



# GEO NEWS

NORTH  
**Dakota** | Mineral Resources  
Be Legendary.™

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# FEATURES

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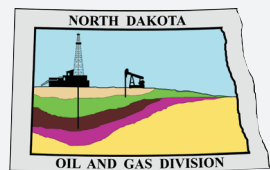
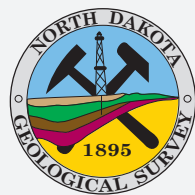
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## ON THE COVER:

Ed Murphy exposes a coal seam near Medora in 1982 (left), and at the Leonardite Products pit near Williston, ND in June of 2026 (right), his 50th year of fieldwork for the North Dakota Geological Survey.



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## GEO NEWS

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# AFTER 25 YEARS: NORTH DAKOTA STILL HAS AN 800-YEAR SUPPLY OF COAL

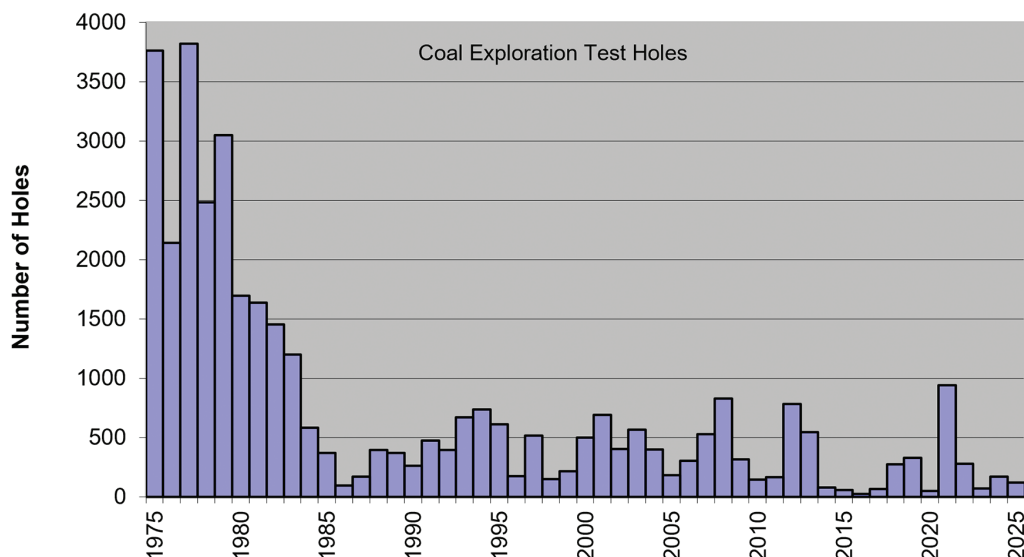
BY ED MURPHY

The statement “North Dakota has an 800-year supply of coal” is as true today as it was when I wrote it 25 years ago in a Geological Survey report (Murphy, 2001). What I actually wrote was “At the current rate of mining, it would take 835 years to exhaust North Dakota’s supply of economically recoverable lignite.” Five years later, I rounded that number down when I wrote in another Survey report (Murphy, 2006) that it would take more than 800 years to exhaust the 25.1 billion tons of lignite reserves at the present rate of mining. That is the nice thing about large, rounded numbers, they tend to stay relevant for a long, long time. In some ways, I first started working on that coal reserves project 50 years ago.

In 1977, I was hired as a summer temp to field check the reclamation and plugging of coal exploration test holes throughout the western half of North Dakota. Little did I know, as I was field checking thousands upon thousands of those holes, that one day I would be interpreting the electric logs that were generated from those very same holes. After I was hired full-time in 1980, one of my first projects was to correlate the coals within the Fort Union Group across western North Dakota. As I started that project, I quickly realized that the average spacing between exploration test holes was about six miles. To test the accuracy of tracing thin lignites using this average spacing, I constructed a cross-section just to the northwest of the Gascoyne Mine in eastern Bowman County. In this area, as around most of the existing coal mines, the spacing between exploration holes was much closer, roughly 0.5 miles. I then took the same cross-section and added all of the 0.5-mile-spaced

data points into it and discovered that many of my original coal correlations were wrong. As a result of this revelation, I decided to pause the coal-correlation project until sufficient coal exploration holes were drilled to generate better electric log control. As the years passed, it became clear that the years 1975 to 1983 were the peak of coal exploration in North Dakota, averaging 2,400 test holes per year at the high point and then dropping to fewer than 400 holes annually in the intervening years (fig. 1). Additionally, these latter test holes were primarily drilled to guide expansion at the existing coal mines. Given that, I shelved the coal correlation project and turned to a number of other projects (oil and gas, solid waste, municipal wastewater, and pesticides) along with surface mapping and sedimentary/stratigraphy studies of the dinosaur-bearing rocks (Hell Creek Formation), the coal-bearing rocks (Fort Union Group), and the rhinoceros-bearing rocks (White River Group and Arikaree Formation).

Then, in 2000, I became aware of the Lignite Vision 21 Program, an Industrial Commission grant program administered through the Lignite Research Council, to promote the construction of a new, clean-coal energy conversion facility in North Dakota. Knowing that a powerplant could require the opening of a new coal mine, I determined I could no longer delay the coal correlation project and set out on a comprehensive undertaking to define North Dakota’s economic coal deposits. First, I reached out to the coal companies that were active in North Dakota to determine what criteria they used when establishing a new coal mine (Murphy, 2001, 2006). The criteria were: 1) a minimum



**FIGURE 1.** Coal exploration test holes drilled in North Dakota from 1975 – 2025.

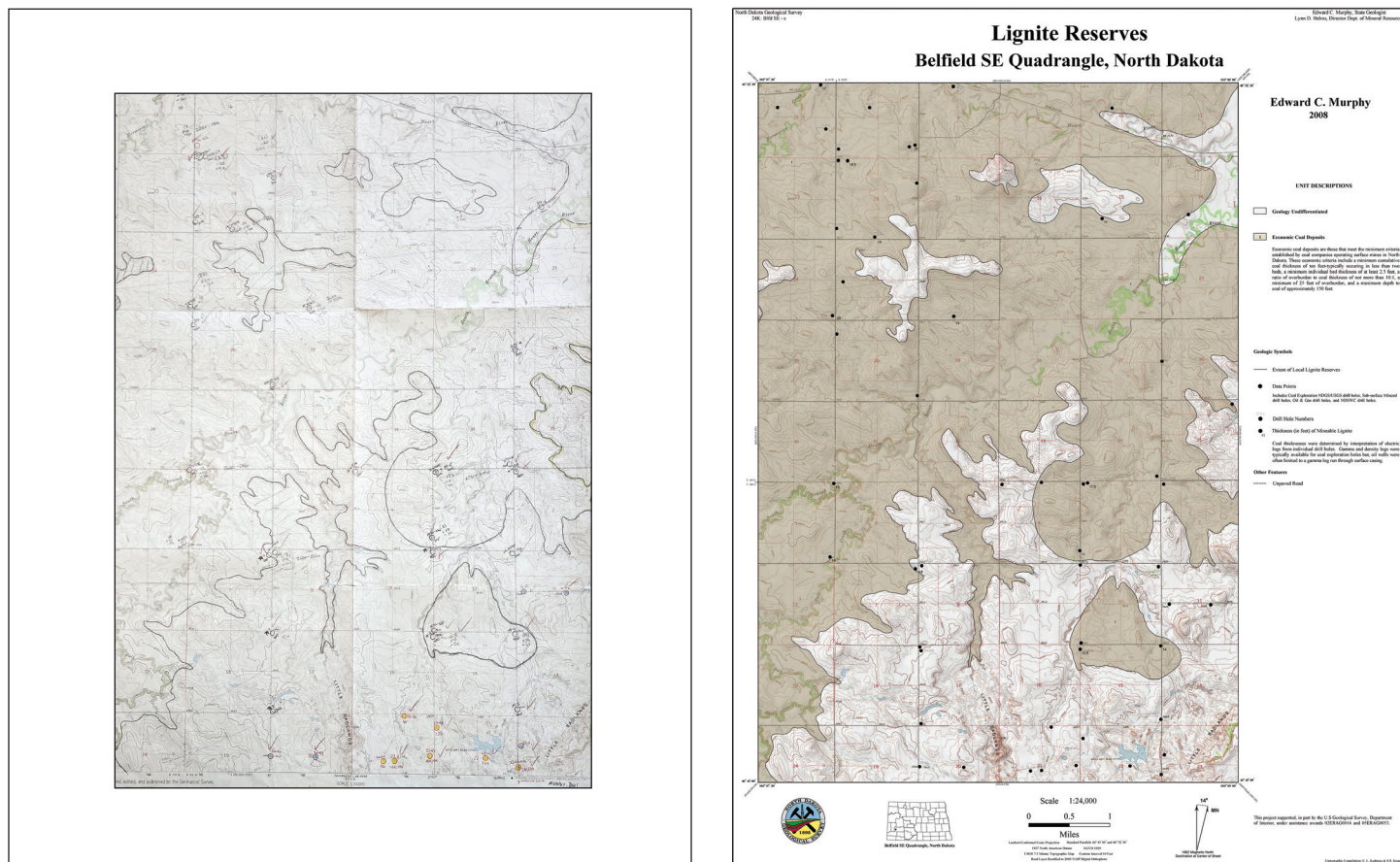
cumulative coal thickness of ten feet, typically occurring in one or two beds, 2) a minimum individual bed thickness of 2.5 feet, 3) a maximum stripping ratio of 10 feet of overburden for every foot of coal, 4) a minimum of 20 feet of overburden to minimize the effects of weathering, and 5) coal beds were generally not considered below a depth of 150 feet beneath the surface (in a few rare instances this depth was extended to 160 feet).

I then reached out to Romeo Flores and others in the Minerals Division of the U.S. Geological Survey in Denver to see how quickly they could enter the coal data we had been supplying to them (the National Coal Resources Data System) into their software program that calculates reserves. Unfortunately, they were busy with other coal resource projects and would not be able to get to North Dakota for at least 18 months, which meant I would have to do the calculations by hand. Luckily, Survey temps plotted many of the coal exploration holes onto quadrangle maps in 1991. Most importantly, in the 1990s and early 2000s, Survey temporary geologists Gerard Goven, Ned Kruger, Quentin Vandal, Michelle Gutenkunst, and Kim Jacobs had interpreted 19,000 coal exploration logs and many of the oil well gamma logs that were run to the surface. I recorded the coal thicknesses to a depth of 150 feet alongside each hole location and then correlated the coal beds and approximated the overburden across each topographic map, enabling the economic coal deposits to

be defined (fig. 2). Nine long months, and 1,650 hours later, the project was completed.

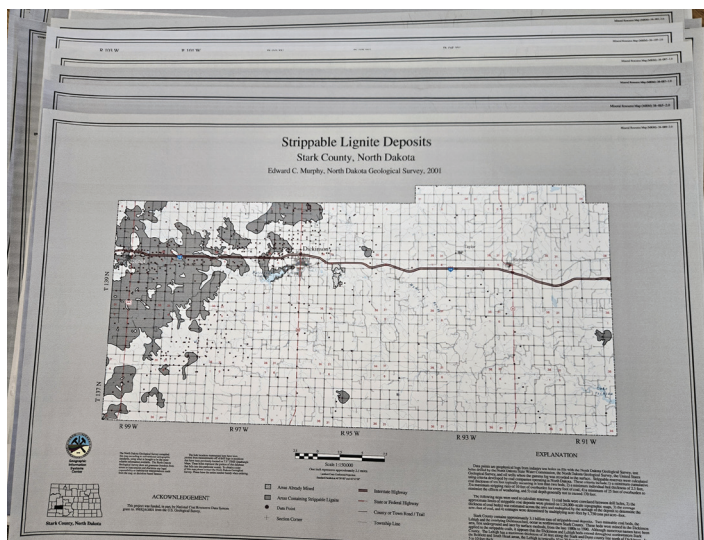
The resulting 644 coal-reserve quadrangles overwhelmed our two-person Map Making Section, so priority was given to generating coal reserve maps for the 20 coal counties. The fastest way we could think of publishing the county maps was to make successive copies of the quads through Xerox reduction until they were at a scale of 0.5 inches to the mile. The ultimate reductions were then taped together to form the county. The resulting, distorted product was then constantly reoriented and adjusted (georeferenced) to the county base map while it was being digitized into ArcInfo. The coal reserve maps for all 20 coal counties were published in 2001 – a truly remarkable feat (fig. 3). It took another eight years to publish all of the quadrangles that contained coal reserves. The remaining quadrangles were published in 2018 and 2019. These latter maps did not contain any economic lignite deposits, but the data control was useful, and it completed the set of maps within the coal-bearing area of western North Dakota.

The economic coal criteria for a new coal mine are generally considered conservative. Once the infrastructure is in place, a surface coal mine can generally operate economically with less stringent criteria for coal thickness, the stripping ratio, etc. Therefore, if a surface coal mine were to be established



**FIGURE 2.** Left: The original Belfield SE quad on which the economic coal deposit boundaries were penciled in after comparing coal thickness, depth, and topography. Right: The published map of the lignite reserves of the Belfield SE quadrangle.



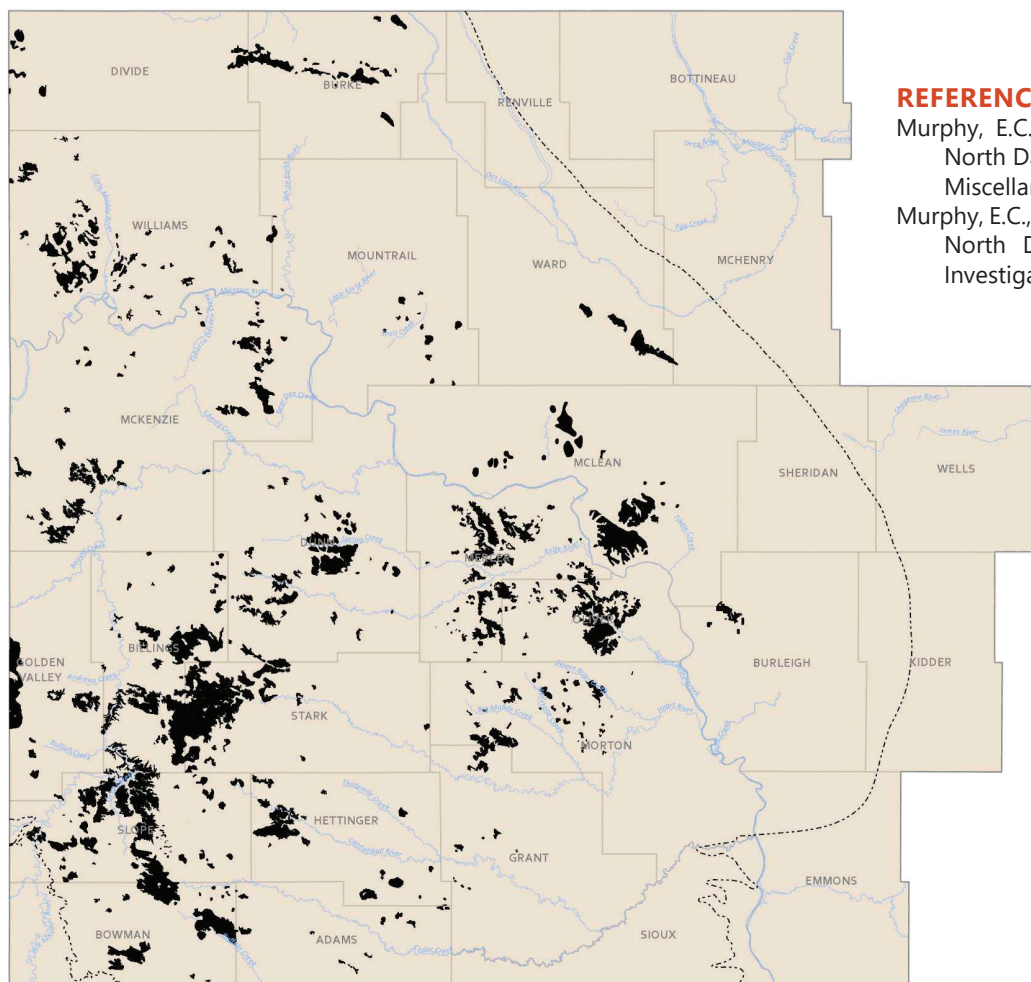


**FIGURE 3.** Paper copies of the strippable (economic) lignite deposits of 20 North Dakota counties published by the Geological Survey in 2001. The Stark County map is on the top of the pile.

anywhere within these deposits, it would likely be able to economically utilize marginal portions of these deposits that were not identified because the overburden was slightly thicker or the cumulative coal thickness was less than the stated minimum.

Five years after completing the coal reserve maps, I went back to my original notes, reran the reserve calculations, and reported the acre-feet and tonnages for the individual deposits rather than by county as first reported. Based upon the 2006 results, North Dakota contains 25.056 billion tons of economic coal reserves in 245 individual deposits (fig. 4), slightly lower than the 25.057 billion tons I reported in 2001. At that time, North Dakota was mining approximately 30 million tons of lignite per year. The "800-year supply of coal" came from dividing the 25.1 billion-ton reserve by 30 million tons/year = 835 years and then rounding that down to 800 years.

North Dakota has mined roughly 700 million tons of coal since the first coal reserve report was published in 2001. On paper, this has resulted in a 3% reduction in North Dakota's lignite reserves from 25.1 to 24.4 billion tons (from 25,057,000,000 to 24,357,000,000), although it is likely that some of the coal that was mined did not meet the reserve criteria and was therefore not included in the estimate. Over the last 25 years, North Dakota's annual lignite production has declined by 15%, from an average of 30 to 25.4 million tons per year. At the current rate of production, the lignite reserves in North Dakota would now last for roughly 1,000 years (960 years, to be exact).



**FIGURE 4.** A map of the economic coal deposits (black) in the western half of North Dakota. Modified from Murphy (2001).

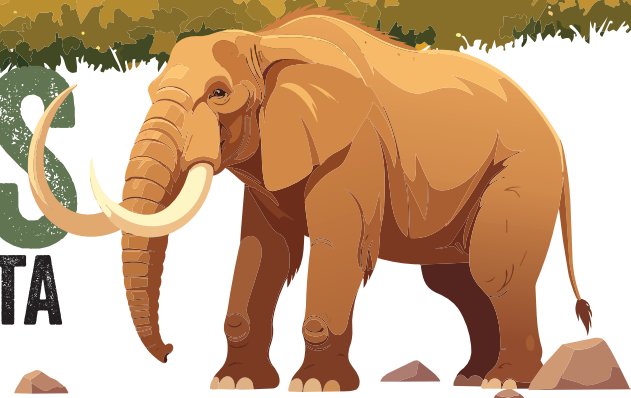
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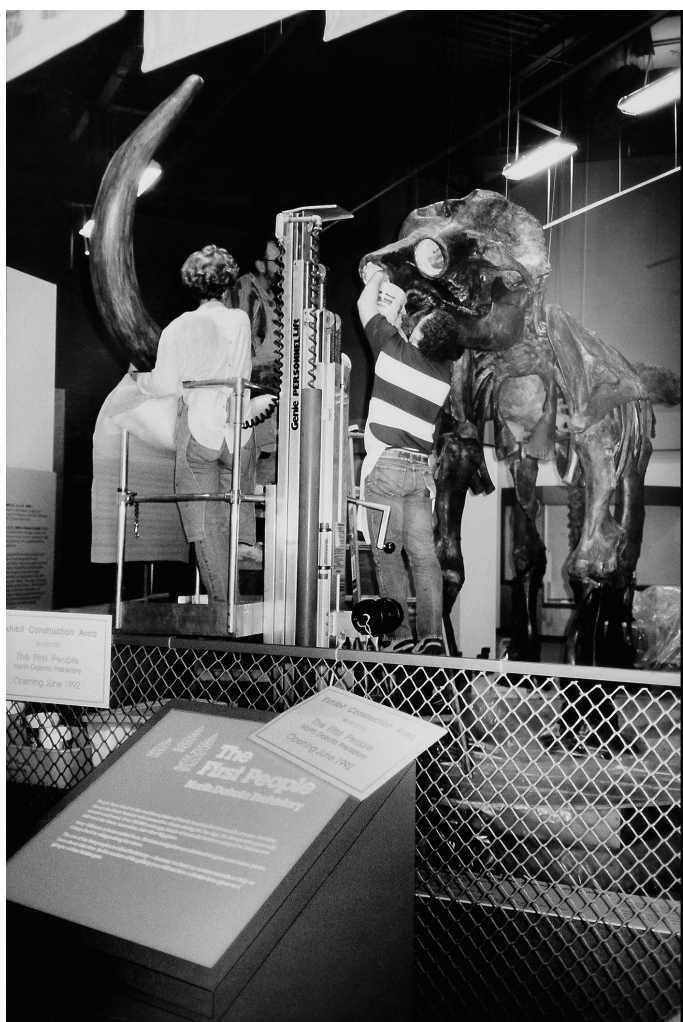
# FOSSIL GIANTS IN NORTH DAKOTA

BY JEFF PERSON



Can you imagine having teeth that are six feet long? And not just any teeth, but your incisors (the teeth you have right in the front of your mouth, the ones we see when you smile). This is the reality of modern-day elephants. Their incisors have been modified over the millennia to become large, long tusks projecting sometimes six feet or more in front of them. Tusks are composed of various layers of biological material and are defined as very large mammal teeth that project outside of the lips. The very tip of the tusk is made of enamel, the same material that covers our teeth's chewing

surfaces. In adult and older elephants, this enamel tip has worn away and does not grow back. The outermost portion of the tusk, thought of as the outer crust, is made of cementum. Under the cementum is dentin, which forms approximately 95% of the tusk. Finally, the innermost portion is the pulp cavity where the nerve endings and blood vessels are located. From the smallest mouse to humans to the tallest giraffe, all mammal teeth are made up of these same materials (enamel, cementum, dentin, and pulp). We have all heard the term ivory, which was originally used to describe the tusks



**FIGURE 1.** Left: Claudia Berg and John Hoganson mounting the foam tusks on the Highgate Mastodon in 1992. These tusks were carved out of foam and mounted due to the weight of the original tusk. Right: The original tusk recovered with the Highgate Mastodon. Portions of the outermost layer of cementum are missing or have been replaced with plaster (white portions seen in photo). SHSND1988.240.1





**FIGURE 2.** Mammoth tusk recovered by dragline at the Coteau Properties Company's Freedom Mine near Beulah, ND. This photo was taken shortly after its discovery showing how immaculately the tusk was preserved.

of elephants, but all tusks are chemically the same, so ivory is now defined as any tooth or tusk that is large enough to be carved or scrimshawed (Espinoza and Mona, 1999). This means tusks from walruses, whales, hippopotamuses, and warthogs are all considered to be ivory.

Elephants and their relatives (all grouped into the Order Proboscidea) have a long history beginning in Africa during the Miocene approximately 17 million years ago and eventually branching out to every continent except Australia and Antarctica (Kurten and Anderson, 1980). Modern species of Proboscidea still survive today in the tropics of the Old World. Their closest living relatives are the sirenians (manatees) and the hyraxes (small mammals living almost entirely in Africa).

North Dakota was home to three species of Proboscidea during the late Pleistocene approximately 10,000 years ago. The American mastodon (*Mammuthus americanum*), the woolly mammoth (*Mammuthus primigenius*), and the Colombian mammoth (*Mammuthus columbi*) all once called this region home. The American mastodon shares a common ancestor with modern elephants, but has no true modern descendants. The mammoths, however, are the great relatives of modern Asian elephants.

The Highgate Mastodon is a nearly complete skeleton of an American mastodon on exhibit at the North Dakota Heritage Center and State Museum in Bismarck, ND. Originally collected near the town of Highgate, Ontario, these animals once roamed the region in and around North Dakota during the Pleistocene. The tusks on exhibit were carved out of foam in the early 1990s and mounted on the skull due to the weight and fragility of the fossil tusk that was originally

recovered (fig. 1).

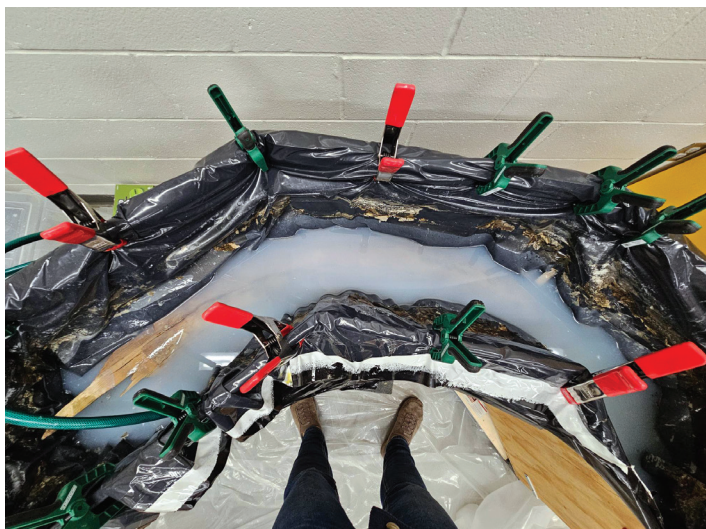
Isolated teeth from woolly mammoths have been recovered from North Dakota, but no skeletal elements have been associated with those woolly mammoth teeth. Woolly mammoths were the smallest of the mammoths, but were still 9 feet (2.8m) tall at the shoulder (Kurten and Anderson, 1980).

Remains of the Columbian mammoth were not identified from North Dakota until very recently. In 2023, the Coteau Properties Company's Freedom Mine north of Beulah, North Dakota uncovered a large (~6-foot) tusk and other bones during routine overburden removal with a dragline (fig. 2). Miraculously, the tusk was undamaged when it was removed, although the rock and consequently the tusk were waterlogged. The North Dakota Geological Survey was contacted to excavate the remaining bones from the site and to identify the animal. Though we initially thought we uncovered a variety of bones from the skeleton, after cleaning and consolidating the bones it was discovered that most of the bone fragments were from one large bone, the innominate, that forms one half of the pelvis.

In order to stabilize the waterlogged tusk, a series of steps was taken to first replace the water in the tusk with consolidant and then to slowly remove the remaining water (Dzenowski, 2023). The ultimate goal is to have a dry, stable fossil (tusk in this case) that will not delaminate or flake apart. The tusk was immersed in a bath of a consolidant called Acrysol W-24 that was chosen for its solubility in water. The strategy was to gradually replace the water inside the tusk with the consolidant, stabilizing the tusk. This is done by adjusting the ratio of consolidant to water in the bath of solution the tusk is soaking in. The initial solution consisted of 10% Acrysol and 90% water, and over the course of five baths the concentrations were adjusted to a 50/50% solution of Acrysol and water. Next, the remaining water had to be removed. To accomplish that goal, the tusk was soaked in a second series of solutions containing water and isopropyl alcohol. These solutions were changed monthly, gradually increasing the concentration of alcohol and decreasing the concentration of water, until the final bath that was 100% alcohol (fig. 3). The isopropyl alcohol acts as a drying agent, allowing the water to evaporate at a quicker and more efficient rate. The total process to stabilize and dry this tusk took approximately 16 months from the first bath until the tusk was completely dry and placed into its final archival cradle (fig. 4).

If these steps and procedures are not followed with a waterlogged tusk (or other bones), the results can be catastrophic. Within the paleontology collections at the University of North Dakota in Grand Forks there is a mammoth tusk that was allowed to dry without any intervention. It is unknown (to the author) when the damage began and how long it has been allowed to proceed, but the resulting damage from uncontrolled drying is substantial and potentially irreversible (fig. 5). The bending and spalling





**FIGURE 3.** The Freedom Mine tusk going through the dewatering process. The ratio of Acrysol (which gives the liquid the milky white color) and water was altered several times throughout the months-long process.



**FIGURE 4.** The Freedom Mine tusk in its current stable form after the dewatering process.



**FIGURE 5.** Tusk in the paleontology collections at UND that was allowed to dry without intervention. The outer layer (cementum) is drying at a different rate than the inner layers, causing cracking and spalling.

of the tusk occur due to the differential rate at which the layers of the tusk dry. Cementum, dentin, and enamel all dry at different rates, causing a difference in pressure between the various layers, creating cracks and resulting in the layers peeling apart.

In 1988 near Powers Lake, ND, bones were discovered while a crew was digging footings for a new garage. The members of the construction crew, just a few years out of high school, contacted their old science teacher, and he recognized the bones as likely coming from a mammoth. Professors at the University of North Dakota in Grand Forks and North Dakota State University in Fargo, as well as archaeologists at the State Historical Society of North Dakota, were all contacted to gauge their interest in assisting the Geological Survey with recovery of the fossils. Unfortunately, a variety of factors prevented the recovery of the specimen at that time: the garage floor was already poured and the garage completed; the homeowner was willing to have the slab removed as long as it was repoured within 30 days; the fall school semester had begun; and funding for the excavation was unavailable. Fast forward 36 years. In 2024, the North Dakota Geological Survey partnered with the ND State Historical Society and made a trip to the site with ground penetrating radar to search for more of the skeleton. While the radar data showed some interesting results, none of the radar points were obviously bone. In late 2024, while working closely with the new landowner, some test pits were dug near the walls of the garage to search for evidence of fossil material. Fossilized bone fragments were recovered and their initial identification pointed to them being remains of a mammoth. One year later, these test pits were expanded and larger bone fragments, partial mammoth teeth, and a tooth from a small rodent were recovered. All evidence points to the high likelihood that additional bones will be found under the floor of the garage. As of this writing, plans to return to the site in 2026 are in place, and we hope more of this skeleton will be uncovered...stay tuned.

The current fossil record of proboscideans in North Dakota is sparse, but the Freedom Mine and Powers Lake specimens are filling in gaps about our knowledge of these animals that lived more than 10,000 years ago. Every fossil that is discovered is unique and helps us to paint a clearer picture of what life was like in North Dakota during its long history.

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# BOULDERS FROM THE FIELD PART 2:

## LARGE GLACIAL ERRATIC FOUND IN NORTHERN MCINTOSH COUNTY

BY FRED J. ANDERSON

After the publication of our recent newsletter article on North Dakota's largest glacial erratic just west of Mandan (Anderson, 2025), we received some follow-up comments from the public on other large erratics found in North Dakota that could also be contenders for the top spot.

One such erratic, called "The Rock" by Napoleon Homestead newspaper reporter Donna Ruff, was originally found a few miles east of Lehr and captured in a 2012 picture on the Henry Buchholz farm (fig. 1). This erratic was found during cleanup of a rock pile during the unusually warm winter months of 2012. When first discovered, only one foot of this erratic was exposed, the literal "tip of the iceberg." After excavating with trackhoes and payloaders for the better part of three days, this boulder was finally unearthed. This erratic eventually sank into the ground under its own weight and tipped over (Ruff, 2012).

This past summer (mid-July 2025) Jerry Mayer of Streeter, North Dakota contacted our offices with this past newspaper report. After some brief discussion Mr. Mayer agreed to see if he could determine where this erratic was originally located. In mid-October of 2025, Mr. Mayer determined that he had found the erratic and submitted a photo of his find (fig. 2).

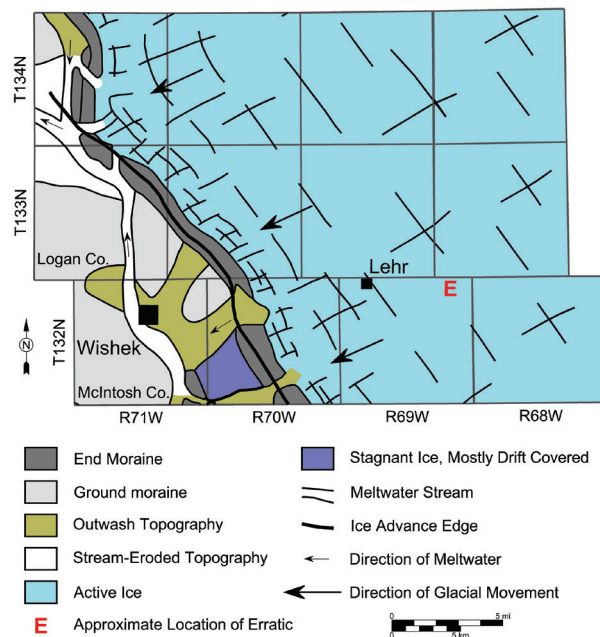
It was then subsequently determined, based on its location, that this erratic was deposited during the formation of the Burnstad End Moraine (fig. 3) which formed in central McIntosh County around 10,000 years ago (Clayton, 1962).

Based on its size, this glacial erratic is certainly one of the larger intact erratics found in North Dakota. Time will tell



**FIGURE 2.** "The Rock" relocated by Streeter native and retired petroleum geologist Jerry Mayer (at right), is a very large and intact, red granitic glacial erratic located in northern McIntosh County.

if other larger erratics will be unearthed and found to be even larger than those currently on record. We appreciate and welcome continued comments and submissions from the public.



**FIGURE 3.** Approximate location of "The Rock," the large glacial erratic (signified by the red letter E) deposited at the western margin of the Missouri Coteau during the formation of the Burnstad end moraine around 10,000 years ago (modified from Clayton, 1962).



**FIGURE 1.** Photograph of "The Rock" discovered during cleanup of a rock pile on the Henry Buchholz farm in northeastern McIntosh County. This behemoth was measured at 16-ft tall and 14-ft wide, tipping the scale at an estimated 200 tons.

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# GRAVITY AND AEROMAGNETIC SURVEYS OF NORTH DAKOTA: A BRIEF HISTORY AND RECENT DEVELOPMENTS

BY STEVE CHITTICK

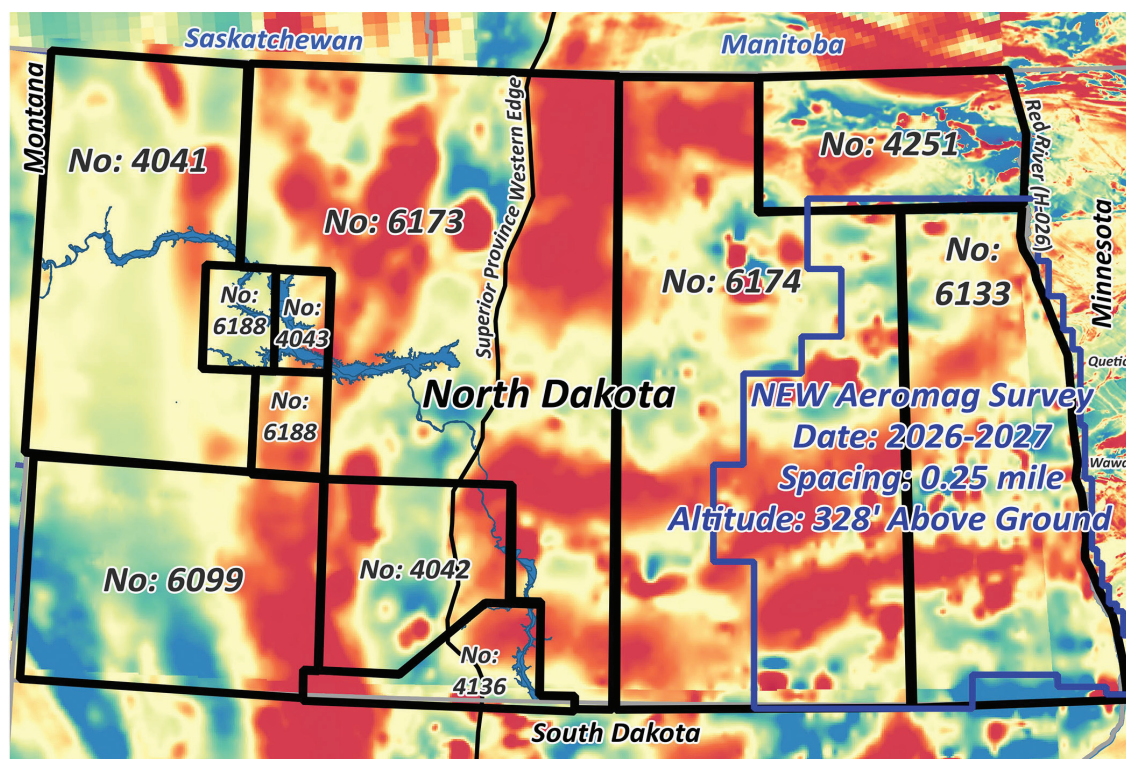
Aeromagnetic and gravity surveys are geophysical remote sensing techniques that provide information on physical properties of rocks in the subsurface. Aeromagnetic surveys measure variations in the Earth's magnetic field due to the presence of magnetic materials, such as magnetite and other ferromagnetic minerals. Gravity surveying detects differences in the density of subsurface materials. Gravity and aeromagnetic surveys are relatively inexpensive for regional surveys. Most high-resolution gravity surveys are still ground based as the aerial alternative to the high-resolution aeromagnetic survey is a gravity gradiometry survey. A gravity gradiometry survey is currently about 10 times the cost of an aeromagnetic survey with similar resolution (Ben Drenth, personal communication). In combination with physical information from subsurface materials, these surveying techniques can be used to help map out the basement geology of the subsurface (Hinze et al., 2013; Dentith and Mudge, 2014).

## AEROMAGNETIC DATA

Aeromagnetic and Radiometric surveys were flown in North Dakota and throughout the United States in the late 1970s

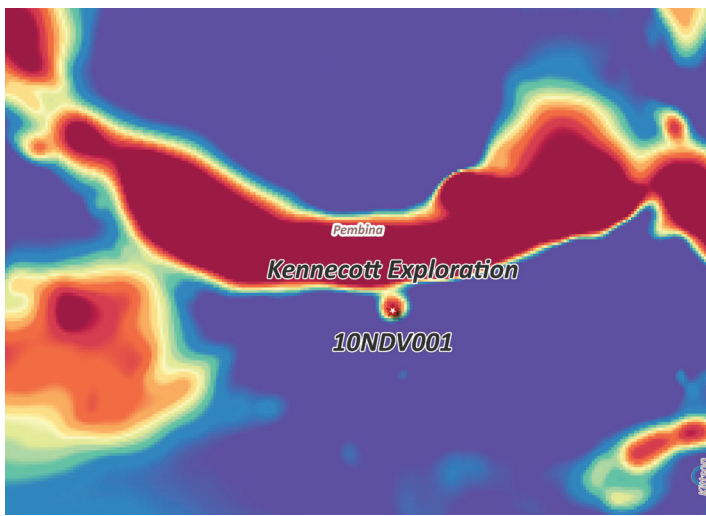
and early 1980s as part of the Department of Energy's National Uranium Resource Evaluation (NURE) program (Hill et al, 2009) with the data now maintained by the United States Geological Survey (USGS). The NURE aeromagnetic surveys in North Dakota were of low resolution, but there were two higher resolution surveys performed later, one in 1985 in Sioux County, North Dakota (block no. 4136), and the other (block no. 4251) in the northeast corner of North Dakota (fig. 1 and table 1). The last aeromagnetic survey flown in North Dakota (2000 – 2001) was utilized in part to select the location for a diamond exploration well (fig. 2) that Kennecott Exploration drilled in 2010 (Nesheim, 2013, 2016).

An aeromagnetic survey of eastern North Dakota (south of the current high-resolution aeromagnetic block no. 4251 in northeast North Dakota in figure 1) contracted by USGS Earth Mapping Resources Initiative (Earth MRI) will begin in late 2026-2027, with completion forecasted for the end of 2027. This survey's purpose is to help map out a portion of Precambrian shallow basement rocks (less than 3300 feet or 1000m depth) of the western edge of the Superior Province of the Laurentian Shield to foster exploration for critical minerals as defined by the USGS:



**FIGURE 1.** Aeromagnetic anomaly map of North Dakota with block numbers from Table 1. The newly contracted aeromagnetic survey for eastern North Dakota is outlined in blue. Note the much higher resolution of the data in the northeast corner of North Dakota and in Minnesota from post-NURE surveys.





**FIGURE 2.** The small, round aeromagnetic high that Kennecott Exploration drilled in southeast Pembina County, northeast North Dakota, looking for a diamond bearing Kimberlite. Sadly, no Kimberlite tube was discovered.

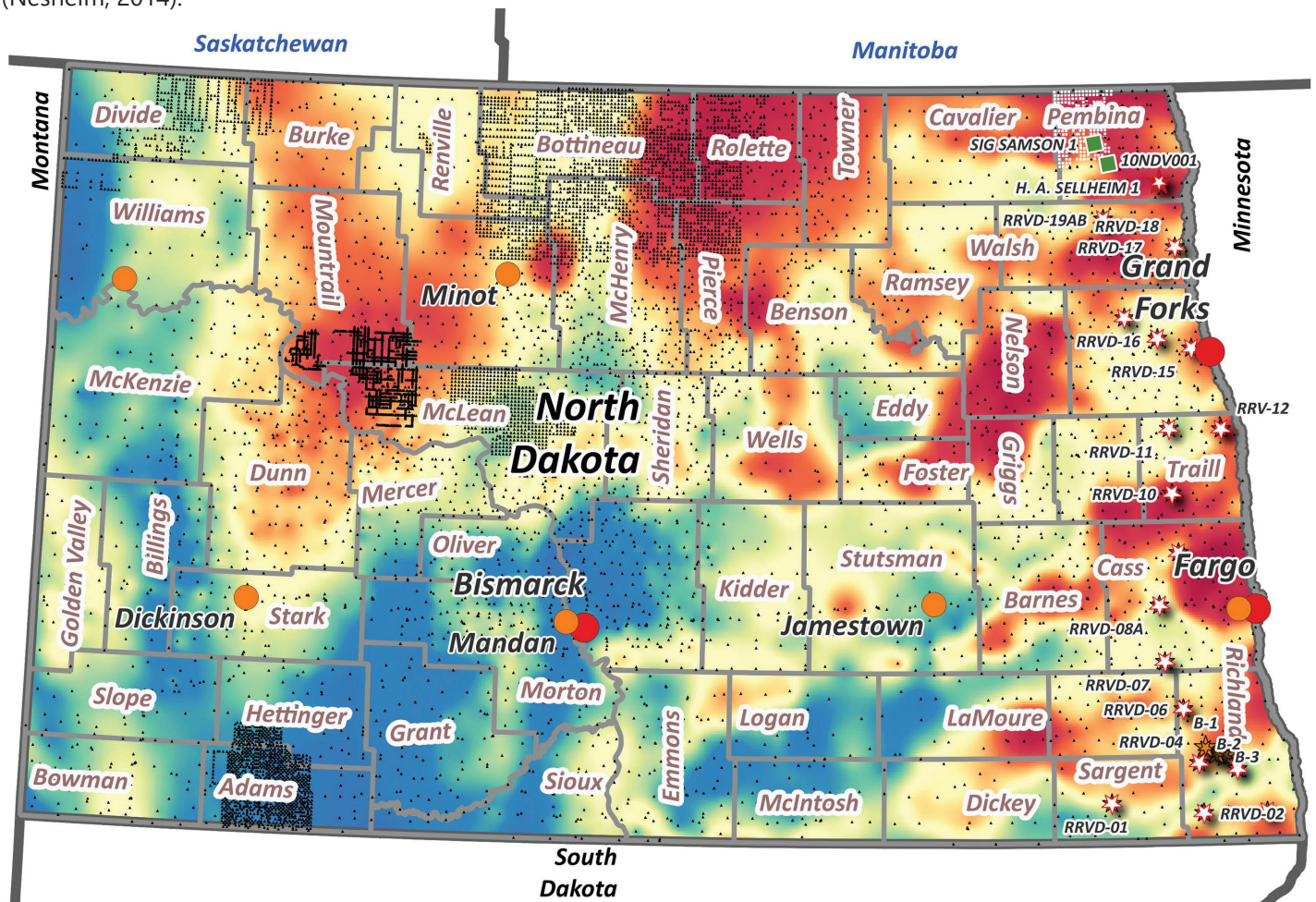
<https://www.usgs.gov/news/science-snippet/interior-department-releases-final-2025-list-critical-minerals> (retrieved April, 13, 2026). Iron, nickel, gold and other elements are currently mined from rocks of the Superior Province in surrounding states and Canadian provinces (Nesheim, 2014).

## GRAVITY DATA

Gravity data in North Dakota is generally sparse, especially in eastern North Dakota, but is just as important as aeromagnetic data in interpreting basement geology. Figure 3 shows a Bouguer gravity anomaly map with the gravity data points used in creating the map. There are gravity data clusters in the north-central, the west-central, and the southwest central parts of the state. A high-resolution gravity survey was initiated in 2025 in Pembina County (fig. 4) where the highest-resolution aeromagnetic data has already been flown. Recent advances in collecting elevation data from lidar to correct gravity data (Murchek et al., 2025) have significantly improved efficiency and lowered the cost of gravity surveys. The Pembina County gravity survey should be completed in the summer/fall of 2026.

## CORE DATA

The New Jersey Zinc Exploration Co. drilled and cored two wells in the very southeast corner of North Dakota in Richland County in 1964. Five years later Amerada-Hess drilled and cored in search of minerals in Pembina County in 1969. The Red River Valley Drilling project cored 18 wells in the Precambrian along the Red River Valley in North Dakota during the late seventies as part of NURE, and Exxon Minerals Co. drilled and cored 3 wells in west-central Richland County. In addition to the aeromagnetic and



**FIGURE 3.** Bouguer gravity anomaly map of North Dakota. Black dots represent historic gravity survey stations. White squares in the very northwest of Pembina County are stations from the new gravity survey of 2025. White stars on red stars indicate wells sampled for Zircon age dating.



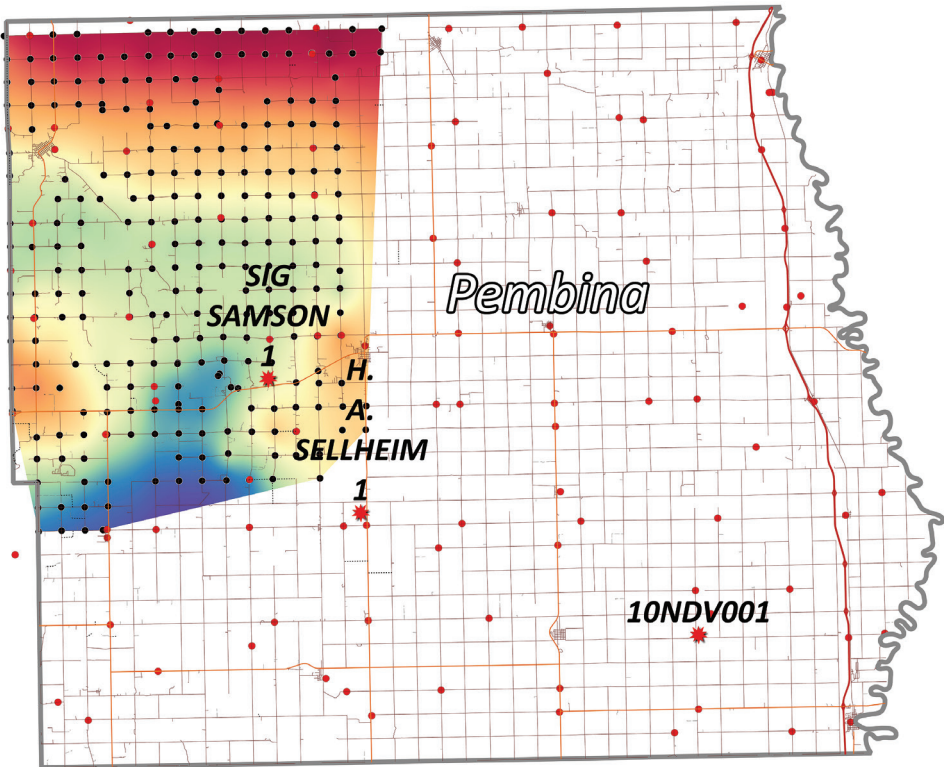
gravity data, samples were taken from these cores (fig. 3) for whole rock geochemistry and geochronology. This will give us timing of the emplacement of the igneous rocks and their chemical makeup. Thin section and X-ray diffraction analyses will provide mineralogy.

Mineral exploration occurred in eastern North Dakota from 1964 until 2010 with poor subsurface knowledge. Acquiring

high resolution aeromagnetic and gravity data combined with core data will allow geologists to define the Precambrian basement geology of eastern North Dakota with much greater detail than currently possible. This in turn may lead to investment in mineral exploration and discoveries of minerals critical to the economy of the United States for decades to come.

**TABLE 1.** List of most current aeromagnetic surveys flown in North Dakota depicted in figure 1, listing flight spacing and altitude (AG = feet above ground, B = height in feet based on barometer) which determines resolution. The new high-resolution aeromagnetic survey over eastern North Dakota will have a flight spacing of about 0.25 miles (400 meters) and nominal altitude of 328 feet above ground (100 meters). Edited from: [https://pubs.usgs.gov/of/2003/ofr-03-249/html/nd\\_indtab.html](https://pubs.usgs.gov/of/2003/ofr-03-249/html/nd_indtab.html) (retrieved April 4, 2026).

| No   | Type  | Name                       | Flown By | Date Flown  | Spacing  | Dir | Altitude | Datum         | Publication   |
|------|-------|----------------------------|----------|-------------|----------|-----|----------|---------------|---------------|
| 4041 | M-Dz  | Northeast Mt.-Western N.D. | Airmag   | 09/80       | 3 mi.    | E-W | 4000 B   | IGRF75, 59059 | 81-434        |
| 4042 | M-D   | South-central North Dakota | Airmag   | 09/80       | 3 mi.    | E-W | 3500 B   | IGRF75, 59028 | 81-433        |
| 4043 | M-Dz  | Raub                       | Airmag   | 09/80       | 3 mi.    | E-W | 3500 B   | IGRF75, 59165 | 81-434        |
| 4136 | M-DP  | Standing Rock              | Airborne | 09/85       | 0.62 mi. | E-W | 300 AG   | IGRF80        | Unpublished   |
| 4251 | M-D   | NE North Dakota            | Spectra  | 11/00-02/01 | .25 mi.  | E-W | 500 AG   | DIGRF         | Unpublished   |
| 6099 | M/R-D | Dickinson-Lemmon           | GeoData  | 09/78       | 3 mi.    | E-W | 400 AG   | IGRF65        | GJBX-138(79)  |
| 6133 | M/R-D | Minnesota Project          | GeoMet.  | 08/79-09/79 | 6 mi.    | E-W | 400 AG   | IGRF75        | GJBX-013(80)  |
| 6173 | M/R-D | N.-cent. Great Plains      | GeoData  | 07/80-09/80 | 6 mi.    | E-W | 400 AG   | IGRF75        | GJBX-067(81)+ |
| 6174 | M/R-D | Eastern Dakotas            | Aero     | 07/80-10/80 | 6 mi.    | E-W | 400 AG   | IGRF75        | GJBX-353(81)+ |
| 6188 | M/R-D | Montana-North Dakota       | HighLife | 08/80-10/80 | 6 mi.    | E-W | 400 AG   | IGRF75        | GJBX-180(81)  |



**FIGURE 4.** Bouguer Anomaly Map of the NW corner of Pembina County, the northeastern most county in North Dakota. Red dots are historical gravity data stations and black dots are from the recent, 2025, survey. Note the increased data density of the new survey. Red stars represent wells with core from the Precambrian basement.



*"Earth MRI is mapping the critical minerals needed to drive the U.S. economy and bolster national security. The North Dakota Geologic Survey is helping with the work of the nation – and adding to state knowledge crucial to the resource economy."*

Jamey Jones, Science Coordinator  
for the USGS's Earth MRI

*"The North Dakota Geological Survey is appreciative of the opportunity to partner with the U.S. Geological Survey in an effort to generate much needed data on the Precambrian rocks in eastern North Dakota. The half dozen or so companies that have explored for various minerals in these basement rocks over the last 60 years would have greatly benefited from the information that will be generated by this project."*

Ed Murphy, North Dakota State Geologist

The U.S. Geological Survey plans low-level airplane flights over eastern North Dakota and small nearby areas of Minnesota and South Dakota to image geology using airborne geophysical technology. The survey is scheduled to begin Monday, June 15 and will continue into the fall, weather and other flight restrictions permitting.

The flights are a collaborative effort between the USGS and the North Dakota Geological Survey. The USGS Earth Mapping Resources Initiative is a national effort to modernize the nation's maps of geology and mineral resources and to identify energy and groundwater resources and natural hazards.

The survey is designed to map buried crystalline rocks in a region known to have critical mineral potential. However, the regional geology is poorly understood, with rocks of interest being entirely concealed under younger rocks.

The planned survey includes magnetic and radiometric data collected from fixed-wing aircraft along flight lines spaced 400 meters apart and a nominal terrain clearance of 100 meters. The USGS has contracted with Sanborn Geospatial to collect the airborne data. Their small fixed-wing aircraft will be equipped with an elongated "stinger" that extends from the main cabin which houses sensors that collect data. These scientific instruments are completely passive with no emissions that pose a risk to humans, animals, or plant life. No photography or video data will be collected.

The aircraft will be flown by experienced pilots who are specially trained and approved for low-level flying. These pilots work with the FAA to ensure flights are safe and in accordance with U.S. law. The surveys will be conducted during daylight hours only.

Flights will be based out of several regional airports, including Barnes County, Casselton, Kindred, and Wahpeton Airports and fly over parts of 28 counties: Barnes; Brown (SD); Cass; Clay (MN); Dickey; Eddy; Foster; Grand Forks; Griggs; LaMoure; Logan; Marshall (MN); Marshall (SD); McPherson (SD); Nelson; Norman (MN); Polk (MN); Ramsey; Ransom; Richland; Sargent; Steele; Stutsman; Traill; Traverse (MN); Walsh; Wilkin (MN).

The survey fits into a broader effort by the USGS, the North Dakota Geological Survey, and other partners—including private companies, academics and state and federal agencies—to modernize our understanding of the Nation's fundamental geologic framework and knowledge of mineral resources. The Earth Mapping Resources Initiative includes airborne geophysical surveys like this one, geochemical reconnaissance surveys, topographic mapping using LiDAR technology, hyperspectral surveys, and geologic mapping projects. The data collected will be made freely available to the public on the USGS ScienceBase website.

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# THE 33RD WILLISTON BASIN PETROLEUM CONFERENCE

BY ED MURPHY

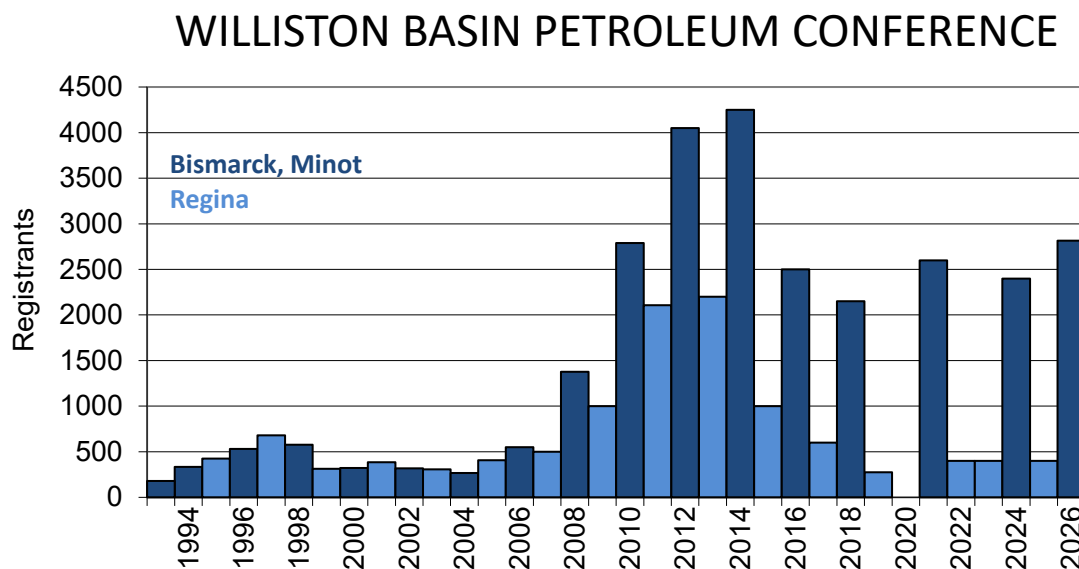
In 1992, geologists with the North Dakota Geological Survey and the Saskatchewan Geological Survey saw the need for sharing information across the international border on the relatively new technology of horizontal drilling. They determined the best way to do that was through an annual conference that would alternate between Regina and either Minot or Bismarck. Thus was born the International Williston Basin Horizontal Well Workshop, its title was changed to the Williston Basin Petroleum Conference in 2006. The first two conferences, 1993 and 1994, were held in Minot and then after the conference was held in Regina in the odd-numbered years and in either Bismarck or Minot in the even-numbered years. The North Dakotans preferred the even-numbered years because the state legislature typically meets from the first week of January through the third or fourth week in April during the odd-numbered years, creating an added burden to conference planning in those years.

In May of this year, we held the 33rd Annual Williston Basin Petroleum Conference. Thirty-three years of conference longevity is considered a significant milestone for any annual conference; this is especially true for a conference I suggested that we end in 2005. ND Department of Mineral Resources Director Lynn Helms had just appointed me State Geologist when I told him I thought we should consider either ending the conference or bringing in the North Dakota Petroleum Conference as partners. For the previous 12 years, Survey geologists had spent a considerable amount of time on conference planning, including lining up technical talks and posters as well as booth displays, even in the odd-numbered years when the conference was held in Regina. Lynn agreed we should discuss the issue with Ron Ness, the President of the ND Petroleum Council. Convincing Ron to partner with

us was one of the easier tasks I have ever been involved with. As it turns out, some of his board members had suggested to him the previous year that the Petroleum Council become involved in the conference.

It did not take long to see the impact the addition of Lynn Helms and the ND Department of Mineral Resources along with Ron Ness and the ND Petroleum Council (just a two-person operation at that time) would have on the conference. Conference attendance in 2006 was double that of the 2004 conference. In fact, conference attendance would roughly double each time it was held in North Dakota from 2006 through 2012 before peaking at 4,250 attendees in 2014 (fig. 1). Not bad for a conference that started with 200 attendees in 1993. Since 2014, the conferences in Bismarck have averaged approximately 2,500 attendees. The first 10 years of the Dept. of Mineral Resources and Petroleum Council's involvement required an amazing amount of planning as the conference moved from one venue to another. It was not until the last ten years that it settled into the newly expanded Exhibit Hall in the Bismarck Event Center, and the meeting rooms and booth space remained the same from conference to conference.

The combination of Lynn and Ron's managerial skills, along with a little bit of help from the Bakken play, has made the Williston Basin Petroleum Conference one of the most successful oil and gas conferences in the nation for the last 20 years. Lynn Helms retired after the 2024 conference, but Ron Ness and the ND Petroleum Council (currently with a staff of seven) carried on the tradition. The result was another very successful conference this year with more than 2,800 people in attendance.



**FIGURE 1.** Registration numbers for the Williston Basin Horizontal Well/Petroleum Conference from 1993 – 2026. There was no conference held in 2020 due to the COVID-19 pandemic. Registration numbers for the 2022, 2023, and 2025 conferences in Regina are estimates.



# FARGO GEOLOGY UNDERFOOT IN FARGO, NORTH DAKOTA

BY FRED J. ANDERSON

When one is out and about in downtown Fargo, enjoying the exciting variety of local shops, restaurants, and entertainment options, it's easy to overlook that at one time this area was covered by the southern reach of an expansive\* glacial lake. This lake, glacial Lake Agassiz, was present at its southernmost extent in southeastern North Dakota around 11,000 years ago. The lake left behind a thin blanket of offshore silts and clays that overlie clayey subglacial sediments (commonly referred to as glacial till or sometimes boulder clay) emplaced by repeated glacial ice advances (as many as seven) occurring across the region (fig. 1) during the Pleistocene or what we may more commonly refer to as the ice age.

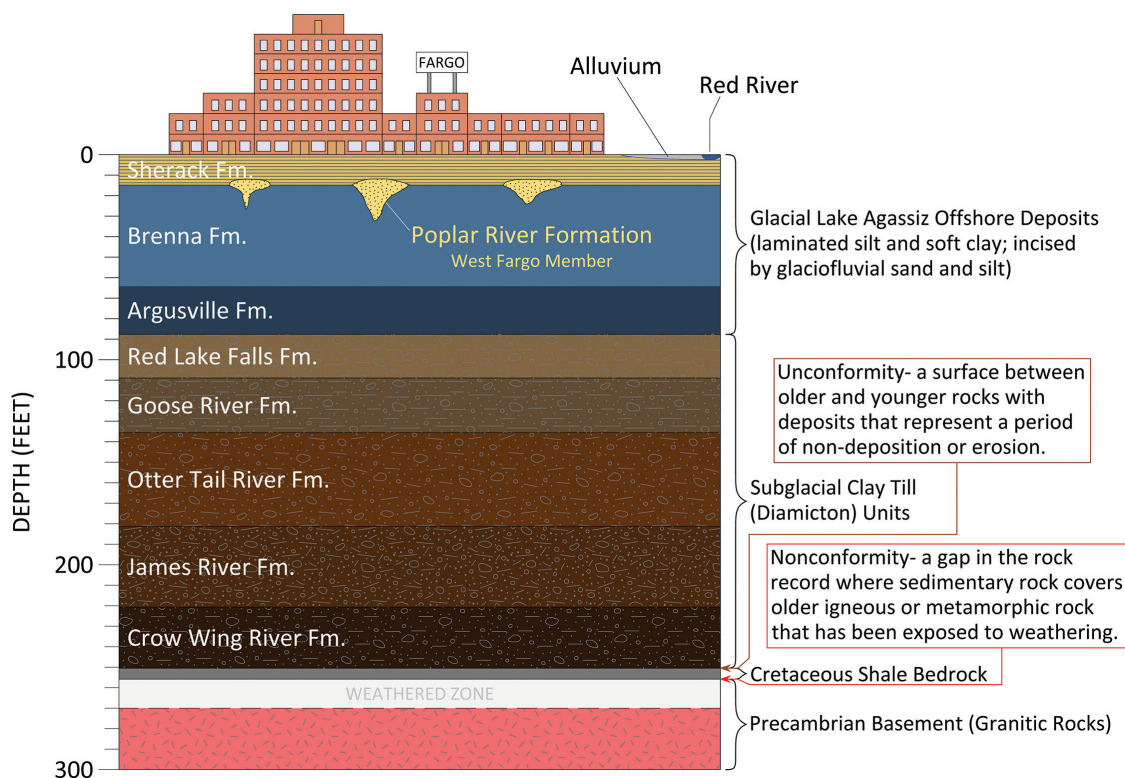
Beneath this blanket of glacial sediments lay localized remnants of Cretaceous age shale that cover the underlying

Precambrian basement (dominantly granitic rocks) when this area was occupied by a large inland sea known as the Cretaceous interior seaway. Most of the upper surface of Precambrian rocks has been weathered into a grayish-white kaolinic clay, as recorded in numerous drilling records and rock cores collected in this area.

\* For a brief discussion of the extent of glacial Lake Agassiz and some of the landforms left behind, refer to the July 2022 *Geo News* article: Icebergs in North Dakota and the Curious Ice Drag Markings of Glacial Lake Agassiz, p. 1-4.

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**FIGURE 1.** Generalized stratigraphy of geologic units beneath the City of Fargo, North Dakota. Precambrian granitic rocks are overlain nonconformably by Cretaceous age shales in some locations. In others, the basement is directly overlain unconformably by glacial deposits. Pleistocene subglacial units unconformably overlie bedrock shale and may be separated into as many as five different units representing different glacial ice advances over the area. Silts and clays of the Sherack and Brenna Formations overlie the subglacial tills and were deposited in the offshore environments of glacial Lake Agassiz. Glaciofluvial sediments of the West Fargo Member of the Poplar River Formation incised into the former lake floor comprised of Brenna Formation clays, later covered by the Sherack Formation. Formal stratigraphic names are labeled on their respective units as described in Harris and others (2020).



# NORTH DAKOTA'S GLACIAL LANDFORMS: ICE-THRUST “MOUNTAINS” OF CENTRAL NORTH DAKOTA

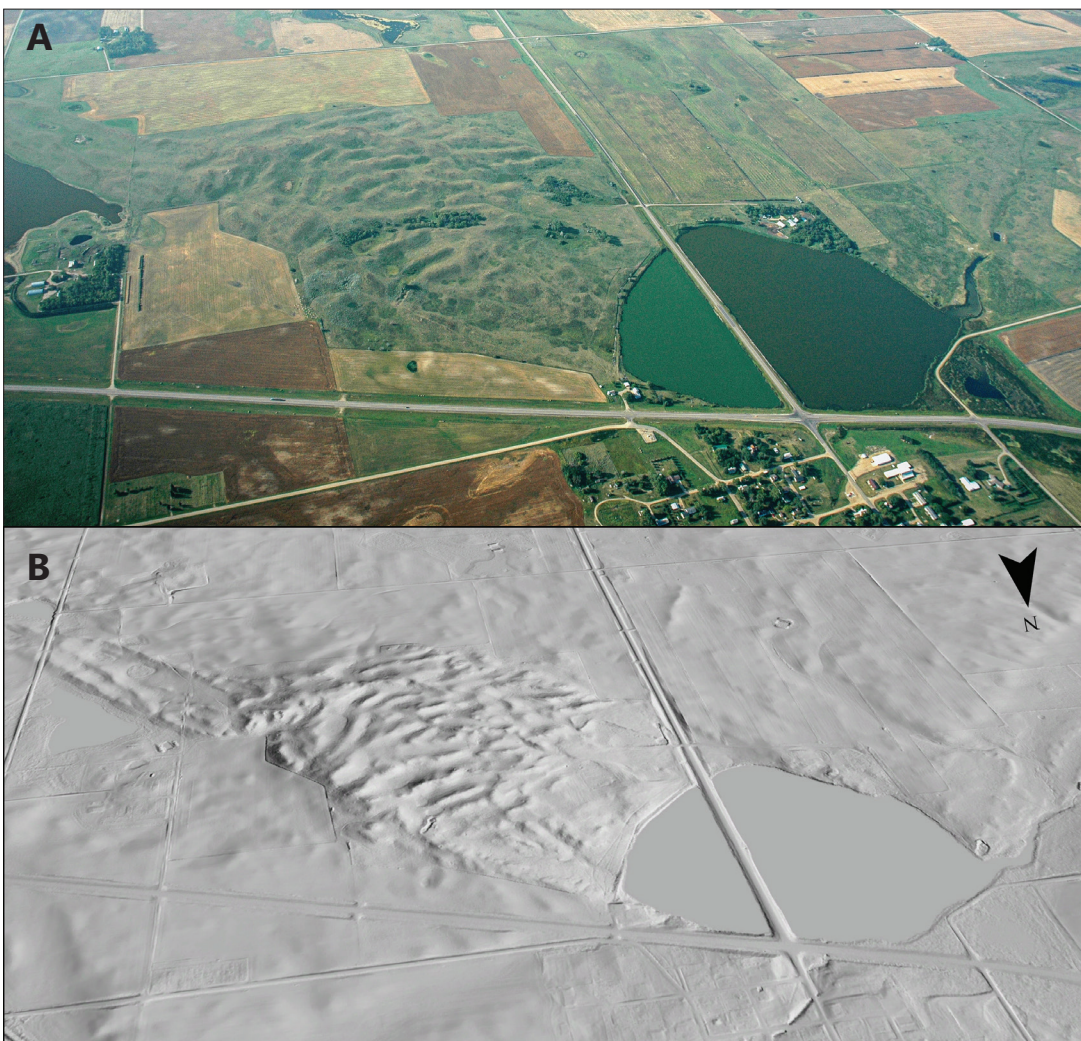
BY BENJAMIN YORK

*This is the first of many North Dakota Geological Survey Geo News articles that will cover different glacial landforms from across the state. Some will address specific locations, while others will focus on larger glacial-related mechanics.*

In the last newsletter, I discussed the formation of the Turtle Mountains on the North Dakota—Canada border (York, 2026). This article examines most of the remaining “mountains” in North Dakota. Every “mountain” in North Dakota has its origin tied to the recent Wisconsin glaciation episode, except for the Killdeer and Turtle Mountains. The Killdeer and Turtle Mountains both began as erosional outliers that resembled mesas. However, the most recent glaciation buried the original bedrock of the Turtle Mountains (York, 2026). The remaining mountains in the state have one thing in common: they are the product of the glaciotectionic process of ice thrusting.

Three main types of glaciotectionic ice-thrust mechanics are identified in North Dakota: “1) roughly equidimensional hills containing thrust masses located down-glacier from a source depression of similar size and shape (hill-hole pairs); 2) transverse or imbricate ridges above overturned folds or at the ends of thrust slabs; and 3) irregular, complex thrust forms” (Bluemle, 1992).

The first type, hill-hole pairs, as the term implies, consists of an often isolated “hill” made of material crumpled and thrust by either the edge or base (near the edge) of the advancing glacier. The source of this material, the “hole,” is a depression up-glacier from the hill that normally contains a lake. Because the hill and hole are normally the same size and shape, the pairs can be reliably identified. One of the most notable hill-hole pairs in North Dakota is near the town of Anamoose in McHenry County (fig. 1). In this case, a



**FIGURE 1. (A)** Aerial photograph of a hill-hole pair just outside Anamoose, North Dakota, in McHenry County. The depression, now occupied by Steele Lake, is roughly the same size as the adjacent elevated terrain (Photograph looking to the south by Anderson, NDGS 2005). **(B)** Corresponding view using a 2x vertically exaggerated QL2 LiDAR (flown in 2020) hillshade; linear eskers in the upper left are more clearly visible in the hillshade.

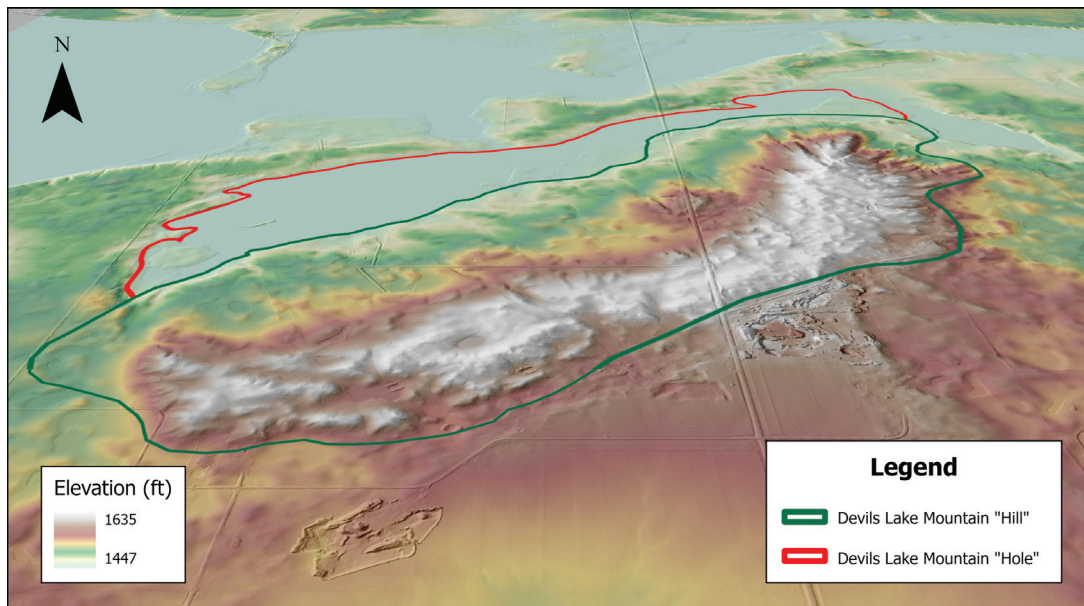


single block of material was moved to the southeast, leaving behind a depression that is now occupied by Steele Lake. When glaciotelectonics was first studied in North Dakota in the 1960s, this type of ice thrusting was briefly called an “anamoose,” but grammatical issues ultimately prevented its adoption (Bluemle, 1979). “Mountains” of this type include Devils Lake Mountain in southern Ramsey County (fig. 2) and Blue Mountain in Nelson County (fig. 3). Both are associated with the complex of ice thrusts that created the large depression that is now occupied by Devils Lake and Stump Lake (Bluemle, 1992).

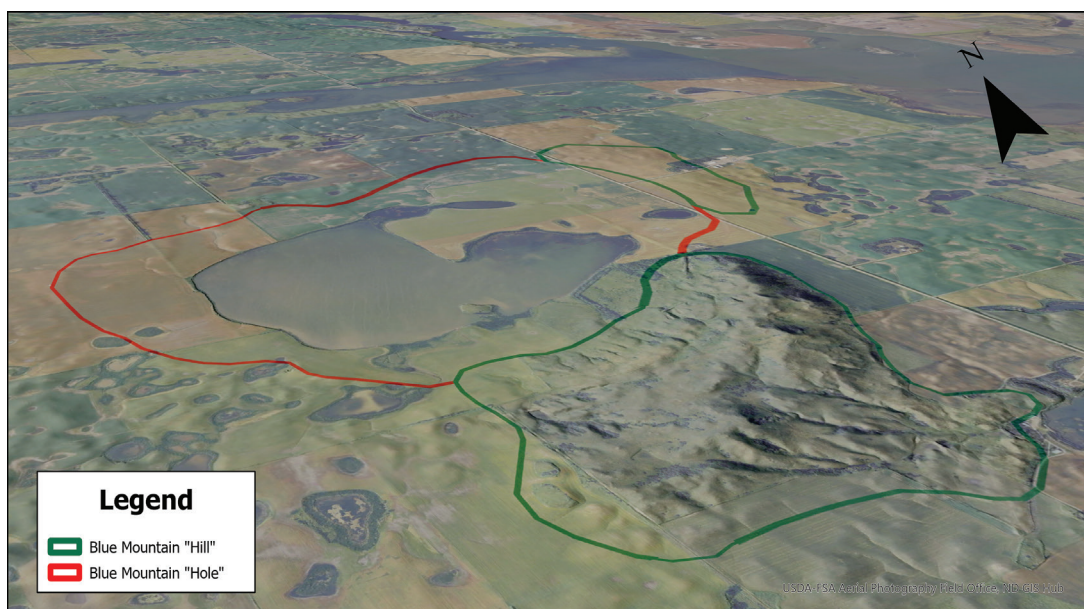
The second type of ice thrust, rather than transplanting material and leaving a depression, shoves material into transverse ridges formed as overturned folds or imbricated thrust slabs (Bluemle, 1992). This type tends to be oblong compared to the hill-hole ice thrust. Its long axis, parallel to the ice margin and a mile or more in length, consists of multiple smaller ridges. The altered material is typically 90 to 300 feet thick and dips up-glacier between 30 and 80

degrees (Clayton and others, 1980). The material is generally older glacial sediment beneath the glacier that has been reworked; however, because there was no preexisting bedding, these structures are not well preserved. The best-preserved transverse ridge ice-thrusts consist of lake or river sediment of Pleistocene age, along with some Cretaceous or Paleocene rock. The Prophets Mountains, one of the largest ice-thrust complexes in the state, in western Sheridan County are a well-preserved example of this type of ice thrust (fig. 4). Although they are composed mostly of imbricated glacial till, contorted Cretaceous sandstone and Paleocene sandstone and shale are exposed in roadcuts. These formations are roughly 300 feet higher than those identified in nearby test holes (Bluemle, 1992).

The third type of ice thrust is a combination of the previous two types and consists of irregularly distributed hills, ridges, and depressions. Terrain is highly variable, and the associated depressions created by material accumulation are difficult to identify.

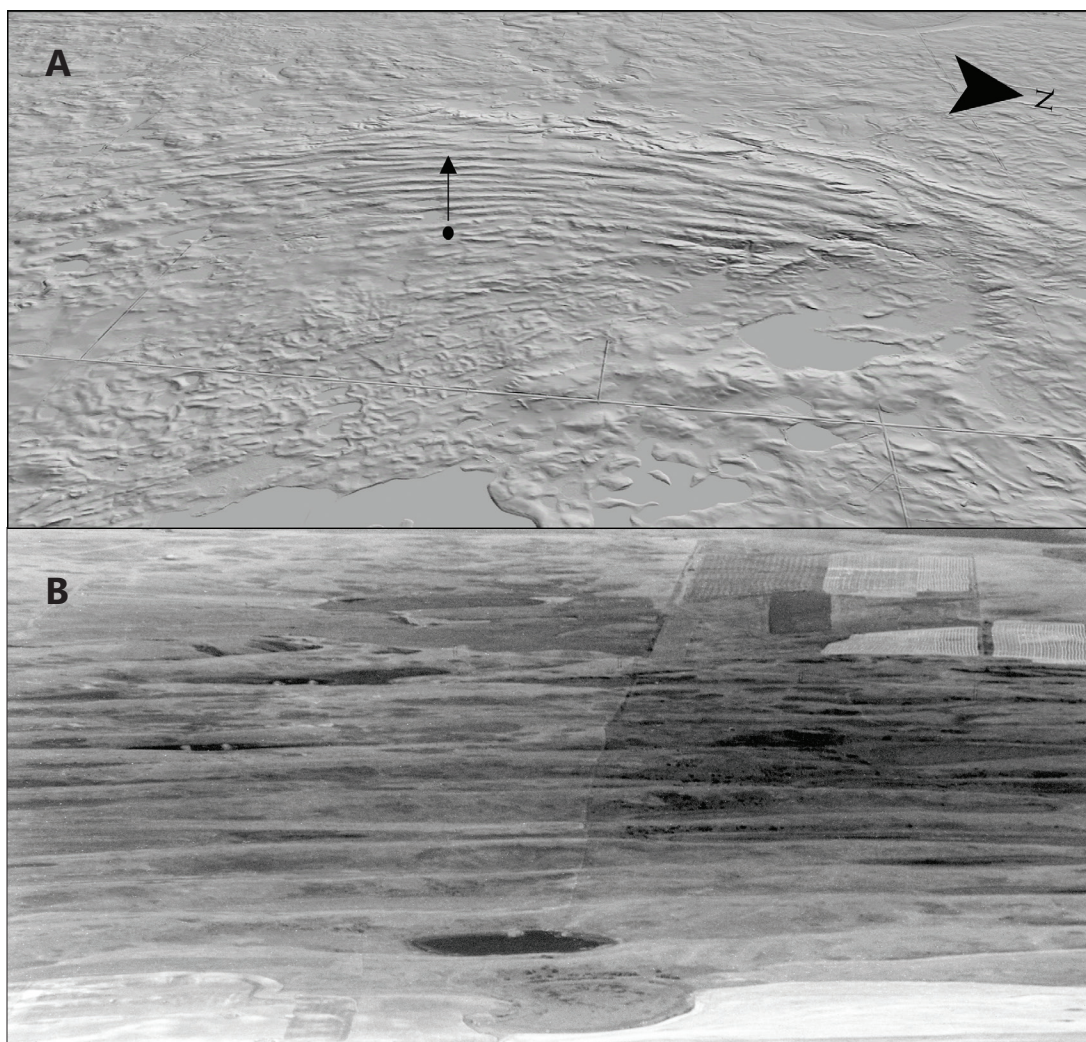


**FIGURE 2.** One-meter digital elevation model draped over a 2x vertically exaggerated one-meter LiDAR (flown in 2021) hillshade of Devils Lake Mountain in southeastern Ramsey County, just south of Devils Lake. There is nearly a 200-foot elevation difference between the “hole” lake to the northwest and the summit of the Devils Lake Mountain “hill.” Some of the material may have originated from excavation associated with the formation of Devils Lake.



**FIGURE 3.** Partially transparent 2024 USDA NAIP imagery over a 2x vertically exaggerated QL2 LiDAR (flown in 2020) hillshade of Blue Mountain and the lake to the north. The “hole,” now partially filled by a small lake, is a broad, shallow depression. Devils Lake Mountain and Blue Mountain exhibit a corresponding hill-hole pairing aligned along a northwest–southeast trend.





**FIGURE 4. (A)** One-meter LiDAR (flown in 2020) hillshade at 2x vertically exaggeration of the Prophets Mountains in western Sheridan County. This is a well-preserved example of imbricated ridges oriented parallel to the glacial margin and perpendicular to ice movement. **(B)** Low-angle aerial photograph, looking west from the black point in Figure 4a, highlighting the relatively regular 150–200-foot spacing of the transverse ridges (Photograph by NDGS).

Ice thrusts in North Dakota were initially identified by aerial photographs and later confirmed with drill hole data showing that Pleistocene sediment, or Paleocene and Cretaceous rock overlain by glacial till, exhibited folding or displacement. Later, it was deduced that ice thrusting primarily occurred when certain hydrogeologic and hydrologic conditions were met (Clayton, 1977). Glacial movement opposite to northeastward regional drainage, combined with the immense weight of the ice on local aquifers, resulted in elevated pore pressure (Bluemle and Clayton, 2006). A large volume of groundwater accumulated at the margin of the glacier as it melted. Coupled with the extreme weight of the ice, this groundwater forced sediment and rock upward in order to release pressure in the confined aquifer. Water would escape during pressure release, often lubricating the material and allowing the mass to move a short distance. The escaping water would also sometimes form eskers at the down-glacier end of the thrust body of material (fig.1) (Clayton, 1977).

The hill-hole pairs near Anamoose, Devils Lake Mountain, Blue Mountain, and the Prophets Mountains are just a few examples of the nearly 200 ice-thrust features identified in Clayton and Others' 1980 Geologic Map of North Dakota; many more likely remain undocumented without extensive

drilling. Additional ice-thrust features occur primarily along the Missouri Coteau and south of Devils Lake. When traveling through the glaciated region of central North Dakota, keep an eye out for large out-of-place hills, which are likely ice-thrust features and serve as reminders of the immense weight of ice that once covered the region.

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# NEW PUBLICATIONS

All Survey publications (maps, posters, and reports) are available for free download from our website (<https://www.dmr.nd.gov/dmr/ndgs/publications>).

## COUNTY LANDSLIDE MAPS

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Anderson, F.J., 2026, Offshore Glaciolacustrine Deposits of Glacial Lake Agassiz: The Brenna-Argusville Formation in Richland County, North Dakota, North Dakota Geological Survey, Geologic Investigation No. 292, 1:125,000.

## LANDSLIDE 24K MAPS

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Dahle, J.R. and Maike, C.A., 2026, Areas of Landslides Epping Quadrangle, ND Quadrangle: North Dakota Geological Survey 24K Map Series No. Eppg - I3.

Dahle, J.R. and Maike, C.A., 2026, Areas of Landslides Fort Yates SE Quadrangle, ND Quadrangle: North Dakota Geological Survey 24K Map Series No. FtYt SE - I3.

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Geothermal Resources: Ned Kruger (GS)

Oil and Gas Permits: Todd Holweger (OG)

Paleontological Resources: Clint Boyd (GS)

Petroleum Engineering: Jared Thune (OG)

Seismic: Tom Torstenson (OG)

Subsurface Minerals: Ned Kruger (GS)

UIC Class II: Ashleigh Thiel (OG)

UIC Class III: Ned Kruger (GS)

Solid Waste Disposal: Fred Anderson (GS)

Field Supervisors: Dickinson - Nicole Ewoniuk (OG),

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Oil & Gas Measurement: Allen Christensen (OG)