seemingly wearing costumes or headdresses

rain and hail returned, we beat a hasty retreat back to the cars and decided to head to our next stop, the New Mexico Mining Museum located near the historic mining town of Grants, New Mexico, the "Uranium Capitol of The World" in the 1950s.



Kevin Miller stands in front of part of a tunnel drilling machine

At the New Mexico Mining Museum we first explored the outdoor exhibits that included a collection of old mining equipment. The headframe would have sat on top of the main shaft and was positioned to guide the cables connecting the lift to the drive motor. The lift operator worked in a nearby building that housed the motor and controls to raise and lower the miners, supplies and ore in and out of the mine or to move them between various levels. Exhibit signs also explained the complex system of buzzers and bells used to let the lift operator know exactly how they wanted the lift to move. Each level in the mine would have had a communication system so the lift operator would have been kept busy.



The museum displayed old ore cars, a plow, and a headframe (or hoist)

Inside, we examined the mineral collection and then moved on to our guided tour of a simulated underground uranium mine built into the basement. There we saw rooms constructed to resemble a mine that showcased the various mine parts: the lift, main tunnel with train and tracks, the active mining area, the lunch room, and repair shop. Our guide, a retired miner, had worked in underground uranium mines as well as other mines in the area and was extremely knowledgeable about uranium mining and the local history of the industry. He also helped get the museum approved and funded.



Our guide explained the complex system of buzzers and bells that were used to let the lift operator know exactly how they wanted the lift to move

simply pictorial art, spiritual images, informational images such as representing different individuals or groups that passed through or regularly used the area or they could represent a combination of these and other messages. After more

rain and hail returned, we beat a hasty retreat back to the cars and decided to head to our next stop, the New Mexico Mining Museum located near the historic mining town of Grants, New Mexico, the "Uranium Capitol of The World" in the 1950s. At the New Mexico Mining Museum we first explored the outdoor exhibits that included a collection of old mining equipment. The headframe would have sat on top of the main shaft and was positioned to guide the cables connecting the lift to the drive motor. The lift operator worked in a nearby building that housed the motor and controls to raise and lower the miners, supplies and ore in and out of the mine or to move them between various levels. Exhibit signs also explained the complex system of buzzers and bells used to let the lift operator know exactly how they wanted the lift to move. Each level in the mine would have had a communication system so the lift operator would have been kept busy.

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Our tour started in the simulated mine shaft with an underground rail line and a small train engine and cars used to move equipment and ore inside the mine. Just like in the actual mine, the walls were covered with wire netting and secured with bolts and metal plates to stop

rocks from falling. The yellow tube near the ceiling was part of the ventilation system that pulled huge amounts of air out of the mine to try to lower radon gas and dust levels. It also pulled fresh air into the mine. Amazingly, this seemed to be the only dust protection in the mine so the miners likely inhaled uranium contaminated dust all the time they were underground. However, in a few areas, respirators were required where ventilation was especially poor.



The mine's underground rail line and the yellow ventilation equipment plus the mine walls with wire netting and anchor bolts meant to keep rocks from falling

Another set of displays showed the working of an active mine stope and illustrated how miners drilled holes about 4 feet deep into the ore body using air-powered drills. They drilled holes in a radiating pattern to prepare it for blasting. The drill holes were then charged with explosives and blasting caps and were either wired to an electric detonator or connected with fuses to set off the timed explosions. They were ignited starting in the middle and moved out to the edge with the bottom holes being ignited last. This helped push the ore into the open tunnel for easier removal. The blasts were timed to occur just thousandths of a second apart. They rigged a drag line to move the ore into the main tunnel to facilitate filling the ore cars and to ensure everyone was in a safe area during blasting. During blasting, the whole mine was shut down and all the workers were either in break rooms for lunch or they all left the mine if the blast was occurring at the end of a shift. The mine would have been a very dark and dusty place to work. The guide said workers did have special coveralls to wear while in the mine, but they did not use dust masks. The mine operated around-the-clock with about 40 workers on each shift. Our guide said the underground mining became uneconomical as new, less expensive sources of uranium became available.



The radiating pattern shows the blasting holes



A drag line moved ore into the main tunnel

The mines were mostly closed by the mid-1980's. Our guide said the underground mining became uneconomical as new, less expensive sources of uranium became available.



All employees had to sign in and out on the Blast Board to ensure everyone was in a safe area during blasting

The mines were mostly closed by the mid-1980's. **Day 7, May 20: El Malpais National Monument by Dave Wilhelm**

On Tuesday, May 20, our last official day, we visited the sprawling El Malpais National Monument and nearby locations. The name El Malpais comes from the Spanish term Malpaís, meaning badlands, due to the extremely



Map of five lava flows of El Malpais

barren and dramatic volcanic field that covers much of the park's area. The lava flows, cinder cones, and other volcanic features of El Malpais are part of the Zuni-Bandera volcanic field, the second largest volcanic field in the Basin and Range Province. This volcanically active area on the southeast margin of the Colorado Plateau is located on the ancient Jemez Lineament, which provides the crustal weakness that recent magmatism and Cenozoic volcanism are attributed to.

The rugged pahoehoe and 'a'a lava flows of the Zuni-Bandera eruptions filled a large basin, created by normal faulting associated with the Rio Grande Rift, between the high mesas of the Acoma Pueblo to the east, Mt. Taylor to the north, and the Zuni Mountain anticline to the northwest. Five major flows erupted from at least eight volcanic vents over the past 60,000 years, with the most recent 3,900 years ago.



Pottery in the trading post

We started our day at the visitor center just south of Grants, where the rangers gave us advice on what to see.



Kevin by a spatter cone



Joanie celebrates at Lookout Point over Bandera Volcano

gnarled trees and spatter cones to Bandera, the largest volcano in the area. It erupted around 10,000 years ago in two stages. First, its cinder cone developed, from which a massive lava flow broke out its southeast side. This flow is 23 miles long and covers much of the national monument. At the end of the eruption, the lava suddenly fell back into the main vent, making the bottom of the cone deeper than the outside lava flow. At 1,440 feet wide and 800 feet deep, it is an impressive sight. Over

time,



Joanie, Janet, Dave, Mary Kay, Kevin, & Randy enjoy Bandera Volcano from Lookout Point



Randy, Dave, Kevin, & Joanie in Bandera Ice Cave

erosion and gravity have taken their toll, and the crater is slowly filling with cinders and rocks. The crater is too fragile and unstable to descend; we respected the



Mary Kay, Janet, and Kevin on Sandstone Bluffs

warnings to stay back. From Bandera, the trail took us through its pahoehoe and 'a'a lava outflows past collapsed lava tubes to perhaps the most fascinating sight on the field trip: the Bandera Ice Cave. We descended a few dozen stairs into this otherworldly feature, which felt pleasantly cool when we visited at midday. Inside the cave, the natural layers of ice glisten blue-green in the reflected rays



The western edge of Sandstone Bluffs with lava fields below



La Ventana Natural Arch

of sunlight, illuminating natural arctic algae. The temperature in this cave never gets above 31° F. As rainwater and snowmelt flow into the cave, the ice floor thickens. The ice is approximately 20 feet thick.

Depending on summer rainfall, the cave floor may accumulate water until the prevailing temperatures drop below 30° F. The water from summer rainfall freezes, adding new layers of ice to the floor. The deepest ice dates back to 1100 BC.

The land that contains the ice cave was purchased by Sylvestre Mirabal in the early 1900s. Mirabal mined ice in the cave to cool beer in a saloon that he operated. His daughter married into the Candelaria family, which continues to own and operate the ice cave. Ice mining was halted in 1946, and no trace of this practice remains.

After lunch back at Old Time Trading Co, we explored other areas of El Malpais National Monument including the Sandstone Bluffs on the eastern side of the park to see one of the few overlooks within the area. From those, the sweeping vistas offered different views and features. Below the bluffs we saw the lava flows of El Malpais. To the north, we saw a dramatic view of Mount Taylor. The ground we stood on was the Dakota Sandstone which contrasted with the dark lava flows farther below.

Another scenic location we visited was La Ventana Natural Arch, the second largest sandstone arch in New Mexico and a popular attraction just off Hwy 117, 18 miles south of Interstate 40. The name La Ventana is a Spanish term, meaning "the window." The arch is composed of Zuni Sandstone which was deposited as desert aeolian sand dunes about 165–175 Ma, during the middle Jurassic period. Wind and water eroded away the softer parts of the sandstone cliff, leaving behind a spectacular arch tucked away in a small canyon.

Our visit to El Malpais marked the official end of our field trip, although all 8 of us stayed one further day to visit the Zuni Pueblo Visitor Center. There we met our guide Kenny, who described Zuni culture, and then led us to an archeological site (Village of the Great Kivas) with a reconstructed kiva and many petroglyphs and pictographs.

As we have come to expect, Randy and Joanie organized another incredible field trip, which all of us enjoyed and learned much from. We are pleased to share the experience with those unable to join us.

Dave's Field Trip Photos: To see more of the photos I took on this trip, download this document with all of the links: <https://photos.app.goo.gl/LhEjQGtgc7cbrxBA>

GSM Markers History and Inventory

Prepared by Patrick Steury - July 7, 2025
Report summarized by Kate Clover

Editor Note: This is a summary of a 32-page report on the GSM Markers around the state written by Patrick Steury. Patrick joined GSM less than a year ago and wanted to get involved in a project. The job he took on was investigating and documenting the Markers. He traveled the state, found the existing markers, documented their conditions, shot photos, came home, and did further

research. Others have dabbled in documenting the Markers over the years, and Patrick took on the work in earnest. His 32-page report is well-documented and well-illustrated.

Here I will summarize his report, which will be posted on the GSM website.

Patrick's introduction includes an excerpt written in the 1960s by former GSM President Lawrence King:

"About 70 miles south of Oklahoma City, Highway 77 passes through a scenic and recreational area located in the granite stumps of the Arbuckle Mountains, an ancient range that crossed part of the state in an east-west direction. On the south flank of this granite core rests a series of upturned sedimentary formations, the outcrops of which are exposed at the roadside for several miles between Turner Falls Park and Ardmore to the south. On these exposures, the Lions Club of Ardmore has erected large wooden signs, describing each formation by name, character of deposit and its importance with respect to the oil industry of Oklahoma. About a dozen of these signs, spaced at varying intervals, give a comprehensive story of the geology and economic value of the sandstones, limestones and shales that comprise the oil bearing formations of this region. Written in non-technical language, the texts provide information of interest not only to local residents but to the large number of travelers who use this busy highway. The opportunity for a similar project in Minnesota is apparent to anyone who is at all familiar with the geology of the state."

This excerpt by Lawrence King from the Spring 1996 GSM newsletter details the inspiration behind constructing markers across Minnesota. King was instrumental in making this happen from 1949 to 1960. Twenty markers were funded through the Louis W. and Maud Hill Family Foundation and an additional 13 were funded by GSM, with the exception of the Lake Pepin marker that was partially funded by MnDOT. The last of this original set was installed in 1966. Spearheaded by Doug Zibkowski, funding was secured for another batch of 15 markers in 1998, plus one in 2001. Many of these replaced markers from the 1950s that had information that was outdated. In 2003, another 15 were proposed, but none were installed. Many of the texts for these proposed 2003 markers were published in the newsletter, mistakenly implying they were not just proposals, but real metal markers. This information was then given to Sarah Rubinstein at the MHS for the 2003 update of the classic guidebook *Minnesota History Along the Highways*. As useful as this book was during my site surveys, an updated version is sorely needed. The book notes six markers from 2003 that do exist; these six markers are dated 2009 and most were installed that year. A number of historical society markers also exist, which are listed here as they are tagged as geological markers in the book and appear on our website."



Lake Pepin Marker

Editor's note: Lawrence King's "In Memoriam" in the March April 1976 GSM News, mentions his services to GSM. He served as president, led field trips and most notably spearheaded the geologic marker project, resulting in many markers set up around the state. He died in March 1976 at age 89.

Patrick documented 72 markers. He counted 49 markers "currently present," four intact pedestals missing their markers, and nineteen markers that were perhaps designed, but not installed. He also noted the condition of the markers, and found 30 in good condition, 13 in fair condition, and six in poor condition.



Marker #216 – Good Harbor Bay

Here are two entries from his report.

Marker #216 – Good Harbor Bay Brief History: Installed after 1954 and present in 1978. Replaced in 1998 with the current marker.

Coordinates: 47.726226, -90.442477

Current Status: Fair

Notes: Stonework on the wall is cracking along with the marker stone, but since it's happening everywhere at the pull-off, I expect the DOT will deal with it at some point.



Marker #252 – Geology of the Mesabi Region

Marker #252 – Geology of the Mesabi Region Brief History: Installed in 1957 and replaced in 1998 with the current marker

Coordinates: 47.434317, -92.937375

Current Status: Fair

Notes: Located in Bennett Park, just east of the large picnic shelter.

Steuery scouted sites for future GSM Markers. Patrick wrote that while planning site visits, he also made stops at what he thought would make good points for new GSM markers. Most of these sites he first visited



Salt Lake

virtually, then physically. He took pictures on the ground and from the air. His criteria were interesting geology, ease of site access, a well-traveled area, and the site having a compelling story that can be understood and appreciated by the layperson. Not all of these sites are of equal quality, and he assigned them a ranking out of 10. This does not include any of the missing or never-installed markers.

Salt Lake: In the land of 10,000 lakes, we have one oddity. A lake south of Ortonville is the state's only closed lake, and its salty water supports brine shrimp. Birdwatchers visit the lake to see rare species. People online wonder why this salt lake exists, and experts differ on the theories! I paid a visit, tasted the lake, and zipped the drone around. The current display on birds is at 44.960639, -96.435596. Suitability Score: 8.

Wadena Drumlin Field: A large drumlin field in central MN. Sookhan et al. (2016) increased the drumlin count from ~2000 up to ~6000 across the formation. Proposed site: the intersection of US-210 and County Road 11 at 46.325353, -94.946187. This intersection lets you see the rippling drumlins in all directions and even has fieldstones deposited by the drumlins on the site. Suitability Score: 7



Wadena Drumlin Field

St. Cloud Granite: A monument to the St. Cloud Granite from the 1930s exists just off US-10. A colorful laminate marker on the geology of granite could be a neat addition. Current site at 45.540588, -94.107509. Suitability Score: 5



St. Cloud Granite

Future Work: Steuery asks,

"Where to go from here? This work has not been without its challenges, but I'm very glad to have completed it. Naturally, it also leads to more things to tackle. I believe that preserving the existing markers is the most important place to put efforts now."

Steuery concludes his report and acknowledges prior work: "I'd like to give my appreciation for everyone involved in getting the markers project to this great stage. It's taken many decades of work by lots of hardworking people to not only create the markers but maintain records and keep notes of relevant details! And, of course, the current members who have upheld the mission of the organization for more than eighty years. Thank you, everyone! It is my hope that this document can serve as a touchstone for generations of GSM marker stewardship going forward."

Dave Wilhelm thanks Patrick for his work. "You probably have the unofficial record as biggest contributor for a one-year (actually 10-month) member. Thank you for your diligent work."

GSM Membership Application/Renewal 2025-2026

Membership year begins September 1

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