NEWSLETTER

NDGS

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John P. Bluemle, Editor

December, 1982

EDITOR'S NOTE

This Newsletter for December is diverse and includes articles by eight people besides myself. Generally, I wrote the uncredited articles, with help from various people, and the other articles were written by the people I've indicated.

Two articles deal with the Williston Basin Symposium held in Regina in early October. Several of us attended the Symposium, and I think all of us were impressed by the level of interest currently being shown in the Williston Basin, even during the downturn we hear so much about--I think we have a lot of activity to look forward to in the Basin in the not-so-distant future.

I'm also more convinced than ever now of the need for our geologists to "get out and meet the public" (see "On the Road Again") and let people know what the NDGS is here for. It seems like there are a lot of people who need and want information about geology. Speaking for myself at least, I think I now have a clearer notion what we can do to help provide that information. In fact, I think that providing understandable "instant" information (as opposed to formal publications) may be one of the most important things the Survey staff should be doing. I suppose we've already been aware of this to a certain extent as this Newsletter has been published now for nearly 10 years, but a Newsletter like this one reaches only a relatively small number of people and it is a sort of "one-way" communication--we tell you what we think is useful or whatever grabs our fancy; it's so much better to talk to you, or at the very least, hear from you, so we can zero in on problems. Of course, we don't have nearly all the answers, but it's surprising how many questions we can answer at a place like the State Fair in Minot or the Dickinson Oil Show.

We have several new publications I've described later on in the Newsletter. The new bedrock map is the first in 13 years; the Pierre structure map has been popular with oil men concerned about setting surface casing. We've also published several technical articles that may be important to some of you.

Finally, this issue of the Newsletter includes several essays: on concretions, formation volume factor, permafrost, and climatic evolution. These articles represent our effort to provide some of the information about geology I just referred to. I hope we've succeeded.

Let us hear from you!

SOME SURVEY ACTIVITIES

Geologists and engineers at the NDGS are working on a variety of things and I won't attempt to provide a specific "catalog" of projects. This article is just sort of a potpourri to give you an idea of some of the things we are doing.

Our county groundwater studies program, which has resulted in the mapping of almost all of the State's geology, is finally nearing completion with several more counties now in the report-preparation stage. The report on McHenry County is recently completed, although not yet back from the printer (see "New Publications," in this Newsletter), Morton County is almost ready for the printer, and studies are progressing on Towner, Bottineau, Emmons, Billings, Golden Valley, Slope, and McKenzie Counties. The NDGS cooperates with the North Dakota State Water Commission and United States Geological Survey on these studies, which have been underway since 1960. Those parts of the reports dealing with groundwater basic data and with hydrology are published by the Water Commission; we publish the geology.

We've already done some preliminary work and we expect soon to begin detailed compilation of 1° x 1° maps of North Dakota. This detailed mapping and resource evaluation project is a logical "next-step" following completion of the county groundwater studies. The 1° x 1° series will be part of an atlas containing surface geologic maps, a Pleistocene stratigraphic framework, land-use planning derivative maps, mineral resource maps, landfill-suitability maps, and other useful geotechnical information.

Our studies of the geologic conditions of urban areas continue with the Minot area report now nearly finished. Evaluations of geologic, geochemical, and various geotechnical aspects of surface mine reclamation are also underway by NDGS staff. Our geologists are also evaluating the impacts made on groundwater by disposal of thermo-electric utility wastes, by reclamation of abandoned surface mines, by oil and gas mud pits, and by sanitary landfills and municipal lagoons. Also, at the request of various State and other officials, Survey geologists have evaluated the potential effects that hazardous waste disposal facilities proposed for Marshall and Clay Counties, Minnesota would have on North Dakota ground and surface water.

We have recently finished our part in compiling a detailed stratigraphic correlation chart for the Northern Rocky Mountains (we previously published a Williston Basin Correlation Chart, which is already available: NDGS Miscellaneous Series 61). The new, expanded chart will be published by the American Association of Petroleum Geologists, and it should be available early in 1983. The COSUNA (Correlation of Stratigraphic Units in North America) project is in its sixth and final year and should be completed by December, 1983. About 25 charts will be published. It is expected that the final AAPG published charts can be produced at a low price, thereby ensuring maximum distribution and use by the geological community.

Additional projects underway by Survey geologists include a map of the bedrock (preglacial) surface of the Lake Agassiz region. This map, now being printed, will be an NDGS publication that will also be included in a Symposium Volume on glacial Lake Agassiz being published by the Geological Society of Canada. Our draftsman is also working on a map of North Dakota that will show both bedrock units and preglacial topography. We will probably publish this map at a scale of 1:750,000. A nontechnical landform "photo-atlas" of North Dakota that will show pictures of the State's landforms and explain their origin is also in preparation. Our engineer is constructing production performance curves (decline curves) for all of the oil fields in North Dakota.

We expect to be able to publish a volume including a substantial number of them, hopefully early in 1983. Our detailed studies of several stratigraphic units in the Williston Basin continue. We expect to redo structure maps of each major horizon, utilizing the vast amount of data resulting from the great number of exploratory wells drilled during the past 5 years. Spearfish, Jurassic, and basal Cretaceous maps are now underway.

We continue our efforts at providing nontechnical information for students and other North Dakota citizens with the release of a publication on geologic time and several similar ("educational") items in progress. One of the most useful aspects of these efforts has been the personal contacts we have been able to make (see "On the Road Again," elsewhere in this Newsletter). Several of us have spoken to service groups and to school classes throughout North Dakota. These activities will definitely continue.

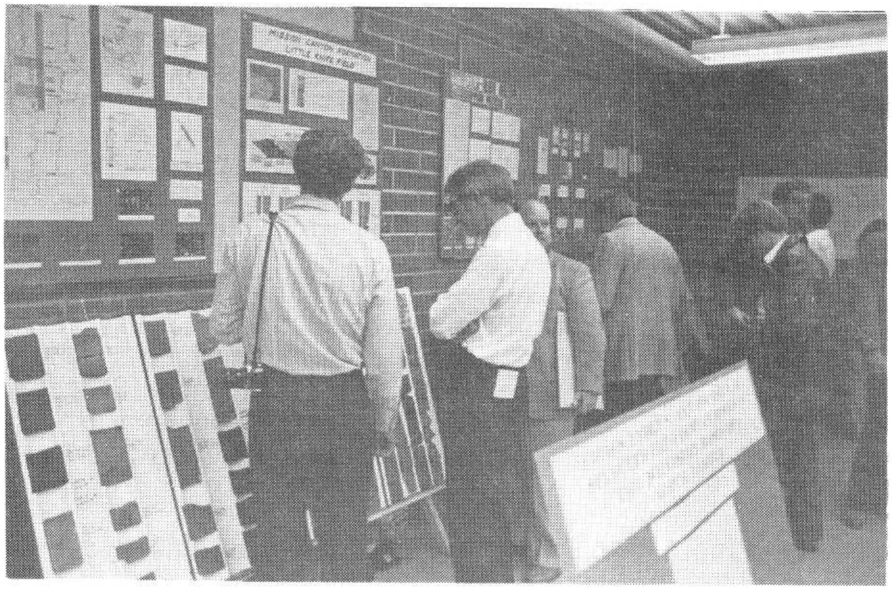
Our new Core Library is already filled to capacity. We hope to construct a mezzanine in the receiving room and additional shelving to store lighter weight well cuttings. We are also out of space for our electric logs and we expect to install additional compact, rolling shelving soon. It is vitally important to keep these valuable resource materials properly cataloged so they are readily accessible to the many people who regularly come to our offices to use them in their research--their search for oil and gas.

FOURTH INTERNATIONAL WILLISTON BASIN SYMPOSIUM

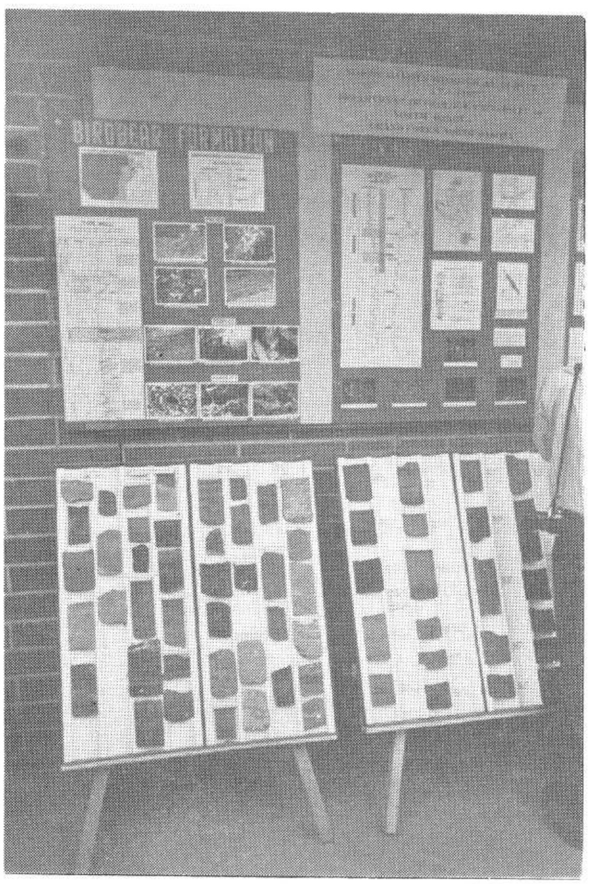
On October 5-7, 1982, the Saskatchewan and North Dakota Geological Societies sponsored a conference and workshop that focused on the regional geology, geophysics, stratigraphy, sedimentology, and economics of oil and gas fields in the Williston Basin. The conference, which was held in the Hotel Saskatchewan in Regina, was attended by 442 petroleum geologists from all over North America, about half from the U.S., with the largest contingent from Denver. A major reason for such high attendance was interest in the deep oil play currently developing in Saskatchewan, North Dakota, and Montana. Several NDGS geologists and geology students from the University of North Dakota (see next article) attended the Symposium, many of them giving technical presentations. This was only the fourth such Symposium; previous conferences were hend in Bismarck in 1956 and in Regina in 1958 and 1964.

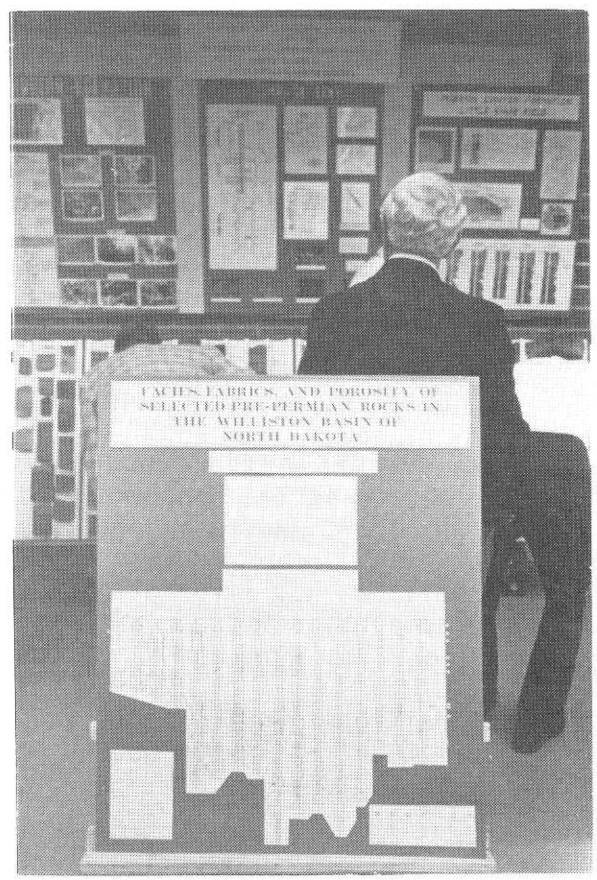
The Symposium was definitely a success with a good number of really excellent papers. A total of 40 technical papers were presented at the conference, including oral presentations as well as poster and core displays. A proceedings volume (Saskatchewan Geological Society Special Publication Number 6) was published in time for the Symposium. The 326-page, soft-cover book includes 33 full-length papers and 7 abstracts by a total of 65 authors from the U.S. and Canada. The book includes papers on sedimentology, stratigraphy, and geophysics of Williston Basin rocks ranging in age from Archean to Tertiary. The volume is available from the Saskatchewan Geological Society, P.O. Box 234, Regina, Saskatchewan, S4P 2Z6 for $40.00 (Canadian) or $37.00 (U.S.), postpaid. Interest in the proceedings volume was high; 125 copies were sold at the conference in addition to those distributed to each registrant.

Highlights of the conference included two field trips. A four-day excursion before the conference examined the sedimentology and stratigraphy of the Lower Paleozoic strata of Manitoba. The trip was led by Dr. Hugh R. McCabe and Dan Barchyn from the Manitoba Department of Energy and Mines in Winnipeg. An excursion after



Poster and core slab displays at the Williston Basin Symposium in Regina were well received by petroleum geologists attending the meeting. The display was conceived and directed by Randy Burke of the NDGS and compiled by NDGS personnel, UND Geology Department graduate students and industry geologists.





the Symposium examined the sedimentology and stratigraphy of upper Paleozoic rocks in the Little Rocky Mountains of Montana. The Little Rockies trip was led by Dr. James H. Clement from Shell Oil Company in Houston. Both field trips focused on geological equivalents of Williston Basin hydrocarbon reservoirs; both generated a high degree of interest, with all 36 places on the Manitoba trip and all 30 places on the Little Rockies trip subscribed several months prior to the Symposium.

NDGS geologist Randy Burke attended both field trips and he says both were excellent. Randy hopes to conduct the trips sometime in the future for other NDGS geologists. Perhaps any of our readers interested in attending might let Randy or me know and we'll contact you when the "rerun" takes place.

Other Symposium activities included an icebreaker, a wine and cheese party, and a banquet sponsored by Saskoil in Regina. Mr. William J. Douglas, Acting President of Saskoil, gave a brief address at the banquet. Commercial exhibits at the Symposium included displays by several Canadian and U.S. companies. Commercial sponsors of the Symposium included Saskoil, Regina; Aqua Terra Consultants Ltd., Calgary; and Shell Oil Company, Houston.

Overall, the high degree of interest in the Symposium, especially in the midst of a slowdown of industry on both sides of the border, is most encouraging. The Symposium and the proceedings volume represent a valuable and timely service to the international geological community.

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"HIGH CALIBER" OF SUBSURFACE STUDIES LAUDED

-- Randy Burke

Don Kent, Chairman of the Symposium Committee, closed the Williston Basin Symposium with a summary statement that singled out the "substantial contribution of high-caliber research" presented by the North Dakota geologists (see abstracts included with this article). It is the second time this year (the first was at the AAPG meeting in Calgary--see June, 1982 NDGS Newsletter) that the professional community has honored the results of subsurface research done by University of North Dakota graduate students collaborating with the NDGS staff, as well as work done by the NDGS staff itself. Eight of the 34 oral presentations and two of the 12 poster presentations were made by North Dakota Geological Survey staff persons and by UND Geology Department graduate students working under the guidance of Survey geologists. Forty feet of wall space was used at Regina for the expanded version of the AAPG award-winning core and poster display--see the abstract that follows this article. The expanded display included the Silurian Interlake Formation, by C. LoBue, and the Pennsylvanian Tyler Formation by S. Sturm.

The Symposium was co-sponsored by the Saskatchewan Geological Society and the North Dakota Geological Society. The bulk of the committees were manned by geologists from the Saskatchewan Department of Energy and Mines with assistance from North Dakotans, especially J. E. Klemer, C. B. Thames, and F. Wosick. All of the committees deserve a round of congratulations for a meeting exceptionally well planned and executed.

A lasting mark of their efficiency is the pre-meeting publication of the Proceedings (see previous article, this Newsletter). All participants received copies of the 326-page Proceedings when they registered. The soft-bound volume is well printed and contains numerous black and white photographs and cross-section foldouts.

ORAL PRESENTATIONS BY SURVEY STAFF AND UND STUDENTS AT THE SYMPOSIUM

Geological Development and Origin of the Williston Basin

by L. C. Gerhard, Department of Geology, Colorado School of Mines;
S. B. Anderson and J. A. LeFever, North Dakota Geological Survey;
and C. G. Carlson, North Dakota Industrial Commission

Abstract

The Williston Basin, in North Dakota, South Dakota, Montana and south-central Canada (Manitoba and Saskatchewan) is well known for its extensive energy and mineral resources, principally oil, gas, lignite and potash. Active exploration in the basin has stimulated large-scale stratigraphic and structural studies contributing greatly to the information available.

The Williston Basin forms an irregularly shaped depression on the western edge of the Canadian Shield. Structural trends within the basin reflect major directional changes in the structure of the Rocky Mountain belt. Sedimentation in the basin has been relatively continuous through Phanerozoic time, with carbonate deposition dominating the Paleozoic and clastics dominating the Mesozoic and Cenozoic eras.

Four features border the basin: the Sioux Arch, the Black Hills Uplift, the Miles City Arch, and the Bowdoin Dome. The characteristic northwest structural grain of the region appears to be related to the displacement of the central portion of the Rocky Mountains (Fig. 1). This movement in pre-Phanerozoic time resulted in the formation of a series of basement blocks which strongly influenced later sedimentation and structures.

Sedimentation within the basin is characterized by cyclical transgressions and regressions exhibited by repeated sequences of clastics and carbonates. Initial sedimentation occurred over a highly irregular Precambrian crystalline surface, beginning with deposition of Sauk (Cambrian-Lower Ordovician) sequence rocks which show a change from clastics to carbonates up section. Tippecanoe (Ordovician-Silurian) sequence rocks represent the second cycle of transgression, sedimentation and regression. By this time the basin was a well-defined structural depression with marine connections from the southwest depositing clastics followed by carbonates. Seaways developed northward during Devonian time, as a result of activity on the Transcontinental arch which tilted the basin and structures northward. Again during the Kaskaskia (Devonian-Mississippian), a transgressive and a regressive sequence of sediments was deposited. A reorientation of seaways also occurred during Madison time as the basin opened to the west. This reorientation is related to the development of shear systems in Montana. Terrestrial clastics interbedded with marginal marine and evaporite sediments are characteristic of Absaroko (Pennsylvanian-Triassic) sequence rocks. The setting for deposition of the last sequence of marine sediments occurred during Zuni (Jurassic-Cretaceous) time with a deepening of the western interior Cretaceous seaway. Uplift, erosion and volcanism occurred during this time in the Laramide Rockies supplying extensive quantities of detritus to the basin. Tejas (Tertiary-Quaternary) sequence rocks generally consist of shaly sandstones and lignites, with some limestone and volcanic ash.

Phanerozoic sediments trangressed from the west across crystalline terrane, mostly Churchill Province rocks, and across the Churchill-Superior provincial boundary. The basin depression originated in the Ordovician (pre-Tippecanoe) with a main seaway connection to the southwest. During the Devonian, uplift occurred along the Transcontinental Arch breaking the connection with the Cordilleran geosyncline, tilting the basin northward and connecting it with the Elk Point Basin sea. Mississippian transgression followed with the subsidence of the Transcontinental Arch. A Cordilleran seaway connection developed at this time through the central Montana trough. This connection persisted through Absaroka time.

Two major structures are present in the basin which are both surface-mappable and oil-productive, the Nesson and Cedar Creek Anticlines. The Nesson Anticline has a Precambrian crystalline core with fault displacement on its western limb. Reversal of movement occurred through times during its history reflecting changes in stress regimes. The Cedar Creek Anticline also shows displacement on its western limb. Again, like the Nesson Anticline, movement reversed direction through time.

A change in structural grain is evident between the central portion and the northern and southern portions of the Rocky Mountains. This change appears to coincide with the Fromberg fault zone and the Colorado-Wyoming shear zone. These two zones were probably formed by left-lateral shearing on the edge of the pre-Phanerozoic continental plate. The central Rocky Mountain block was then caught as a slice between shears with resultant left lateral drag, forming numerous basement-rooted faults within the central Rocky Mountains, Black Hills and Williston Basin. Since the formation of these faults it is questionable whether any actual motion has occurred along the two major shear zones. The shear zones, however, have been stressed repeatedly, with resultant vertical motion occurring along the basement planes of the structural discontinuity.

Oil Exploration and Development in the North Dakota Williston Basin

by S. B. Anderson and J. P. Bluemle, North Dakota Geological Survey;
and L. C. Gerhard, Department of Geology, Colorado School of Mines

Editor's Note: No abstract was included in the Proceedings volume for this talk. However, the content of the talk is contained in a new NDGS publication, MS 62 (see article in this Newsletter describing this publication).

Depositional Environments and Diagenesis of the Silurian Interlake Formation, Williston Basin, Western North Dakota

by Charles LoBue, UND Department of Geology

Abstract

The Interlake Formation is a succession of Silurian dolostone and limestone beds in the Williston Basin. Lower Interlake rocks are dominated by supratidal and intertidal lithofacies which are characterized by felted anydrite nodules, laminated and non-laminated dolostones, hypersaline oolites and laminar or columnar stromatolites. Middle Interlake rocks are typified by subtidal lithologies characterized by fossiliferous wackestones which may contain brachiopods, gastropods, pelmatozoan fragments, tabulate and rugose corals and stromatoporoids. Upper Interlake rocks are generally absent due to extended erosion during Late Silurian-Early Devonian times. Where present, the intertidal and supratidal upper Interlake rocks are characterized by peloidal, intraclastic wackestone/packstones and grainstones which locally contain gastropods as well as fenestral peloidal wackestones. Well-developed karst, caliche and lateritic soil zones occur throughout the section indicating periodic subaerial exposure.

The Interlake Formation represents two transgressive-regressive sequences containing a wide variety of shallow water to subaerial environments. The depositional systems active during Interlake time were very dynamic, resulting in extreme vertical variations of lithofacies.

Environments of Deposition and Diagenesis of the Winnipegosis Formation (Middle Devonian), Williston Basin, North Dakota

by Nancy A. Perrin, UND Department of Geology

Abstract

In the Williston Basin, the Winnipegosis Formation is the major carbonate unit of the initial transgressive-regressive pulse of the Kaskaskia sequence. Following a brief hiatus separating the Ashern Formation from the Winnipegosis Formation, a clear, quiet shallow marine environment became widely established in the North Dakota portion of the Elk Point Basin. Preferential dolomitization of bioturbated areas was the major diagenetic alteration of the rocks.

During the transgressive phase, the basin differentiated into two distinct regions due to varying amounts of carbonate production: 1) a deeper basin with scattered pinnacle reefs, and 2) an encompassing carbonate shelf. In the basin region two environments became established: a) the pinnacle-reef environment where several lithofacies developed due mainly to exposure of the upper portion of the reefs; diagenesis was extensive and included pervasive dolomitization, cementation, stylolitization and vadose alteration; b) the deeper basin environment surrounding the reefs where slow deposition gave rise to laminated limestone. In the shelf region, proceeding landward, there developed shallow marine, patch reef, lagoon and tidal flat environments, each of which produced a variety of lithofacies. The dominant diagenetic alteration was preferential dolomitization of bioturbated areas, but stylolitization, anhydrite replacement and displacement, and pyrite formation also occurred.

The regressive phase is seen in the shelf region as a series of rocks with progressively shallower subtidal faunas and growth forms, capped by an intertidal to supratidal series of dolomites and anhydrites. Diagenesis of the subtidal rocks is similar to those of the transgressive phase for that environment; however, deposition and diagenesis of the rocks of the intertidal and supratidal regressive phase were penecontemporaneous. Dolomitization, anhydrite displacement and replacement and pyrite formation were the major diagenetic changes in these rocks. In the basin region, as sea level fluctuated, stromatolites and supratidal dolomites were deposited upon the pinnacle reefs. Eventually, when sea level fell substantially, redbeds formed on the exposed reefs. In the shallow inter-reef environment surrounding the emergent reefs, restricted shallow marine to supratidal dolomites formed and subaqueous algal mats developed. Rocks of the basin region were affected primarily by dolomitization and anhydrite displacement. Deposition of additional dolomite followed, then anhydrite and finally halite of the Prairie Formation.

Porosity Types, Geometry and Interpore Minerals of the Lower Duperow Formation, Billings Nose Area, Williston Basin, North Dakota

by Randolph B. Burke, North Dakota Geological Survey; and
Gary L. Stefanovsky, UND Geology Department

Abstract

Three types of porosity, 1) intercrystalline, 2) moldic and 3) vuggy, are recognized in cores from wells drilled in the lower Duperow Formation in the Billings Nose area of North Dakota. The principal type of porosity is intercrystalline, formed during dolomitization. Dolomitization appears to be fabric selective, preferential to mudstones, mudstones and wackestones associated with intraclasts, oncolites(?) and stromatoporoids. Dolomite rhombs range in size from an average of 20 to 30 microns to 50 microns. Scanning electron photomicrographs of epoxy casts of intercrystal porosity show the pores to have regular, mostly polyhedral shapes ranging in size from 70 microns down to a few microns. The pores are joined by irregular-tabular-polyhedral pore throats a few microns in size. Total porosity is estimated to be 20 to 30%. Local, scattered limpid rhombs of dolomite in some mudstones suggest that dolomitization was eogenetic having formed shortly after deposition of the sediments. A replacive origin for other dolomites is indicated by the clouded dark centers in some rhombs and the penetration of skeletal allochems by rhombs.

Most moldic porosity results from the dissolution of mollusc shells and anhydrite pseudomorphs. Permeability is limited by clay laminae and the micritic matrix. Pore size varies from tens of microns up to a few millimeters except where enlarged by dissolution to form vugs.

Vugular porosity is generally less than 7 millimeters in size and irregular in shape. Most vugs appear to have formed in the mesogenetic environment by the enlargement of moldic pores, and from the dissolution of anhydrite and unreplaced limestone patches that survived earlier pervasive dolomitization.

A variety of minerals are found within the pores on the faces of dolomite rhombs and in pore throats, including quartz, (both authigenic and detrital), anhydrite, calcite, ilmenite, possibly muscovite, and clays of the chlorite, illite and smectite (montmorillonite) families. The presence of these clays within pores can be misleading to both the exploration geologist trying to interpret the high water saturations calculated from electric logs, and also the production engineer trying to optimize hydrocarbon recovery.

Depositional Environments and Sandstone Diagenesis in the Pennsylvanian Tyler Formation of Southwestern North Dakota

by Stephen D. Sturm, UND Geology Department

Abstract

The Tyler Formation in North Dakota may be divided into upper and lower units, reflecting changes in lithology as well as depositional environment. The lower unit is dominated by shales, mudstones and siltstones, thin coal beds and sandstones. In the Medora field area, the upper unit can be divided into a lower subunit, dominated by argillaceous limestones and calcareous shales, and an upper subunit dominated by anhydritic limestones, calcareous shales and local, thin anhydrite beds. In the vicinity of the Dickinson field, the upper unit is locally dominated by various lithologies, which indicates rapid changes in depositional environments.

The lower unit is interpreted to represent sedimentation on a progradational delta plain. Distribution maps of lower unit sandstones indicate an east-west trend (in Billings and Stark Counties) of medium-grained well-sorted quartz arenites, interpreted as a delta front deposit. To the south the maps indicate a northwest-southeast trend of medium-grained, poorly to moderately-sorted quartz arenites, interpreted to be distributary channel-fill deposits.

Barrier islands controlled deposition of the upper unit in Billings and Stark Counties. Barrier island development was followed by northward progradation of lagoonal and estuarine environments in the Dickinson area (Stark County) and transgression of a shallow anoxic sea in the Medora area (Billings and Golden Valley Counties). Still-stand or northward progradation in the Dickinson area, and regression in the Medora area created similar tidal flat deposits in the uppermost Tyler.

Each sandstone facies exhibits a distinctive diagenetic history. Channel sandstones are characterised by low original porosity and permeability due to large proportions of detrital clay. Porosity and permeability were reduced by authigenic kaolinite and late stage ankerite cement. Delta-front sandstones are tightly cemented by anhydrite: as much as 30 percent of the original porosity has been eliminated by precipitation of calcium sulfate derived from local hypersaline lakes. Porosity in barrier island sandstones has been reduced by quartz overgrowths. Detrital clay coatings on quartz grains inhibited overgrowth and total cementation. Late-stage authigenic kaolinite has further reduced primary intergranular porosity and permeability.

Carbonate Sand Bodies Within the Basal Swift Formation (Upper Jurassic) of Northwestern North Dakota

by Tina M. Langtry, UND Geology Department

Abstract

The carbonate bodies of the basal Swift Formation (Upper Jurassic) occur as anomalous deflections on a relatively uniform mechanical well log section. The areal distribution, stratigraphic relationships and genesis of the carbonate bodies were determined by using the gamma ray log, the spontaneous-potential log, the resistivity log suite, and megascopic and microscopic core analysis.

The carbonate bodies of the basal Swift Formation are coarsening-upward sequences composed of predominantly sand-sized, recrystallized mollusk grains. These grains were transported by strong bottom currents across the irregular sea floor of the shallow epicontinental Jurassic sea, and were deposited under agitated water conditions in the offshore environment. These carbonate sand bodies are analogous to offshore bar deposits of similar age that are recognized across the midcontinent region.

The carbonate sand bodies are up to 22 miles in length and 7 miles in width, and attain a maximum thickness of 155 feet. The bioclastic sand bodies have a lower contact that is apparently gradational with the underlying very fine-grained quartzarenites. The base of the carbonate body is composed of a finely-laminated, recrystallized molluscan packstone that has a low porosity and contains moderate amounts of siliciclastic material in the matrix. This recrystallized molluscan packstone becomes cleaner and coarsens upward into a massive, recrystallized molluscan grainstone with high moldic porosity and good permeability. The upper contact of the carbonate bodies is unconformable with the overlying basal lag deposit and shales.

The convex shape of the carbonate bodies, the high moldic porosity and good permeability of the grainstones, and the overlying shales make these basal Swift carbonate bodies good reservoir rocks. The absence of thermally generated hydrocarbons within the body probably results from the shallow depth of burial and the thermal immaturity of the surrounding shales. The possible presence of biogenic gas derived from the surrounding shales makes these deposits potential sites for exploration.

A Volcanic Airfall Marker Bed in the Upper Fort Union Formation (Paleocene) of Western North Dakota

by Nels F. Forsman, UND Geology Department

Abstract

A well-preserved volcanic ash layer occurs near the middle of the Sentinel Butte Member of the Paleocene Fort Union Formation. Exposures of this layer are widespread and correlative over an area of at least 130 square miles in western North Dakota. This tuff is everywhere "sandwiched" between two bentonite layers which, together with the tuff, record 9 to 15 feet of accumulated volcanic material. The tuff contains a rhyolitic glass and mineral assemblage, but has undergone some authigenic mineral growth and possibly contamination by detrital feldspar. Bentonites and tuffs are useful isochronous marker beds and commonly can be radiometrically dated and/or geochemically "fingerprinted." Many bentonites, and at least several tuffs, occur in the Paleocene rocks in and around the Williston Basin. A cooperative examination of bentonites and tuffs can help geologists establish a geochronology and reliable time-stratigraphic framework for the Fort Union Formation.

CORE AND POSTER PRESENTATIONS

Facies, Fabrics and Porosity of Selected Pre-Permian Rocks in the Williston Basin of North Dakota

by R. B. Burke, North Dakota Geological Survey; D. M. Catt, Arco Exploration Co., Lafayette, LA; R. F. Lindsay, Gulf Exploration & Production Co., Tulsa, OK; F. K. Lobdell, C. L. LoBue, P. T. Loeffler, T. J. Obelenus, N. A. Perrin, S. D. Sturm, and R. L. Webster, UND Geology Department

The Pre-Permian rocks presented include most major carbonate depositional facies, fabrics, porosity types and, also, a terrigenous-clastic delta and barrier island complex. Stratigraphic units discussed span the Tippacanoe to Absaroka sequences. Formations and intervals included are the Tyler, Mission Canyon, Ratcliffe, Frobisher-Alida, Bakken, Birdbear, Duperow, Winnipegosis, Ashern and the Interlake. All of these units, except the Ashern Formation have produced substantial amounts of hydrocarbons, and cores show different facies, fabrics and porosity types associated with them.

Facies and fabrics vary considerably throughout the Pre-Permian sequences presented, both inter- and intra-formationally. Depositional facies represented in the rocks include subtidal, intertidal and supratidal deposits from both the marine and transitional marine (Deltaic and Barrier Island) depositional environments. The most common carbonate lithofacies are mudstones, wackestones and packstones, although boundstones and grainstones are also present. The most common terrigenous clastic lithofacies are shales, silty mudstones and both mature and immature sandstones. Notable facies include evaporites (both shallow and deep water), stromatoporoids, ostracodal limestones and thin coal beds. Significant sedimentary structures include burrows, flat pebble intraclasts, desiccation cracks, birdseye structures, cone-in-cone structures, compaction slickensides and collapse breccias.

Porosity types common to all, except the Ashern, Bakken and Tyler, are intercrystal, interparticle, moldic, vuggy and breccia. Significant porosity in the Ashern and Bakken Formations is from fractures, whereas in the Tyler, interparticle porosity dominates.

The Wilson M. Laird Core and Sample Library of the North Dakota Geological Survey--More than A Library

by Rodney S. Stoa and Sidney B. Anderson, North Dakota Geological Survey

Considered to be one of the most complete and readily accessible collections of subsurface geologic data in the United States, the Wilson M. Laird Core and Sample Library is actually more than a library.

In addition to housing samples and cores from various test holes in North Dakota, also available for patrons' use are thin sections, reports, and a large variety of other information. All core and sample data will be readily accessible by an on-line computer system, which will be capable of sorting information in a variety of ways.

The library is available for public use, and equipment is provided for visiting geologists. A sample preparation lab is available, as well as lighting for sample and core photography. There is no charge for use of the facility, with the exception of a small charge to cover costs for use of equipment in the Carbonate Studies Lab. A copy of any work completed using our materials is requested for inclusion in our reference collection, which is housed in the laboratory.

ON THE ROAD AGAIN: NORTH DAKOTA GEOLOGY DISPLAYED FROM REGINA TO DICKINSON

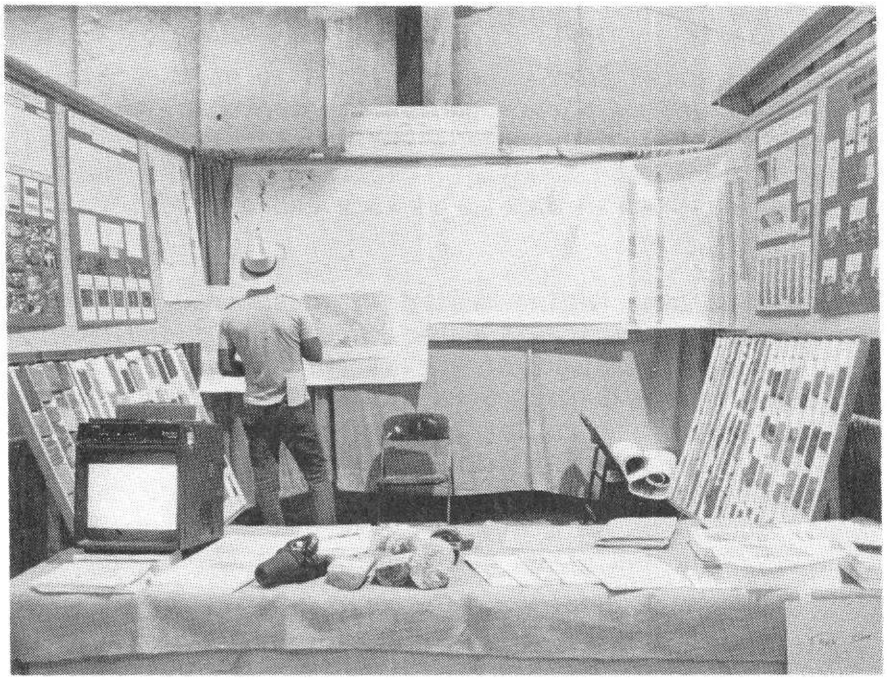
-- Randy Burke

Geologists with the North Dakota Geological Survey were invited to participate in several energy-related events this past year. Survey geologists traveled to Calgary in May to attend the annual Association of Petroleum Geologists meeting (described in the June, 1982 NDGS Newsletter), and to Minot, Dickinson, and Regina during the last six months of 1982 to discuss North Dakota geology and display various aspects of it.

The Survey information booth at Regina (the Regina meeting is described in another article), was well-received by many participants eager to obtain reliable basic geologic information about the North Dakota part of the Williston Basin. Our information booth exhibited many of the numerous maps, correlation charts, and other publications provided by the NDGS. The demand for copies took us completely by surprise and our supply of 50 correlation charts and 50 stratigraphic columns was gone within the first 45 minutes the booth was open. People who arrived after the initial supply disappeared wrote their addresses on a sign-up list and we later mailed several hundred copies of various Survey maps and other publications to these people, after we returned to Grand Forks.

We took similar displays to the Energy Exhibit at the State Fair in Minot and to the Oil Expo '82 in Dickinson. In addition to the maps and other publications, the displays at these two events included technical posters, slabs of cores, a 15-minute automated audiovisual slide program about the geology of North Dakota, and other materials. Here again, we noted a great demand for Survey publications and maps at each event. Interest in North Dakota's geology is intense and we had many interesting conversations with landowners, students, teachers, legislators, citizens--all of whom are genuinely concerned about everything from resources (petroleum, coal, geothermal, groundwater, etc.) to fossils, pollution, and glaciers. John Bluemle and I manned the booth in Dickinson during the two-day show there and I doubt that there was a single 5-minute interval during which we weren't talking to someone; more often we were trying to converse with six or eight people at once. People are intensely interested in knowing more about the geology of North Dakota.

After the State Fair in Minot, representatives from several counties requested appearances by the Survey similar to those at Minot and Dickinson at their own county fairs, but prior obligations simply made it impossible for us to participate. It is probably unfortunate that Survey geologists were unable to attend these and other such events because many citizens not only do not realize the many different services the State Geological Survey provides, but they are also confused regarding the different responsibilities and obligations of the Geological Survey, the Oil and Gas Division of the State Industrial Commission, and the Geology Department at the University of North Dakota, three distinct agencies with equally important, but totally differing missions. Next year we hope to meet with more North Dakotans to try to alleviate some misconceptions and, more importantly, tell them about the geology of our State.



Our booth in Dickinson during a lull in the activities. We had the chance to talk to hundreds of North Dakotans about geology during the two-day oil show in Dickinson.

TRIASSIC OIL PLAY -- Sidney Anderson

Across the U.S. Border north of Bottineau County in the Westhope area an oil play which began in early 1981 has been quietly gathering momentum. Omega Hydrocarbons Ltd. set off the play with an oil discovery in the Triassic Spearfish Formation near Waskada, Manitoba. Since the discovery, Omega has completed, as producers, 102 out of 103 wells. Completions average about 30 BOPD, but some are in the 100 BOPD range. Drilling depths are in the 3000-foot range. The company's location map for next year apparently indicates another 220 potential wells. Some analysts expect the play to develop into a 1000-well field with gross reserves of as much as 100 million barrels.

The area is northeast of the Newburg-South Westhope fields in North Dakota. These fields also produce from the Spearfish. By all indications, the play will continue to expand and may spill over into North Dakota. The play has not been widely noticed on the U.S. side of the border, probably because of the "International Fault." Commonly, state boundaries and international borders act as "faults" as the information does not seem to cross the lines very readily.

NDGS COMPUTER SYSTEM ALMOST READY -- Julie LeFever

The North Dakota Geological Survey has recently acquired the use of an IBM System 34 mini-computer for data management. Well data and production statistics, which are currently being handled through the University of North Dakota computer system, will be transferred to the new system. The System 34 presently has the ability to communicate with the University computer center. Communications will also be installed between the System 34 and the System 6, the Geological Survey's word processer.

Well data will be maintained in an on-line mode for retrieval at any time. Production statistics, core and sample information, and locations will also be stored on floppy disks for easy retrieval.

Future plans for the System 34 include: storage of information for oil production decline curves and the storage of water well, gravity, and stratigraphic data.

HYDROTHERMAL STUDY COMPLETED

-- Ken Harris

The final technical report of Phase III of our Department of Energy cooperative study (DOE-FCØ7-79ID-12Ø3Ø) of the hydrothermal resources of North Dakota has been released. This report marks the completion of our formal contract with the DOE through their State Coupled Hydrothermal Resource program. The North Dakota Geological Survey will, however, continue to maintain our computer libraries and make the data available to anyone interested in developing this resource.

Our study of the hydrothermal resources of the state was conducted over the last 3½ years and consisted of three phases.

Phase I (January 15, 1979 to March 7, 1980) consisted of an evaluation of potential hydrothermal aquifers based on the North Dakota Geological Survey's records of oil and gas wells drilled in the state. The Phase I study assembled a computer library system (WELLFILE) of the oil and gas well data, and used this data to construct a geothermal gradient map of North Dakota and summarize the characteristics of potential hydrothermal aquifers.

Phase II (March 8, 1980 to April 30, 1981) dealt with three main topical areas: geothermal gradient and heat-flow studies, stratigraphic studies, and water quality studies. Geographically, our efforts were concentrated in areas of interest indicated by our Phase I study, and stratigraphically they were concentrated on Mesozoic and Cenozoic rocks.

The geothermal gradient and heat-flow studies involved running temperature logs in groundwater observation holes in areas of interest indicated by the Phase I study; and locating, obtaining access to, and casing "holes-of-convenience" to be used as heat-flow determination sites. Dr. Francis Howell, UND Physics Department, built and calibrated our downhole temperature logging equipment and was the guiding-spirit and prime-mover for the heat-flow investigation.

The stratigraphic and water quality studies involved two main efforts. First, WELLFILE was updated and expanded. Second, a computer library system (WATERCAT) was assembled for all water wells drilled in the state. WATERCAT combines data from the United States Geological Survey Water Resources Division's (USGSWRD) WATSTOR and GWSI computer libraries; and includes physical, stratigraphic, and water quality data.

Phase III (April 30, 1981 to August 1, 1982) continued our Phase II work and expanded it to a state-wide scale. The Phase III Final Technical Report contains discussions of our data bases, results, and mapped summaries of selected, potential hydrothermal aquifers. Five appendices contain mapped and tabulated summaries of the stratigraphic, water quality, and depth-and-temperature data used in this study. The appendices are intended to present our data in a location-oriented format that will enable potential developers to assess the available data at a specific location.

The following reports summarize the results of our study. They are available from either of the following agencies:

1) North Dakota Geological Survey
University Station
Grand Forks, ND 58202-8156

2) Engineering Experiment Station
University of North Dakota
University Station
Grand Forks, ND 58202

Harris, Kenneth L., Winczewski, Laramie M., Umphrey, Howard R., and Anderson, Sidney B., 1980, An evaluation of Hydrothermal Resources of North Dakota; Phase I Final Technical Report: University of North Dakota Engineering Experiment Station Bulletin Number 80-03-EES-02, 176 p.

The Phase I Final Technical Report is available through the UND Engineering Experiment Station for a charge of $2.00 for postage and handling.

Harris, Kenneth L., Anderson, Sidney B., Umphrey, Howard R., Howell, Francis L., Winczewski, Laramie M., and Gaugler, Bruce A., 1981, Geothermal Resources of North Dakota: North Dakota Geological Survey, Grand Forks, Map Scale 1:500,000.

This map is a Phase I summary of potential geothermal resources in North Dakota. It is available from the North Dakota Geological Survey free of charge.

Harris, Kenneth L., Winczewski, Laramie M., Umphrey, Howard R., 1982, Computer Management of Geologic and Petroleum Data at the North Dakota Geological Survey: North Dakota Geological Survey Report of Investigation No. 74, 34 p.

This report summarizes the computer data management systems developed by this study. It is available through the North Dakota Geological Survey for $2.00.

Harris, Kenneth L., Howell, Francis L., Wartman, Brad L., Anderson, Sidney B., 1982, An Evaluation of Hydrothermal Resources of North Dakota; Phase III Final Technical Report: University of North Dakota Engineering Experiment Station Bulletin Number 82-08-EES-01, 210 p.

The Phase III report is available through the UND Engineering Experiment Station ($2.00 for postage and handling) or through the North Dakota Geological Survey at no cost.

FOSSIL INSECT STUDIES CONCERNING THE CLIMATIC AND ENVIRONMENTAL EVOLUTION OF NORTH DAKOTA AND ADJACENT AREAS

-- John Hoganson

Those of us who have resided in North Dakota most of our lives are well aware that agriculture is one of our most important industries. The year-by-year success of that industry profoundly affects the economic stability of the state and the people who live here. But, from a geological perspective, it has been only recently that North Dakota has had the climate and resulting environmental setting conducive for agricultural development because, about 15,000 years ago, three-quarters (all but the southwest corner) of the state was overlain by glacial ice. Understanding how the state's present climate and environment has evolved, by analyzing fossil insects, is the subject of part of my research with the North Dakota Geological Survey. Studies such as these have been carried out by Drs. Allan Ashworth and Donald Schwert, Geology Department, NDSU over the last few years. A cooperative effort has been initiated between them and myself to expand these studies. Joint research projects have begun between the NDSU Fossil Beetle Laboratory and the newly renovated Quaternary Research Laboratory here in Grand Forks.

Fossil beetles are the most useful insects in our research because their hard parts are durable and preserve well in lake, pond and bog sediments. Beetles have evolved little over the last million years, consequently the fossils we find are the same species that live today whose environmental requirements are known through biological studies. Beetles are sensitive to their environment and will migrate, if climatic conditions become unacceptable, to areas more favorable to their existence. Past climatic and environmental conditions of an area can be determined by applying, to the fossil beetle species, our knowledge of the distribution and habitat requirements of those species today.

The following discussion is an outline of what has been determined about the climatic and environmental history of North Dakota and adjacent states through fossil insect studies. These findings are the result of Allan Ashworth and Don Schwert's work and condensed here from numerous scientific articles published by them. I will conclude with a discussion of cooperative projects currently in progress by us and our future research plans.

The oldest (greater than 46,900 years) fossil beetles found in our area come from the Gervais Formation, exposed along the Red Lake River in western Minnesota (see figure 1). Although many of the species recovered from the site live today in the coniferous forest in Minnesota, some exist only in the tundra-forest transition zone in northern Canada. One species is known to live only in the Northwest Territories today. The fossils indicate that a spruce woodland with open areas existed, and temperatures were much cooler in northwestern Minnesota than they are today. A major gap in our fossil beetle record occurs between the time of deposition of the Gervais Formation until about 17,000 years ago. Few fossil sites have been discovered and no fossil insects have been studied from this time interval.

One of the most interesting fossil sites recently discovered is near Iowa City, Iowa (figure 1). The beetle fossils are found in wind-blown sediment deposited about 17,000 years ago near what was then the southern edge of the continental ice sheet. At that time the glacier covered most of North Dakota and Minnesota and portions of South Dakota and Iowa. Species living today at the treeline in northern Canada dominate the fossil assemblage, but a number of species found in the site inhabit only tundra areas of the Northwest Territory, Alaska, and Siberia. The implication is that eastern Iowa, 17,000 years ago, had a cold, steppe, probably tundra-type environment with summer temperatures about 10°C colder than today.

Climatic warming, resulting in recession of the glacial ice, is reflected by a 12,400-year-old assemblage of fossils recovered near Norwood in south-central Minnesota. Most species found at the Norwood site live today in the Canadian boreal forest. This indicates that, by 12,400 years ago, summer temperatures had increased by a number of degrees relative to the 17,000-year-old Iowa City record. Climatic warming continued through the 12,400 to 9,500 year time interval as determined from fossil assemblages occurring at sites on the Missouri Coteau in North Dakota. The 10,800-year-old John's Lake Site in Sheridan County contains a spruce-forest beetle assemblage indicating that, unlike today, forest conditions existed in central North Dakota. A similar forest dwelling beetle assemblage, 9,900 years old, was obtained from the Mossbeck Site in Pennington County, Minnesota. Forest habitats, evidently, were widespread in our area about 10,000 years ago. The Seibold Site (9,750 years old) in Stutsman County, North Dakota, contains fossils that also indicate spruce-forest conditions, but with prairie-like openings. Summer temperatures, 9,750 years ago, were slightly warmer than those at the southern margins of the Canadian boreal forest today, but conditions were significantly drier on the Missouri Coteau than earlier, since prairie habitats were beginning to develop.

Another major gap in the record exists between about 9,500 and 3,500 years ago. This is a critical interval because we know from the Seibold fossils that prairie habitats were beginning to become established about 9,750 years ago and that our present climatic regime was well established by 3,500 years ago as indicated by fossils recovered from a site at Bongards, Minnesota. Therefore, the exact time when North Dakota's present climatic and environmental setting was established is not known, but apparently this occurred sometime during the 6000-year unstudied time interval between 9,500 and 3,500 years ago.

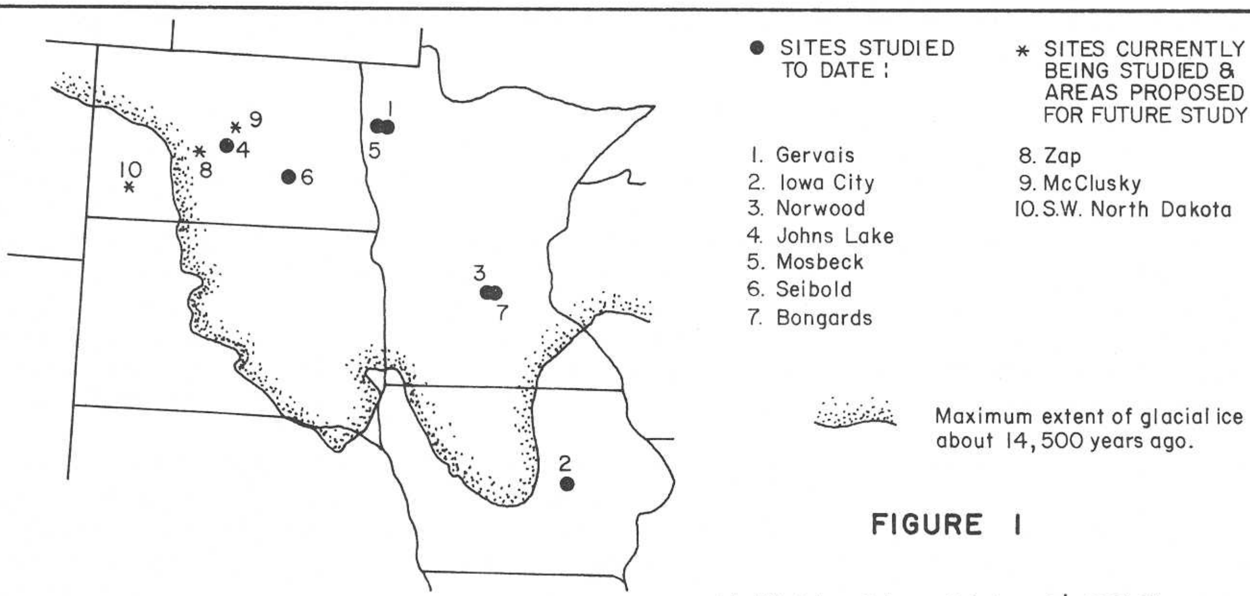


FIGURE 1

Modified from Schwert & Ashworth's 1981 Figure

We are beginning to understand the climatic and environmental history of North Dakota through studies of fossil insects. However, very few sites from isolated time intervals have been studied, and there are major periods of time and large geographic areas from which we have no record at all. Perhaps the most critical time interval yet to be studied is between 9,500 and 3,500 years ago because of the reason stated above and also because it is believed (as a result of other studies) that North Dakota experienced relatively warm and dry conditions between about 7,500 and 4,000 years ago. Documentation by insect studies of these warm and dry conditions has not been possible until recently. A 5,500-year-old site was discovered some time ago when a high-water diversion channel was excavated in the valley of Spring Creek on the Dallman Ranch west of Zap, Mercer County. Attention was drawn to the site because it contained fossil bison bones. Subsequently, beetle fossils were found to be associated with the bones. It has been suggested, because of the dense concentration of bones, that the area may have been a bison kill site. Consequently, the site is important not only geologically, but from an archaeological perspective as well. Don Schwert, Shelly Kraft (a student of anthropology at NDSU) and I visited the site this fall to explore the possibility of excavation. Mr. and Mrs. A. J. Dallman cordially welcomed us to their ranch, took us to the site area, and were supportive of our research plans. Unfortunately, because of exceptionally high rainfall during the summer, the 5,500-year-old fossil-bearing sediments were below creek level and impossible to collect. We hope to revisit and excavate this important site next summer if conditions are drier.

Another significant North Dakota site was unearthed during excavation of the McClusky canal in Sheridan County, north of the town of McClusky. Sediments and fossils were deposited there between about 13,000 and 9,600 years ago. This is an important time period because parts of Europe experienced a significant climatic cooling between about 11,000 and 10,000 years ago. Scientists disagree whether other parts of the world also suffered a similar climatic reversal during that time (see my June, 1981 Newsletter article). So, examination of insect fossils from the site is important not only to define central North Dakota's past climate, but also to contribute information relative to the global climatic picture during that time. A former UND geology graduate student, Linda Okland, studied the snails, clams, seeds, and fish recovered from the site. Kris Carter, a UND geology graduate student, and I are currently examining the insect fossils.

In addition, we are now seeking other North Dakota sites, particularly from the southwest corner of the state, spanning the 18,000 to 14,500 year time period. As stated earlier, southwest North Dakota was unglaciated when the rest of the state was covered with glacial ice. Determining the climate and environment there, during full glacial conditions, is necessary to gain a full understanding of the climatic and environmental history of North Dakota. We have explored the area for potential sites, but with no success. Our search will continue. Most sites, however, are discovered by accident during construction of stock ponds, diversion canals, pipeline ditches, etc. They are brought to our attention by citizens who realize that they have uncovered something unusual.

I consider North Dakota's climatic and resulting environmental setting to be its main natural resource, because that setting has permitted North Dakota to become one of the world's greatest agricultural producing areas. It is as important to understand the genesis of North Dakota's climatic and environmental setting as it is to understand the conditions that led to deposition of other economically important resources such as petroleum and coal. An important difference exists though: the conditions necessary for generating our petroleum and coal resources, present here in very ancient times, no longer exist. Those resources are unchanging, non-renewable and they will be available only until they are depleted. However, the climate and environmental setting necessary for agriculture production is, as I have tried to show here, dynamic and it can change from favorable to unfavorable or vice-versa over relatively short periods of time. Knowledge of how this resource has changed in the past is the key to understanding the present conditions and, perhaps, predicting future changes.

NEW PUBLICATIONS

The following publications were issued by the Survey during the past six months.

Miscellaneous Map 21--"Bedrock Geologic Map of North Dakota," was compiled by John P. Bluemle. This colored map shows the bedrock surface found beneath the mantle of glacial sediment in North Dakota. As it is used on the map, the term "bedrock" refers to the materials of Tertiary age and older. In those parts of North Dakota covered by thick glacial sediment, the geology shown on the map is interpreted from test-hole data. Throughout most of the area southwest of the Missouri River, where glacial deposits are thin and discontinuous, the geology is based largely on surface exposures. A total of 23 bedrock units are represented on the map. The bedrock map is printed at a 1:1,000,000 scale (1"=16 miles) and measures 27" x 30". A small inset map that is also included shows the depth to the bedrock surface (the thickness of the glacial overburden). The inset map is also done in color. This new bedrock map of North Dakota is the first one published by the Survey since 1969 (an earlier version was also published in 1956) and, as a result of the intensive, detailed work that has been done in the state over the past 13 years, it is considerably revised over the earlier edition. Miscellaneous Map 21 is available from the North Dakota Geological Survey for $1.00.

Miscellaneous Map 22--"Generalized Bedrock Geologic Map of North Dakota," was drawn by John P. Bluemle. This page-sized map measures 9" x 11", and is printed in color. This map is intended primarily for use by students and other non-geologists. It is available free of charge from the North Dakota Geological Survey.

Miscellaneous Map 23--"Structure Map on Top of the Cretaceous Pierre Formation in North Dakota," was drawn by C. G. Carlson. It shows the elevation, in feet above sea level, of the Pierre Formation shale wherever it is present in North Dakota. Areas where the shale can be seen at the surface are shown in green on the map. The structure map will be of special interest to oil explorationists who need to know the depth to the Pierre Formation to enable them to estimate how much surface casing will need to be set. Miscellaneous Map 23 is available free of charge from the North Dakota Geological Survey.

Bulletin 69, Part III--"Ground-Water Resources of Ransom and Sargent Counties, North Dakota," was prepared by C. A. Armstrong of the U.S. Geological Survey. The report is one of three parts dealing with the geology and groundwater flow systems in the two counties. With the publication of Part III of this bulletin, all three parts of the bulletin are now available. The report is the result of an investigation to determine the quantity and quality of groundwater available from glacial-drift and preglacial bedrock aquifers. The glacial-drift aquifers with the greatest potential for development are the Spiritwood aquifer system and the Brampton, Elliot, Gwinner, Englevale, Milnor Channel, Oakes, Sheyenne Delta, and Sand Prairie aquifers.

Properly constructed wells in the more permeable parts of these aquifers will yield from 500 to 1,500 gallons of water per minute. A total of about 3,000,000 acre-feet of water is available from storage in the glacial-drift aquifers. Water from the glacial-drift aquifers varies in chemical quality. Dissolved-solids concentrations in samples from these aquifers range from 203 to 4,670 milligrams per liter.

The top of the Dakota aquifer system underlies Ransom and Sargent Counties at depths that range from about 500 to 1,000 feet below land surface. Water in the Dakota is under sufficient head to flow at land surface in most parts of the two-county area. Unrestricted flows from wells tapping the aquifer system generally are less than 10 gallons per minute, but may be as much as 50 gallons per minute. Water in the Dakota aquifer system generally is a sodium sulfate type and has dissolved-solids concentrations ranging from 2,170 to 3,340 milligrams per liter.

Bulletin 69, Part III is 51 pages long and includes a map showing the availability of groundwater from glacial-drift aquifers in the two counties as well as several geohydrologic sections. The report is available free of charge from the North Dakota Geological Survey.

Bulletin 74, Part I--"Geology of McHenry County, North Dakota," was prepared by John P. Bluemle. With the publication of Part I of this bulletin, the first two parts of the bulletin are now available. Part II includes groundwater data; Part III, which is not yet published, will deal with the groundwater resources in the county. Part I describes the subsurface and surface geology, the geologic history, and economic geology of McHenry County. Emphasis is on description of the glacial deposits and on surface landform development. The report includes a detailed, colored geologic map of the county and 55 pages of text and figures. It is available free from the North Dakota Geological Survey.

Miscellaneous Series 62--"Oil Exploration and Development in the North Dakota Williston Basin: 1981 Update," was written by Sidney B. Anderson and John P. Bluemle. This nontechnical report provides general background on oil development in North Dakota from the discovery of oil in 1951 through 1981. The 30-page booklet contains a wealth of information including statistics such as annual crude oil production in North Dakota since 1951, annual oil and gas production tax collections, and oil and gas lease bonus income figures. It summarizes annual crude oil production, new pool discoveries, total wells drilled, and wildcats attempted, all since oil production began in 1951. By means of a series of maps, the pattern of oil development in the North Dakota Williston Basin is clearly traced over the years. All the new discoveries for 1981 are listed in the report. The report is available from the North Dakota Geological Survey for $1.00.

Miscellaneous Series 63--"Geological Development, Origin, and Energy Mineral Resources of Williston Basin, North Dakota," was written by Lee C. Gerhard, Sidney B. Anderson, Julie A. LeFever, and Clarence G. Carlson. This is an important summary of current knowledge about the Williston Basin. The publication is a reprint of an article that appeared in the August, 1982 issue of the American Association of Petroleum Geologists Bulletin. In addition to analyzing the oil exploration and development history of the Williston Basin, the report deals with the tectonic setting, stratigraphy, and structural history of the basin. Miscellaneous Series 63 can be obtained from the North Dakota Geological Survey for $1.00.

Educational Series 14--"Geologic Time in North Dakota," was prepared by John P. Bluemle and Lee Clayton. It is a non-technical discussion of geologic time and what it means in North Dakota. The publication includes a short discussion of the length of geologic time and of the various ways it has been and can be measured. This discussion is followed by a series of seven diagrams, the first representing the entire 15 billion years of the history of the universe, the second representing the last 1.5 billion years of the earth's history, and continuing to the last diagram, which depicts events that have taken place in North Dakota during the most recent 15 thousand years. Additional diagrams illustrate how North Dakota's climate has changed during the last 15 thousand years and how North Dakota's geology has evolved.

The 17-page report, which is available free of charge, should be quite useful to Earth Science teachers and to students. It can be obtained from the North Dakota Geological Survey.

Miscellaneous Series 47 (reprinted from 1971)--"Newburg-South Westhope Oil Fields, North Dakota," by Hussein Marafi, was first released by the NDGS in 1971. It deals with two fields in Bottineau County, North Dakota, which are excellent examples of stratigraphic traps, although structural elements are involved in trapping the oil accumulations. The oil is produced from two adjacent zones separated by a major unconformity, and they are considered to be a common reservoir. The productive units are the Ratcliffe interval of the Mississippian Charles Formation and the Saude Member of the Triassic Spearfish Formation. Post-Paleozoic migration of the oil is indicated because, even though the Ratcliffe was exposed to considerable erosion, it is productive at the unconformity.

This publication should be of interest in view of the Triassic oil play now underway in southwestern Manitoba (see article on page 14, this Newsletter) just north of the Newburg-South Westhope area. Miscellaneous Series 47 is available from the North Dakota Geological Survey for 50¢.

CHANGES IN PERSONNEL

Audrey Schmidt resigned her job as the Survey's receptionist last Spring due to health reasons. We all miss her. Marvelyn Anderson is the new Receptionist. Marvelyn had been the University of North Dakota Geology Department Secretary prior to coming to the Survey, so she came well prepared to handle our front desk. Originally from South Dakota, Marvelyn attended Northern State Teachers College in Aberdeen. Prior to moving to Grand Forks in June of 1981, she lived in Grafton, North Dakota, where she was Deputy Treasurer for Walsh County for 14 years. She has a son and daughter, both of whom live in California.

Julie LeFever recently joined the North Dakota Geological Survey as a structural geologist. Her interest is in Williston Basin tectonics, although she is currently involved in maintaining and updating the Survey's well file. Julie is from Los Angeles, California. She has B.S. and M.S. degrees in geology from California State University, Northridge. Julie's husband, Richard, also a geologist, is an assistant professor in the University of North Dakota Geology Department.

Robert E. Seidel joined the NDGS staff last summer. Originally from Fort Wayne, Indiana, Bob has Bachelors and Masters degrees from Indiana University. He has taught at several colleges and universities, including Indiana University, Bemidji State University (Bemidji, Minnesota), Kirtland Community College (Roscommon, Michigan), and the University of North Dakota in both the geography and geology departments. He is currently completing a Ph.D. at UND; this involves a paleoclimatic study of southwestern North Dakota. Bob's research background includes geologic investigations in Quaternary and glacial geology including research on surging glaciers in the Yukon with the Arctic Institute of North America. Bob's wife, Jaymee, is secretary to the Superintendent of Schools here in Grand Forks. They have two children, Erik and Amy, who attend South Junior High School in Grand Forks.

SURVEY PROFILES

The last Newsletter included a profile of Marilyn Rood, our Account Technician. At that time, I did not have a picture of Marilyn, but I promised then to include her picture in the next Newsletter, so here it is.

Cheryl Schreiner

Originally from Buxton, North Dakota, Cheryl graduated from Central Valley High School. She has an A.A. in Secretarial Science from Mayville State College. Cheryl is married to Ron Schreiner. Her hobbies include sewing and camping and she also enjoys participating in several sports. Cheryl has been with the Survey since 1979. She started in our publications department and is now secretary for all of our geologists. She has a special skill of completing everyone's work on time--many times doing a magnificent juggling act to keep all of us happy.

Marilyn Rood

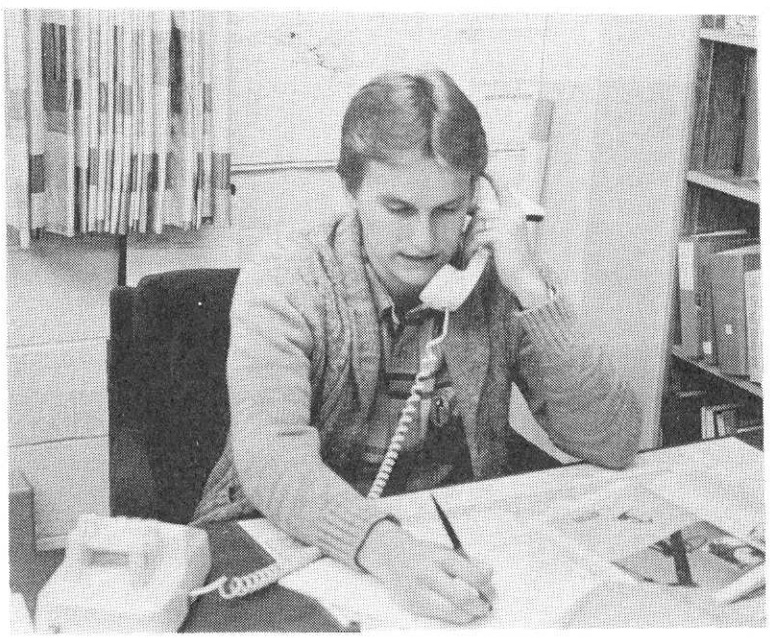
Cheryl Schreiner

Marvin Rygh

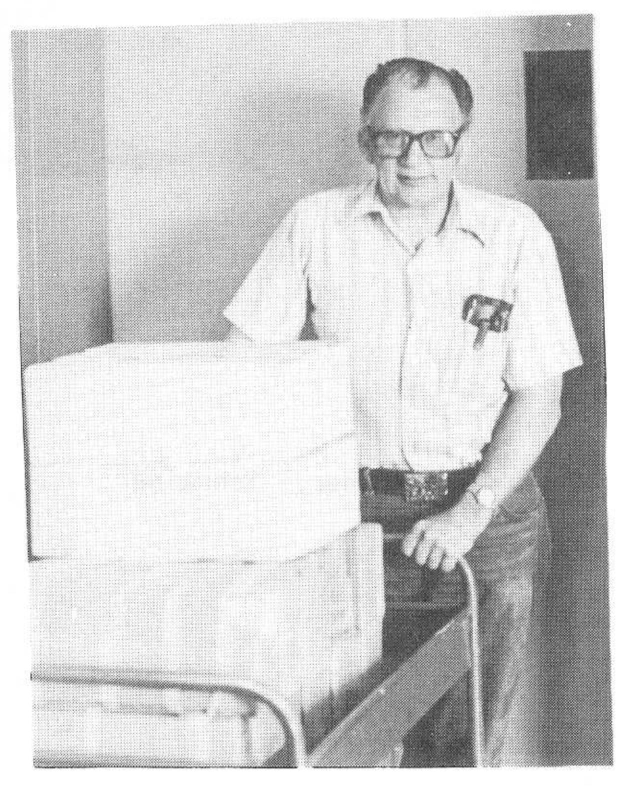
Marvin has been our Petroleum Engineer since May of 1982. Originally from Greenbush, Minnesota, Marvin graduated with a B.S. in Petroleum Engineering at the University of North Dakota last spring. Marvin has experience as a motorcycle mechanic, laboratory technician, and as a water-well driller. He is involved in several research projects for the Survey, including constructing production performance curves for all of North Dakota's oil fields.

Palmer Roos

Palmer has been our Technician since January, 1973. He is originally from Thief River Falls, Minnesota. Palmer and his wife, Ruth, have five children, two of whom are married. They also have three grandchildren. I think we all appreciate Palmer's willingness to help with just about anything he can. Whenever we need almost anything done, we all find ourselves asking "Where's Palmer?" (he's usually nearby, working on something). It's possible, Palmer missed his true calling because I'm sure he could have been a highly successful comedian with his virtually inexhaustible supply of wholesome jokes and split-second repartee.



Marvin Rygh



Palmer Roos

TWO INTERESTING CONCRETIONS

--Dave Brekke

One of the functions of the Survey is to provide information about the geology of North Dakota. This includes identifying various types of rock and mineral specimens brought to us by the public. Concretions seem to be a popular geological unknown that arouses curiosity in people who find them. A concretion is a hard, compact mass of mineral grains, normally subspherical to disk-shaped, that is cemented together by mineral matter precipitated from water. Concretions are formed in, and generally found in, sedimentary rocks.

Concretions usually form when minerals that are dissolved in the groundwater precipitate from the water. For example, the bicarbonate-rich water often tends to precipitate calcium carbonate (calcite) between grains of loose sand, cementing the sand to sandstone. It's not quite clear why this happens beneath the water table, but perhaps as the groundwater moves nearer the surface or from a zone of higher pressure to one of lower pressure, carbon dioxide escapes from the water, allowing the calcite to precipitate. In the case of concretions, the minerals are cemented around a central nucleus of some kind, perhaps a piece of shell or plant material, and once begun, the crystallization continues, building up in all directions from that nucleus, thereby forming a sphere or spheroid of hard, cemented material.

Two unusual concretions were brought to us recently, the first from Warwick, about 20 miles southeast of Devils Lake, and the second, similar specimen, from Mohall, about 40 miles north of Minot. The two concretions are fine-grained, black, smooth-surfaced, almost spherical, and they are about 1½" in diameter. Color and roundness are the features that make these particular specimens unusual. Most concretions are various shades of red. Concretions are also usually flattened in shape. Initial speculation on the origin of the two objects by Survey personnel, and others, included: Indian artifact, meteorite, small cannonball, mudball, ceramic grinding ball, petrified handball or racquetball, and, finally, concretion.

We obtained permission to cut open one of the objects, then cut and polished a thin section made of a slice. Examination with an optical microscope showed that the object is composed of thin, parallel layers of silt-size grains and clay material. Other features include thin cracks filled with barite, slight bedding-plane distortion, probably due to compaction, and a weathering rind. A scanning electron microscope/microprobe was utilized to determine the specific mineralogy and chemistry of the grains. Our analysis shows an abundance of quartz and lesser amounts of plagioclase feldspar, potassium feldspar, muscovite, and accessory minerals. The accessory minerals pyrite, zircon, barite, garnet, and an abundance of sphene--$CaTi(SiO_4)(O,OH,F)$. The grains are apparently bonded together by a silica cement.

The structure, texture, and mineralogy of the two specimens confirms a concretionary origin. The assemblage of accessory minerals, especially sphene, suggest that the source of the sediments was probably near a silica-deficient rock type. The concretion was likely formed in a water-saturated siltstone adjacent to the Canadian Shield. The concretions were transported by glaciers from the north. The areas where the specimens were found in North Dakota are near places the glacier stopped or began retreating. The unusual sphericity of the concretions is difficult to explain, although fine-grained rocks tend to be eroded into spherical shapes and glaciers have the ability to do this. Running water in a glacial meltwater channel could also have tumbled the concretions round. The weathering rind is the result of resting near the present-day surface for thousands of years.

Concretions come in many different sizes, shapes, and compositions. They can be mistaken for various other objects, either natural or man-made. Although they are quite common, they are still interesting to find and study.

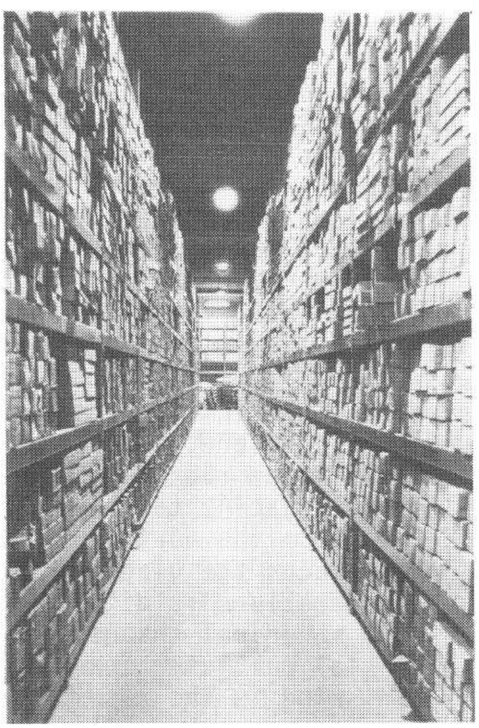
THE WILSON M. LAIRD CORE AND SAMPLE LIBRARY

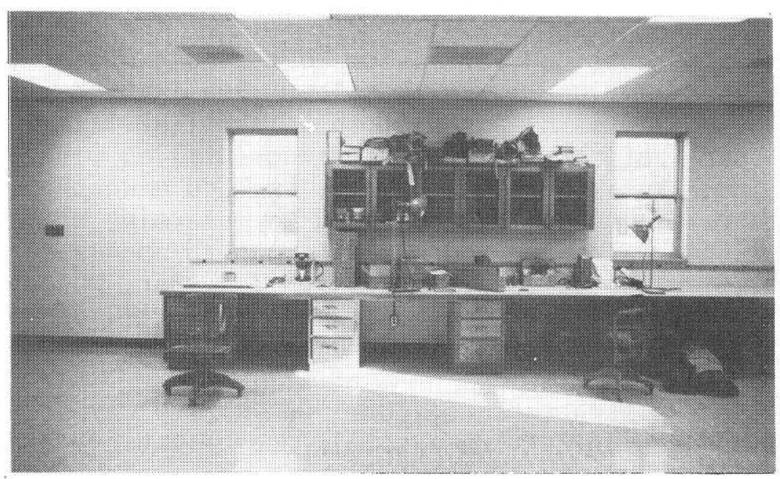
--Rod Stoa

Housed in a new building on the campus of the University of North Dakota is undoubtedly the best collection of subsurface geologic materials in the United States. These materials include samples and rock cores from virtually every well that has been drilled in search of oil and gas in North Dakota. These cores and samples are continually being used in the search for new deposits of minerals in the State.

Often, we see geologists from several different companies examining core at the same time in their search for oil and gas. By studying subtle changes in the rock from one hole to another, a geologist is better prepared to accurately evaluate his company's mineral properties. Certain conditions in the rocks are known to be commonly associated with oil and/or gas; the study of these conditions enables the geologist to determine whether it would be profitable to drill an exploratory (wildcat) well. As a result, a new pool may be found, resulting in more oil production for our state.

The majority of the visitors to the Wilson M. Laird Core and Sample Library are from the oil and gas industry. They come to Grand Forks from throughout the United States, as well as from Canada. Geologists also come from many other mineral-related industries, uranium and metals exploration, for example.





The racks in the new Core Library are already filled with core (left). The laboratory in the Core Library is now equipped and in almost constant use by industry and other geologists.

Scientific research is carried out almost continuously on the materials stored at our storage and laboratory facility. Students with the University of North Dakota Geology Department are our most consistent patrons. A number of master's theses and doctoral dissertations are currently being completed on the subsurface rocks and minerals in the state.

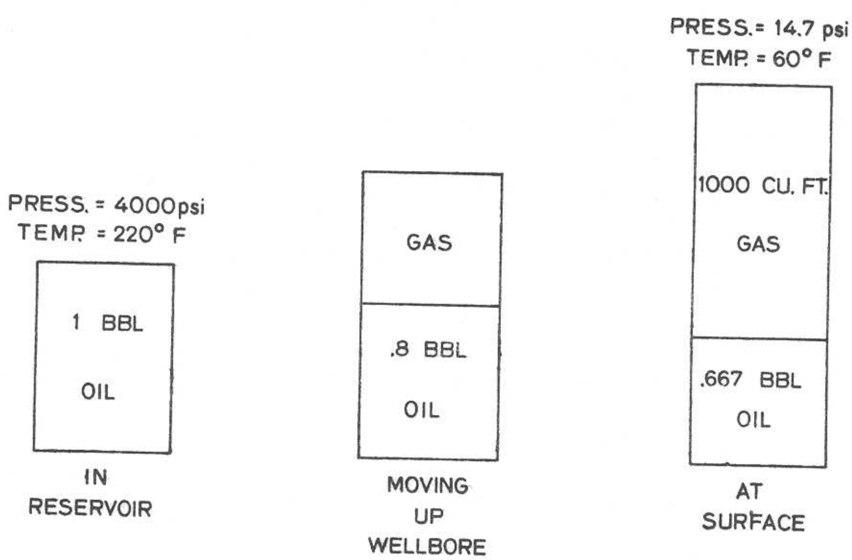
All of these activities contribute to our knowledge of the mineral wealth that occurs in our state. Because of the foresight of Wilson M. Laird, former State Geologist who was instrumental in establishing this collection of materials, North Dakota can boast of this priceless treasure, contained in the Wilson M. Laird Core and Sample Library.

FORMATION VOLUME FACTOR

--Marv Rygh

The formation volume factor is a ratio relating the change in liquid hydrocarbon volume from reservoir conditions to surface conditions. Engineers who perform reservoir analysis become very familiar with the terms "net pay thickness," "porosity," "bottom hole pressure," "recovery factor," etc. Numerous other factors are also used in reservoir engineering, but the formation volume factor, although a very basic concept, is probably not quite as self-explanatory as some of the other reservoir parameters.

The formation volume factor is the volume of reservoir oil needed to produce one barrel of stock tank oil. It is usually denoted by the symbol B_o and has units of bbls/bbls. It is essentially a dimensionless number. The value of B_o is always greater than 1 because of thermal expansion and dissolved gas within the oil. An example illustrating the above concept is as follows:



The diagram depicts a hypothetical hydrocarbon reservoir in which every barrel of reservoir oil has 1000 cubic feet of gas dissolved within it. The reservoir temperature and pressure are 220°F. and 4000 psi. As the oil moves out of the reservoir and travels up the well bore, gas starts to come out of solution because of the lowered pressure. The same thing happens when you open a can of pop. At the surface (standard temperature and pressure), the original barrel of oil in the reservoir now consists of 1000 cubic feet of gas and .667 or 2/3 stock tank barrel of oil. From this information, the formation volume factor (B_o) can be calculated.

$$B_o = \frac{1 \text{ bbl (reservoir oil)}}{.667 \text{ bbl (stock tank oil)}}$$

$$B_o = 1.5$$

What we see from this example is that the liquid hydrocarbon volume has decreased in the process of production. Some of the lighter fractions (methane and ethane) exsolve from the oil and exist in a gaseous phase at the surface.

If the factors B_o, effective porosity, water saturation, and recovery efficiency are known, the actual volume of reservoir rock needed to produce a barrel of stock tank oil can be calculated. This is done by using a straightforward volume equation:

$$V_{st} = V_{rr} \times \frac{\emptyset_e \times (1-S_w) \times R.F.}{B_o}$$

where:

V_{rr} = Volume of reservoir rock

V_{st} = Volume of stock tank oil

$\emptyset_e$ = Effective porosity

S_w = Water saturation

R.F. = Recovery factor

B_o = Formation volume factor

For example, if:

V_{st} = 1 bbl = 5.615 cu. ft.

$\emptyset_e$ = 10% or 0.1

S_w = 30% or 0.3

R.F. = 20% or 0.2

B_o = 1.5

Then V_{rr} = 602 cubic feet.

In other words, under these conditions, a cube of reservoir rock measuring about 8½ feet on a side will produce 1 barrel of stock tank oil and 1500 cubic feet of gas.

Even though this was a simplified example, it shows some of the preliminary steps that a reservoir engineer uses when trying to correctly estimate the amount of recoverable oil in a reservoir. The values I have used cannot be considered average because every reservoir has its own unique set of parameters. However, the values are realistic in terms of magnitude.

NORTH DAKOTA HAS "BETTER THAN AVERAGE" WATER YEAR --USGS

(Editor's Note: The information in this item was provided by the United States Geological Survey Water Resources Division district office in Bismarck. Working in cooperation with other Federal, State, and local agencies, the USGS compiled the following information on streamflows, groundwater levels and reservoir storage in North Dakota for the water year ending September 30, 1982. A water year, as used by USGS hydrologists, runs from October 1 of one year through September 30 of the following year. It is designed to coincide with the growing season and to begin and end during a period of generally low streamflows.)

Heavy winter snows followed by abundant summer rains added up to a "better than average" 1982 water year for streams, wells, and reservoirs in North Dakota, according to the U.S. Geological Survey. The Red River of the North at Grand Forks, the Cannonball River at Breien, the level of groundwater in the Sheyenne Delta near Wyndemere, and storage in Lake Sakakawea were monitored.

Red River of the North at Grand Forks had an average flow of 3,600 cubic feet per second (cfs), or about 2.3 billion gallons per day (gpd), which was 49 percent more than normal for the 100 years that records have been kept on that river. Average monthly flows ranged from a low of 1,074 cfs (694 million gpd) in February up to 17,600 cfs (11.4 billion gpd) in April.

The highest flow of the year on the Red River of the North occurred April 13, when a flow of 23,670 cfs (15.3 billion gpd) was recorded at the USGS index station at Grand Forks. That rate of flow, however, didn't come close to the all-time record daily flow of 85,000 cfs (55 billion gpd), which occurred April 10, 1897. The lowest 1982 daily flow, 884 cfs (571 billion gpd), occurred on the first day of the water year, Oct. 1, 1981. That low flow, however, was far greater than the all-time record low flow of only 1.8 cfs (1.16 million gpd), which occurred Sept. 2, 1977.

Cannonball River at Breien had an average flow of 820 cfs (530 million gpd), more than five times normal for the 48-year period of record. Average monthly flows ranged from a low of 3.9 cfs (2.5 million gpd) in January up to 3,800 cfs (2.5 billion gpd) in April.

The highest daily flow of the year on the Cannonball River was 12,900 cfs (8.3 billion gpd) on April 16. That figure, however, is far below the all-time record daily flow of 63,100 cfs (40.8 billion gpd), which occurred April 19, 1950.

There were several days in late January and early February when the daily flow of the Cannonball was less than 1 cfs (646,317 gpd), but in contrast to several other years, there were no days of zero flow on the Cannonball during the 1982 water year.

Partly in response to the abundant surface water, groundwater levels in two USGS observation wells rose and at year's end were higher than at the end of the 1981 water year. The level in a well tapping the Sentinel Butte Formation near Dickinson established a record low for January of 19.6 feet below ground surface, but rebounded to a level of 18.07 feet below ground surface in September. That was 0.43 foot above normal for September and 1.22 feet higher than it had been a year earlier.

The level of a well tapping the Sheyenne Delta aquifer near Wyndemere dropped to 8 feet below ground surface in February, which was the low for the year, but rose to 4.14 feet below ground surface in April and May. The all-time low for that well was 8.73 feet below ground surface in February 1977 and the record high was 1.12 feet below ground surface in April 1969.

Storage in Lake Sakakawea increased throughout the year and at the end of September was 20.8 million acre-feet, only 8 percent less than the lake's normal maximum capacity of 22.7 million acre-feet. At the end of the 1981 water year, storage in Lake Sakakawea was 17 million acre-feet, which was 25 percent less than the lake's normal maximum capacity. (One acre-foot equals 325,851 gallons.)

PERMAFROST IN SOUTHWESTERN NORTH DAKOTA

Permanently frozen ground, known as <u>permafrost</u>, is present almost everywhere within the Arctic and Antarctic circles where the earth's surface is land rather than water. In fact, a quarter of all the land surface of the earth overlies permanently frozen ground. In the most northerly regions of Canada, Alaska, Greenland, Scandinavia, and the USSR, permafrost is continuous (fig. 1). In parts of Siberia,

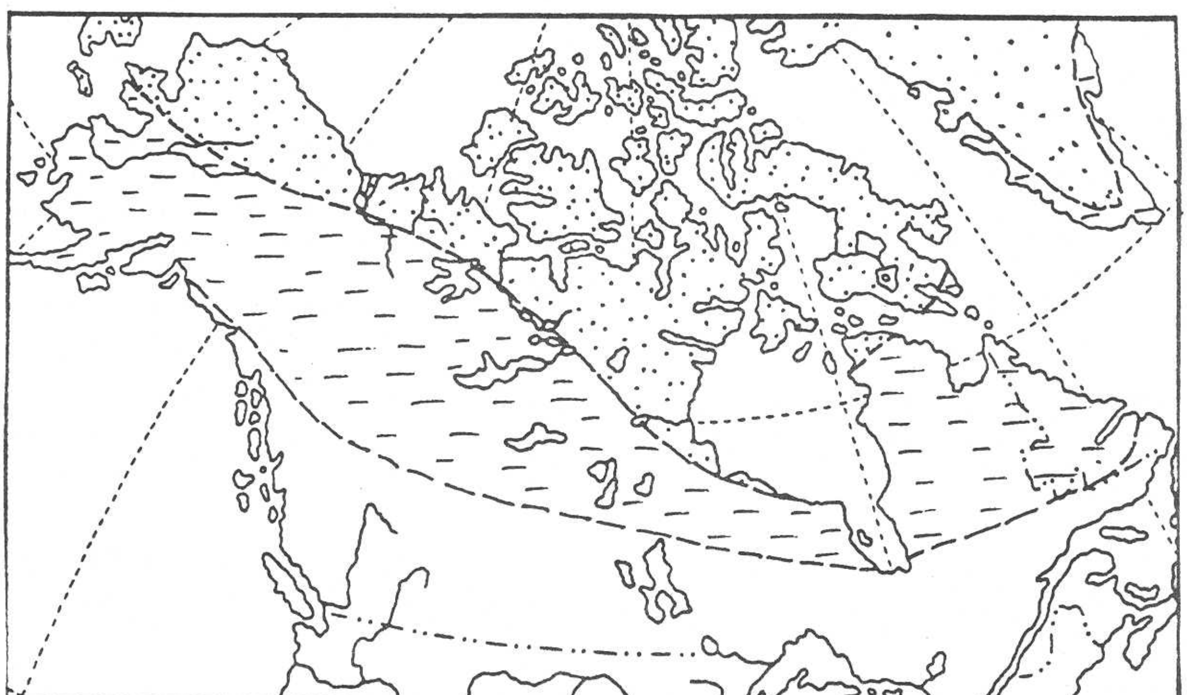


Figure 1. Permafrost in North America. The dotted area is the zone of continuous permafrost. Dashed area is the zone of discontinuous permafrost.

the permafrost is as much as 2000 feet thick. Permafrost is also present in some places in the higher elevations of the Rocky Mountains. Except in the high Andes and in Antarctica, however, permafrost is absent in the southern hemisphere.

By and large, the most important requirement for the formation of permafrost is an average overall temperature below about 0°C (32°F), but some authorities indicate that an annual temperature below about -5°C (23°F) is required before permafrost can form. The low temperature alone doesn't necessarily guarantee that permafrost will develop. The salinity of the groundwater, the fluid pressure, the grain size distribution of the soil, the soil composition, and the soil structure all may tend in various ways to lower the temperature that is required to allow permafrost to form. Permafrost doesn't form in dry ground either. The presence of water is necessary because unsaturated materials will warm much more rapidly during even a short summer season and not remain permanently frozen.

The study of permafrost is a science in itself and I won't go into any great detail about it in this article. However, I will mention a few of the more interesting features that can be found in areas of permanently frozen ground. One example is the pingo. Pingos form as a result of the uppermost layer of permafrost melting downward from the surface during a summer, to a depth of several feet. During the following winter, when this thawed layer refreezes downward again, the groundwater trapped beneath the impermeable permafrost beneath and the freezing front moving down from above builds up great pressures that can be relieved only by forcing the overlying materials upward out of the way (fig. 2). Sometimes the pingo mound that results from this pressure will rupture, causing an "ice volcano" when the trapped water flows out through the rupture and refreezes at the surface, building up a mound of ice (like a lava flow). A pingo may be as much as 150 feet high and more than a thousand feet across. Pingos are conical and generally nearly circular.

Other features characteristic of areas of permanently frozen ground form as a result of expansion and contraction of the ground surface, due to repeated cycles of warming and cooling. Cooling of the ground during the winter to extremely cold temperatures results in contraction cracks (the ground shrinks as it cools) that may extend downward 20 feet or more. The crack pattern, viewed from above, is usually polygonal, with the polygons being up to several hundred feet in diameter. When snow and water flow downward into the crack, an ice-wedge forms. If rocks and boulders are present in the soil, they are commonly forced upward ("heaved") by the frost action and they accumulate at the surface of the ice wedges, resulting in rock polygons. Rock polygons are common at higher elevations in the Rocky Mountains; I've seen them in several places in the Big Horn and Wind River Mountains in Wyoming. They can exist in an area where permafrost is present today or they may simply indicate that permafrost was present at some time in the past.

All of which brings us to North Dakota. No, we don't have any permafrost today in North Dakota although it can be found in the mountains of Wyoming and Montana. We do, however, have evidence that parts of the state at least, were permanently frozen beyond the limit of the glaciers when the rest of the area was covered by glaciers. Not surprising of course, but until about 10 years ago, no one had recognized the evidence. That evidence is in the form of fossil ice wedge polygons (or relict polygons), which are located in places where ice wedges formed during a time when the ground was permanently frozen. These fossil ice wedges occur throughout southwestern North Dakota in at least 200 places (fig. 3). The fossil polygons, which generally have either 4 or 5 sides (viewed from above) are from 30 to 300 feet in diameter (fig. 4). They are found only in areas of gravel--on remnants of pediments (old erosion surfaces), alluvial fans, and river terraces.

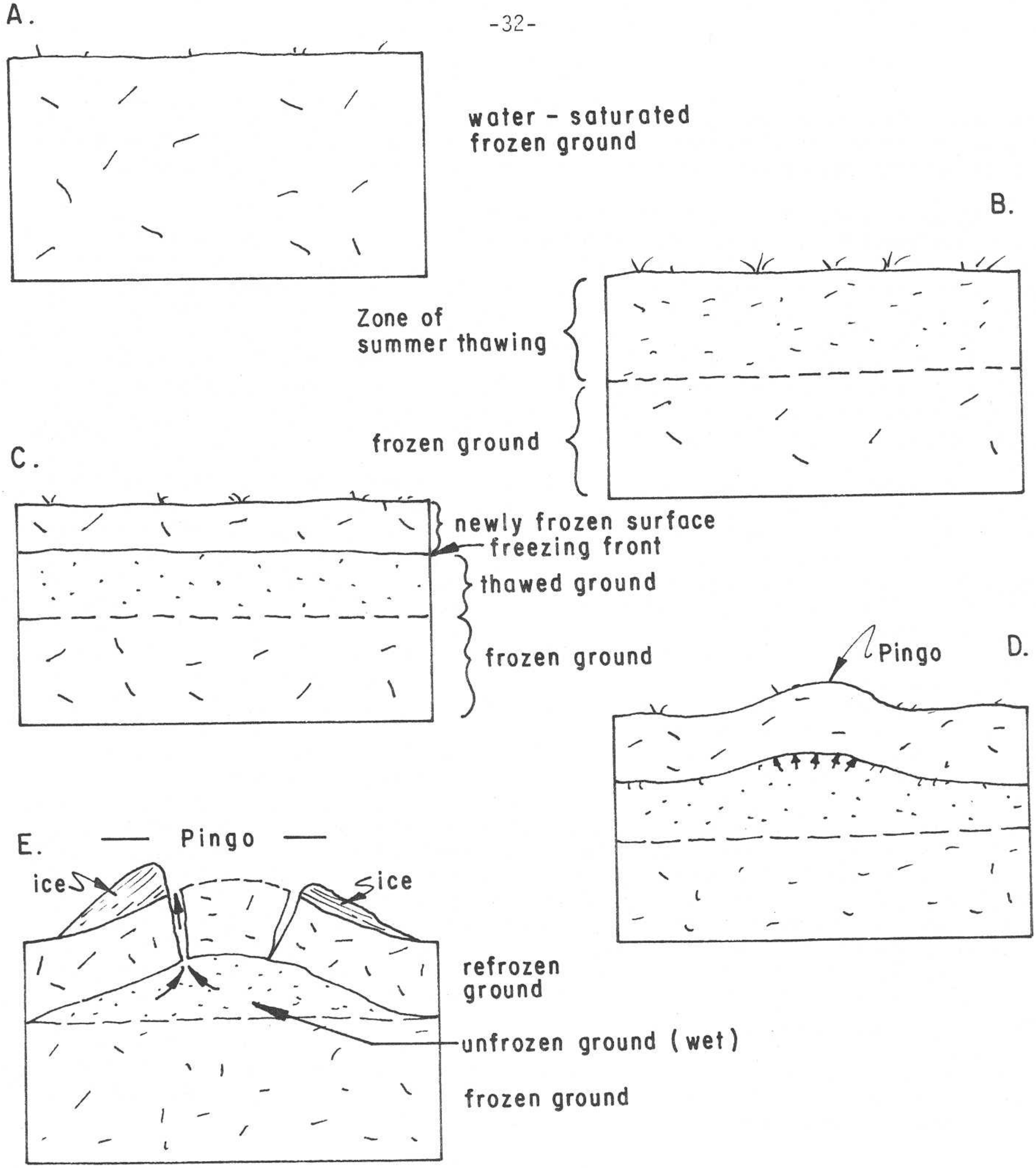


Figure 2. This series of diagrams illustrates how a pingo forms in an area of permafrost. The diagram on the upper left (A) represents a vertical cut through the upper part of the permanently frozen zone. During the summer months, the ground can thaw to a depth of several feet (B). When the weather turns cold again the following winter, the surface again freezes downward toward the permanently frozen layer at depth (C), causing the water in the unfrozen layer in between to be subjected to considerable pressure. This pressure can be relieved only on the top, so as winter freezing continues, the surface may be forced upward into a conical-shaped mound, a pingo (D). Sometimes the pingo may rupture (E), allowing the trapped water to escape to the surface where it quickly freezes, adding to the size of the pingo.

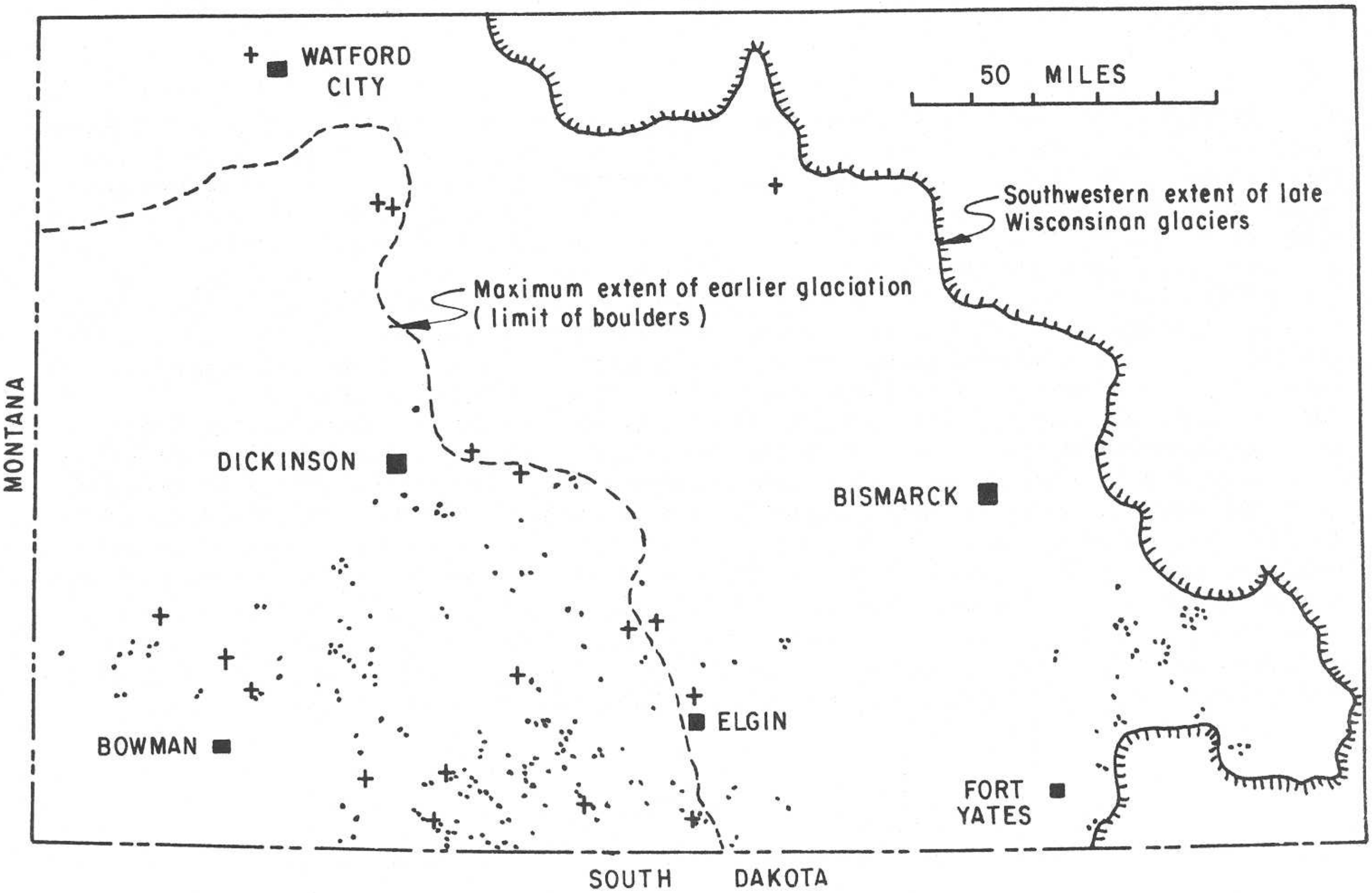


Figure 3. Distribution of fossil ice-wedge polygons in southwestern North Dakota. The dots represent locations where polygons were recognized on air photos. The crosses represent places where fossil ice wedges were seen in gravel pits. The line of tick marks is the southwestern extent of late Wisconsinan glaciers and the dashed line is the maximum extent of earlier glaciations, recognized mainly by the fact that boulders occur east and north of the line, but not southwest of it.

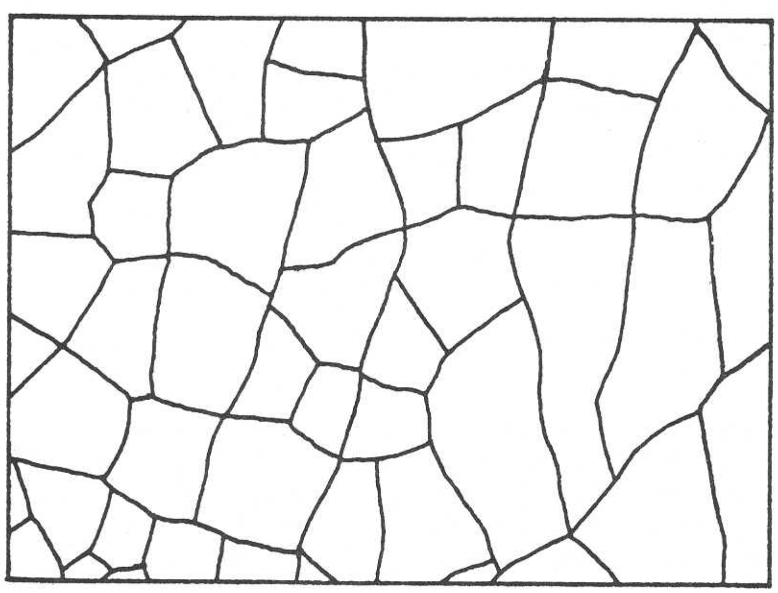


Figure 4. Sketch map of ice-wedge polygons in the Northwest Territories, Canada. The area shown is about 0.3 mile wide (approximately a tenth of a section of land). Notice that most of the polygons have either 4 or 5 sides.

Exposures of the fossil ice wedges can be seen where they have been cut by gravel pits in southwestern North Dakota (fig. 5), but unless a pit is present, the ground-based observer will have difficulty recognizing the features. A typical wedge consists of a zone that lacks bedding, but has vertical foliation (the rocks and pebbles have an up and down orientation) resulting from the growth of the ice wedge and from the overlying sand and gravel slumping into the crack as the ice melted out. The top of the wedge, near the surface of the ground, widens into a trough as the result of near-surface sand and gravel running into the underlying crack as the ice itself melted out. The sand and gravel in which the polygon formed is generally overlain by about 3 or 4 feet of wind-blown sandy silt. The presence of this silt means that North Dakota was subjected to considerable wind erosion during the time the area was permanently frozen. The silt fills the trough, leaving a flat surface so that the wedge and its trough generally have no topographic expression and can't be seen from the ground. Because they generally have no surface relief, fossil wedges are visible only when the soil is more moist or the vegetation is thicker over the wedges. The wind-blown silt is thicker in the troughs (fig. 5), making more moisture available to grasses and other plants than is available where the silt is only a thin layer over the gravel (silt holds much more moisture than gravel). For this reason, the polygons are visible only during dry periods, and probably only a small portion of the existing polygons have been observed and recorded in North Dakota (fig. 6).

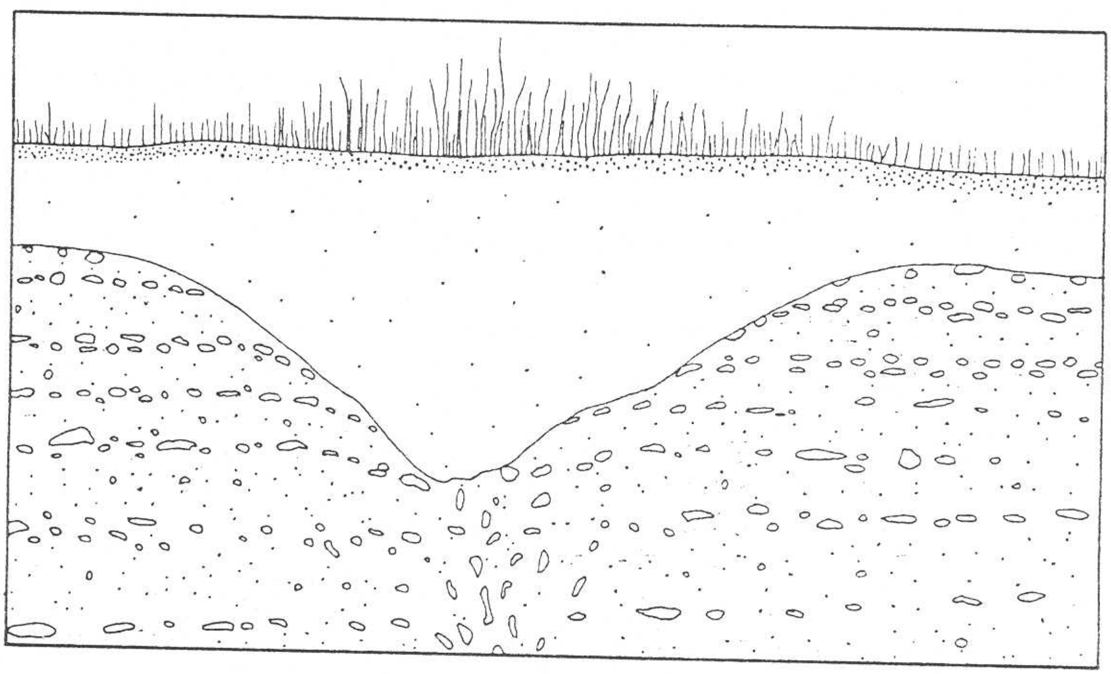


Figure 5. Cross section of a typical fossil ice wedge in southwestern North Dakota. The height of the section is about 6 feet. The fluvial (water-lain) gravel slumped into the fissure left by the melting ice wedge, resulting in disrupted bedding with vertically oriented pebbles and cobbles. Wind-blown silt fills the resulting trough. During dry periods, vegetation is most lush where the moisture-retaining silt is thickest. During wet periods, vegetation grows well everywhere so that no difference can be discerned.

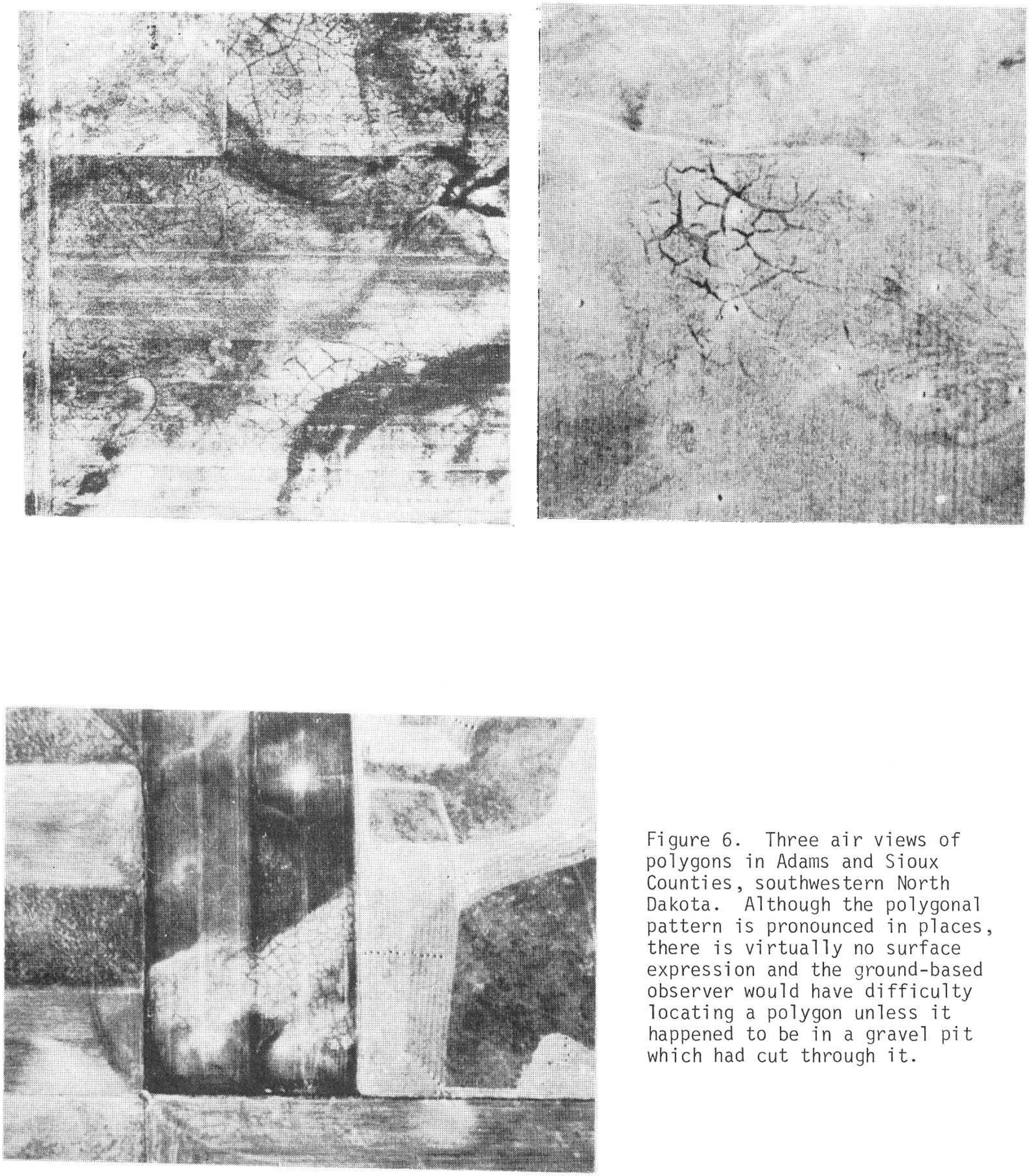


Figure 6. Three air views of polygons in Adams and Sioux Counties, southwestern North Dakota. Although the polygonal pattern is pronounced in places, there is virtually no surface expression and the ground-based observer would have difficulty locating a polygon unless it happened to be in a gravel pit which had cut through it.

As I already mentioned, ice-wedge polygons form today in areas such as northern Alaska where continuous permafrost colder than about -5°C exists. The late Cenozoic paleontology and paleoecology of southwestern North Dakota is largely unstudied, and as a result, little or no evidence of a tundra climate has been documented. Possible solifluction landforms and deposits have been noted, but they have not been studied in detail. Solifluction is the movement of water-logged soil downslope due to creep, etc.; it is usually associated with permafrost processes, although not necessarily. Solifluction landforms probably did exist in southwestern North Dakota, along with the polygons, but they would have formed in areas covered by fine-grained materials and have probably been eroded away in the time since they formed. The polygons, on the other hand, were preserved because they are located in places where the soil is so permeable (gravel) that there has been little runoff. That is, precipitation falling in areas of gravel tends to soak in rather than run off, whereas precipitation falling in areas of finer-grained sediments tends to flow over the surface, eroding it as it runs off. At the time they formed, the polygons were probably present in many places, on areas of clay as well as gravel, but they were preserved only in the gravel areas.

One especially interesting location to study these permafrost features is Cow Butte in southwestern Adams County, about 15 miles west of the town of Hettinger. Cow Butte has a surface that is covered by a resistant layer of silcrete, a material that caps many buttes in the area. The surface is also marked by distinct polygons. Grass grows much thicker along the lines between the polygons--the fossil ice wedges--where the silt fills the wedges.

Two points should be made about the polygons found on the surface of Cow Butte. First, they had to form at a time when the groundwater table was near the surface of the butte. The water table today is far below the surface of the butte and the butte is much too small to allow a high water table to develop. Therefore it is likely that the butte was considerably larger when the polygons formed than it is today. Second, the polygons extend as straight lines right to the edge of Cow Butte. When they form on a butte, polygons normally show the effect of the edge of the butte (fig. 7); that is, the polygons near the edge of a butte should have at least one side parallel to the edge of the butte. The fact that the polygons on Cow Butte intersect the edge of the butte rather than run parallel to it reinforces the idea that the butte is much smaller today than it was when the polygons formed. That is, much of the butte that existed at the time the polygons formed has been removed by erosion since then (fig. 7).

How old are the fossil ice wedge polygons of southwestern North Dakota? In other words, when did the area have a tundra climate that resulted in the permafrost that once existed there? Certainly the evidence of Cow Butte points to an ancient time, probably early Pleistocene (maybe over a million years ago) for the polygons on that butte at least. However, it is also logical to assume that each time glaciers advanced into North Dakota--and we had several separate periods of glaciation--a tundra climate developed ahead of the advancing ice. The polygons probably date to more than one tundra event, depending on the particular situation in which they are found.

Because the Pleistocene stratigraphy of southwestern North Dakota is largely unstudied, the exact age of any of the polygons is unknown. Shells of more than a dozen species of mollusks have been found in the sand and gravel wedges at three sites. None is extinct, with the possible exception of *Pupilla sinistra*, which was thought to be restricted to interglacial beds of Yarmouth age (about a half-million

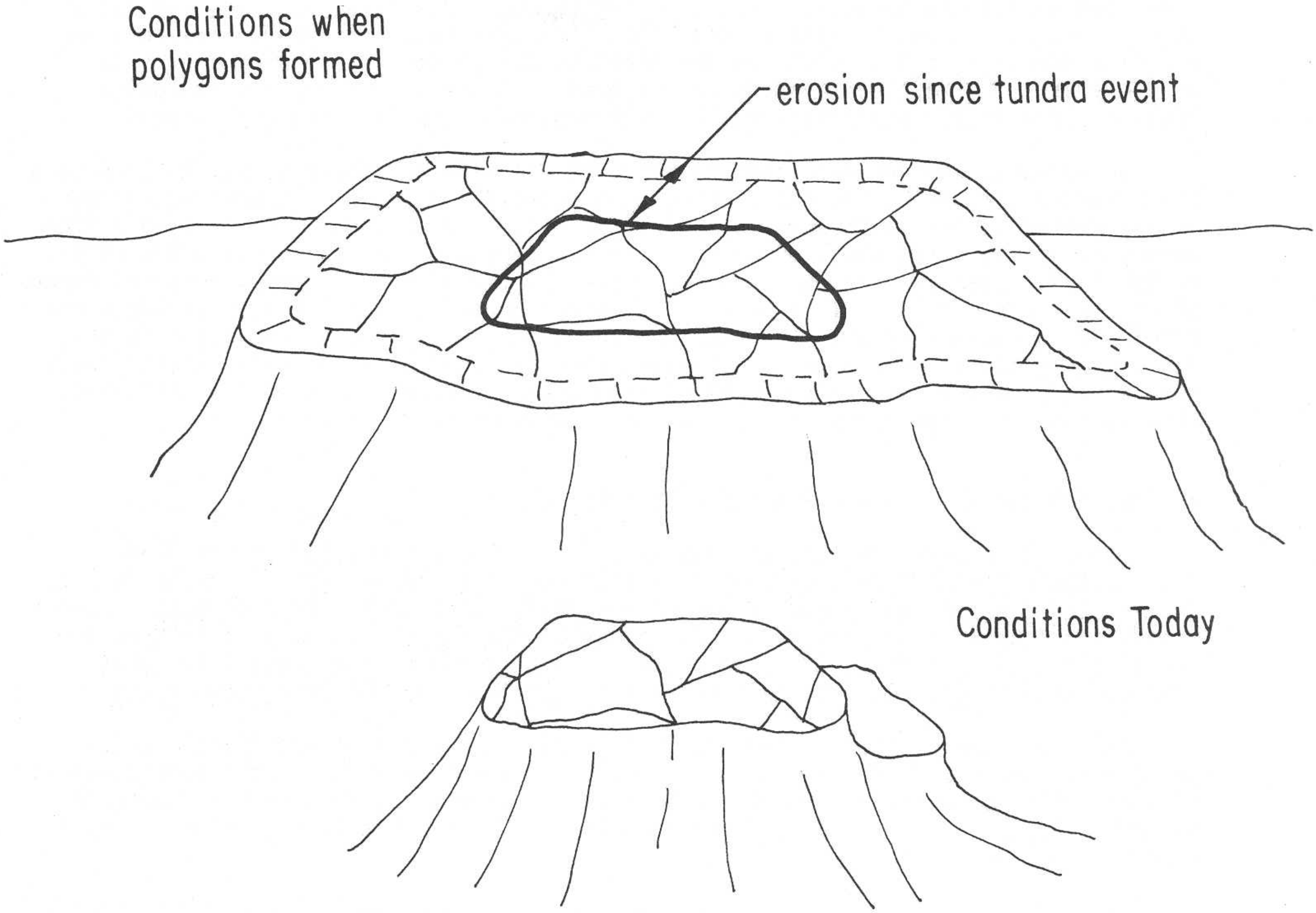


Figure 7. Diagrams illustrating Cow Butte in Adams County, North Dakota. The upper diagram represents the butte at a time in the past when permafrost conditions existed. The butte at that time was much larger, the water table was higher, and the polygons formed in such a way that the ones near the edge of the butte had a side parallel to the edge. The lower diagram shows how erosion has reduced the size of the butte, leaving the polygon pattern intact over that part of the butte surface that remains.

years old). The polygons are absent on surfaces formed during latest Wisconsinan time (ten to fifteen thousand years old) throughout North Dakota so it is unlikely that tundra conditions existed at that time (or any time since then). Polygons do occur on stream gravel as young as the Napoleon Glaciation in the area southeast of Bismarck. The Napoleon Glaciation may have occurred during Early Wisconsinan time, perhaps 40,000 years ago, so the polygons there are at least that young.

In summary, we have two lines of evidence pointing to the fact that North Dakota had a tundra climate in the past. First, we have the polygonal patterns we can see on air photos of the southwestern part of the state. Second, we can see fossil frost wedges in gravel pits, the depressions over the wedges filled with wind-blown silt. We don't know exactly when the frigid climate existed, but it probably occurred ahead of the glaciers each time they spread over North Dakota. It's not likely that permafrost was so widespread when the glaciers receded again, because then the climate was warmer (that's the reason the glaciers were melting). And finally, it is likely that North Dakota has had permanently frozen ground several times in the past, each time glaciers covered parts of the state or nearby parts of Canada.

A STUDY AND ANALYSIS OF AMERICA'S ENERGY FUTURE

Recently, I took the time to read parts of a report published by the Rand Corporation entitled "The Discovery of Significant Oil and Gas Fields in the United States" and a companion volume of appendixes listing about 500 pages of data. Even though I disagree strongly with certain parts of the report, I found it interesting and I'll include a summary of its conclusions here (most of the summary is taken from the Rand Checklist, a monthly newsletter published by the Rand Corporation).

The study was first published in 1981 and was sponsored jointly by the U.S. Geological Survey and the Department of Energy. It examines U.S. petroleum potential in light of past patterns of exploration and discovery and concludes that there is not much oil and gas left to be discovered in the United States, no matter how hard America's oilmen hunt for it.

The study estimates that the U.S. can continue producing domestic supplies of petroleum liquids for 20 to 40 years and natural gas for 17 to 26 years at 1979 rates of production, allowing for exploration and production costs of up to $40 a barrel. The estimates refer to conventional petroleum resources of crude oil, natural gas, and natural gas liquids--as opposed to nonconventional oil produced from tar sands, oil shale or coal, and similar nonconventional sources of natural gas.

The study's pessimistic prognosis is based on the notion that geological possibilities have been exhausted. The study notes that the amount of oil discovered has declined steadily since the 1930s, and the amount of natural gas discovered has declined just as steadily and substantially since the 1950s, particularly in the onshore areas of the contiguous 48 states.

The study goes on to say that increased drilling efforts--up from 27,602 wells sunk in 1973 to an anticipated 70,000 this year--will not reverse the trend.

What this means, according to the Rand study, is that approximately 80 to 90 percent of all the relatively "cheap" oil to be produced in the U.S. has already been discovered. Future discoveries will be considerably smaller than most analysts have predicted, and output is likely to fall faster than expected. Most of our future increases in production of petroleum liquids will come from reserve growth in known fields, not from new discoveries. Of the additional 35 to 110 billion barrels of petroleum liquids that the report says will most likely be added to known reserves, "18 to 38 billion barrels will come from new discoveries and the remaining 17 to 72 billion barrels from reserve growth."

The report focuses primarily on "significant" oil and gas fields, defined as fields containing at least 10 million barrels of petroleum liquids or the equivalent in natural gas--at least 60 billion cubic feet.

The report also evaluates--with generally pessimistic conclusions--the contentions that there are still substantial amounts of petroleum to be found in the United States at depths below 15,000 feet, in "subtle stratigraphic traps," in very small fields, and in frontier regions.

The report includes some mention of North Dakota specifically and of the Williston Basin in general. I'd like to comment briefly on its treatment of this area. To begin, the listing of references used to compile the study is curious for North Dakota, to say the least. The authors do state that their Bibliography is not comprehensive, but the 12 references they list for North Dakota include 5 older than 1960 and virtually nothing that is current. Their table listing North Dakota oil fields ("The Significant Oil and Gas Fields of North Dakota") is especially curious. It lists the following fields (no others): Class AAA--Greater Beaver Lodge, including Beaver Lodge, Capa, and Hofflund; Class AA--Tioga Plus Tioga North; Class A--Antelope; Class B--Charlson, Blue Buttes, Newburg-Westhope, South, Dickinson, Fryburg, Sherwood; Class C--Rival, Hawkeye, Medora, Red Wing Creek, Glenburn, Elmore, Clear Creek, and Wiley. That's a total of 21 fields, some old and some new, but certainly an unusual selection. We currently have about 300 producing fields in North Dakota, many of which are far more productive and geologically more significant than the ones listed in the Rand report. The report defines Class Size as follows:

FIELD SIZE CLASSIFICATION SYSTEM

Field Size Category	Field Size
Class AAAA	500 million barrels or more of petroleum liquids and natural gas expressed in liquid equivalents*
Class AAA	200 to 500 million barrels
Class AA	100 to 200 million barrels
Class A	50 to 100 million barrels
Class B	25 to 50 million barrels
Class C	10 to 25 million barrels
Class D	1 to 10 million barrels

* We use a conversion rate of 6000 cubic feet per barrel. For example, 500 million barrels is equivalent to 3.0 trillion cubic feet, 200 million barrels to 1.2 trillion cubic feet, 100 million barrels to 600 billion cubic feet, and so on.

I've not read the entire report, not scrutinized it carefully, and I'm not certain how accurate it is overall. On the face of it, though, it appears that the writers made some serious errors in their analysis of the situation in North Dakota. We know we have numerous areas and horizons to examine and, undoubtedly, a great deal of oil is still to be found in North Dakota. Of course, one immediately questions whether the report is as out-of-date and inaccurate for other states as it is for North Dakota; I don't know that it is.

Too often, it seems to me, government-funded research appears to be devoted to showing that "it can't be done." If such a study as this one had to be farmed out by the DOE and USGS, it might better have gone to a group of private, knowledgeable petroleum geologists and engineers with experience in the real world. Even a cursory polling (at virtually no cost) of the various state agencies involved would probably have resulted in statistics that would be more accurate and valuable than those in the report. Certainly, in North Dakota, either the Oil and Gas Division or the State Geological Survey could have provided any amount of far more accurate statistics on the situation here and any number of up-to-date, pertinent publications.

I think most experts do agree that the United States has reached the point in its oil-development history when we can expect additional reserves discoveries to come with increasing difficulty. In fact, we are now on the declining side of our oil reserves and numerous studies verify this. But that's not the case in North Dakota and probably not in many other states and provinces. We had about 100 new pool discoveries in 1982 and, although that probably won't make much of an impact on total U.S. production, it can make a significant impact on North Dakota's economy.

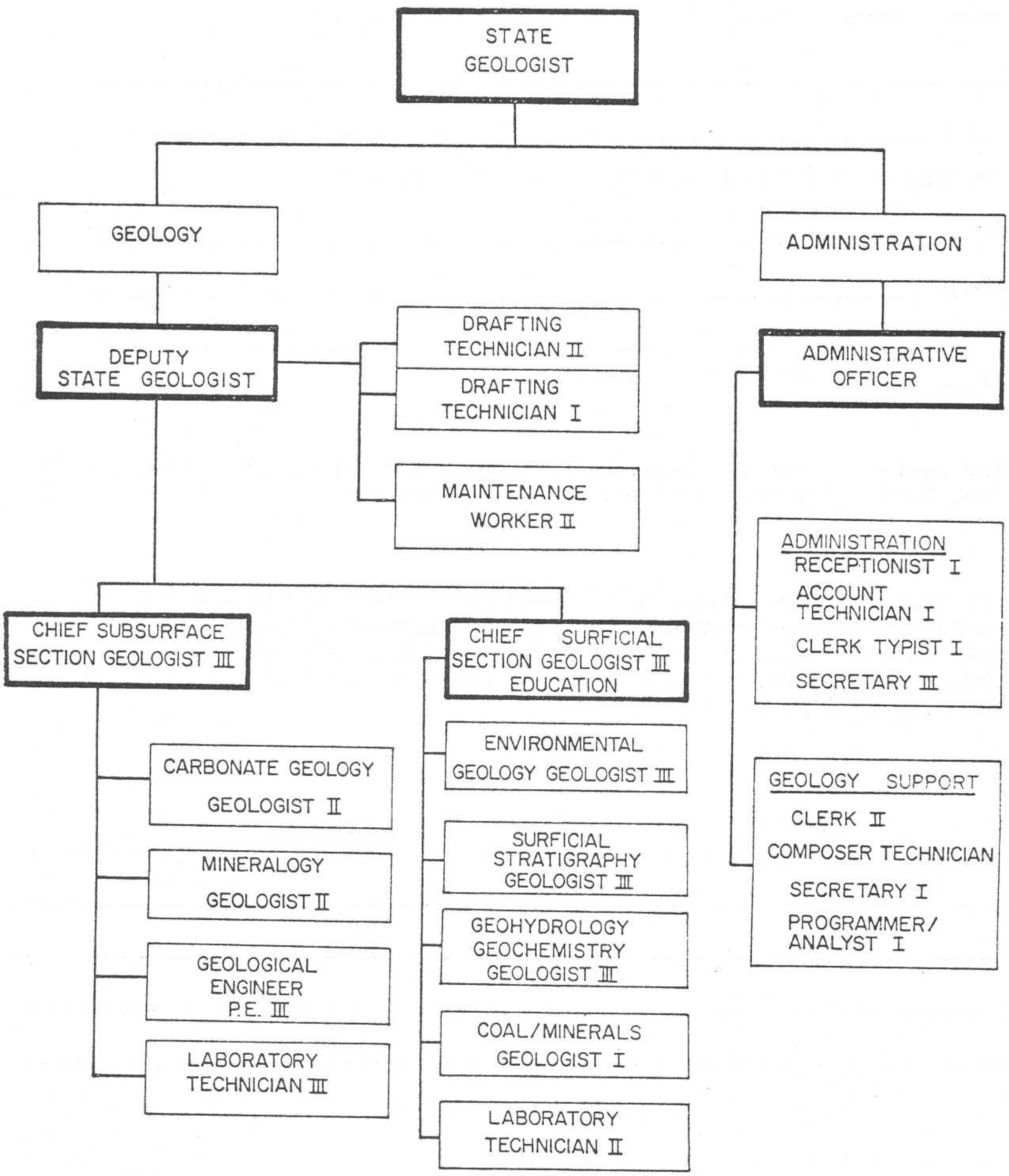
One of the dangers with studies such as this one is that some people may assume it is fruitless to continue searching for oil. Granted, we may eventually run short of oil, but we haven't begun to exhaust the possibilities in the Williston Basin yet and we still need to keep on looking. Fortunately, the majority of petroleum geologists are optimists, I think, and in spite of pessimistic reports like this one, they will keep looking as long as they continue finding oil.

NEW APPOINTMENTS AND REORGANIZATION IN THE SURVEY --Don Halvorson

As of January 1, two new appointments have been made within the Survey staff. Robert E. Seidel was appointed Deputy State Geologist. Bob joined the Survey Staff in the summer of 1982 and is currently completing his Ph.D. in geology at the University of North Dakota. He has previously taught both geology and geography in Michigan, Minnesota, Indiana and at UND. He is a Pleistocene geologist with interests in the areas of glaciology, geomorphology, and meteorology. His responsibilities will be divided between administration, research coordination, and personal research pursuits.

Dr. John P. Bluemle has been appointed Chief of the Surficial Section of the Geological Survey. He is a Senior Geologist with many years of experience and a thorough knowledge of the surficial geology of the state. I am sure John is known to you as the Editor of this Newsletter and also for his many maps, charts, and other publications throughout the years. In addition to his current duties, he will be responsible for directing research and coordinating activities within the Surficial Section.

Some organization changes have also been made in the Survey for the purpose of improving research coordination, communications, and administrative procedures. The major changes are the structuring of the geology staff into the Subsurface Section under Sidney Anderson, the Surficial Section under John Bluemle, and the establishment of the advisory board consisting of the Section Chiefs, the Administrative officer, the Deputy, and the State Geologist. The accompanying diagram illustrates structure and relationships within the Survey. The intent of this reorganization is to better unify our efforts and thereby to help us keep apace with the research needs of North Dakota.



NORTH DAKOTA GEOLOGICAL SURVEY
ORGANIZATION CHART
JAN. 1983

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

COMMENTS

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