NDGS NEWSLETTER

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COVER PHOTO

The photo on the cover shows part of the crew excavating 35-million-year-old mammal bones from the Fitterer Quarry south of Dickinson, Stark County, in June, 1984. The partially exposed bone horizon illustrates the high concentration of fossils preserved beneath a channel sandstone (Fitterer Bed) in the Dickinson Member of the Oligocene Brule Formation. Most of the exposed bones in the photograph are from the hornless rhinoceros, Caenopus. Concentrations of fossil mammal bones, from numerous taxonomic groups, are rarely found in Oligocene age sediments in western North Dakota making the Fitterer site one of the most significant occurrences in the state. The animals were probably washed onto a sandbar in a river and covered quickly with sediment when the river migrated over the decayed carcasses. Photo by John W. Hoganson.

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OIL PUMPER DONATED TO NDGS

This oil pump was donated to the North Dakota Geological Survey by Mr. Earl Schwartz, a North Dakota oilman. We have installed the pump on the lawn of the Wilson M. Laird Core and Sample Library. The pump is equipped with an electric motor so we can, when we wish, simulate a pumping well. Our well, however is only 10 feet deep and produces only an oilfield atmosphere.

THE FITTERER QUARRY: AN UNUSUAL AND SIGNIFICANT OLIGOCENE MAMMAL FOSSIL OCCURRENCE IN STARK COUNTY

--John Hoganson

The North Dakota Geological Survey and the Manitoba Museum of Man and Nature are engaged in a cooperative program to recover and study a variety of 35-million-year-old mammal fossils from the Oligocene Brule Formation in Stark County, North Dakota. The project is directed jointly by George Lammers, curator of paleontology at the Manitoba Museum in Winnipeg, and John Hoganson of the NDGS. Although isolated occurrences of various species of vertebrates have previously been reported from the Brule in North Dakota, no major concentration of bones from a diverse fauna had been discovered, or at least publicized, until this recent find about twelve miles south of Dickinson. The discovery was made by a field party from the Manitoba Museum. George Lammers subsequently contacted the NDGS for professional and technical assistance. Lammers' inquiry was timely because cooperative paleontological studies between out-of-state researchers and the NDGS is one of the directions the NDGS has hoped to take in our recently initiated effort to expand our involvement in the study of North Dakota fossils. The NDGS's paleontology program was, in part, initiated because of our concern for the past loss of significant North Dakota fossil specimens to out-of-state institutions.

The vertebrate fauna of equivalent age from the Badlands of South Dakota is relatively well known, but little attention has been given to the North Dakota fossils. We expect that our current study will be useful, not only in comparing the fossil faunas between the two states to see if there are paleobiogeographic differences, but also to expand our knowledge of the types of beasts that inhabited western North Dakota 35 million years ago and to determine the type of environment in which they lived.

Three excavations have been made at the fossil site to date, each lasting about two weeks. The field parties have consisted of George Lammers, Chris Lammers, Jack Dubois (MMMN), Leon Kinsbergen (MMMN), Bill Blight (MMMN), Shelly Hoganson, John Hoganson, and numerous University student volunteers from the Manitoba Museum. The dig began with extraction of a few bones from a ravine and progressed to a major quarrying operation initially opened with a bulldozer. The fossil exposure now consists of a six-inch-thick bone bed about twenty feet long. The bone horizon is remarkably rich with specimens intertwined and stacked on top of one another. Extraction of the bones has, therefore, been difficult because of the problem in finding a convenient place to remove manageable sized field packages (blocks containing bones still in the sediment are usually encased in plaster to prevent breakage and facilitate extraction). Various types of skeletal elements (i.e., vertebra, limb bones, ribs, jaws, skulls, etc.) have been recovered in an excellent state of preservation. Although the majority of specimens have been remains of the rhino, Caenopus (ten lower jaws with teeth have been found, along with three skulls and numerous limb bones and vertebra), Mesohippus (the three-toed horse), giant pig, camel, rabbit, fish, various rodents, etc., have also been found. Two new species of shrew were discovered through washing and screening sediment from the quarry. Preliminary indication is that these animals lived in a riparian (river bank) habitat, were washed onto a sand bar in the river, and were subsequently quickly buried during migration of the river channel.

Of particular interest to me are the invertebrate fossils associated with the bones. Five species of snails (three fresh water and two terrestrial), fresh-water ostracods, beetle pupal cells, and bee larval cells have been found in proximity of the quarry. Plant fossils (i.e., Hackberry seeds) and fossilized mammal excrement (coprolites) also occur with the bones. These additional fossils will provide useful information in evaluating the environmental conditions in which the mammals lived.

The mammal fossils have been taken to the Manitoba Museum of Man and Nature in Winnipeg for preparation and restoration. Disposition of most of the fossils will be at that institution; however, a representative collection will be placed on permanent loan here at Leonard Hall on the University of North Dakota campus. In fact, a display of fossils from the site is currently on exhibit in the museum area of Leonard Hall. George Lammers and I are preparing a technical report of our findings from what is probably the most significant Oligocene mammal fossil site yet discovered in North Dakota. Hopefully this report will be published through and available from the NDGS soon.

Figure 1. Excavation crew at the Fitterer Quarry, June, 1984. Left to right: George Lammers, Lynn Dyck (Winnipeg high school student volunteer), Frank Herr (owner of Herr's Rock Shop, Dickinson and frequent visitor to the dig), Kim Bell (volunteer from the University of Winnipeg), Chris Lammers (MMMN volunteer), John Hoganson, Leon Kinsbergen (retired artist, MMMN volunteer and restorer of most of the fossils), Shelly Hoganson (UND anthropology student and volunteer), and John Bakkelund (volunteer and geology student at the University of Manitoba). The ninth member of the crew, Jack DuBois (chairman of Natural History, MMMN) took the photograph.

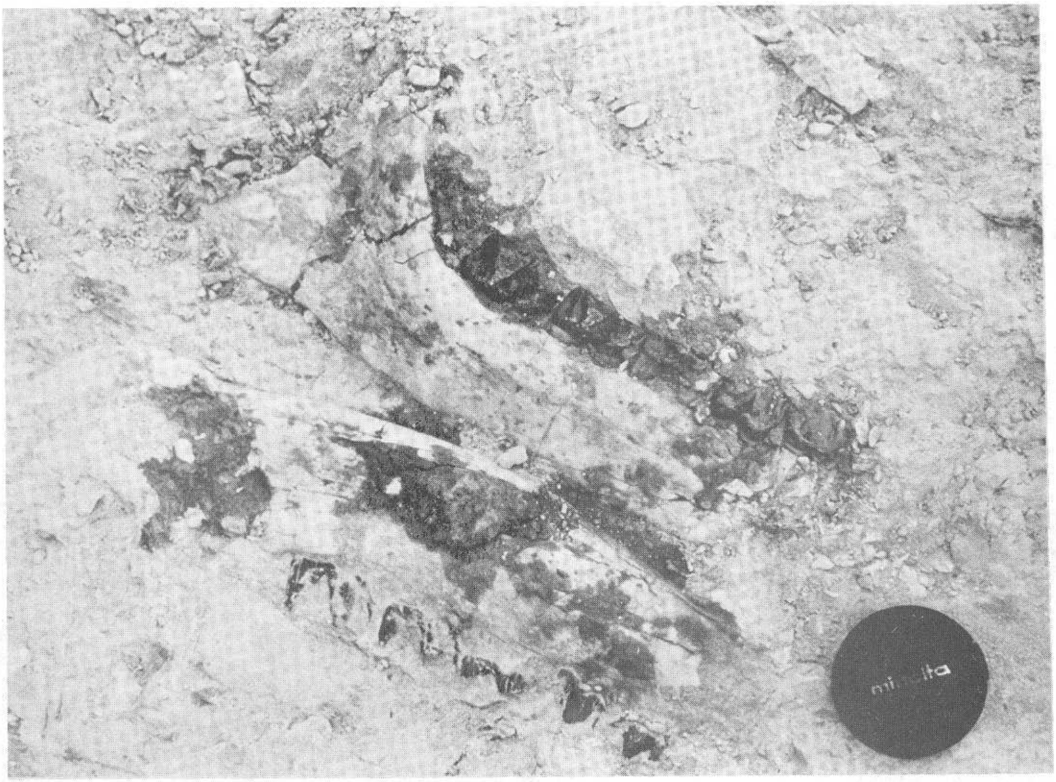


Figure 2. Partially exposed right and left lower jaws of the rhino, Caenopus.

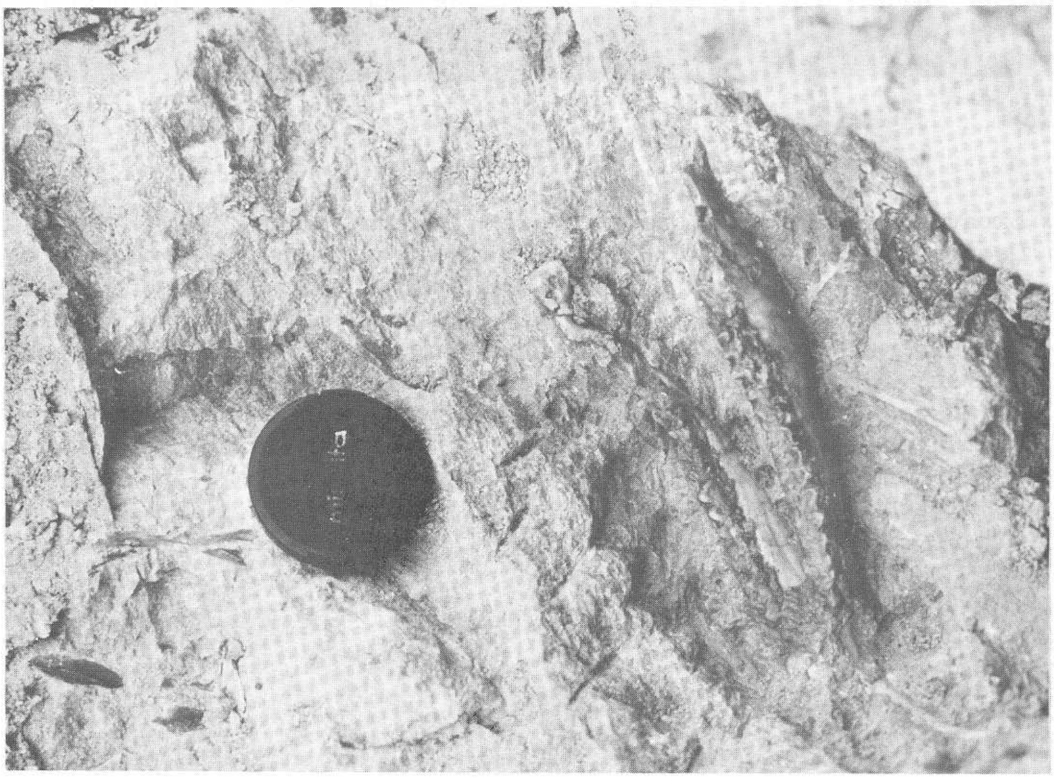


Figure 3. Partially exposed articulated lower jaws of the three-toed horse, Mesohippus.

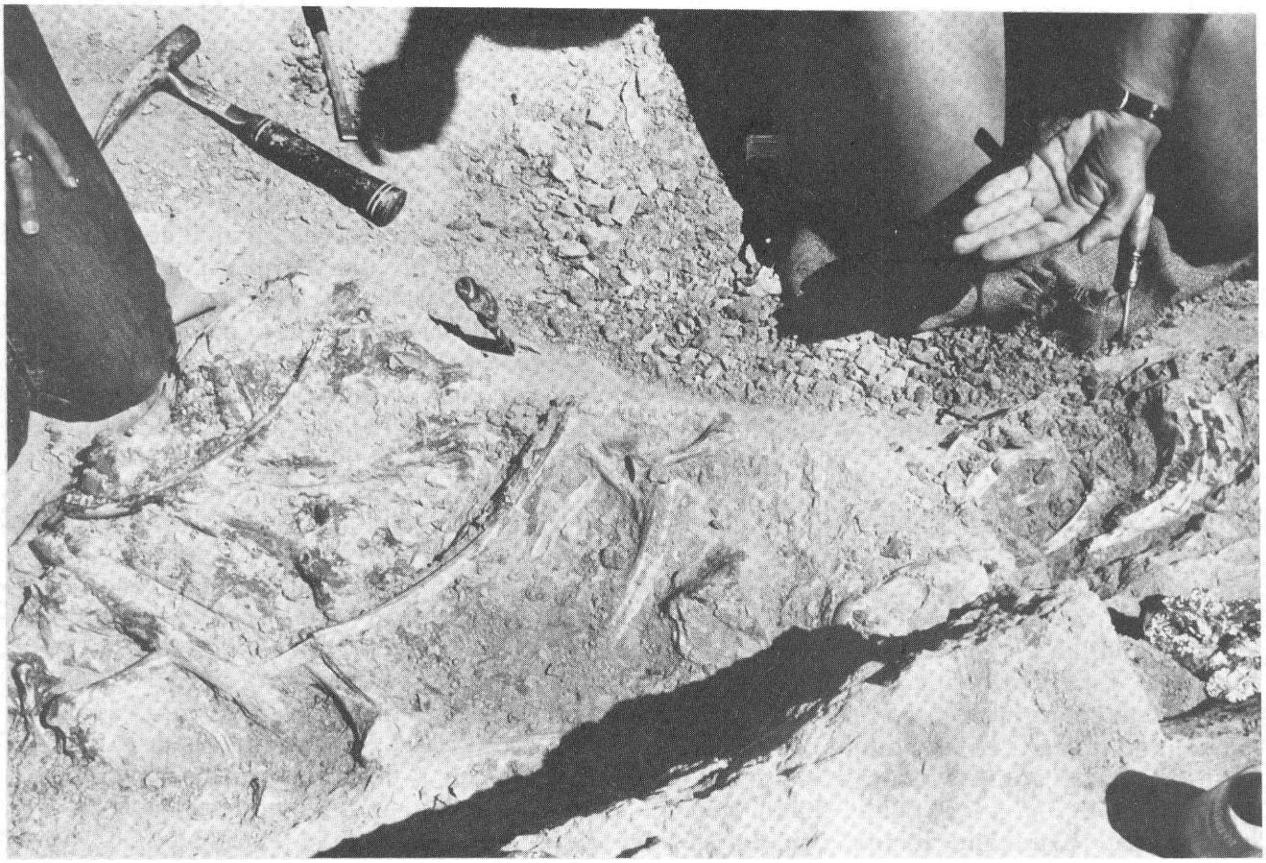


Figure 4. A portion of the exposed bone horizon. Most of the rib and leg bones on the left are rhino. Note the partially exposed lower jaw on the extreme right.

ONE-DEGREE UPDATE

--Ken Harris

It's time for an update on our one-degree surface mapping program. As some of you probably remember, this project is intended to present the surface geology of the state at a scale of 1:250,000 (¼" = 1 mile). At that scale, 21 reasonably sized maps, each covering an area of one-degree latitude by one-degree longitude, are required to cover the state. The one-degree series maps should provide a somewhat broader perspective to the geology of the state than the County Ground-water Series Bulletins (½" = 1 mile is the scale of the maps in this series), while retaining a useful level of detail. This series of maps can also provide an "atlas" of derivative studies that may include near-surface stratigraphy, bedrock geology, drift thickness, sand and gravel resources, or other special maps as required or desired.

Ed Murphy and I have been working on this project, at least part-time, for the past two field seasons. Our work in each map area includes a compilation of existing studies, interpretation of airphoto geology, test drilling, and shallow probing for sediment samples, and field checking the resulting compilation.

Ed is mapping in the area south and west of the Missouri River where the bedrock and the rattlesnakes are exposed at the surface. He is currently working on Charging Eagle Bay Map Sheet (the eastern half of the USGS Watford City, 1:250,000-scale topographic map sheet), which covers almost all of Dunn County and generous portions of McKenzie, Mountrail, McLean, and Mercer Counties. Ed plans extensive fieldwork in the area next summer.

I will be mapping north and east of the Missouri River, in the glaciated parts of the state. My work, to date, has been on the Sheyenne River Map Sheet (the North Dakota portion of the USGS Fargo, 1:250,000-scale topographic map sheet) located in the southeastern corner of North Dakota. This area consists of Richland, Ransom, and Sargent Counties plus parts of Barnes and Cass Counties. The Sheyenne River Map Sheet should be finished next summer and my plans are to complete the eastern (Lake Agassiz) map sheets before starting on areas farther west.

NEW OIL AND GAS FIELD MAPS

--David Brekke

A year-long project to recompile our oil and gas field map series has recently been completed. The maps are an improvement over the previous series in that oil and gas wells are plotted by footage. Each well is identified by permit number and is shown on the map by a symbol indicating its current status (fig. 1). Other features on the maps include field names, active field boundaries, abandoned or non-producing field boundaries, unit boundaries, and county and federal boundaries. The map series consists of 67 individual maps, each covering 12 townships at a scale of 1½" = 1 mile. Each map is posted weekly and is approximately 30" x 42" in size. Blueline print copies of the maps are available from the Survey for $1.50 per map. An index to the maps is available free of charge. An explanation of symbols used on the maps is provided with orders for maps.

Several other oil and gas maps have been recompiled. A new exploratory drilling map and new depth-of-penetration maps are available. These maps are drafted to a 1:500,000 scale (1" = approximately 8 miles). The exploratory drilling map (EX-1) shows all permitted oil and gas wells in the state not covered by the field map series. This area is approximately the eastern half of the state. The depth of penetration maps show wells that are drilled to a particular stratigraphic interval. Symbols are used to distinguish between wells penetrating to and those penetrating through a geologic system. The series includes wells penetrating Precambrian (DP-1), Ordovician (DP-2), Silurian (DP-3), Devonian (DP-4) and Madison (DP-5). Blueline-print copies of each of the above maps are available from the Survey for $1.50 per map.

Example of N.D.G.S. Oil & Gas Field Map

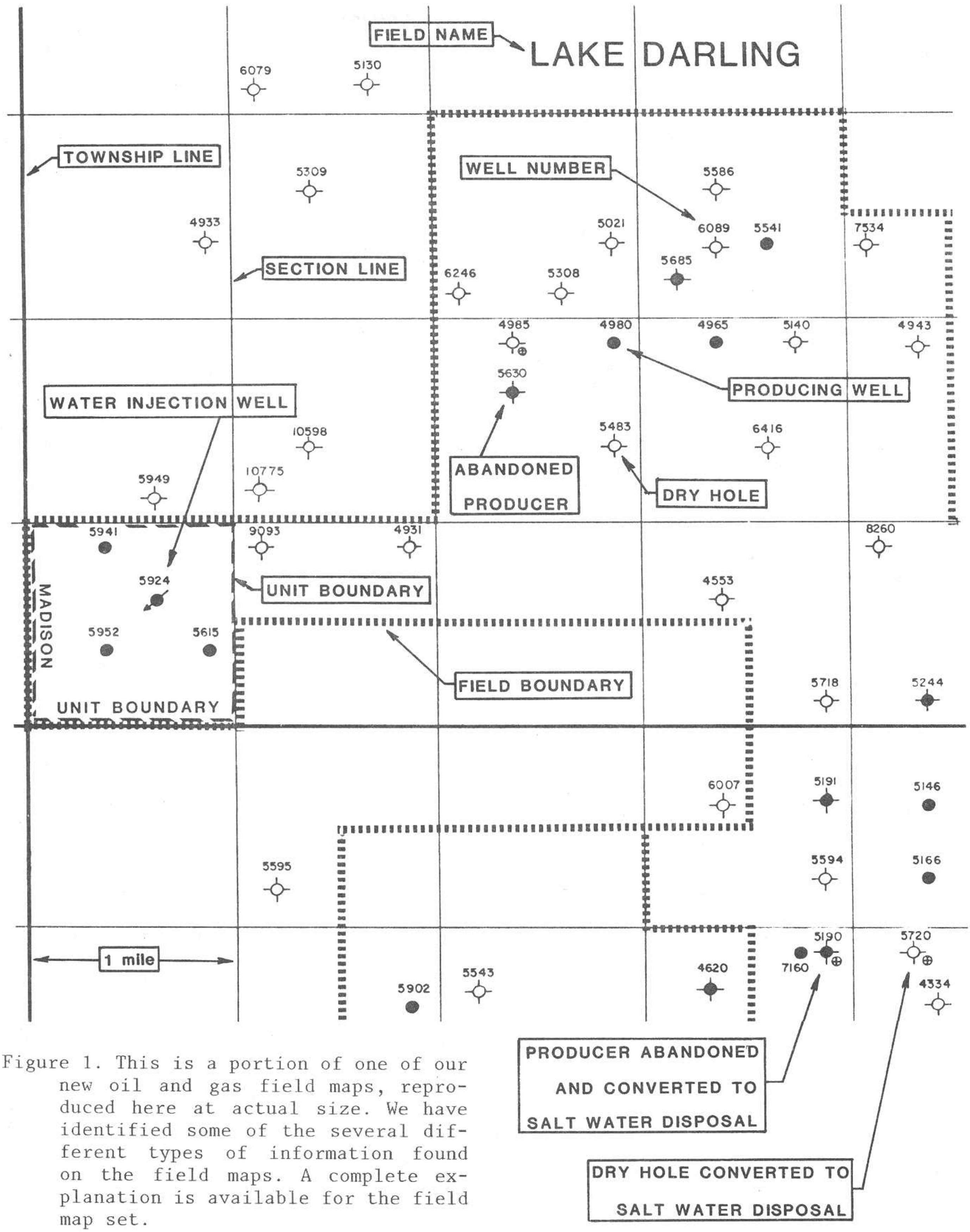


Figure 1. This is a portion of one of our new oil and gas field maps, reproduced here at actual size. We have identified some of the several different types of information found on the field maps. A complete explanation is available for the field map set.

NEW PUBLICATIONS

The following new publications were issued by the Survey since the last issue of the Newsletter in June:

Report of Investigation 82--"The Effect of Oil and Gas Well Drilling Fluids on Shallow Groundwater in Western North Dakota," was written by Edward C. Murphy and Alan E. Kehew. This report is the result of a study ordered about 4 years ago by the North Dakota State Industrial Commission. The North Dakota Geological Survey was instructed by the Industrial Commission at that time to study the possible hazards caused by the disposal of various drilling-fluid additives at oil and gas well drill sites.

Upon completing an oil or gas well in North Dakota, the drilling fluid is buried in the reserve pit at the drill site. This drilling fluid is generally very salty and contains a variety of additives, some of which include toxic trace-metal compounds. The authors concluded in their study that some of the chemicals in the pits have produced small amounts of leachate, and some of this material has reached the groundwater table. They also concluded that these leachates have not tended to move more than a short distance (less than 100 yards) from the reserve pit sites. The water immediately beneath the disposal area can be quite toxic and should not be drunk, but this degrated water has not contaminated nearby groundwater supplies and generally does not pose a danger. Apparently, the amount of drilling fluid-generated leachate that reaches the groundwater table is minimized by both adsorption onto the abundant montmorillonitic clays within the normally thick unsaturated zone and by evapotranspiration. The portion of leachate which enters the saturated zone is often diluted by mechanical dispersion.

Abandoned reserve pits in western North Dakota are generally reclaimed by trenching. This process involves the digging of trenches away from the pit and flooding them with the fluid in the pit. The authors of this report suggest that a new method of reclamation in which a snow-blower-like machine is used to blow sediment into the pit is a better procedure. The fluid is retained in the liner and has less chance to escape or spread from the immediate vicinity of the pit.

Report of Investigation 82 is 156 pages long. It can be obtained for $3.00 from the Survey.

Report of Investigation 83--"Little-Known Mid-Paleozoic Salts of Northwestern North Dakota," was written by David W. Fischer and Sidney B. Anderson. The report describes several deeply buried salt beds of Devonian and Silurian age. The salt deposits, which have not been described before in North Dakota, are laterally continuous with salt beds in Saskatchewan. An awareness of the presence of the salts may be helpful to geologists looking for oil as they design drilling and testing programs for wells in areas where the salts occur. Furthermore, a knowledge of these salts is helpful in understanding the overall geological history of the Williston Basin.

Report of Investigation 83 is 18 pages long and includes 14 figures. The cost is $2.00.

Bulletin 66, Part 1 (also designated County Groundwater Study 23)--"Geology of Emmons County, North Dakota," was written by John P. Bluemle. Reports are also available on groundwater basic data and hydrology of Emmons County. The new report describes the subsurface and surface geology, the geologic history, and the economic geology of Emmons County.

This report on Emmons County should be useful to anyone interested in knowing more about the physical nature of the materials underlying the area. Such people may be water-well drillers or hydrologists interested in the distribution of sediments that have potential to produce usable grundwater; civil engineers and contractors interested in such things as the gross characteristics of foundation materials at possible construction sites, criteria for selection of and evaluation of waste disposal sites, and the locations of possible sources of borrow material for concrete aggregate; industrial concerns looking for possible sources of economic minerals; residents interested in knowing more about the area; and geologists interested in the physical evidence for the geological interpretations.

Bulletin 66, Part 1, is 69 pages long and includes a colored geologic map at a scale of a half inch to a mile, along with 3 other plates, two of which are also colored. The report is available free of charge.

Bulletin 78, Part 3 (also designated County Groundwater Study 35)--"Groundwater Resources of Bottineau and Rolette Counties, North Dakota," was written by P. G. Randich and R. L. Kuzniar of the U.S. Geological Survey. A report is also available on groundwater basic data of the two-county area. The new report provides detailed geologic and hydrologic information needed for the orderly development of water supplies for municipal, domestic, livestock, irrigation, industrial, and similar uses.

The report includes information on the location, extent, and characteristics of the major aquifers; it evaluates the occurrence, movement, recharge, and discharge of groundwater; it estimates the quantities of water stored in the glacial and alluvial aquifers; it estimates the potential yields to wells penetrating the major aquifers; and it describes the chemical quality of the groundwater.

Maps of the bedrock topography of the two counties drawn at a scale of ½" to a mile and maps showing estimated potential yields from major aquifers are included. A map showing the potentiometric surface of aquifers in Rolette County and geologic cross sections through both counties are also included in the report.

County Groundwater Study 35 consists of 41 pages and includes six plates (maps and cross sections). The report is available without charge.

Miscellaneous Series 65--"Oil Exploration and Development in the North Dakota Williston Basin: 1982-1983 Update," was written by Sidney B. Anderson and John P. Bluemle. This report reviews North Dakota's history of oil and gas discovery and production. It analyzes the several exploration cycles the Williston Basin has undergone and reviews the development of significant oil reservoirs. The authors analyze current conditions and offer their best prognosis of future possibilities.

The report includes 17 illustrations and 4 tables to help the reader better understand the role of oil and gas in North Dakota's economy. Graphs of wildcat wells drilled annually since oil was discovered, the number of new oil pools discovered each year, annual crude oil production, average number of drilling rigs operating in the state, and the amount of oil gas and tax revenues collected by the state are included along with many other illustrations. Tables are included detailing all the new-pool discovery wells for 1982 and 1983.

This 38-page report is available for $1.00.

"Oil in North Dakota--Production Statistics and Engineering Data for 1981" is now available. This 532-page compilation of statistics includes the monthly oil and water production figures for each well operating in North Dakota during 1981 as well as total cumulative production for each well since it was drilled. Additional information is also included (gravity, gas/oil ratio, well status, runs and lease use, etc.). Statistics on oil field production and annual production are also included in the volume, which is available for $15.00.

A new North Dakota oil- and gas-field map series is now available from the North Dakota Geological Survey. These maps are drawn at a scale of 1½" to a mile. Each map in the series measures 30 by 42 inches in size and each map includes 12 townships. The information on these maps includes the locations of all oil and gas wells in the state, the current status of each well, and the location and name of each oil and gas field. An index to the 67 maps is available free of charge. Maps can be obtained for $1.50 each.

"AAPG Geological Highway Map #12"--Map of the Northern Great Plains Region. Finally, although it's not one of our publications, it is worth mentioning that the finale to the American Association of Petroleum Geologists geological highway map project, Map No. 12, has finally been published. This colored map covers the states of North Dakota, South Dakota, Iowa, Nebraska, and Minnesota. The map is drafted at a scale of 1 inch=30 miles. The map sheet includes stratigraphic columns, a physiographic map, a pre-Pleistocene bedrock geologic and tectonic map, area cross sections, and a highway mileage chart. In addition, the map includes two location maps: one to places of general geologic interest; the second locating key fossil and mineral locations within the states. Each marker from the map is keyed to a detailed description and commentary on that area.

To obtain a copy of the AAPG Map of the Northern Plains Region, write to the AAPG Bookstore, P.O. Box 979, Tulsa, Oklahoma 74101 and ask for "Catalog 672." Price is $4.50 plus shipping for single copies. Bulk shipments are less expensive per copy.

SURVEY PROFILES

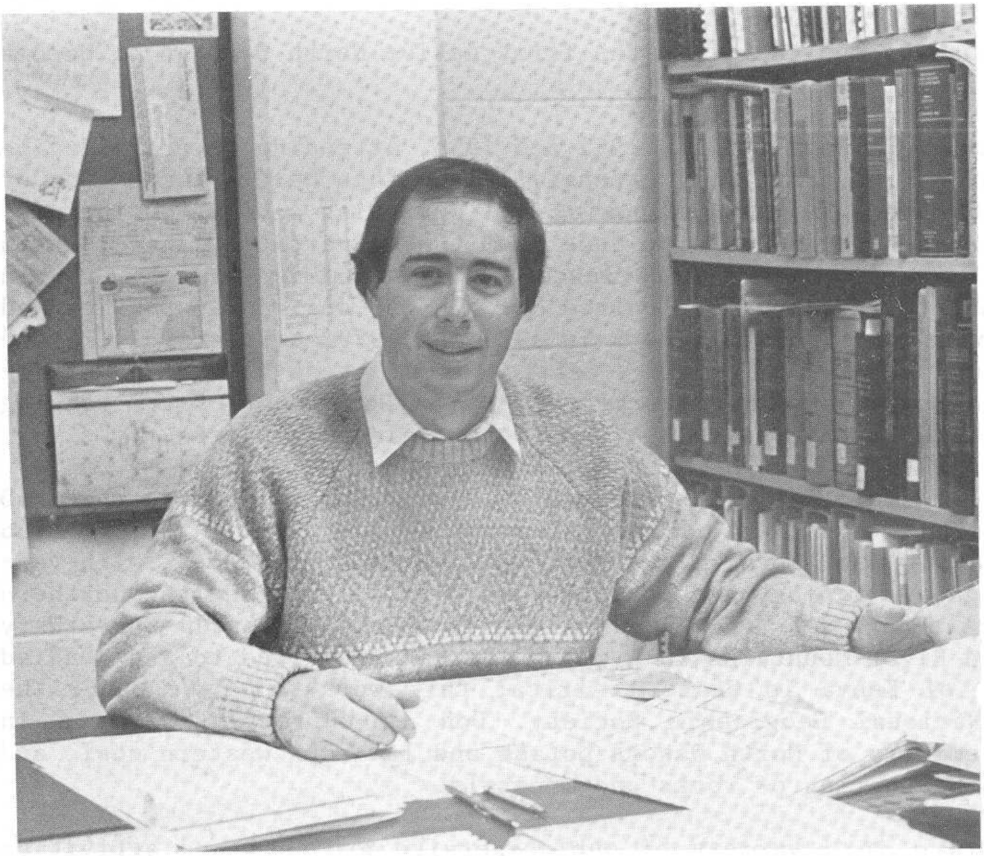
Edward C. Murphy

Edward C. Murphy joined the North Dakota Geological Survey as a geologist in May of 1980. He has been involved since then in a variety of hydrogeologic studies, studies of the Tertiary sedimentary section, and various types of groundwater research. He has also acted as a field inspector for coal exploration and reclamation for the Survey. Ed recently authored a report for the Survey on the reclamation of oil well drilling sites (see the description of this report elsewhere in this Newsletter).

Born in Illinois, Ed grew up in and attended high school in Bismarck. He has degrees from Bismarck Junior College and from the University of North Dakota (B.S. and M.S. in geology). Ed is interested in a variety of indoor and outdoor athletics, hunting, fishing, and science and wildlife photography (his color slides of western North Dakota geology are spectacular!). During part of the past summer, Ed spent some time on a bicycle tour of Ireland.

Don L. Halvorson

Don L. Halvorson has been State Geologist of North Dakota and Chairman of the Geology Department at the University of North Dakota since 1981. He is originally



Edward C. Murphy

Don L. Halvorson

from Wildrose, North Dakota and therefore the first native North Dakotan to become State Geologist.

Don served in the U.S. Navy between 1952 and 1956, attending several service schools during that time, and travelling extensively. He then held a succession of jobs in the late 1950s and early 1960s, owning and operating several businesses. After graduating with a degree in earth science from the University of Colorado in 1965, he was a high school teacher of science and mathematics and a coach in Anton, Colorado and Hulett, Wyoming. Don earned MST and PhD degrees in physics and geology from the University of North Dakota in 1971 and 1979, respectively. Since then, he has worked at a number of geology-related jobs; these have included the teaching of several courses at the University of North Dakota in topics ranging from mineralogy, crystallography, petrology, and other related subjects.

Don has done considerable geologic research on Devils Tower, Wyoming (his PhD dissertation dealt with the geology and petrology of Devils Tower). He has also climbed Devils Tower 13 times. Much of his geologic research has dealt with various aspects of the igneous geology and petrology of Devils Tower and the northern Black Hills region, although he has worked on and continues to study Quaternary deposition in the Wind River Mountains in Wyoming. He has travelled to and studied the geology of parts of Kenya in eastern Africa; this work was done under the sponsorship of the National Geographic Society. Don is currently involved in research on the geochemistry of North Dakota potash and low-rank western coal, and the rates of chemical weathering of rocks and minerals.

Don has been active in a variety of public-service projects and activities including Boy Scouts, Lions Club, Kiwanas, and numerous volunteer church activities. As State Geologist, he is a member of the Association of American State Geologists and the Interstate Oil Compact Commission. Among the professional societies he belongs to are the North Dakota Geological Society, North Dakota Petroleum Club, American Institute of Mining Engineers, Society of Economic Geologists, Geological Society of America, and Sigma Xi.

Don's wife, Dawn, has a master's degree in Theology from Chicago Lutheran Theological Seminary. Don and Dawn have 3 boys, Chris, John, and Jim. Chris is working on a PhD in physics at the University of Colorado; John is a student majoring in history at the University of North Dakota, and Jim is a student at Schroeder Junior High School here in Grand Forks.

In his capacity as State Geologist, Don Halvorson has helped to restructure the North Dakota Geological Survey since 1981 when the Legislature removed the Division of Oil and Gas from the Survey, placing it in Bismarck. The Survey is now more strictly a research-oriented agency with fewer regulatory responsibilities. Don has helped to define our new responsibilities and to point the Survey in the new directions it has taken.

DEFLATION BASIN STRATIGRAPHY--SOUTHWESTERN NORTH DAKOTA --Bob Seidel

Located beyond the glacial margin in southwestern North Dakota are a large number of small basins which are difficult to see from the ground, but which show up clearly on air photos. The basins are scattered across a wide area, but the heaviest concentration of them is in eastern Slope County. Grant and Hettinger Counties also have numerous basins. Slope County and the western two-thirds of

Hettinger County were chosen as the study area for this project to determine the occurrence of the basins and to attempt to learn whether the sediments contained in them record significant climatic fluctuations.

The largest of the basins are about 3 miles long, but the majority are less than a mile long. Few of them contain water, although many of them are wet enough to make it impossible to farm there. For this reason, the basins are often used as pasture for livestock. Many of the basins are elongated, northwest to southeast, a direction that coincides with sandblast scour marks on Paleocene chert beds in the area and suggests that the basins are the result of, or were initiated by, wind erosion. The age of the basins is not known exactly, but they are likely not older than pre- to early Wisconsinan as they occur on a stability surface that probably formed at that time.

The basins are located fairly close to the Wisconsinan glacial margin in North Dakota, so any sediments that accumulated in them during glaciation should have been affected by a steep climatic gradient. Studying these sediments should therefore yield information about the basins' geologic and climatic history and the history of the surrounding area.

Texture analyses show that the sediments in the basins are, for the most part, comprised of small particles ranging in size from fine sand to silt and clay. Larger particles are present, but they represent only a small proportion of most of the samples. Textural analysis of a sequence of cores across a basin shows relationships that substantiate the presence of standing bodies of water in these basins, if only intermittently, during past, wetter climatic periods.

In proposed shoreline/nearshore locations within the basins the sediments may consist of over 80% sand-sized particles, whereas in deeper water locations they may be nearly 100% clay-sized particles. In addition, analysis of a core may show a range of particle sizes associated with stratigraphic layers that can be differentiated with depth. Comparisons of textural changes from one core to another indicate that similar sediments occur at similar levels, not only within a basin, but from one basin to another. In general, more sand at a given horizon may indicate that that layer was deposited during a drier period of time whereas more clay may indicate a wetter period.

If the sediments in these deflation basins have shared a similar history, their mineralogic composition should reflect that similarity. X-ray diffraction analyses of the mineralogy of the sediments provided data that made it possible to construct graphs depicting changes with depth in the relative amounts of specific minerals such as quartz, feldspar, or montmorillonite. Visual inspection of the graphs shows that correlation of changes in the amounts of these minerals with depth is possible. To test this observation, computer analyses were performed on the samples. These resulted in significantly high correlation values, strongly suggesting that the changes in mineralogy with depth from core to core are not the result of random occurrence, but rather, they are systematic. Correlation of mineral composition as well as texture should therefore be possible both within and between basins.

An unexpected problem arose because of the similar character of the Tertiary bedrock and Quaternary basin sediments being studied. Since the basin sediments are derived largely from the bedrock in which they lie, it is difficult to distinguish them from the bedrock. Some of the cores bottomed in lignite or contained undisturbed lignite stringers--a good indication that bedrock had been penetrated. Texture and mineralogical analyses, as well as study of the degree of lithification of materials from other cores, indicate changes corresponding to the depths of these lignite stringers making the delineation of the bedrock-basin sediment boundary more definite.

The lignite in the bedrock also caused a related problem. The study area is surfaced primarily by Sentinel Butte Formation as well as by the Bullion Creek and Slope Formations and all of these Paleocene formations contain lignite. With erosion of the bedrock, lignite was incorporated into the younger Quaternary sediments so that radiocarbon dating of these sediments is virtually impossible. Wood fragments or other materials which could be used for dating purposes, have not yet been found.

In spite of these problems, it appears that a few tentative conclusions are possible. Texture analyses of cores used in constructing cross sections across the basins indicate that standing bodies of water have been present in these basins in the past. Changes in the sand/silt/clay ratios show that depositional environments have varied geographically and with time, and these environments are likely related to changes in past climates.

Distinct color changes are present in the sediments. These colors correspond largely to changes with time from reducing to oxidizing conditions. Some evidence exists to show that the color changes may be closely related to textural changes; this might help to substantiate possible climatic shifts from wetter to drier conditions resulting in shifts in depositional processes. The reducing environments would be associated with the presence of smaller silt- and clay-sized particles, whereas the oxidizing environments are more closely related to larger sand- and silt-sized particles. Two or three highly oxidized zones occur at comparable levels over a broad geographic area.

The basins are relatively shallow, on the order of 10-15 feet deep. The ephemeral nature of these bodies of water, coupled with the possibility of intermittent erosion, makes the establishment of a continuous record of deposition nearly impossible. However, the sediments contained in these basins do appear to have shared a similar geologic/climatic history.

THE CENTRAL HIGH ATLAS AND THE WILLISTON BASIN: SOME ANALOGIES --Randy Burke

The Paleozoic section in the North Dakota Williston Basin is characterized by a series of well-developed carbonate facies, a large proportion of which are shelf and marginal marine deposits. However, these rocks are deeply buried everywhere in North Dakota and our knowledge of them comes entirely from drill-hole and seismic data. In the Central High Atlas of North Africa, a vast and spectacular variety of carbonate facies can be observed and studied in the field. The depositional processes that formed these facies are quite similar to those responsible for our own Williston Basin carbonate sequences; this is particularly true of the shallow shelf and marginal marine facies. The sedimentary textures and structures that are the keys to recognizing the depositional facies can be easily seen in the extensive exposures in the Atlas because they lack both pervasive destructive diagenesis and small-scale, disruptive structural deformation. Studying the lateral changes in facies laid open in the arid canyons and cliffs is a true asset to a subsurface geologist from North Dakota accustomed to trying to make facies models from cores, drill cuttings, and remote-sensing tools. Few experiences in geology are more valuable.

The opportunity to work in the High Atlas in Morocco prompted me to take a thirteen-month leave of absence from the North Dakota Geological Survey beginning in the summer of 1983. I was charged with managing a National Science Foundation grant to John Warme of the Colorado School of Mines to compile a book on the Jurassic history of Morocco. My responsibilities included such things as equipping our office/petrographic laboratory and overseeing doctorate and masters students, particularly during the six months of field work in Morocco.

The evolving tectonic setting during the latest Triassic through middle Jurassic time provided the highly variable structural stage and allowed a wide spectrum of carbonate facies to be deposited. The structural character and sedimentary stratigraphy of the High Atlas represent an aborted phase of rifting during the formation of the Proto Atlantic Ocean. The Alpine orogeny during the Cenozoic formed the Atlas by compressional forces. Ultimately, this event produced the spectacular outcrops seen in a series of thrust blocks and sheets that can be traversed on well-paved roads in about three hours of driving.

A north to south traverse of the facies begins in shallow shelf/marginal marine deposits, passes through spectacular debris flows, and into basinal deposits of interbedded marls and limestones (called rhythmites). Sponge/mud mound build-ups three to five hundred feet thick are common on ancient deepwater paleohighs, whereas spectacular shallow-water pinnacle reefs rim ancient basinal platforms. The basinal marls and rhythmites that surround these structures grade into carbonate turbidites along the southern shelf-edge margin of the trough. The turbidites near the shelf edge are dominated by channels filled with oolites and coral debris from the shallow shelf. Mountain-sized blocks that broke off from the Jurassic shelf are interbedded with the turbidites and can be seen along the shelf margin too. Driving through the canyons across the southern shelf edge deposits one sees shelf reefs, large bivalve banks, oolite-filled channels surrounded by marls, and cross-bedded oolite shoals. The marginal marine deposits farther south, where the Atlas gives way to the Saharan Shield, are recognized by stromatolites, supratidal exposure surfaces, and birdseye and tepee structures.

Many of the marginal marine and shallow shelf deposits of the Atlas are sedimentalogically identical to deposits in the Paleozoic section of North Dakota. The vertical and lateral facies relationships observed in the field and the numerous samples returned to the States should prove very helpful in developing and evaluating models for Williston Basin carbonates.

FOX HILLS FORMATION STUDY UNDERWAY

--Dan Daly

(Editor's Note: Dan Daly is a 1984 University of North Dakota graduate in geology who is doing research on the Fox Hills Formation).

The Upper Cretaceous Fox Hills Formation, a predominantly sandy unit, comprises the deepest source of potable water in the Williston Basin. It consists of marginal marine sediments deposited as the Cretaceous sea drained from the area about 68 million years ago. The unit is exposed at the surface around the margin of the Williston Basin (fig. 1). It is positioned beneath the Hell Creek Formation and above the Pierre Formation. The stratigraphy of the Fox Hills Formation along

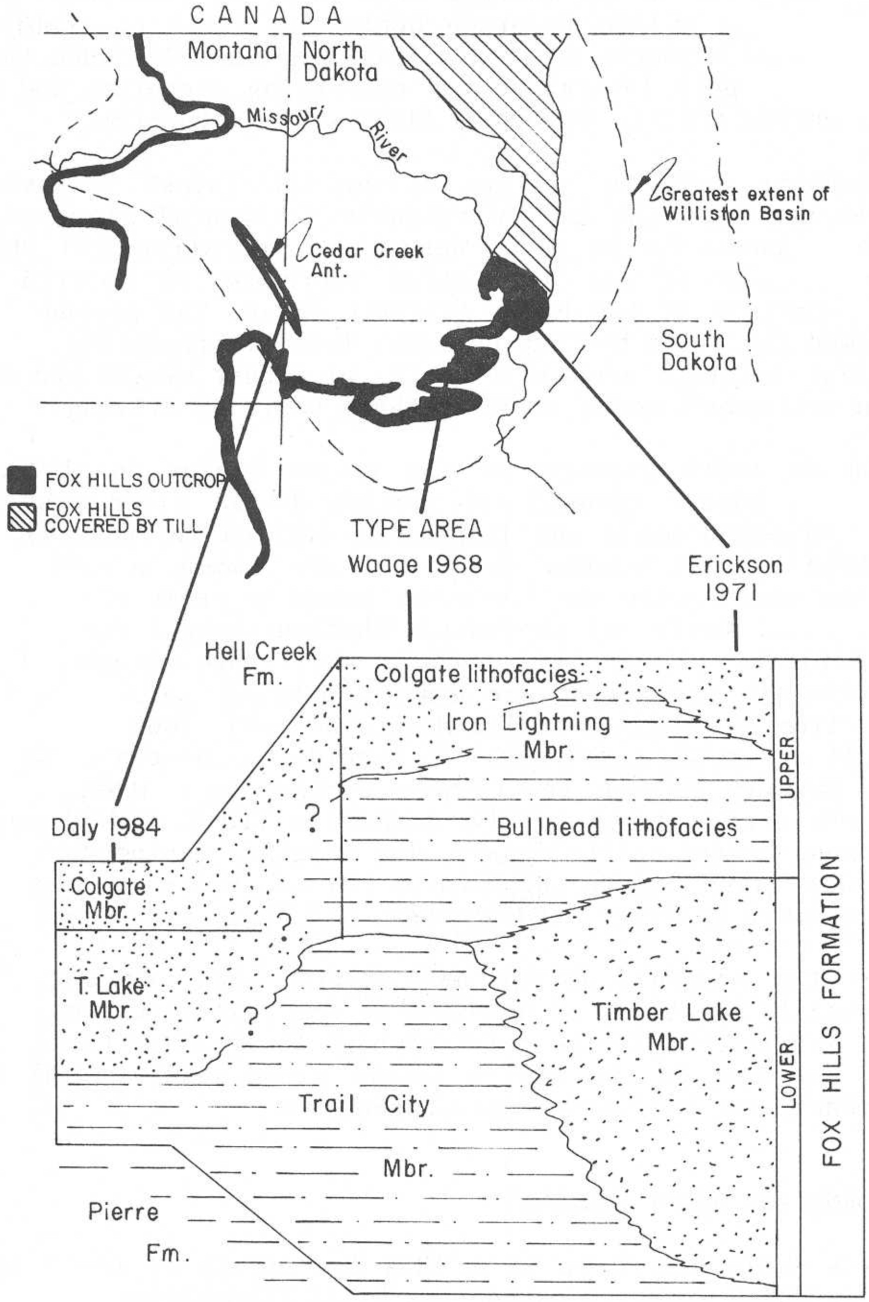


Figure 1. Extent of the Fox Hills Formation exposures (black areas on the map). The cross section shows regional stratigraphic relationships of the Fox Hills Formation members, from the Cedar Creek Anticline eastward to the Missouri River.

the southeast rim of the basin underwent reevaluation in the late 1960s when three members in the type area were formalized by Waage (1968). I am suggesting a revised stratigraphic terminology, including the introduction of the Trail City Member, for the outcrops along the southwest rim of the basin.

The NDGS report I am writing will, hopefully, provide the most complete stratigraphic and environmental picture of the Fox Hills Formation to date, in outcrop as well as in the subsurface throughout the Williston Basin. Measured sections representative of each major outcrop area around the basin will be included in the report. Emphasis will be on lithology, trace fossils, and sedimentary structures. Subsurface correlations, based on more than 300 oil and gas logs and supplemented by North Dakota State Water Commission logs, will provide coverage mainly for the North Dakota portion of the basin.

The preparation of this report was supported by the NDGS during the spring of 1984; publication is tentatively scheduled for the summer of 1985.

NDGS publications containing information on the Fox Hills Formation include Report of Investigation No. 55 and Bulletins 14, 26, 61, 65, and 67.

THE PROMOTION OF EARLY DRILLING VENTURES

--John Bluemle

In the early years of this century, numerous efforts were made to find oil and gas in various parts of North Dakota. However, more energy was probably expended soliciting for investments in stock in the small corporations formed to explore for the oil and gas than in actually looking for oil. These solicitations invariably involved testimonials from eminent geologists, engineers, and other "credible" people. Even the State Geologist of North Dakota sometimes supplied letters of reference for use by the stock companies, and these testimonial letters were exploited extensively for advertising purposes.

Time has shown which of these ventures were realistic ones, which were misguided, and which were out-and-out swindles. Almost all of them were wildly optimistic in their claims and promises, with pictures of "gushers" and promises to investors that they might become millionaires overnight for only a few dollars invested. The "geological evidence" for the oil-bearing structures promoted in the stock offers often consisted simply of a scribbled "map," a circle or oblong figure to represent an "anticline" insofar as the average person understood it in those days.

Recently, we were going through some old correspondence files in our offices and came upon a collection of some of these newspaper clippings, photographs, brochures, letters, and proposals to sell stocks. A dollar a share was a typical price for stock in the companies. The stock prospectus usually extolled the virtues of this or that oil company and explained why certain areas were sure to be rich in oil or natural gas (gas was usually the preferred target of these companies because it could be used on the spot).

One of the prospect areas in North Dakota included the Pembina Hills Region, which was promoted in 1927 by a "former Montana geologist". This area was written up in the April 14, 1928 issue of the Montana Oil Journal and included a complete report on the "Pembina River Oil Structure." Another important area of interest was near Marmarth in 1917. Here, testimonials were solicited from several people, including State Geologist A. G. Leonard. And, of course, the Cedar Creek Anticline ultimately did become an important gas-producing structure and still is. In 1927, the Turtle Lake area in McLean County was promoted by another Montana geologist. Apparently, being from Montana, where gas was already being produced, and being somehow associated with the Montana Bureau of Mines (this is implied from the article) helped to assure potential North Dakota investors that these people and, of course, the prospect, were reliable.

In the New England area a considerable effort was made to raise funds in the early 1920's. This is an involved story that apparently included mainly local people until the initial venture folded about 1923. Then, according to an article in the Hettinger County Herald on April 4, 1927, "A. C. Townley himself" became involved. Townley was an interesting man who played a fascinating role in North Dakota oil history, to say the least, but that's a story in itself.

Still another venture took place, this one in 1926, by the Beaver Lake-Shell Butte Oil Company in Logan, McIntosh, and Emmons Counties. It involved the Red Lake and Shell Butte areas of the Beaver Creek District, according to the prospectus. In the prospectus, three Montana geologists are quoted as saying (in unison) that the Beaver Creek District is "one of the largest and best defined structures it has been my pleasure to examine" (it's not clear which of the three is writing). One of the geologists goes on to say "In view of the intensive and world-wide search for petroleum, and of the stratigraphic and structural features here obtaining, I believe this district affords the most remarkable opportunity for a test well of any of the unexplored and undeveloped portions of the North American Continent." This promotion included a curious drawing that was purported to be a "structural sketch map." At best, the "map" may have shown some glacial moraine features, but I can't tell for sure.

Finally, one of the areas that was heavily promoted between about 1917 and 1920 was near Mohall in Renville County. I'll go into more detail about the Mohall events.

Natural gas had already actually been utilized in the Mohall area and the Westhope and Lansford areas of Bottineau County prior to 1910. This gas, which occurred in a 19-foot-thick sand at the base of the glacial sediment, had been used to heat and light 13 homes in Lansford by way of a 20-mile-long underground pipeline system. Many local farmers in that area had installed separators and used the gas to heat barns and other structures, apparently for several years prior to 1910.

The Mohall oil play of 1919 is quite well documented in our files. It involved a feature referred to as the "Mohall Anticline," which was described in one ad as "about 60 miles in length, beginning just across the Canadian line, northwest of Loraine, and extending in a southeasterly direction about 70 miles just a little to the west of Mohall and Loraine, thence about 40 miles in a southeasterly direction" (that description sounds like more than 60 miles to me, but the ad says "60 miles"). State Water Geologist Howard E. Simpson, who also served as Assistant State Geologist and as a UND Geology Professor, in a letter and report dated March 31, 1919, to the Great American Gas and Oil Company in Mohall, described the general geology of the area. I'll quote from part of his report:

> "The bed-rock in this part of the state is very nearly level, the (sic) having a very slight dip to the southwest. That there is a broad and gentle

anticline trending from northwest to southeast and extending from Canada into the United States is very strongly suggested by the topography of the region. The great broad loop of the Mouse River suggests that this stream is turned from its general easterly course in Saskatchewan by an elongated dome or anticline, which extends southeast along the axis of the loop, and that, having slipped off the slopes of this very gentle uplift, the stream follows around the base of the slope, regaining its easterly direction again, in Manitoba.

"The great amount of erosion, which has taken place in this region in such a way as to separate the Turtle Mountain outlier from the main front of the Missouri Plateau, also strongly suggests an arching of the earth's crust from the northwest to the southeast along the general line of the axis of the loop and parallel to the Coteau du Missouri, as the front portion of the Missouri Plateau is called.

"Further evidence of the anticlinal structure is seen in the occurrence and pressures of the gas in the wells of the region. Traces of gas are found in most of the wells over 150 feet in depth in the east central portion of the loop district and in all wells over 200 feet deep in the west central portion. The abundance and pressure of the gas in two nearly parallel belts extending from northwest to southeast indicates a possible secondary anticlinal structure within the area of the uplift. The longer of these belts passes west of Loraine, near Mohall, east of Lansford and Glenburn, and appears to die out at a point about 6 or 8 miles east of Deering. About ten or twelve miles east of Mohall is a small area in which occur two or three artesian wells, which flow without evidence of gas. These must lie to the east of the Mohall anticline and mark a slight syncline, though their flow may be due to the pressure of gas in the water bearing stratum at some distance away."

I am not sure what ever became of the so-called Mohall Anticline (Simpson later referred to it as the "Mohall Dome."). I don't know of any modern geologic evidence that might confirm its existence; certainly it's not an anticline that accounts for the route of the Souris River, as was suggested by Simpson. For what it's worth, on one of the pieces of promotional material referring to the Mohall Dome, someone has scrawled the word "Bunk"--the handwriting looks like that of A. G. Leonard. As I noted earlier, the gas that had been used in the Mohall-Lansford area occurred in a sand at the base of the glacial deposits and was not related to any significant geologic structure like an anticline.

The Great American Gas and Oil Company eventually ran into other troubles with the state "blue sky commission," which regulated and supervised the sale of these stocks. The following quotation is from a newspaper clipping dated April 3 (but I can't find either the year or the name of the newspaper).

"A well was started near Mohall, Renville County. A mammoth sales campaign was inaugurated. Autos met prospects at the train and took them to the well. Gas had been found, it is said, and wells burned brightly at night when prospective buyers for stock were on hand.

"When the well was only partly down to the depth it was planned to drill, the contract with the well drillers was broken. The Great American sued the drilling company. The company sued the well drillers. An attempt was made by some parties to remove part of the equipment to Montana, it is charged.

"It is also charged by the state that stock salesmen sold stock to some people at the par value of $1 a share and would sell stock to others the same day for as high as $5 a share."

Except for the exorbitant salaries and commissions paid officials of the company, the commission charged that nearly all of the remaining money was spent on promoting the venture and almost nothing was actually spent in exploring for oil.

The most interesting part of all this, I think, and the reason I am writing this article, is the way these early North Dakota oil companies went about promoting stock sales. One of the best examples I found in our files is a composite picture extolling the use of gas for farm use (fig. 1). As nearly as I can tell, the farm was probably that of Ole Hellebust in Renville County; it's impossible to be certain. The photo was made in 1919, about the same time that Great American Gas and Oil Company hired a firm called Publicity Film Company to make some movies along Mohall's Main Street. According to a Mohall newspaper clipping I came across (it's undated, but apparently is 1919 also), these movies showed the exterior and interior of the office as well as the officers of the oil company. They also showed a threshing scene on the Mohall Anticline of a 60 h.p. gasoline engine pulling a 42-inch separator, the engine being operated by natural gas in place of gasoline. I'll quote part of the article:

"No important changes were made on the carburetor and the pressure from the gas wells forced the natural gas into the carburetor and the engine worked perfectly and seemed to handle its load as easily as it would on gasoline. This is probably the first time in history that such a threshing rig has ever been operated by natural gas power. They also photographed a washing scene, the gasoline engine being operated by natural gas coming direct from the well. The pictures taken of the tapping of one of the company's wells which they have put down since they began operating this Spring will also be a very interesting scene to theatre goers. Then they photographed the cooking and lighting with natural gas and also the operation of the large standard oil drillers outfit operating southwest of this city.

"The company has gone to considerable labor and expense having this film company come to the Mohall fields and we hope the pictures will do the different scenes photographed justice. If they do, this will be one of the most unique advertising films ever produced."

I suppose I could continue indefinitely with examples of the early oil exploration promotional efforts, but for now I'll close with several old photos. I don't know why the original prints of these photos were in our files. All of them were used in brochures promoting sales for the Great American Gas & Oil Company in Mohall.

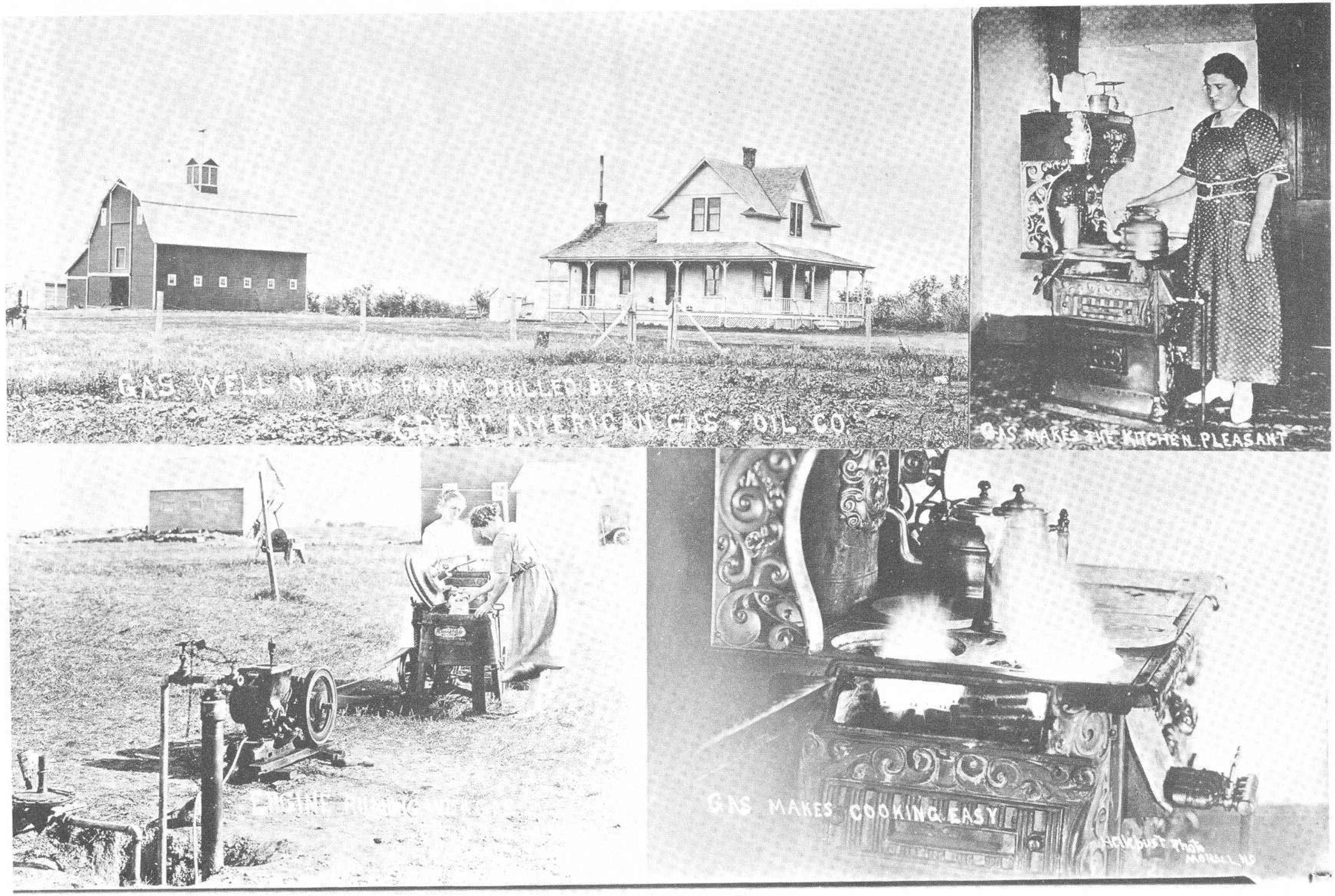


Figure 1. Composite photo dating to 1919. These scenes are probably from the Ole Hellebust farm in Renville County, although I can't definitely verify this.

Figure 2. This picture appears on many pieces of promotional literature. It is referred to in one place as "One of Mohall's Gushers," on the Mohall Anticline.

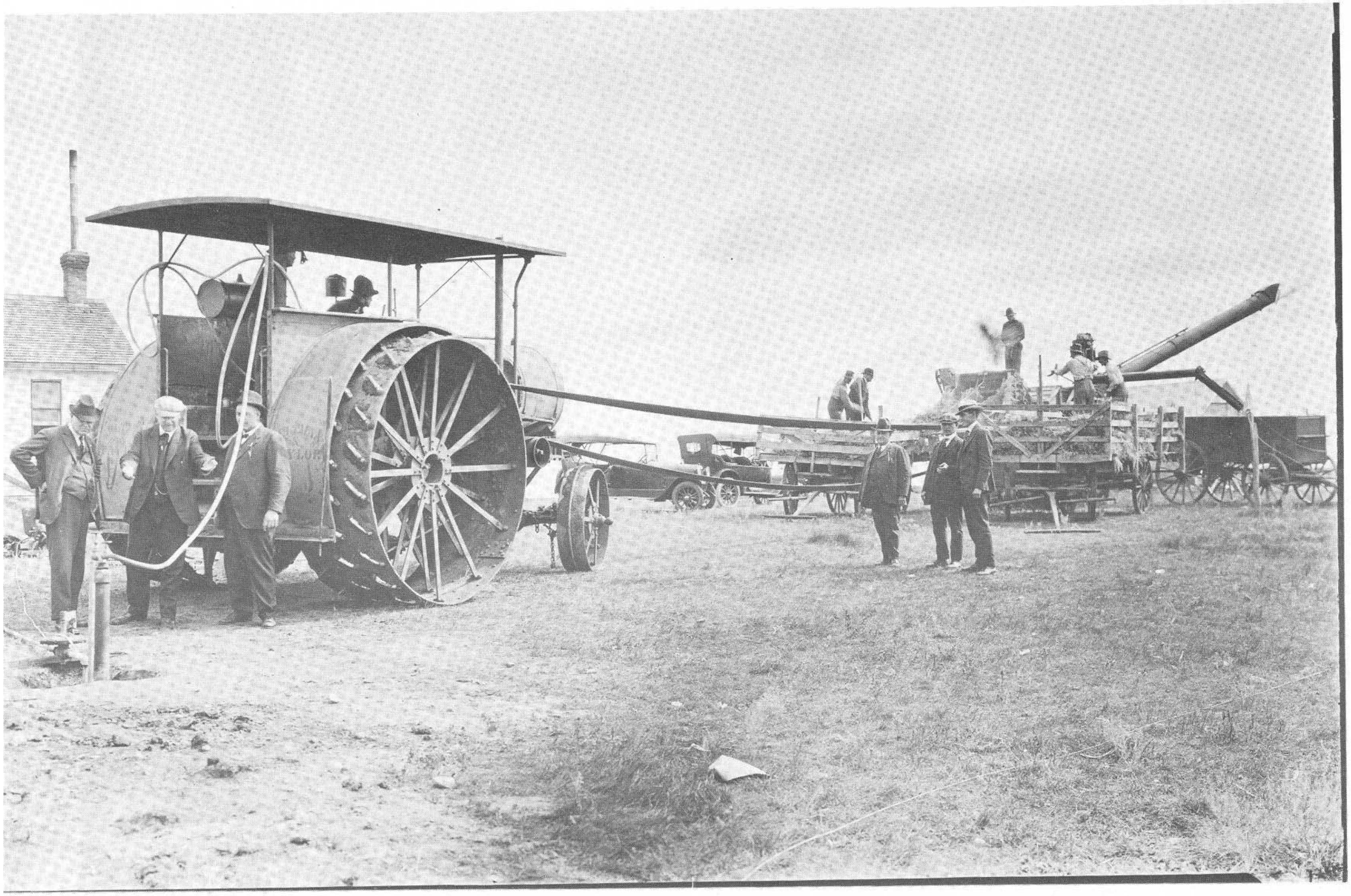


Figure 3. Scene of a threshing machine operating with gas. This photo appeared in several pieces of literature. The scene is apparently the same one I've included a description of in the text of this article.

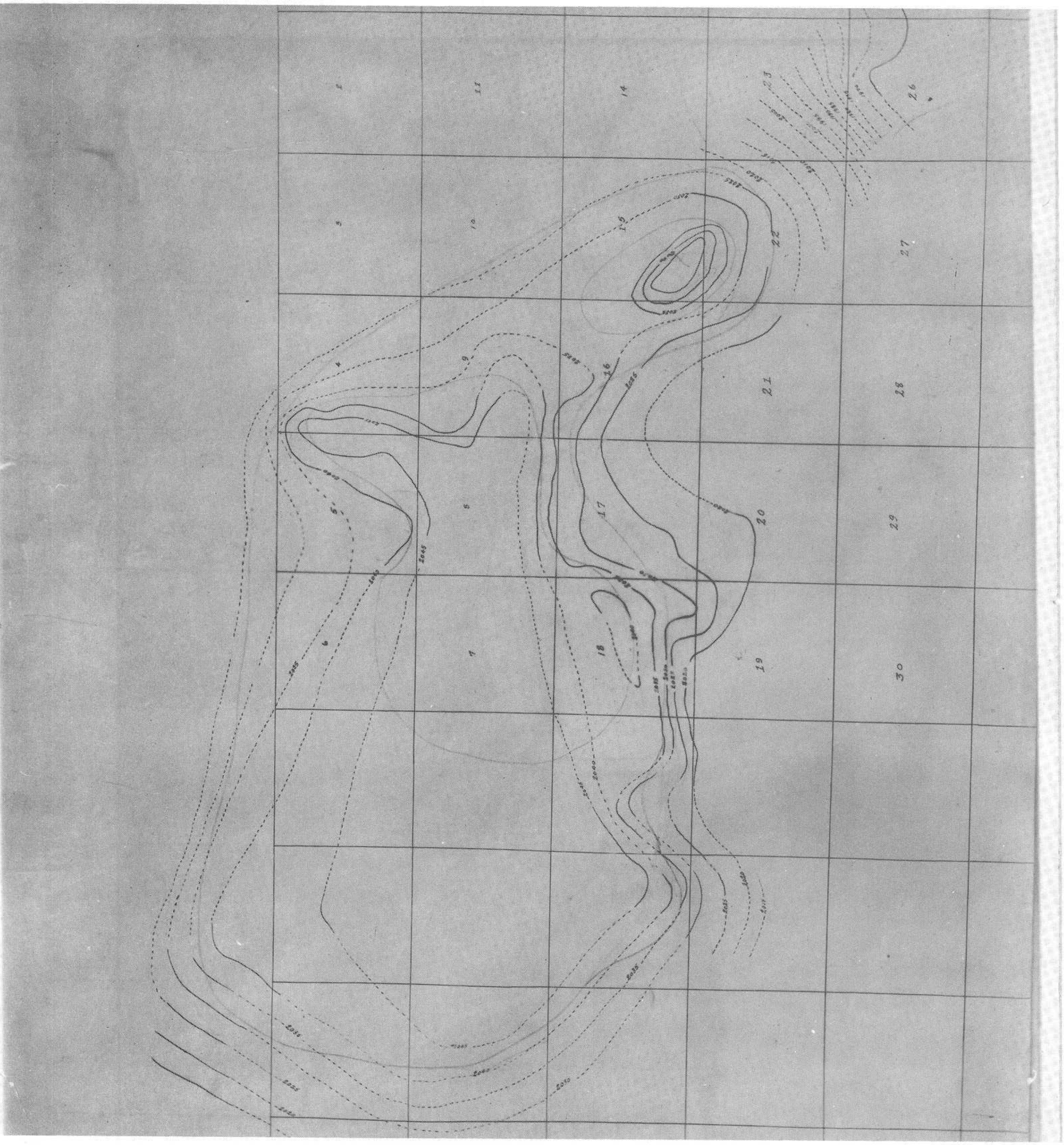


Figure 4. "Geologist's map" of the New England structure, an anticline, that appears on many promotional brochures. On the brochures the map is always far less clear and much harder to read than is the copy I've reproduced here. I can't guess what geologic information was used in compiling the "map," and the geologist who compiled it is not identified.

WHAT IS A UNITIZED OIL FIELD?

--Marv Rygh

Every so often the topic of unitization of an oil field comes up and often it is not quite clear what is meant by the term "unitization." The words "pooling" and "unitization" should not be confused. Pooling relates to the integration of separate interests for a single well. It is a joining together of two or more surface tracts in an oil field whereby the various owners and/or lessors of mineral interests agree to share the expected benefits from a specific oil reservoir located under their land. Pooling may be necessary because much of the oil in a reservoir or related spacing unit could be removed by a single well on just one of the tracts within the unit. This could be harmful to the owners of the other tracts who may also wish to drill a well to protect their interests. However, drilling additional wells would be harmful and unnecessary. An alternative is to form a pooling arrangement whereby the owners of interest within a specific area share in the production from one or more wells according to the proportion of total mineral interests owned within the area.

Unitization refers to the practice of combining all of the tracts with a common source of supply (oil pool) into a unit, similar to a cooperative, for the benefit of everyone involved. For example, there may be four wells in a 160-acre unit. The owners of interest may agree to shut down one well, decrease production in two wells, and increase production in the remaining well if this is the best method of getting the most oil or gas from the total 160-acre unit. Another method might be for the owners of interest to agree to drill a new well in the center of the four wells and pump water into the old wells, hoping to force more oil to the new well. I will give a hypothetical example to highlight some of the more important aspects of the unitization procedure.

Assume that a substantial oil accumulation is discovered and that the areal extent of this oil field is delineated by development drilling, with the wells located on a regular pattern in accordance with spacing rules determined by the North Dakota Industrial Commission (this is done for all oil fields in North Dakota). As the production of oil continues, the reservoir pressure declines because the natural reservoir energy is depleted as it pushes the oil toward the well bore. This is a normal occurrence for wells operating under primary (flowing or pumping) production.

To replenish reservoir energy and recover additional oil, the operator or operators of the field may begin planning a secondary recovery or enhanced oil recovery (EOR) project. This involves a comprehensive engineering study of characteristics of the reservoir to determine the feasibility of such a project. If the results of the study appear promising and the operator decides to go ahead with the project, the field must first be legally unitized before the project can be undertaken.

Almost every method of secondary recovery or EOR involves the injection of some substance (water, gas, air, steam, etc.) into the reservoir through injection wells. Injection is done in an attempt to move additional oil toward producing wells. Since oil is forced to move across property lines, a <u>unitization agreement</u> has to be implemented that will protect the correlative rights of the royalty and working-interest owners.

The operator or operators must draw up a unitization agreement and have it approved in writing by 80% of the lessees or operators and 80% of the royalty owners. The North Dakota Industrial Commission must also approve the plan of unitization before it can go into effect.

Basically, a unit agreement must have these provisions:

1. An explanation of unit management, operation, and financing. Working-interest owners vote on who will be the sole unit operator;

2. A determination for <u>each tract</u> of fair and equitable apportionment of unit production based on:
   a. acreage
   b. recoverable hydrocarbons under the tract
   c. location on structure
   d. probable productivity without unitization
   e. any other pertinent geologic or engineering factors;

3. A procedure for compensation for wells, equipment, etc. taken over for unit operations;

4. Creation of an operating committee to have general management and control of the unit;

5. A stated time when unitization becomes effective;

6. An explanation of the method in which the unit may be dissolved.

A map of the unit showing all tracts involved is constructed and a concise description of the geologic formation being unitized is also included. Each unit must have one single source of supply although more than one producing horizon may be included in the unit if it is shown to be advantageous. Usually, if the field has more than one producing horizon, each horizon is given separate consideration as to whether or not it will be unitized. Sometimes, only a portion of a field is unitized if it can be shown there will be no adverse effect on the rest of the field. At a later date, the unitized area may be enlarged if proper approval is obtained.

Creating a unit is not a simple matter. However, once all the legal matters are satisfied and approval has been granted, the unit can begin a full-scale secondary recovery or enhanced oil recovery project. Hopefully, the ultimate result will be more oil recovered for less cost and greater benefits to all the working interest owners.

In summary, the orders set forth by the Industrial Commission pertaining to a requested plan of unitization must protect and safeguard the respective rights of the persons affected. More specifically, the plan must prevent waste and, with reasonable probability, result in the increased recovery of more oil and gas from the reservoir than would otherwise be recovered. Finally, the costs of unitization must not exceed the value of the additional oil and gas expected to be recovered.

BEADED SHELTERBELTS

--John Bluemle

The average person travelling from Fargo to Winnipeg or from Grand Forks to Mayville or just about anywhere else in the Red River Valley is likely to be impressed (if that's the right word) by the flatness of the land. Just about everyone knows that this extremely flat area was once the floor of a huge lake, glacial Lake Agassiz. The flat glacial lake plain formed when sediment was deposited in the cold, still water of the lake. The lake sediment consists mainly of deposits of silt and clay, built up when streams flowing into the lake delivered large amounts of material to the lake. This material combined with sediment contained in the glacial ice. When the ice melted, the wet glacial sediment spread out and settled onto the lake floor.

Most everyone knows too that Lake Agassiz left a legacy of rich agricultural land (a good deal of that land is blowing by my office window on the University of North Dakota campus this early December afternoon, mixed with a little snow, cardboard boxes, and occasional flying potatoes). What most people don't know is that some of the small, almost imperceptible changes in the landscape and vegetation from place to place are partly the result of a series of events that happened while the area was flooded beneath the waters of the lake and partly the result of complex, modern biologic and geologic conditions in the Red River Valley.

One of the ways farmers have tried to control the blowing topsoil I just mentioned has been to plant shelterbelts in many places. But have you noticed as you travel through the farmland west of Grand Forks, or in the Mayville or Grafton vicinity, how the trees in these shelterbelts are often far from uniform in the heights they reach? A mile-long shelterbelt, growing along one side of a section on what looks like almost perfectly flat and uniform land, may consist of regularly alternating tall and short trees, so that it takes on a "beaded" appearance (fig. 1). On the adjacent side of the same section, another adjoining shelterbelt may be perfectly uniform with tall, even-crested trees throughout. "Beaded" shelterbelts are found west of the Red River, in North Dakota and Manitoba, but they are not present in Minnesota east of the river. There is a geologic reason for all this and I'll try to explain it.

To begin, the "flat" lake plain we are so used to, those of us who live here, is not really as flat as it looks. Over much of the central part of the Red River Valley the otherwise flat surface is marked by long, almost imperceptible grooves, which are best seen from a small airplane flying at a low altitude. The grooves are as much as six miles long. They may be 3 to 10 feet deep and as wide as 75 or 100 feet.

A number of geological theories have been proposed to account for the presence of these grooves. I think the most logical explanation is outlined in the following theory: During spring break-up of the ice on Lake Agassiz, at a time when the lake was shallow, floating pieces of lake ice or, perhaps more likely, icebergs broken from the glacier to the north, were blown over the surface of the lake. The wind-driven icebergs dragged on the bottom of the lake, gouging grooves in the soft bottom sediment. Similar grooves form today along the north slope of Alaska when icebergs scrape the ocean floor. Areas where the Lake Agassiz plain is grooved in this manner are shown on figure 2.

Studies of aerial photographs of the grooves on the Lake Agassiz plain in Walsh and Grand Forks Counties have shown that a large proportion of the grooves trend northwest-southeast (fig. 3). A possible explanation for this is that the icebergs (or lake ice) were propelled by winds blowing from the northwest or, equally likely, from the southeast. In the spring season, when the ice on Lake Agassiz would have been breaking up, the prevailing wind direction was probably from the southeast, as it is in the spring season today.

Figure 1. Typical "beaded" shelterbelt about two miles south of Grand Forks International Airport (upper photo). Beaded shelterbelts are characterized by alternating clumps of trees separated by spaces where trees don't grow or where they grow only poorly. The lower photo shows an unbeaded, normal shelterbelt.

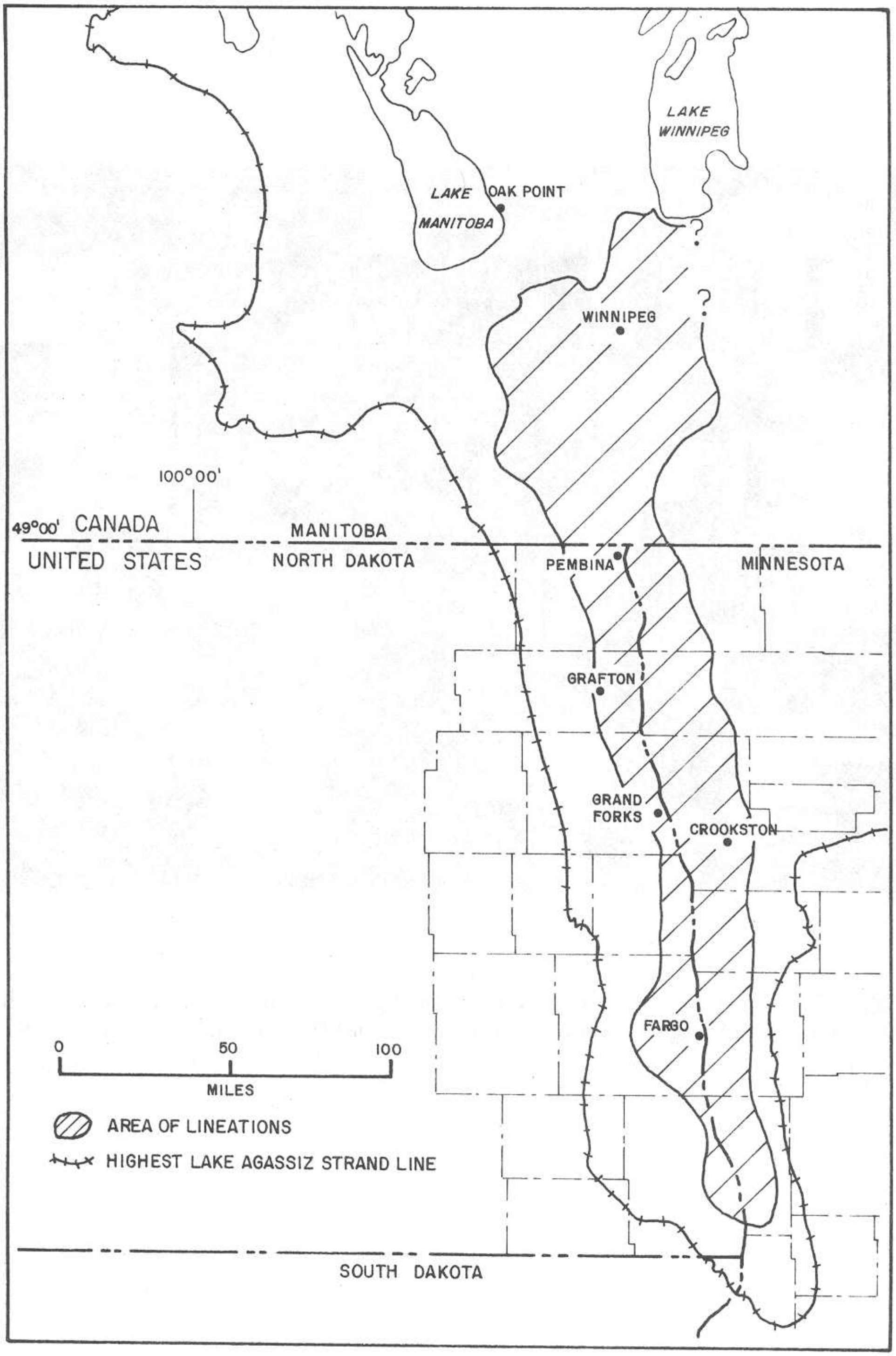


Figure 2. Area in the Red River Valley where ice-gouged grooves occur (lined area). The maximum extent of the glacial Lake Agassiz plain is shown by the tic-marked line.

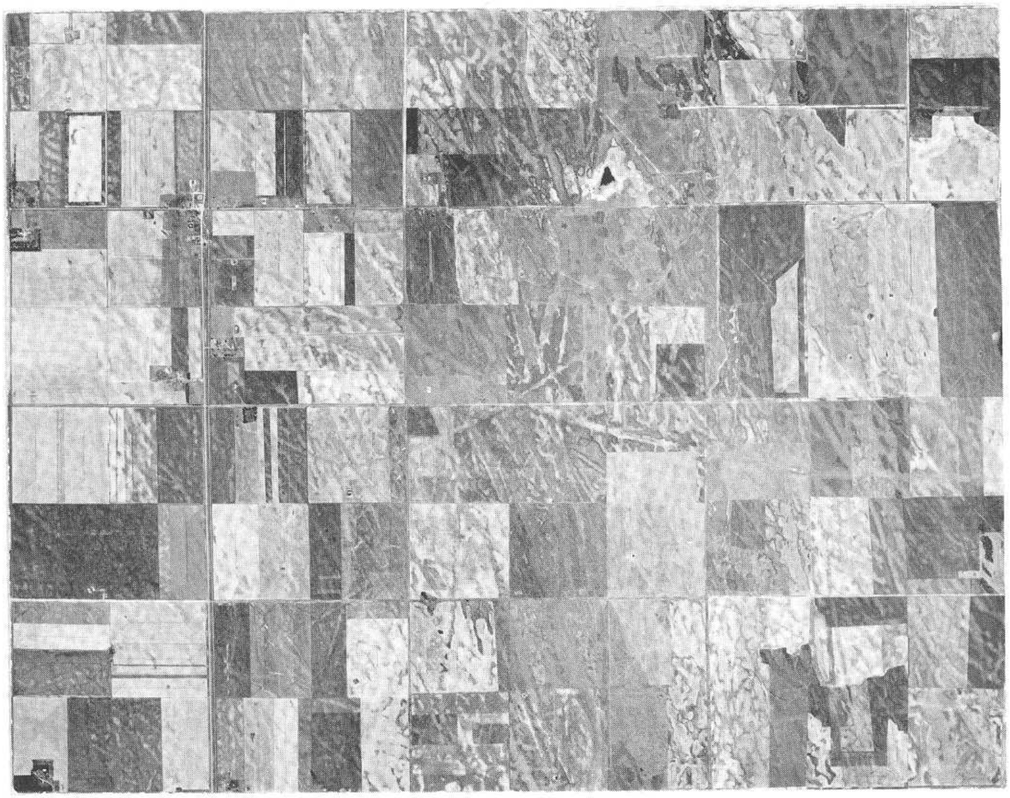


Figure 3. Airphoto of part of Pembina County (T162N, Rs51, 52W). The lines are ice-drag markings. Area shown is 5 miles wide; north is to the top of the photo.

So, do the beaded shelterbelts occur wherever grooves are present in the lake floor? No, they do not. Grooves that may have formed as a result of the wind-blown ice mechanism are present over a much larger area of the Red River Valley than are the beaded shelterbelts. But the beaded shelterbelts do have a definite relationship to the grooves (fig. 4). The taller trees in a beaded shelterbelt grow in the grooves; the shorter, stunted trees grow on the ridges or higher areas between the grooves. That's the main reason it's so hard to detect the grooves; the lower areas are typically filled in with lusher vegetation than are the ridges between the grooves.

The second geologic factor that needs to be considered to understand the reason for the beaded shelterbelts is related to the eastward movement of groundwater. This water has been seeping, under pressure, through layers of buried sandstone for millions of years and it is very salty in places. It comes to the ground surface in a fairly narrow strip of land parallel to and west of the Red River. The reason salty water is escaping to the surface in this particular area is that, farther west, the sandstone is covered by a layer of shale that effectively seals it off so it can't escape upward; the western edge of the area of upward seepage coincides with the eastern edge of the shale seal (fig. 5). The absence of the shale seal allows the salty water to escape in that area. The strip of salty land extends northward from the Wahpeton area to north of Winnipeg.

Salt-water wells and salty sloughs are common over much of the area where salt seeps occur. Where the salty water reaches the surface, halophytes such as Salicornia rubra, a small, red salt-loving, salt-flavored plant, are common. In these areas, "white dirt" may be seen after a summer dry spell. This is salt-encrusted soil from which the walt water evaporated.

Beaded shelterbelts occur only in areas where the ice-gouged grooves coincide with places where the salty water is escaping to the surface. The interaction of these two factors to foster the growth of beaded shelterbelts has only recently become well understood.

Although salty water is escaping to the surface at about the same rate in any given area, it becomes much more concentrated near the surface in the slightly higher areas, such as on the ridges between the ice-gouged grooves. The manner in which the salts become concentrated in higher areas was first explained by Sandoval et al. in an article published in the Proceedings of the Soil Science Society of America in 1964. However, these researchers did not discuss the origin of the grooves in their paper. Infiltration from precipitation helps to flush the salt deposits from near the ground surface. Runoff from precipitation--fresh, salt-free water--flows off of the ridges, down to the lower areas (fig. 4). It infiltrates in the lower areas, flushing the salts from the soil and freshening it there. As a result, the soil in the grooves tends to be less salty (more fertile) and trees and other vegetation grow better there than on the intervening ridges where salty soil remains. The result is a "beaded" shelterbelt, with tall, healthy trees in the salt-free grooves, stunted trees on the salty ridges.

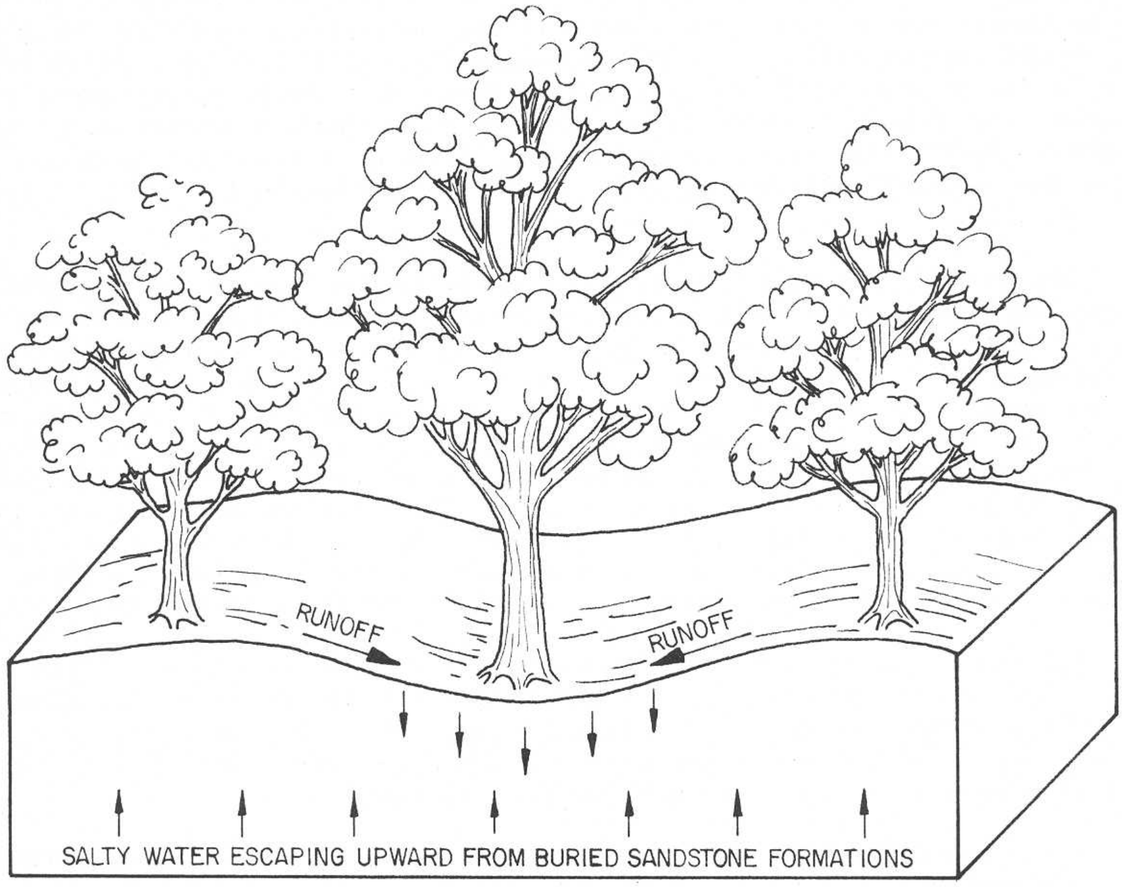


Figure 4. Taller trees grow in the grooves; stunted trees grow on the ridges between the grooves. Magnesium and sodium sulphate salts, which are left as residues from salty water rising from buried sandstone formations, build up to higher concentrations in the ridges than in the adjacent depressions. This is because the salts are flushed downward from the lower areas by runoff water percolating downward, whereas the higher areas retain their higher salt concentrations. As a result, trees tend to grow better in the lower, more fertile, areas.

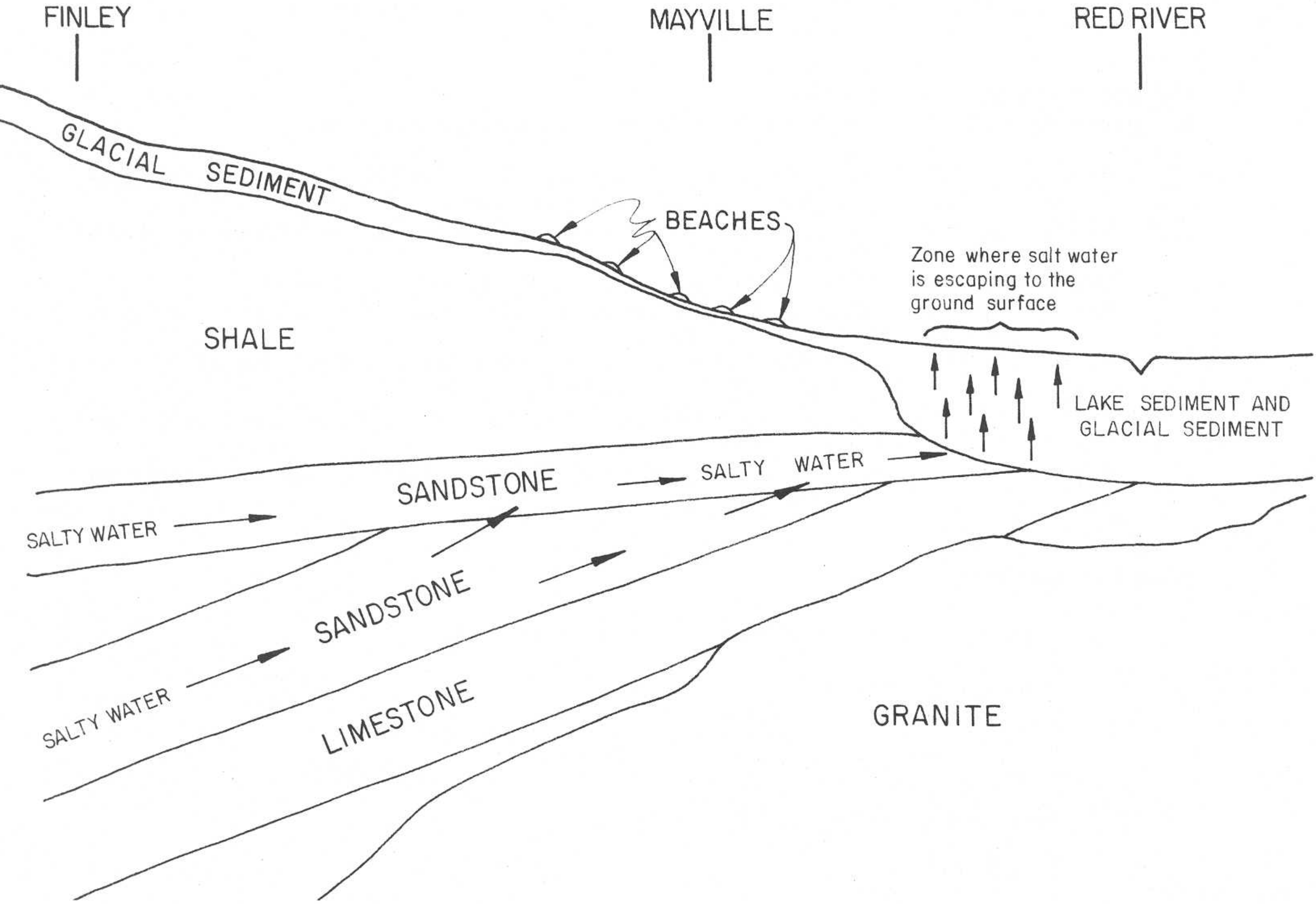


Figure 5. Generalized cross section from west to east along the approximate location of State Highway 200. Salt water escapes to the surface at the point where the shale cover is absent. Arrows represent movement of salty water. The vertical scale of this diagram is greatly exaggerated.

COMMENTS

Do you have questions, comments, or suggestions regarding the newsletter or North Dakota Geological Survey services? For additional information on any of the items mentioned in the Newsletter, please contact John Bluemle, NDGS Newsletter Editor, North Dakota Geological Survey, University Station, Grand Forks, ND 58202-8156.

CHECKLIST FOR NEW PUBLICATIONS

See pages 8-10 of this Newsletter for descriptions of publications.

____	RI 82	($3.00)	The Effect of Oil and Gas Well Drilling Fluids on Shallow Groundwater in Western North Dakota
____	RI 83	($2.00)	Little-Known Mid-Paleozoic Salts of Northwestern North Dakota
____	Bull. 66	(free)	Geology of Emmons County, North Dakota, Part 1
____	Bull. 78	(free)	Groundwater Resources of Bottineau and Rolette Counties, North Dakota, Part 3
____	MS 65	($1.00)	Oil Exploration and Development in the North Dakota Williston Basin: 1982-1983 Update
____		($15.00)	Oil in North Dakota--Production Statistics and Engineering Data for 1981
____	(price varies)		Oil and Gas Field Maps (Contact NDGS for specific ordering information).

ADDRESS CORRECTION

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____ Zip Code __________

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( ) Please add the following to your Newsletter mailing list:

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