NEWSLETTER

NDGS

A publication of the
North Dakota Geological Survey
University Station
Grand Forks, North Dakota 58202
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John P. Bluemle, Editor

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June, 1982

Editor's Note---

This Newsletter is long, more bulky than usual. One reason for this is that it includes several abstracts of talks that were delivered at the annual meeting (June, 1982) of the American Association of Petroleum Geologists in Calgary, as well as some abstracts of talks given at the annual meeting (May, 1982) of the Geological Association of Canada in Winnipeg. These abstracts are somewhat technical and probably won't appeal to those of you who prefer more readable materials--and I've learned that at least half of you are more interested in items of general interest. Even so, I do find that a certain number of geologists who read the Newsletter do appreciate such materials.

Apart from the abstracts, this issue does include a fairly comprehensive run-down of oil and gas activity in North Dakota last year. We expect to include the information in this article (on page 15) in a separate publication available soon; some of you may want the more comprehensive publication. If you do, just let me know. I've also included a general-interest article on groundwater heat pumps. The item on pages 41-42 (Landforms of North Dakota) is also somewhat less technical than the other abstracts and it may be of interest to some of you who want to know a little more about our state's geology.

THE NORTH DAKOTA GEOLOGICAL SURVEY AND UNIVERSITY OF NORTH DAKOTA GEOLOGY DEPARTMENT STAND OUT AT NATIONAL AAPG MEETINGS

--Randy Burke

North Dakota envoys to the 1982 Annual American Association of Petroleum Geologists meeting in Calgary, Alberta demonstrated that the high caliber of subsurface research being done by the two collaborating groups (the Survey and the Geology Department) is appreciated by the professionals running the industry. Eleven papers were presented (see the abstracts included with this article). Rick Webster received an award for Best Student Paper in the Rocky Mountain Section technical session, which was entitled Reservoir Geology of the Williston Basin. The subsurface studies group displayed posters and core slabs of Kaskaskia rocks illustrating characteristic facies, fabrics, and porosity of various formations in the sequence (please see the second abstract at the end of this article). Their poster display won the blue ribbon for Best of Session (41 displays). All eight authors received certificates of merit.

Bob Lindsay of Gulf Exploration and Production in Tulsa, Oklahoma was included in this subsurface group. Others were Randy Burke of the NDGS, Diane Catt of ARCO, and Fred Lobdell, Peter Loeffler, Thomas Obelenus, Nancy Perrin and Rick Webster, all of the University of North Dakota Geology Department. Gulf Oil supplied the easels used to hold the core boxes in the display. Gulf also supplied styrofoam insert core boxes, which helped to display the materials to the best advantage. One of UND'S recent geology graduates, Diane Catt, received leave time from her new job with ARCO to join the group in the Poster session and to orally present the results of her own research.

The poster and rock slabs display was so well received that we have been asked to display it at both the Fourth International Williston Basin Symposium in Regina, Saskatchewan in early October, and at the North Dakota State Fair energy exhibit in Minot in mid July.

BURKE, RANDOLPH B., North Dakota Geological Survey, Grand Forks, ND

Facies, Fabrics, and Porosity, Duperow Formation (Upper Devonian), Billings Nose Area, Williston Basin, North Dakota

The Duperow is a substantial hydrocarbon-producing formation in the "Billings Nose" area. Included in the Billings Nose are the TR (Theodore Roosevelt), Big Stick, Whiskey Joe, Four Eyes, White Tail, Fairfield, Elkhorn Ranch, and Tree Top fields.

Duperow rocks consist principally of dolomites, limestones, and anhydrites. Most of the dolomites appear to be of diagenetic origin although some primary dolomites do occur. Primary dolomites are parallel and wispy laminated mudstones deposited principally as part of the supratidal facies in association with stromatolites. Secondary replacement dolomites occur throughout the section, but seem to selectively replace the matrix in the stromatoporoid zone of the shallow subtidal facies and intraclasts in the intertidal facies. Included in the supratidal facies are anhydrites. Anhydrites range in habit from the typical replacive nodules to the less common "chickenwire" and layered forms. Layered types appear to be associated with ephemeral hypersaline ponds in the supratidal. In general, porosity is poor in this facies.

The intertidal facies consist of intraclastic wacke-packstone. Intraclasts and fragmented brachiopods and mollusks are the principal allochems. Bioturbation has destroyed most laminations. Apparent selective replacement of intraclasts constitute the majority of the porosity in this facies.

The subtidal facies includes stromatoporid and bioturbated zones. Sparsely fossiliferous wackestones are the predominate fabric, but stromatoporid boundstones and coral, brachiopod packstones are common. Good intercrystalline porosity occurs in the matrix of the stromatoporid zone.

BURKE, RANDOLPH B., North Dakota Geological Survey, ROBERT F. LINDSAY, Gulf Oil Exploration and Production Co., and DIANE M. CATT, FREDERICK K. LOBDELL, PETER T. LOEFFLER, THOMAS OBELENUS, NANCY A. PERRIN, AND RICK L. WEBSTER, University of North Dakota

Facies, Fabrics, and Porosity of Kaskaskia Rocks in Williston Basin, North Dakota

Kaskaskia rock sequences in the Williston basin, North Dakota, comprise most major carbonate facies, fabrics, and porosity types. Stratigraphic units discussed are the Mission Canyon, Ratcliffe, Frobisher Alida, Bakken, Birdbear, Duperow, Winnipegosis, and the Ashern formations. All of these have produced substantial amounts of hydrocarbons except the Ashern Formation. Slabs of cores show different facies, fabrics, and some porosity types associated with each.

Kaskaskia sequence deposits represent a period of waxing and waning sedimentation during overall transgression and regression of the late Paleozoic. Facies represented except for the Ashern, are cyclic, composed of supratidal, intertidal, and subtidal depositional settings. Ashern facies are supratidal to highest intertidal. Some facies can be further subdivided into high/low or shallow/deep. Special facies types include stromatoporoid and evaporite, both supratidal and deep. Facies and fabrics vary considerably throughout the sequence, both interformationally and intraformationally. Mudstones, wackestones, and packstones are most common although grainstones and boundstones also occur. Within textural constraints, each fabric contains their respective amounts of skeletal and nonskeletal allochems. Because of frequent and sharp facies changes, it is important to discriminate among different facies that superficially have similar fabrics. Examples are deep/shallow evaporites, or supratidal/subtidal oolites and pisolites. Peloidal wackestones/grainstones, skeletal wackestones/packstones, and mottled mudstones are the prevalent fabric types. Significant sedimentary structures include burrows, flat pebble interclasts, desiccation cracks, bird's-eye structures, and collapse breccias.

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

CATT, DIANE M., University of North Dakota

Depositional Environments of Ratcliffe Interval,
Mississippian Madison Group, Williston Basin, North Dakota

The Ratcliffe interval within the Williston basin in North Dakota is included in the Mississippian Madison Group. It is an informal stratigraphic subsurface unit which includes parts of the upper Mission Canyon and lower Charles Formations.

Deposition of the Ratcliffe sediments occurred in an open to progressively restricted marine environment along the eastern margin of the basin. Six facies have been recognized in the study area. These are the: (1) brachiopod-bryozoan-echinoderm packstone/wackestone facies; (2) peloid-oolite packstone/wackestone facies; (3) ostracod-foraminifer wackestone facies; (4) laminated mudstone/wackestone facies; (5) anhydrite-dolomite mudstone facies; and the (6) organic quartz siltstone facies. Oil found within the Ratcliffe interval is usually associated with the peloid-oolite packstone facies. Some moldic porosity has developed by solutioning. Dolomitization has increased intercrystalline porosity. Dolomitized areas commonly are capped by less porous facies making good potential stratigraphic traps. Formation of traps and reservoir rock is highly dependent on porosity and permeability and also on the amount of diagenesis, especially secondary anhydrite, associated with the sediments.

GERHARD, LEE C., SIDNEY B. ANDERSON, JULIE A. LEFEVER, and CLARENCE G. CARLSON, North Dakota Geological Survey

Geological Development, Origin, and Energy and Mineral Resources of Williston Basin, North Dakota

The Williston basin of North Dakota, Montana, South Dakota, and south-central Canada (Manitoba and Saskatchewan) is a major producer of oil and gas, lignite, and potash. Located on the western periphery of the Phanerozoic North American craton, the Williston basin has undergone only relatively mild tectonic distortion during Phanerozoic time. This distortion is largely related to movement of Precambrian basement blocks.

Oil exploration and development in the United States portion of the Williston basin from 1972 to present have given impetus to restudy of basin evolution and geologic controls for energy resource locations. In consequence, oil production in North Dakota, for instance, has jumped from a nadir of 19 million bbl in 1974 (compared to a previous zenith of 27 million in 1966) to 32 million bbl in 1979 and 40 million bbl in 1980. Geologic knowledge of carbonate reservoirs has expanded accordingly.

Major structures in the basin, and the basin itself, may result from left-lateral shear along the Colorado-Wyoming and Fromberg zones during pre-Phanerozoic time. Deeper drilling in the basin has established several major new structures with indications of others. Most structures probably result from renewed movement or "tensing" of pre-Phanerozoic faults. Meteorite impact events have been suggested as the origin for one or two structures.

HARRIS, KENNETH L., North Dakota Geological Survey, F. L. HOWELL, University of North Dakota, LARAMIE M. WINCZEWSKI, Shell Information Center, Houston, TX, BRAD L. WARTMAN, University of North Dakota

Geothermal Resources of North Dakota

Since 1979, the North Dakota Geological Survey has been involved in a cooperative study with the U.S. Department of Energy (FC07-79ID12030) to evaluate the hydrothermal resources of North Dakota. Initially, emphasis was placed on using existing data on file with state and federal agencies. Oil and gas well data from the North Dakota

Geological Survey and water well data from the U.S. Geological Survey, Water Resources Division, and North Dakota State Water Commission have been compiled into two computer library systems, WELLFILE AND WATERCAT. In addition to summarizing existing information temperature profiles have been measured in available ground-water observation wells throughout the state. We have installed casing in available test holes in selected areas for terrestrial heat-flow determinations.

The information contained in WELLFILE and WATERCAT is being assembled into a catalog of user-oriented aquifer summaries. Depth, thickness, water quality, and temperature data have been summarized for the Madison Group (Mississippian) and the Inyan Kara Formation (Cretaceous) in North Dakota. Work continues on similar data summaries for other Mesozoic and Cenozoic aquifers.

The data from temperature logs run in ground-water observation wells have been incorporated in WATERCAT. This information can be displayed as temperature profiles for individual wells, as "shallow" geothermal gradient maps, and as "slice" maps of expected temperatures at various depths.

Interest in geothermal energy, particularly residential heat pump applications, is increasing in North Dakota. User-oriented data summaries of the information collected during our study are available through the North Dakota Geological Survey.

LOBDELL, FREDERICK K., University of North Dakota

Lithology and Depositional Environment of Ashern Formation (Middle Devonian), North Dakota

The Ashern Formation (Middle Devonian) is the basal unit of the Kaskaskia Sequence in North Dakota. It is unconformably underlain by the Silurian Interlake Formation, and overlain generally conformably, by the Winnipegosis Formation of Middle Devonian age. The Ashern is present in the northwestern one-third to one-half of North Dakota. Beyond the limits of the overlying Winnipegosis Formation, the Ashern is indistinguishable on electric logs from the basal argillaceous members of the Dawson Bay and Souris River formations and, together with these, must be considered undifferentiated basal Devonian.

The Ashern Formation is composed of two members. The lower red member is predominantly an argillaceous microcrystalline dolostone, containing nodular anhydrite and thin shale partings. The upper dark gray member is predominantly a featureless microcrystalline limestone. Together, these two members range in thickness from about 10 m near the limit of the Ashern Formation to about 50 m near the center of the Williston basin.

The red member owes its color to a reworking of a lateritic soil on top of the Late Silurian/Early Devonian erosional surface. The fine-grained dolostone and its nodular anhydrite imply supratidal deposition in a sabkha environment. The featureless gray member was deposited in a low intertidal to subtidal environment. There is an occasional suggestion of bioturbation, though no fossils have been found. No porosity is evident in the formation, except for some partly anhydrite-filled fractures near the top in one core.

LOEFFLER, P., University of North Dakota

Depositional Environment and Rock Fabric, Birdbear ("Nisku") Formation (Upper Devonian), Williston Basin, North Dakota

The Birdbear Formation was deposited as the upper part of a widespread marine carbonate and evaporite system prevalent in the Williston basin during the Middle and Late Devonian. Rock facies representing shallow-water and associated carbonate subenvironments are present in the Birdbear. Stillstands of subenvironments and frequency of transitions between subenvironments are similar to those in the underlying Duperow Formation. Evaporites are dominant in the uppermost part of the Birdbear.

Original depositional environments are recognized with subsequent diagenetic events evaluated. The development of interparticle and moldic porosity is outlined, in particular, with reference to dolomite.

Dolomites are prevalent in the upper section of the Birdbear Formation. Evidence suggests shallow intertidal and supratidal conditions with porosity development associated with the dolomites. Overlying limestones and anhydrites act as caprock.

OBELENUS, THOMAS J., University of North Dakota

Depositional Environments and Diagenesis of Frobisher-Alida Interval, Madison Group (Mississippian), North Dakota Williston Basin

The Frobisher-Alida interval is a well log-marker-defined interval, not lithologically based, which extends across middle and upper Mission Canyon carbonates into lower Charles evaporite from the basin center toward the eastern basin margin. The interval represents a regressive sequence with superimposed minor transgressive pulses. A wide spectra of depositional and diagenetic environments with associated fabrics and porosities are represented in these carbonates.

Basin-margin carbonates are dominated by supratidal sediments with lesser amounts of intertidal and subtidal sediments. Major fabric types of important producing zones consist of major developments of hypersaline, and minor developments of caliche and vadose, ooid and pisolite wackestones to grainstones. Intercalated with these are fenestral mudstones to laminated dolomudstones, gastropod mudstones, and evaporite "mush" dolomudstones. In addition, desiccation cracks and minor occurrences of karst breccias and laminated crusts indicate periods of subaerial exposure. Porosities associated with the supratidal-subaerial realm include well-developed interparticle, fenestral, vuggy, and intercrystal types, and in places are filled with clear spar and/or void-filling clear anhydrite cement.

Basinward, subtidal sediments dominate the interval. These consist of cyclic, shallow open-marine bioclastic mudstones to packstones-grainstones and, partly restricted marine burrowed peloidal mudstones to bioclastic wackestones. Upsection, noncyclic burrowed bioclastic peloidal mudstones to wackestones indicate increasingly restrictive conditions. Interparticle porosity is exhibited in the bioclastic grainstones. Intercrystal porosities are developed from selective dolomitization of burrows and mudstones.

PERRIN, NANCY A., University of North Dakota

Environment of Deposition of Winnipegosis Formation (Middle Devonian), Williston Basin, North Dakota

The Winnipegosis Formation (Middle Devonian) is the major carbonate unit of the first transgressive-regressive pulse of the Kaskaskia sequence. The sea invaded the narrow, elongated Elk Point basin which extended from northern Alberta southeastward to North Dakota. The southeastern end of this basin corresponds to the present-day Williston basin.

In North Dakota, reworking of red beds and deposition of restricted argillaceous carbonates occurred (Ashern). Winnipegosis deposition began after a brief hiatus. Initially, there was a widespread establishment of a clear quiet shallow-marine environment. Subsequently, the basin differentiated into three distinct environments of deposition: (1) scattered pinnacle reefs, (2) a deeper interreef basin, and (3) an encompassing carbonate platform.

Carbonate production in the pinnacle-reef and platform environments was able to keep pace with rising sea levels as the transgression continued. In the pinnacle-reef environment, several lithofacies developed through time. Of special importance, due to recent production, is an upper porous dolomite in which the original limestone has undergone extensive fabric-obscuring dolomitization. In the platform environment, there developed a patch-reef lithofacies and several quiet-water shallow-marine lithofacies which illustrate a vertical subtidal regressive sequence. In addition, the pinnacle-reef and platform environments grade into an uppermost intertidal and/or supratidal regressive series of dolomites and anhydrites. Carbonate production did not keep pace with rising sea level in the interreef environments resulting in topographic relief. Subaqueous laminated lithofacies were depositied throughout the basin and between the pinnacle reefs.

During the regressive phase, barrier reefs formed in northern Alberta which restricted the basin and resulted in the deposition of evaporites (Prairie) which eventually filled the basin.

REISKIND, JEREMY, University of North Dakota

Niobrara Formation (Upper Cretaceous), Eastern North Dakota

The Niobrara Formation (Upper Cretaceous)has recently gained attention as a shallow, low-permeability reservoir for natural gas. Understanding its distribution and the conditions under which it was deposited will contribute to its evaluation as a source of hydrocarbons in this region.

On the basis of outcrop sections and cores in northeastern North Dakota, the Niobrara Formation is approximately 64 m thick and can be divided into two subequal units. The lower 31-m unit is medium dark gray and medium olive-gray, laminated calcareous shale with "white specks" (fecal pellets), comminuted fish remains, *Lingula*, and thin fine-grained sand stringers near the base. The upper 33-m unit is light-gray to light olive-gray, shaly chalk containing abundant "white specks," with a thin (5 m) very light gray, bioturbated chalk at its base. Sediments are bioturbated at the top of the lower unit and the base of the upper unit.

The main controls of sediment character are rates of calcareous plankton productivity and aerobic versus anaerobic bottom conditions. The Niobrara represents, from bottom to top, the following sequence of environments: (1) low productivity anaerobic conditions; (2) low productivity aerobic conditions; (3) high productivity aerobic conditions; and (4) high productivity anaerobic conditions.

Over the eastern half of North Dakota, the Niobrara ranges in thickness from less than 17 m to greater than 75 m. Alternating thinning and thickening bands trend northwest-southeast and suggest structural control of deposition.

STURM, STEPHEN D., University of North Dakota

Depositional Environments of Tyler Formation in Fryburg and Rocky Ridge Area, North Dakota

The Tyler Formation in southwestern North Dakota is a regressive barrier-island system dominated by two environments: (1) lagoon and (2) barrier-beach complex. The barrier islands formed along an east-west line in Golden Valley, Billings, and Stark Counties. Thickening eastward (5 to 20 ft), a gradational, coarsening-upward sequence of very fine to medium-grained, well-sorted quartzose sandstone is developed in the Medora, Fryburg, and Green River fields. Where there is good development of a shoreline, massive fine-grained, well-sorted sandstones with discontinuous, wavy carbonaceous laminae (foreshore environment) overlie fine-grained, well-sorted, cross-laminated, and bioturbated sandstones (shoreface environment).

Northward, several offshore sand bars developed in a predominantly shallow restricted sea, typified by medium-gray to grayish-black ripple cross-laminated argillaceous limestones and shales. On the south, in a landward direction, barrier-island sands interfinger with grayish-black carbonaceous lagoonal shales, coals, and mudstone marsh deposits and varicolored mudstone tidal-flat deposits. The sandstones present in the Rocky Ridge vicinity are characteristically medium grained and silty, and exhibit unidirectional cross-stratification. They are interpreted as channel deposits disecting a landward facies of the lagoonal environment.

The upper Tyler Formation is a regressive sequence characterized by anhydritic mudstones, desiccation features, and local chickenwire anhydrites overlying dark-gray fossiliferous, argillaceous limestones and shales.

WEBSTER, R. L., University of North Dakota

Analysis of Petroleum Source-Rocks of Bakken Formation (Lowermost Mississippian) in North Dakota

The Bakken Formation consists of upper and lower, black, organic-rich shales separated by a middle siltstone member. The sediments of the Bakken are marine in origin.

The middle member consists of very fine-grained sandstones, siltstones, silty limestones, and shale. The middle member generally has low porosity (1 to 5%) and permeability (<0.1 md), except where fracturing is present, as at Antelope field in McKenzie County. The lithologies, fossils, and sedimentary structures of the middle member are indicative of a nearshore marine depositional environment.

The black shales were deposited in quiet, poorly circulated, anaerobic waters. In thin section they exhibit a high degree of orientation of mineral particles and a high kerogen content. Thin-section and chemical analyses show the mineral matter of the shales to be predominantly quartz.

Pyrolysis, total organic carbon determinations, vitrinite reflectance, optical kerogen typing, and chromatography of extractable organic matter were used to determine the depth of onset of hydrocarbon generation, amount of generated hydrocarbons, thermal maturity, kerogen types present, and distribution of organic matter in the black shales of the Bakken Formation. These are extremely rich source rocks, because they contain high amounts of algal kerogen, a prolific source material of oil. Organic carbon values for the black shales average about 13 wt.% and extractable hydrocarbons are typically 4,000 to 5,000 ppm.

NATIONAL REFERRAL CENTER ENTRY

Recently, I wrote a short entry for the National Referral Center describing the North Dakota Geological Survey for the Library of Congress. They plan to enter the information in a computer. Since the entry briefly summarizes the activities of the NDGS, it might be useful to include it here. Perhaps some of you may notice some activity we are involved in about which you were unaware and wish to contact us for more detailed information. The entry follows the format prescribed by the National Referral Center and I think it is pretty much self-explanatory. Following the NDGS entry, I've also included the entry for the University of North Dakota Geology Library.

North Dakota Geological Survey

University Station
Grand Forks, ND 58202-8156
Tel: (701) 777-2231

Location:
Third Floor, Leonard Hall, and W. M. Laird Core & Sample Library, both on University of North Dakota campus, Grand Forks.

AREAS OF INTEREST: Economic geology: emphasizing oil, gas, uranium, carbonates, potash, groundwater, lignite, and other nonmetallic resources; Williston Basin geology; areal geology; stratigraphy; glacial geology; petroleum engineering and geology; hydrogeology; hydrothermal geology; reclamation of surface-mined land; environmental geology.

HOLDINGS: The Survey is a repository for all North Dakota oil-well data, including well records, electrical, radioactivity, etc. logs on about 10,000 wells and test holes and all core obtained during drilling of wells--all of these materials are available for study onsite; North Dakota Geological Survey publications and open-file reports; U.S. Geological Survey publications. The Survey shares the University of North Dakota geology library (see attached reference).

PUBLICATIONS: NDGS Newsletter (twice yearly in June and December), Official Oil in North Dakota (twice yearly, irregularly), Bulletins, Reports of Investigations, Miscellaneous Series, Educational Series, Miscellaneous Maps. A publication list is available.

INFORMATION SERVICES: Answer inquiries; permits onsite reference to well cores and samples and to well logs; provides access to computerized information on oil-well-drilling data, coal-drilling data, and water-well-drilling data; provides technical and nontechnical speakers on geology; provides educational materials for public and private North Dakota elementary and secondary schools; provides field-trip leaders; provides identification of rocks, minerals, fossils.

INDEX TERMS: Environmental geology, Carbonates, Uranium, Lignite, Well logging, Geology, Lecturers, Economic geology, Hydrogeology, Mineral deposits, Crude oil, Natural gas, Educational materials, Williston Basin, Glacial geology, Surficial geology.

University of North Dakota, Geology Library

326 Leonard Hall
University of North Dakota,
Grand Forks, ND 58202
Tel: (701) 777-3221

AREAS OF INTEREST: Geology, paleontology, petroleum engineering, North Dakota geology, Williston Basin geology, hydrogeology, glacial geology.

HOLDINGS: books-10,212; serial volumes-18,622; maps-91,525; air photos-42,610. Depository for USGS publications, maps and open-file reports. Library contains the North Dakota Geological Survey collection received as exchange from other geological surveys, both United States and foreign.

PUBLICATIONS: List of University of North Dakota Geology Theses.

INFORMATION SERVICES: Permits onsite reference use; computer searches of DIALOG, SDC and BRS data bases are available; interlibrary loan is available through Chester Fritz Library, University of North Dakota, Grand Forks, ND 58202.

RECENTLY RELEASED PUBLICATIONS

Since the last NDGS Newsletter was released in December, 1981, the Survey has published several new items. Two publications that I already described in the last issue of the Newsletter should be mentioned again because they are of considerable importance to anyone researching North Dakota geology. They are: "Annotated bibliography of North Dakota, 1960-1979," by Mary Woods Scott, and the "Lexicon of stratigraphic names of North Dakota," by Joanne V. Lerud (the lexicon was released April 8, 1982; at the time I wrote the article for the December Newsletter, I included the lexicon in a description of soon-to-be-released publications). Descriptions of these two publications follow:

Miscellaneous Series 60--"Annotated bibliography of the geology of North Dakota, 1960-1979" was prepared by Mary Woods Scott. The bibliography is a companion to NDGS Miscellaneous Series 49, which is a bibliography of all known geologic literature on North Dakota that was published between 1805 and 1960. Some references to the literature prior to 1960 are also included in the present volume, since they were omitted from the earlier one.

Entries in the bibliography are arranged alphabetically by author. Several reports done by the same author are arranged chronologically from oldest to youngest. Several reports published during a single year by the same authors are arranged alphabetically by title. Reports by two or more authors are listed following the reports done by the first author alone. Each entry includes keywords and/or keyword phrases to describe the contents of the report; in this respect the new bibliography differs from the 1972 version covering years prior to 1960, which included annotations for many of the entries. The keywords are supplemented by terminology from the referenced reports. In most instances, stratigraphic, geographic, and paleontologic terminology were selected from the report.

The subject index has major headings that are subdivided where necessary and where possible. Cross references indicate that the term listed is not used as a heading and the user is referred to the correct index term.

The exhaustive subject index helps the user to locate references to specific topics. The subject index has major headings that are subdivided where necessary and where possible. The Annotated Bibliography includes a total of 290 pages. It is available from the North Dakota Geological Survey, University Station, Grand Forks, North Dakota 58202-8156. The cost is $5.00.

Report of Investigation 71--"Lexicon of stratigraphic names of North Dakota" was compiled by Joanne V. Lerud, formerly a Librarian with the North Dakota Geological Survey, who is now employed by Marathon Oil Company. The Lexicon includes as complete as possible a listing of all terms that have been applied to the various stratigraphic units recognized in North Dakota. The listing includes a history of the terminology applied to each unit, its age, area of extent, lithology, thickness, relationship to other units, characteristic fossils, economic significance, depositional environments, and references to type sections. Two appendices to the Lexicon list are: 1) the named lignite beds in North Dakota, and 2) Pleistocene and Holocene stratigraphic names.

Some of the information on general lithologic descriptions, maximum thickness, mineral resources, and relationships to other units are shown in the "North Dakota Stratigraphic Column," a copy of which is included in a pocket at the back of the Lexicon; some of this information is therefore not listed in the text. A system of capitalization and underlining was used to distinguish stratigraphic names as to their current status. Each unit in the Lexicon was given a ranking so that one not familiar with the stratigraphy of North Dakota would be able to understand the relative importance of each name.

The Lexicon of Stratigraphic Names of North Dakota is 140 pages long and comes with the stratigraphic column. It is available from the North Dakota Geological Survey, University Station, Grand Forks, North Dakota 58202-8156. The cost is $5.00.

In addition to the bibliography and lexicon, we also have three other new publications.

Report of Investigation 74--"Computer management of geologic and petroleum data at the North Dakota Geological Survey," was prepared by Kenneth L. Harris, Laramie M. Winczewski, and Howard R. Umphrey. It describes three data-management systems in use at the Survey and discusses the factors that governed the design, development, and implementation techniques used to make them operational. Examples of verification and data retrieval procedures are included for each of the data sets presented.

The general design philosophy (GEOSTOR) and the specific design requirements of the North Dakota Geological Survey are discussed in detail.

The three data bases, maintained by the North Dakota Geological Survey, are WELLFILE, which contains oil and gas well data; WATERCAT, which contains water well data, and COALBASE, which contains coal exploration data. All three systems are GEOSTOR-based, but the types of data elements selected for storage varies from system to system.

WELLFILE manages data obtained from about 9,000 oil and gas wells drilled in North Dakota. Information from newly drilled wells is added to the file as soon as it is made public. Location, legal, production, and stratigraphic data as well as the availability and storage location of cores and samples are stored for each well. In addition to the basic oil and gas well data, two data subsets contain reservoir water quality data and production statistics.

WATERCAT manages data from about 41,000 groundwater observation, domestic, and stock wells in North Dakota. These are wells that have been inventoried by the United States Geological Survey, Water Resources Division and the North Dakota State Water Commission. Location, physical, stratigraphic and water quality data, as available, are stored for each well. In addition to the basic water well data a subset contains temperature and depth measurements from selected groundwater observation wells.

COALBASE consists of shallow test-hole lithologic data associated with Tertiary coal deposits in North Dakota. The data were obtained from public and private sources.

Copies of Report of Investigation 74 can be obtained for $2.00 from the North Dakota Geological Survey.

Bulletin 74, Part III--"Ground-Water Resources of McHenry County, North Dakota," was prepared by P. G. Randich, U.S. Geological Survey. The report is one of three parts dealing with the geology and groundwater flow systems in McHenry County. Part II, which includes a compilation of groundwater data, is also available, and Part I, which will describe the geology of McHenry County, should be released later this year.

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 have the greatest potential for development in McHenry County. Bedrock aquifers also are a source of water in most of the county, but yields are much less and the water contains more sodium and dissolved solids than water from glacial-drift aquifers.

Glacial-drift aquifers occur in sand and gravel deposits associated with buried valleys and glacialfluvial deposits in McHenry County. These aquifers underlie about 430 square miles and contain approximately 1,748,000 acre-feet of available groundwater. Potential well yields range from 50 to 2,000 gallons per minute from the major glacial-drift aquifers. The water is mainly hard and is a calcium or sodium bicarbonate type.

The Hell Creek and Fox Hills aquifers, which consist of very fine to medium-grained sandstone beds, are the major preglacial aquifers. Most wells developed in these aquifers do not yield more than 50 gallons per minute. The water is soft and is a sodium bicarbonate, sodium chloride, or sodium sulfate type.

The rural population and all communities in McHenry County depend on groundwater as a source of supply. The use of groundwater from glacial-drift aquifers for irrigation exceeds that used for all other purposes, including rural, municipal, or industrial.

This report is available free of charge from the North Dakota Geological Survey, University Station, Grand Forks, ND 58202-8156.

Bulletin 77, Part II--"Ground-Water Data for Logan County, North Dakota," was prepared by Robert L. Klausing, U.S. Geological Survey. The report is a compilation of groundwater data and it makes available the geologic and hydrologic data that were collected during the investigation. It functions as a reference for the other reports, which deal with geology and hydrology. Bulletin 77, Part II includes records of selected wells and test holes. Many of the test holes drilled by the North Dakota State Water Commission were converted to observation wells for periodic water-level measurements and water-quality sampling; the results of these measurements and sampling are included in the report.

Also included in the report are water-level readings for a large number of selected wells that tap the major aquifers in Logan County. The largest portion of the report consists of logs collected from water-well drillers and other sources and logs of test holes drilled as part of the study. Most of the test holes drilled during the study have geophysical logs in addition to a description of the materials penetrated. These logs (gamma ray and resistivity) are extremely useful for geologic correlation purposes.

Bulletin 77, Part II is 299 pages long and includes one plate which shows the location of wells and test holes in Logan County. The report is available free of charge from the North Dakota Geological Survey.

Bulletin 67, Part I--"Geology of Grant and Sioux Counties, North Dakota," was prepared by Clarence G. Carlson. With the publication of Part I of this bulletin, all three parts are now available. The report describes the subsurface and surface geology, the geologic history, and economic geology of Grant and Sioux Counties.

As much as 11,500 feet of sedimentary section is present in northwestern Grant County. The sedimentary section thins southeastward, reflecting the position of these counties on the southern flank of the Williston Basin. Thinning is due to more erosion toward the margin of the basin as well as depositional thickening toward the basin center, so in southeastern Sioux County the sedimentary record has thinned to about 5,600 feet.

Strata at the surface are limited to formations of Upper Cretaceous and Tertiary age. The Upper Cretaceous formations consist of poorly consolidated sand, silt, or clay and carbonaceous shale. Tertiary formations consist of poorly consolidated sand, silt, clay, and lignite. Upland areas have a gently rolling topography held up by more resistant rock types, which in these counties are mostly the cemented sandstones. Major drainages are incised into the upland areas, and where the Hell Creek strata are exposed along these drainages, some "badlands" topography has developed.

Sandstone units within each of the exposed formations are potential sources of groundwater; however, the most reliable, or persistent, is the Timber Lake Member of the Fox Hills Formation. In some areas, in the absence of shallow sands, lignite beds provide a potential aquifer. In a few areas, lignite beds of adequate thickness and appropriate depth provide an economically recoverable resource.

The report includes a colored geologic map of Grant and Sioux Counties, several cross-sections, and 32 pages of text and figures. It is available free of charge from the North Dakota Geological Survey.

CHANGES IN PERSONNEL

At the time the December, 1981 Newsletter was released, Don L. Halvorson was serving as Acting State Geologist. Dr. Halvorson's appointment is now official and he is North Dakota's ninth State Geologist (for those of you who are interested in history, here is a listing of former state geologists of North Dakota: E. J. Babcock, 1895-1902; Frank Wilder, 1902-1903; Arthur G. Leonard, 1903-1932; Howard E. Simpson, 1933-1940; Frank C. Foley, 1940-1941; Wilson M. Laird,1941-1969; E. A. Noble,1969-1978; and Lee C. Gerhard, 1978-1982).

Don is originally from Wildrose in northwestern North Dakota. He earned his BS in Geology at the University of Colorado in 1965, an MST from the University of North Dakota in 1971, and his PhD from the University of North Dakota in 1979. Don has had considerable administrative experience, serving on numerous University curriculum, finance, search, and graduate-student advisory committees and in carrying out administrative duties for the University of North Dakota Geology Department.

As State Geologist and Director of the North Dakota Geological Survey, Dr. Halvorson is responsible for the continuing evaluation of the state's mineral and energy resources and geological studies.

Our new petroleum engineer is Marvin Rygh, who recently earned his B.S. in geological engineering at the University of North Dakota. Marvin's immediate duties include updating the Survey's oil and gas wall map. He is involved in a number of research projects dealing with water injection in Burke County oil fields (see the article on page 31). Marvin comes to us from Roseau, Minnesota. He is recently married and is looking forward to settling in Grand Forks with his wife Ragnhild.

The Survey's new geologist is David W. Brekke. Dave is experienced in the performance of tests, analysis and interpretation of data and operation of our scanning electron/electron microprobe microscope, x-ray diffraction, x-ray fluorescence, and polarized light microscopy on geologic and other research programs. He has been working since 1980 with the Mining and Mineral Resources Research Institute of the University of North Dakota College of Engineering. He has also worked with the University of North Dakota Engineering Experiment Station and with the Department of Energy, Grand Forks Energy Technology Center. Dave has also been very recently married; his wife, Alice, is employed by the Engineering Experiment Station.

SURVEY PROFILES

Debbie Kroese

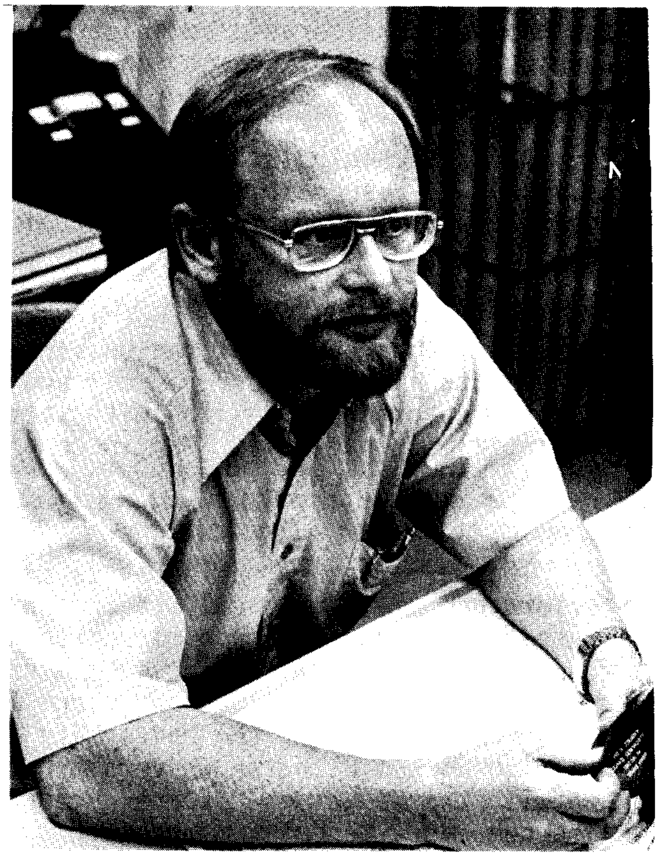
Debbie has been with the Survey since 1979 as our Composer Technician. She prepares Survey publications for printing. This involves typing and recording the original copy and instructions on diskettes, proofing the IBM System 6 playback, and running off the final, photo-ready copies.

Debbie graduated from Red River High School in Grand Forks in 1977. She and her husband, Brian, who is employed at Young Manufacturing, have two children, Heidi and Haley. They enjoy camping and fishing.

Ken Harris

Ken has been working as a geologist with the Survey since 1977. He has been involved in geologic investigations dealing with the Quaternary geology and energy resources of North Dakota as well as computer applications to geology.

Debbie Kroese



Ken Harris

Born in Bismarck and raised in Fargo, Ken has degrees from North Dakota State University (BSEE with a geology minor, 1969) and the University of North Dakota (MS, 1973 and PhD, 1975). Before doing graduate work at UND, Ken worked a year for Schlumberger Well Services in Miles City, Montana. As a field engineer for Schlumberger, he was responsible for running and interpreting downhole geophysical surveys on oil and gas wells in southeastern Montana. After graduating from UND, he worked two years as an exploration geologist for Cities Service Oil Company in Tulsa, Oklahoma and Jackson, Mississippi. The training and experience gained with Cities Service was interesting and useful, but Ken says he and his family missed the quality of life in North Dakota.

Most recently, Ken has been principal investigator on a cooperative agreement with DOEDGE, to evaluate the geothermal resources of North Dakota. This study has generated the Geothermal Resources map of North Dakota, several summary reports, and the computer data management system used by the Survey.

Ken and his wife, Phyllis, a medical secretary at the UND Family Practice Center, have two children, Kristen and Benjamin. The Harris's spend their free time on yard work, camping and canoeing.

Marilyn Rood

Marilyn has been with the Survey as our Account Technician since 1974. She is responsible for all of our accounting procedures involving Federal grants, purchasing of supplies and equipment, payroll (she is the one who gives each of us our checks once a month--that's reason enough to appreciate Marilyn), and she also does a lot of proofreading during the preparation of our publications (that's one more reason--a good proofreader is priceless).

Marilyn graduated from St. James Academy here in Grand Forks and attended the University of North Dakota. Her husband, Jim, has been the Athletic Equipment Technician at the University of North Dakota fieldhouse since 1960. Marilyn and Jim have four sons and two daughters, ranging in age from 25 down to 14. (They also have 5 dogs, one of which eats parakeets, but that's another story).

I think that Marilyn and her family may have a better understanding than all but a very few people about how to take advantage of our short summers and sometimes long winters by getting outside and enjoying everything. They have a cabin on Island Lake, about 86 miles east of here in Minnesota. They spend many weekends boating and fishing at the lake during the summer and some winter weekends as well.

(I'm sorry I don't have a picture of Marilyn at this time. I'll include a picture with the next Newsletter).

OIL & GAS ACTIVITY IN 1981

Even though the NDGS no longer compiles official production statistics for oil and gas in North Dakota, nor are we involved in the permitting procedure, I've compiled a potpourri of unofficial facts that may be of interest to many of you.

Last year (1981) was, by nearly all standards, North Dakota's most successful oil and gas year yet. New-pool discoveries, total production, and revenues all reached new highs. Some of the vital statistics are most conveniently shown in the form of graphs (figs. 1 through 6). Of the total of 848 wells that were drilled in North Dakota in 1981, 463 were listed as capable of producing oil or gas. Of the 286 wildcat wells that were drilled, 83 were listed as producers. Production of oil reached 45.7 million barrels, up from the 39.9 million recorded in 1980. The gross production tax raised about 71 million dollars for the state and the extraction tax another 92 million dollars. In addition, oil and gas lease bonus income from state lands totaled 19 million dollars.

I've compiled a listing of oil and gas discoveries in 1981, showing how many were recorded in each county and how many discoveries were made from the various geologic horizons (table 1). As usual, McKenzie County was the most successful, with a total of 34 new pools--discoveries were made in 12 counties in 1981. The Red River Formation accounted for 37 of the 83 new pool discoveries, the Madison had 22 and the Duperow 13. I've also compiled a listing of all the 1981 discovery wells and arranged them in chronological order (Table 2).

Several of the new pool discoveries may be of more than passing interest. Gulf's Leviathan #1-21-1B (Richardton Field in Stark County) came in with an initial gas production of 3588 MCF and 150 BOPD condensate from the Winnipeg-Deadwood. This deep gas discovery should keep interest high in the deeper horizons throughout the Williston Basin. Terra's October Interlake completion (Terra Resources, Inc.--#1-17 Prange), also in Stark County, should help to maintain interest in the Silurian. Gulf's two Lone Butte discoveries (Gulf Oil Corp.--Bob Creek Federal #1-13-3B in the Madison and Gulf Oil Corp.--Morman Butte Federal #1-25-3C in the Red River) extended the trend of the Little Knife Field northward. Lone Butte appears to have the potential to become an important field. In Dunn County, Amoco's Skachenko "A" #1 came in with 1652 BOPD from the Duperow, placing the Jim Creek Field between Killdeer and Rattlesnake Point Fields, both of which also produce from the Devonian. Finally, the deeper pays coming in along the Nesson Anticline show that a lot of potential for new discoveries still exists there.

Lower prices resulting from an oversupply of crude oil, high drilling costs, and certain other economic factors have resulted in a downturn in exploratory drilling activity in 1982 in the Williston Basin. However, with prices apparently now on the rise, exploratory drilling activity again is picking up. Future possibilities in other parts of the state include shallow gas prospects along the eastern margin of the Williston Basin. The already-proven, deeper, gas-producing horizons of southwestern North Dakota will also probably lead to deeper exploration in other parts of the state.

The number of rotary rigs actually making hole in North Dakota is down considerably from a year ago at this time (Hughes Rig Count for May 31, 1982 compared to the June 1, 1981 count), 54 this year compared to 126 a year ago. That's a 57 percent decrease. Among the other major oil-producing states, only Ohio (down 67 percent from 105 to 35) and Montana (down 64 percent from 72 to 26) have shown greater losses. This compares with a 24 percent national decline in rigs operating at this time compared to last year. Canada, nationwide, is down 52 percent compared to a year ago. In the first two weeks of June, the rig count seems to be rebounding so it is possible the low was reached in May.

TABLE 1

NORTH DAKOTA OIL & GAS DISCOVERIES IN 1981
New Pool Discoveries by County

Billings County

Madison	2
Bakken	3
Birdbear	1
Duperow	2
Red River	3
Total	11

Bottineau County

Madison	1
Total	1

Bowman County

Red River	4
Total	4

Burke County

Madison	2
Total	2

Divide County

Duperow	1
Red River	3
Total	4

Dunn County

Madison	3
Red River	1
Duperow	1
Total	5

Golden Valley County

Red River	2
Total	2

McKenzie County

Madison	5
Bakken	1
Tyler	1
Duperow	8
Silurian	1
Gunton	1
Red River	17
Total	34

Renville County

Madison	3
Total	3

Stark County

Silurian	1
Red River	1
Winnipeg/ Deadwood	1
Total	3

Ward County

Madison	2
Total	2

Williams County

Madison	4
Birdbear	1
Duperow	1
Red River	6
Total	12

Table 2. Oil and gas discoveries in North Dakota during 1982.

County	Comp. Date	Operator, Well, Location	Field	Total Depth	Prod. Depth	Oil (Bbls.)	Gravity	Gas	Water	Producing Formation
McKenzie	1- 3-81	Texaco, Inc. Felland #1 (A) SESW Sec. 15-150-99	Tobacco Garden	14,896	14,042-14,124	72	49.2°	18,055 GOR	20%	Red River
McKenzie	1- 3-81	Pennzoil Expl. & Prod. Co. Mile Butte #36-42 SENE Sec. 36-147-103	Pierre Creek	13,320	12,992-13,044	88	48.2°	2,700 GOR	55%	Red River
Renville	1- 6-81	Abraxas Pet. Corp. Sandburg #1 NENW Sec. 23-161-85	Des Lacs	4,993	4,883- 4,887	35	30.0°	110 GOR	25%	Madison
McKenzie	1-14-81	Texaco, Inc. C. M. Loomer #12 NESE Sec. 6-150-95	Blue Buttes	11,392	11,226-11,232	405	40.7°	731 GOR	61.79%	Duperow
McKenzie	1-31-81	Hilliard Oil & Gas, Inc. Lillibridge #1 C SWNE Sec. 15-150-96	Johnson Corner	14,077	13,908-13,938	271.51	--	4,272 GOR	0%	Red River
McKenzie	1- 5-81	Shell Oil Co. USA 24-4 SESW Sec. 4-149-104	Estes	13,130	12,884-12,870	1,024	40.6°	1,000 GOR	3%	Red River
Billings	2- 3-81	Diamond Shamrock Corp. Rauch Shapiro #21-9 NENW Sec. 9-142-102	Roosevelt	12,762	10,512-10,534	264	44.0°	909 GOR	0%	Bakken
Williams	2-13-81	N. W. Exploration Co. Pederson #2 NESW Sec. 18-158-95	Temple	8,535	8,192- 8,256	47	37.4°	1/2 cu. ft./bbl.	87%	Madison
Williams	2-20-81	W. H. Hunt Trust Est. Cunningham #1 C SWSW Sec. 23-157-100	Marmon	13,400	13,096-13,106 13,138-13,088 13,142-13,091	168	45.0°	1,000 GOR	4.5%	Red River
McKenzie	2-20-81	Ladd Petroleum Corp. Duncan Fed. #30-22 NWNW Sec. 30-145-99	Scairt Woman	13,592	13,110-13,124	184	45.6°	2,060 SCF/bbl.	48%	Gunton
McKenzie	3- 6-81	Shell Oil Co. Burns #44-21 C SESE Sec. 21-149-104	Mondak	13,050	10,995-10,981	116	38.0°	1,000 GOR	64%	Duperow
Billings	3-14-81	Supron Energy Corp. F-6-144-101 #2 NWNW Sec. 6-144-101	Devils Pass	12,990	11,044-11,054	1,540	--	1,500 MCF	45 BWPD	Duperow
Bowman	3-22-81	Roger E. Canter Roger E. Canter #1 NWNW Sec. 33-131-105	Austin	9,234	8,975- 9,106	11	27.8°	100 GOR	18%	Red River
McKenzie	4- 4-81	W. H. Hunt Trust Est. Schlangen #1 C SESE Sec. 26-145-98	Charlie Bob	11,900	11,806-11,811	85	41.5°	590 GOR	50.9%	Duperow

County	Date	Operator, Well, Location	Field	Depth	Pd. Depth	Oil (Bbls.)	Gravity	Gas	Wat(	Formation
Stark	4-22-81	Gulf Oil Corporation Leviathan #1-21-1B C NENW Sec. 21-138-92	Richardton	12,218	11,374-11,394	149 BBL Cond/Day	52.0°	3,588 MCF	225%	Winnipeg-Deadwood
McKenzie	4-23-81	Texaco, Inc. Stenberg "A" #1 C SWSW Sec. 10-151-99	Tobacco Garden	15,266	12,001-12,012	45	43.8°	1,080 GOR	60.5%	Duperow
Williams	4-24-81	Depco, Inc. Fischer #34-18 C SWSE Sec. 18-159-102	Hanks	12,650 (KB-Drlr)	7,900- 7,906	324 (15.5 hrs.)	46.0°	120 GOR	2%	Madison
McKenzie	4-24-81	Gulf Oil Corp. Bob Creek Fed. 1-13-3B NESE Sec. 13-147-98	Lone Butte	9,800	9,320- 9,336	368 (est.)	46.6°	868 GOR	0%	Madison
McKenzie	4-28-81	Al-Aquitaine Explor., Ltd. Thurlow #1-13 NENE Sec. 13-151-102	Lonesome	14,115	13,450-13,569	686	49.3°	1,300 GOR (est.)	1%	Red River
Bowman	4-30-81	Mosbacher Production Co. Helen Hron et al #4-1 NENW Sec. 4-131-106	Ives	9,150	8,858- 8,880	56	36.7°	982 GOR	26%	Red River
Bowman	5-10-81	Anadarko Prod. Co. Bowman Fed. "A" #1 NENW Sec. 1-131-104	Rhame	10,250	9,966- 9,972	13	36.7°	1,230 GOR 16 MCF	85 BWPD	Red River
McKenzie	5-13-81	Pennzoil Co. & Depco Covered Bridge #3-22 BN SENW Sec. 3-146-102	Covered Bridge	13,705	13,036-13,094	466	49.5°	1,494 GOR	11%	Red River
Williams	5-14-81	Samedan Oil Corporation Minerals #1 C SWSW Sec. 13-154-100	Avoca	14,207	14,112-14,004	1,332	48.0°	1,243 GOR	7%	Red River
Williams	5-14-81	Burnett Oil Co., Inc. Germundson #1 C NESW Sec. 2-158-95	Lindahl	8,310	8,128- 8,134	63.58	39.2°	325 GOR	67% 132.36 BWPD	Madison
McKenzie	5-15-81	Amoco Production Co. Storm #1 C SENE Sec. 1-145-100	Beicegel Creek	13,800	11,636-11,644	168	43.0°	892 GOR 150 MCFD	10% 19 BWPD	Duperow
Williams	5-22-81	Getty Oil Co. Temple #32-5 SWNW Sec. 32-157-96	Ray	13,600	13,418-13,422 13,460-13,478	85	55.0°	9,329 GOR	0%	Red River
Williams	5-23-81	Universal Resources Corp. Bendixson #1 C SWNW Sec. 17-157-101	Good Luck	12,985	12,771-12,883	111	34.9°	946 GOR	12 BWPD	Red River
Billings	5-26-81	Apache Corporation Fed. #1-5 C NESE Sec. 5-143-102	Mikkelson	10,464	10,262-10,302	10.01	--	--	0%	Bakken

County	Comp. Date	Operator, Well, Location	Field	Total Depth	Prod. Depth	Oil (Bbls.)	Gravity	Gas	Water	Producing Formation
McKenzie	5-30-81	Pennzoil Co. Grassy Butte #21-21 NENW Sec. 21-146-99	Grassy Butte	14,100	11,842-11,904	409	44.5°	1,491 GOR	13%	Duperow
McKenzie	5-31-81	Energetics, Inc. Tank #22-22 C SENW Sec. 22-151-96	Camel Butte	14,100	12,385-12,428	109	40.0°	4,000 GOR	45%	Silurian
Renville	5-31-81	Monsanto Co. Witteman #1 SWSE Sec. 24-162-84	Cutbank Creek	4,412	4,385- 4,387	10	27.7°	215 GOR	93%	Madison
McKenzie	6- 2-81	Gulf Oil Corporation Rehberg #1-8-2D C SWNE Sec. 8-152-102	Marley	13,500	13,207-13,233 13,254-13,284	94	43.2°	1,260 GOR	31.39%	Red River
Renville	6- 6-81	Clarion Resources, Inc. Lundgren #1-23 C NENW Sec. 23-160-86	West Greene	5,501	5,314- 5,319	51.7	--	--	24%	Madison
Golden Valley	6-7-81	Terra Resources, Inc. Ueckert #1-11 C NENW Sec. 11-141-105	Hoot Owl	12,240	12,041-12,065	295	28.6°	128 GOR	21%	Red River
Dunn	6-19-81	Al-Aquitaine Expl. Co. #1-17 BN SWNE Sec. 17-143-97	Crooked Creek	11,690	9,760- 9,766 9,712- 9,730 9,697- 9,700 9,738- 9,744	120	--	--	76%	Madison
Billings	6-19-81	Patrick Pet. Co. Harris-Fed. #1-30 NESE Sec. 30-141-102	Wannagan	12,380	12,198-12,272	265	44.0°	962 GOR	3% 7 BWPD	Red River
McKenzie	6-29-81	HNG Oil Company Link #34-1 SWSE Sec. 34-151-102	Unnamed	13,700	13,469-13,583	142	53.0°	563 GOR	21%	Red River
Dunn	7- 1-81	Supron Energy Corp. F. V. Buresh #1 C NENE Sec. 32-142-96	Russian Creek	9,550	9,469- 9,500	160	38.6°	1,881 GOR	124%	Madison
McKenzie	7- 2-81	Gulf Oil Corporation Morman Butte Fed. #1-25-3C SESE Sec. 25-147-98	Lone Butte	14,200	13,958-13,994	0 inactive as of 8-21-81	0.0°	5,714 MMCF	0%	Red River
Ward	7- 8-81	Petroleum, Inc. Rudie #1 SWNE Sec. 19-157-84	Hartland	5,715	5,606- 5,610	29	29.2°	TSTM	55%	Madison
McKenzie	7-11-81	Texas Gas Explor. Corp. Nygaard #1-29 NENW Sec. 29-150-101	Pronghorn	13,870	13,747-13,753 13,664-13,670 13,620-13,624 13,614-13,616 13,572-13,575	348	57.6°	4,672 GOR 50 BWPD	12.56%	Red River

County	Date	Operator, Well, Location	Field	Depth	d. Depth	Oil (Bbls.)	Gravity	Gas	Water	Formation
McKenzie	7-12-81	Petroleum, Inc. Nygaard State #1 SENW Sec. 23-150-101	Rawson	13,990	11,617-11,647	70	46.5°	--	52%	Duperow
McKenzie	7-14-81	Pennzoil Company Four Creeks 6-32F SWNE Sec. 6-147-101	Bowline	13,498	9,506- 9,604	11	35.8°	1,200 GOR	97%	Madison
McKenzie	7-16-81	Apache Corporation Bear Den #1 C NWSE Sec. 23-150-94	Unnamed	14,575	10,868-10,904	13.6	--	--	0%	Bakken
McKenzie	7-19-81	Helmerich & Payne, Inc. Matthew #1-20 SWSW Sec. 20-150-94	Spotted Horn	13,700	9,220- 9,395	141 (H_2S Cont.)	40.0°	--	80%	Madison
Ward	7-20-81	Clarion Resources, Inc. Pullen #1-33 C NENE Sec. 33-159-88	Baken	6,673	6,532- 6,534	7.0	--	--	93.0 BWPD	Madison
McKenzie	7-25-81	Traverse Oil Co. #1-30 Nygaard SESE Sec. 30-150-101	Pronghorn	11,722	9,402- 9,452	36	--	--	76%	Madison
McKenzie	7-31-81	Shell Oil Co. USA #43-3-116 NESE Sec. 3-148-104	Mondak	13,293	8,114- 8,056	17	35.5°	1,176 GOR	89%	Heath
Divide	8- 1-81	Texas Internat'l Pet. Corp. Bakke #1 C SWSE Sec. 14-163-99	Ambrose	11,200	8,458- 8,464	81	36.0°	900 GOR	9%	Duperow
McKenzie	8-12-81	W. H. Hunt Trust Est. Cross #1 NWSW Sec. 32-149-102	Moline	13,567	13,490-13,498	490	48.9°	1,326 GOR	0%	Red River
McKenzie	8-13-81	The Superior Oil Co. Donald Link et al "A" #1 SENE Sec. 34-152-102	Elk	13,850	13,687-13,737	319	48.3°	1,411 GOR	4.2%	Red River
Williams	8-13-81	Nucorp Energy, Inc. Rieder #2 C NWNE Sec. 9-155-101	Missouri Ridge	10,905	10,752-10,757	187	39.8°	936 GOR	17%	Birdbear
Burke	8-14-81	C. & K. Pet., Inc. Koch #2-28 C NWNE Sec. 28-162-89	Minnesota	7,105	5,863- 5,868 5,873- 5,875 5,877- 5,882	525	30.1°	900 GOR (est.)	0.58%	Madison
Billings	8-23-81	Supron Energy Corp. F-7-144-101 #1 NWNE Sec. 7-144-101	Devils Pass	11,150	9,275- 9,281	112	36.7°	1,443 GOR 162 MCF	148 BWPD	Madison
Billings	8-24-81	Diamond Shamrock Corp. Red. #34-4 SWSE Sec. 4-142-102	Roosevelt	12,770	12,634-12,646	866	50.5°	3,344 GOR	0%	Red River

County	Comp. Date	Operator, Well, Location	Field	Total Depth	Prod. Depth	Oil (Bbls.)	Gravity	Gas	Water	Producing Formation
Dunn	8-27-81	Mesa Pet. Co. #1-10 Pelton NESW Sec. 10-147-96	Bear Creek	14,306	13,970-13,985 14,040-14,047 14,054-14,065 14,069-14,072 14,080-14,094 14,106-14,162	405	52.0°	2,753 GOR	10 BWPD	Red River
McKenzie	8-27-81	Mobil Oil Corporation Harold J. Rogness #1 C NWNE Sec. 26-150-100	Timber Creek	14,620	14,095-14,159	120 BCPD (Cond.)	57.0°	3,200,000 CFGPD	0%	Red River
Williams	9- 6-81	Mosbacher Pruett Oil Co. James F. Martin #1 NENW Sec. 22-153-102	Trenton	13,322	13,164-13,184	323	43.8°	981 GOR	11%	Red River
Divide	9- 7-81	Tenneco Oil Co. Wehrman #1-19 C SESE Sec. 19-163-101	Big Dipper	11,025	10,848-10,928	342	31.8°	269 GOR	59.4%	Red River
McKenzie	9-17-81	Consolidated Crude Oil Flying J. Skjelvik #4-35 C NWNW Sec. 35-150-97	North Fork	14,280	14,048-14,214	152	57.6°	10,263 GOR	0%	Red River
Billings	9-20-81	Tenneco Oil Co. Graham USA #1-15 NESW Sec. 15-144-102	Buckhorn	10,513	10,350-10,380	222 (22.5 hrs.)	--	178 MCF	0%	Bakken
Williams	9-22-81	Kissinger Pet. Corp. Skarderud #2-7 NWNE Sec. 7-158-95	Temple	12,850	12,631-12,716	158	55.5°	5,557 GOR	1%	Red River
McKenzie	10- 3-81	W. H. Hunt Trust Est. Larson #1 NWNE Sec. 10-148-101	Bear Butte	15,059	11,604-11,610	17	41.0°	542 GOR	24%	Duperow
Williams	10- 8-81	NW Exploration Co. Long Creek #3 SWSE Sec. 36-154-99	Long Creek	12,300	11,740-11,773	82	38.5°	780 GOR	44%	Duperow
Stark	10-15-81	Terra Resources, Inc. #1-17 Prange SW/4 SE/4 Sec. 17-137-95	Schefield	12,050	10,476-10,518	251	37.0°	TSTM	59%	Silurian
Bottineau	10-22-81	Petroleum, Inc. Norderhus #1 C NWNE Sec. 36-164-78	Souris	3,105	3,004- 3,010	33	--	not tested	86%	Madison
Dunn	10-27-81	Amoco Production Co. Skachenko "A" #1 C SWNE Sec. 30-146-95	Jim Creek	13,960	11,542-11,578	1,652	45.0°	821 GOR (1,357 MCFD)	1% 16 BWPD	Duperow
Billings	10-27-81	Wm. H. Hunt Trust Estate Ted Fedora #1 NWNE Sec. 34-143-100	Unnamed (St. Jacobs)	9,702	9,670- 9,702	107	41.2 at 60°	1,897 GOR	6.9%	Madison

[illegible]	[illegible]	[illegible]	Field	Depth	Perf. Depth	Oil (Bbls.)	Gravity	Gas	Water	Formation
Billings	10-28-81	W. H. Hunt Trust Est. #1 Hlebechuk SESW Sec. 27-143-100	St. Jacobs	13,815	11,076-11,083	35	43.0°	3,800 GOR	45%	Birdbear
Billings	10-29-81	Adobe Oil & Gas Corp. State Kordonowy #34-31 C SWSE Sec. 31-142-98	Bullsnake	13,670	13,045-13,048	240	49.0°	1,500 GOR	0%	Red River
McKenzie	10-30-81	Traverse Oil Co. #1-19 Nygaard SESW Sec. 19-151-100	Patent Gate	13,956	13,827-13,834	368.8	53.3°	1,184 GOR	1%	Red River
Stark	10-30-81	Coastal Oil & Gas & Al-Aq. #1 BN C NENE Sec. 27-140-98	Green River	12,510	12,344-12,348	374	46.0°	5,313 GOR	7%	Ordovician (Red River)
Divide	11- 5-81	Lear Pet. Explor., Inc. #1 Gordon Hall NWNE Sec. 30-161-98	Plumer	11,765	11,624-11,634	44	37.7°	909 GOR	79.6%	Red River
McKenzie	11-14-81	Getty Oil Company Alexander #3-7 SWNE Sec. 3-150-102	Unnamed	13,610	9,374- 9,514	8	--	1,500 GOR	60%	Madison
Burke	11-24-81	Monsanto Company Peterson #1 SWNW Sec. 9-162-89	Spiral	6,800	5,704- 5,706	18	36.0°	450 GOR	94%	Madison (Bluell)
Billings	11-24-81	Apache Corporation Federal #2-4 SWSW Sec. 2-144-102	Buckhorn	11,429	11,329-11,333	23	36.0°	550 GOR 12.67 MCFD	67% 47 BWPD	Duperow
Bowman	11-25-81	Davis Oil Co. #1 Buchholz C N/W SW Sec. 1-130-105	Skull Creek	9,530	9,311- 9,221	160	28.5°	--	50%	Red River
Dunn	11-25-81	TXO Production Co. McMahen State #1 NENE Sec. 36-146-93	Werner	12,819	9,081- 9,087	97	31.7°	--	0%	Madison
McKenzie	12-12-81	Patrick Petroleum Co. Enderud #1-17 SWNE Sec. 17-152-98	Banks	15,300	14,617-14,636	3.48 MMCF/D	--	--	--	Red River
McKenzie	12-22-81	Exeter Expl. Co. Hystad #11-31 NESW 31-152-99	Poe	14,370	14,180-14,255	6.2 MMCFD & 621 BCPD	56.5°	11,900 GOR	1%	Red River 'C'
Golden Valley	12-22-81	Anderson Petroleum, Inc. Gasho #2-23 NWSW Sec. 23-144-105	Trotters	12,611	12,365-12,436 12,532-12,535 12,557-12,560	B & C Zones 439.8	40.0°	--	B Zone-15.5% C Zone-44.8%	Red River
Divide	12-29-81	Lear Petroleum Explor. Kvigne #1 SWNW Sec. 11-161-99	Garnet	11,686	11,482-11,490	138	42.0°	3,565 GOR	47.9%	Red River

County	Comp. Date	Operator, Well, Location	Field	Total Depth	Prod. Depth	Oil (Bbls.)	Gravity	Gas	Water	Producing Formation
Williams	12-29-81	Samedan Oil Corp. Donahue #1 NENE Sec. 23-154-100	Avoca	14,824	9,714-10,126	113	35.5°	TSTM	45%	Madison

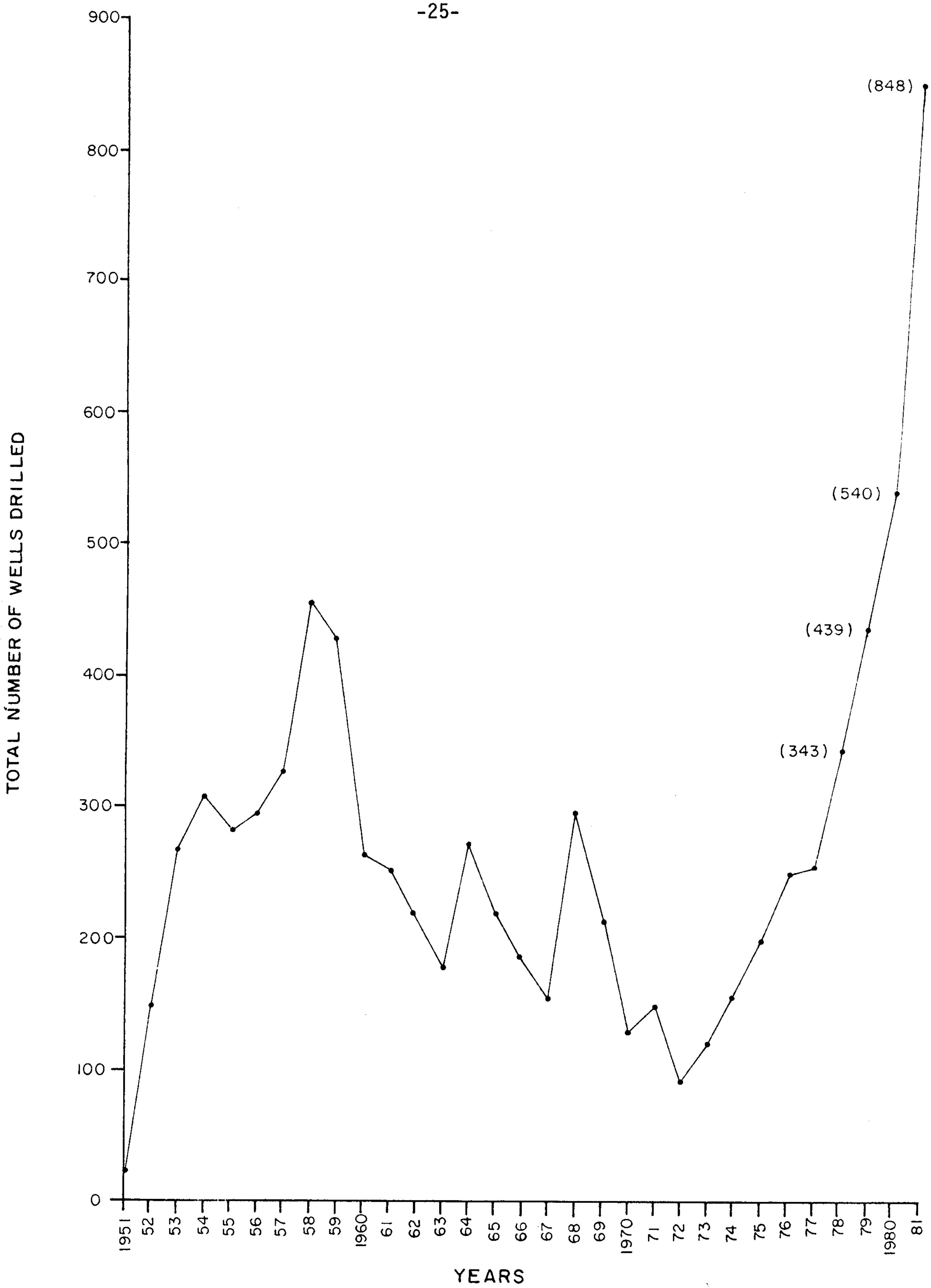


Figure 1. Graph showing the number of wells drilled in North Dakota each year since oil was discovered in 1951. Total includes both exploratory and development wells

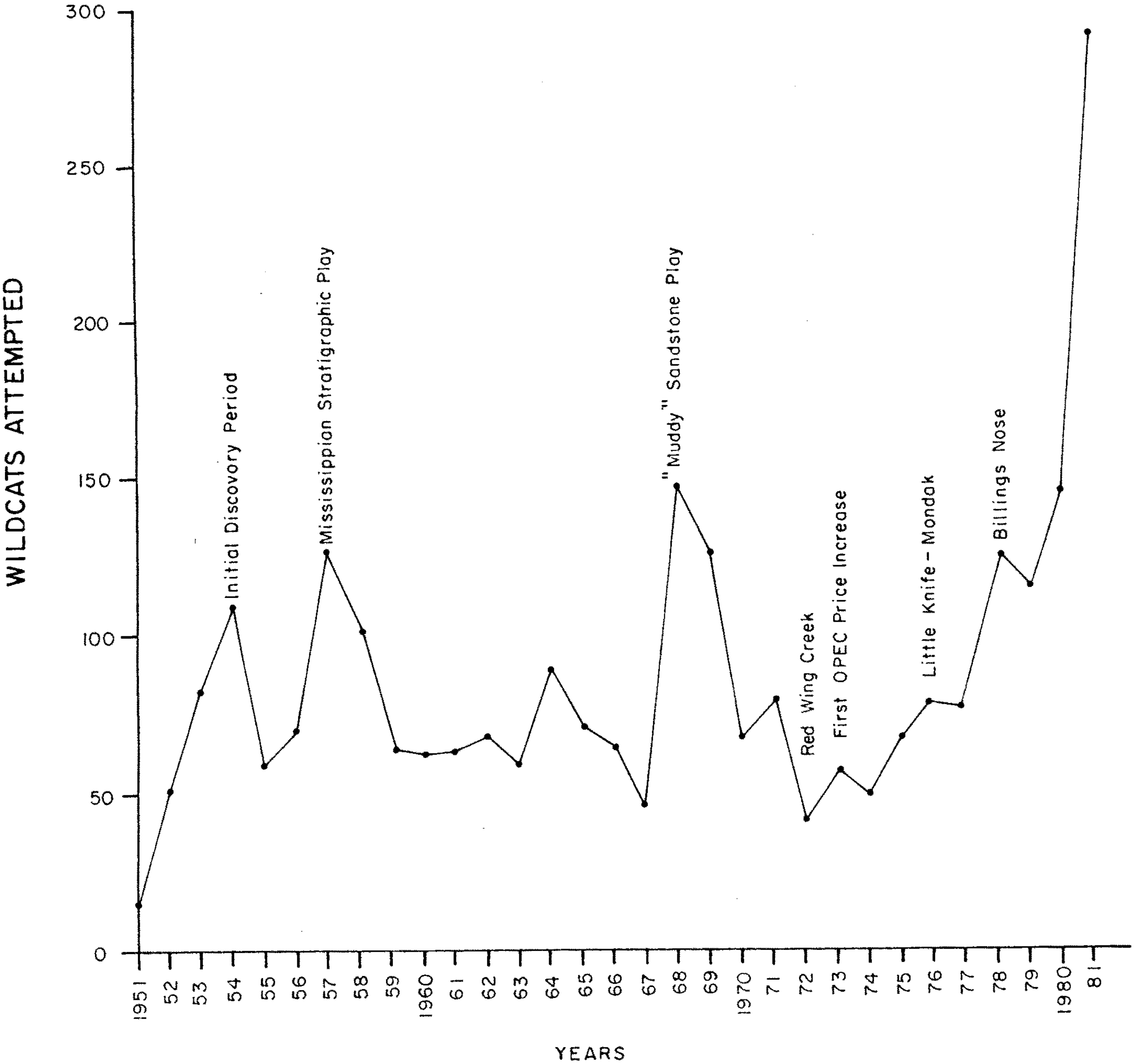


Figure 2. Graph showing the number of wildcat wells drilled in North Dakota each year since oil was discovered in 1951. Some of the major events affecting drilling activity are noted on the graph.

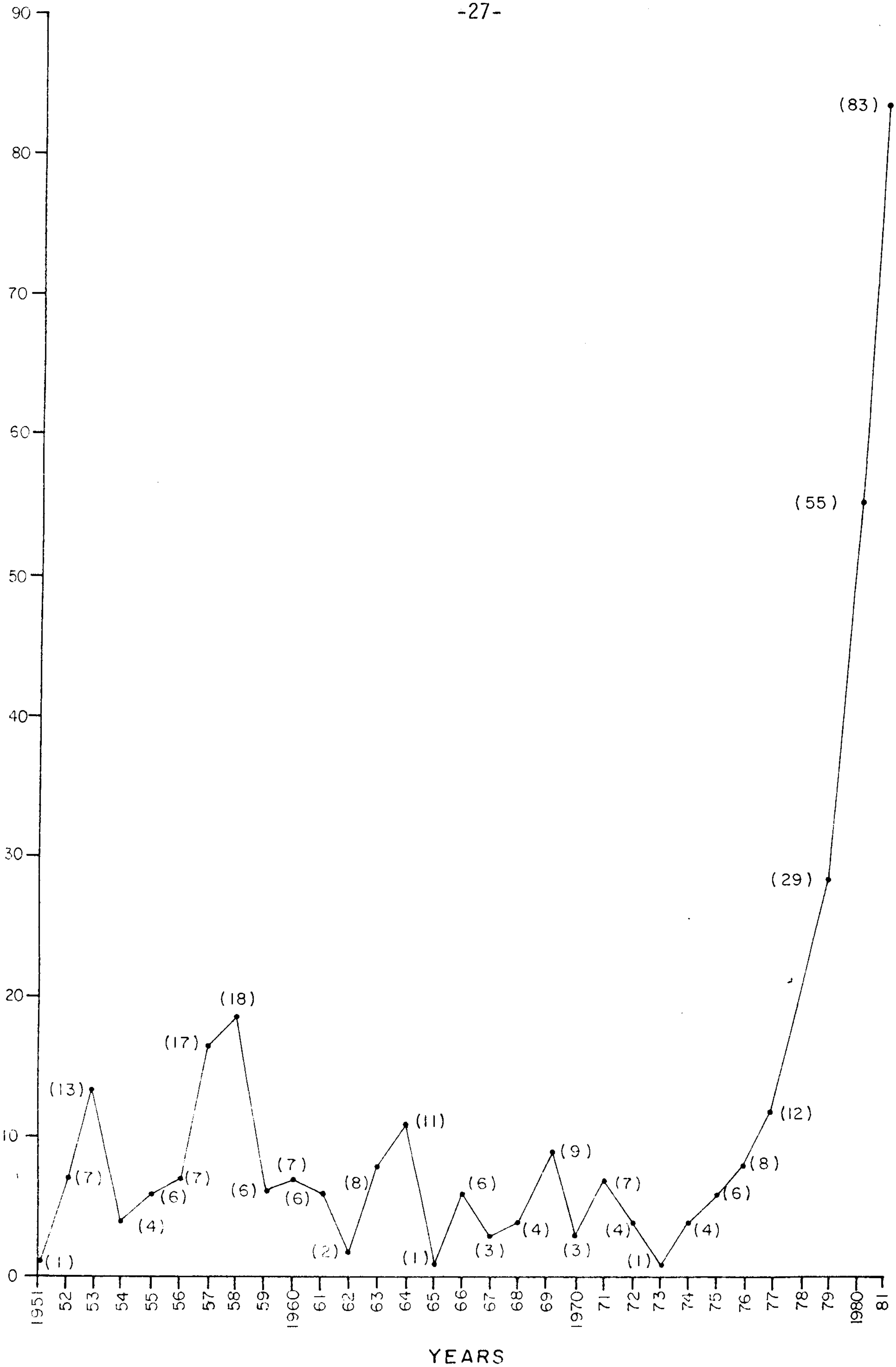


Figure 3. Graph showing the number of new pools discovered each year in North Dakota. The total number of pools discovered each year since 1978 has been much higher than in previous years.

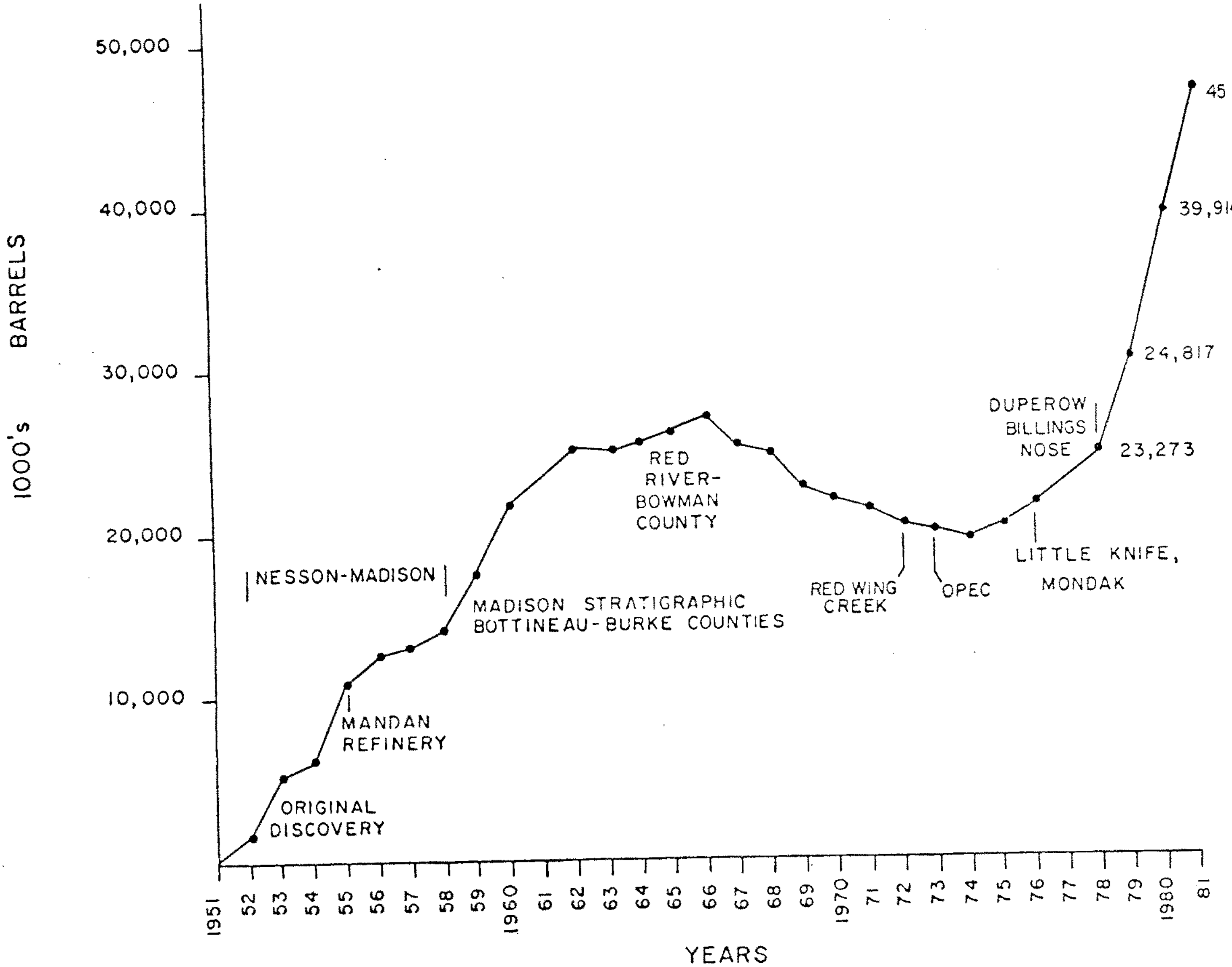


Figure 4. Annual crude oil production in North Dakota. Figures are given in thousands of barrels; thus, the 1981 production was 45,700,000 barrels. Major events affecting oil production history are noted on the graph.

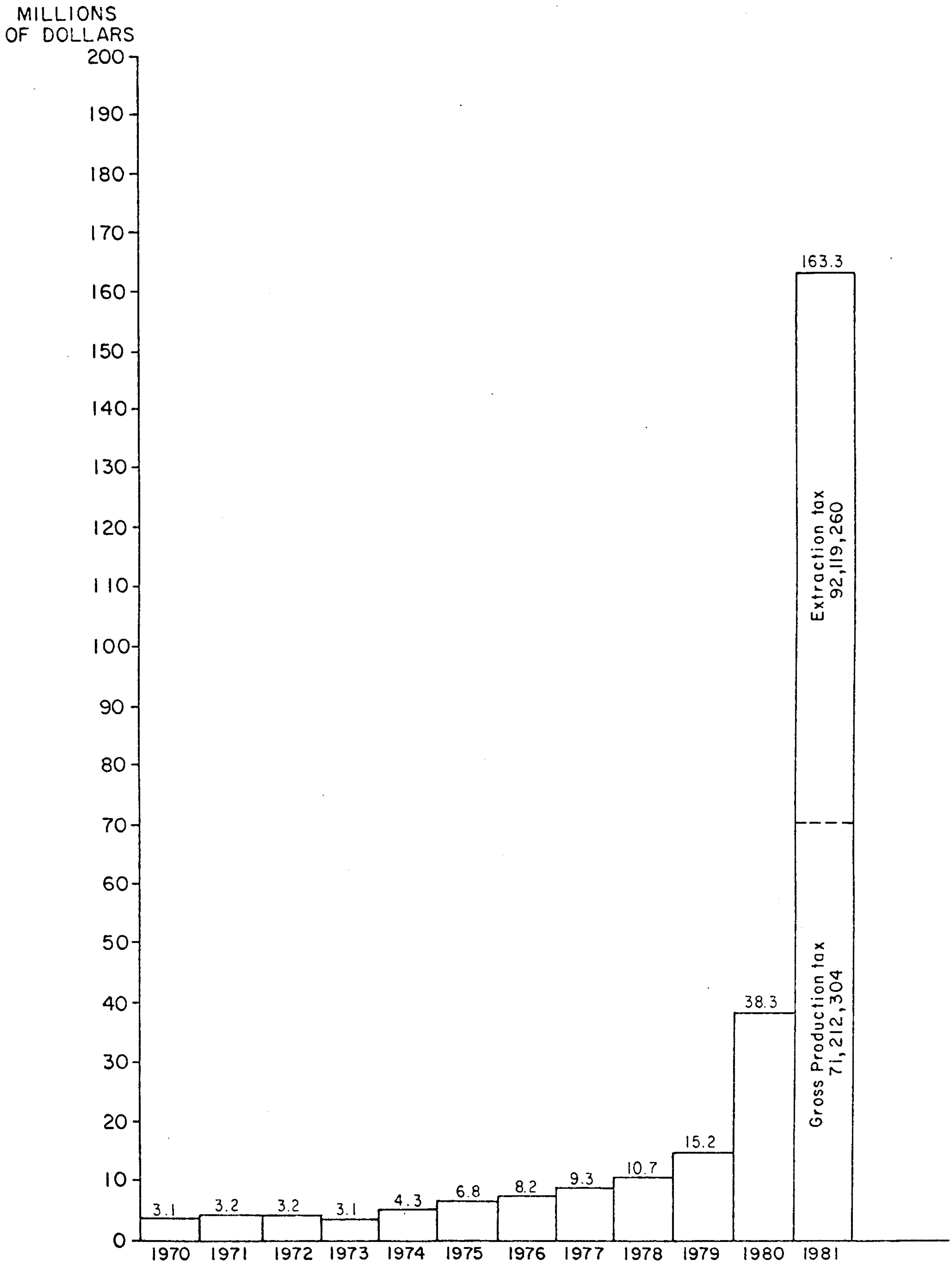


Figure 5. Net oil and gas tax collections since 1970. The dramatic jump in revenues in 1981 was due, in large part, to the implementation of the new extraction tax.

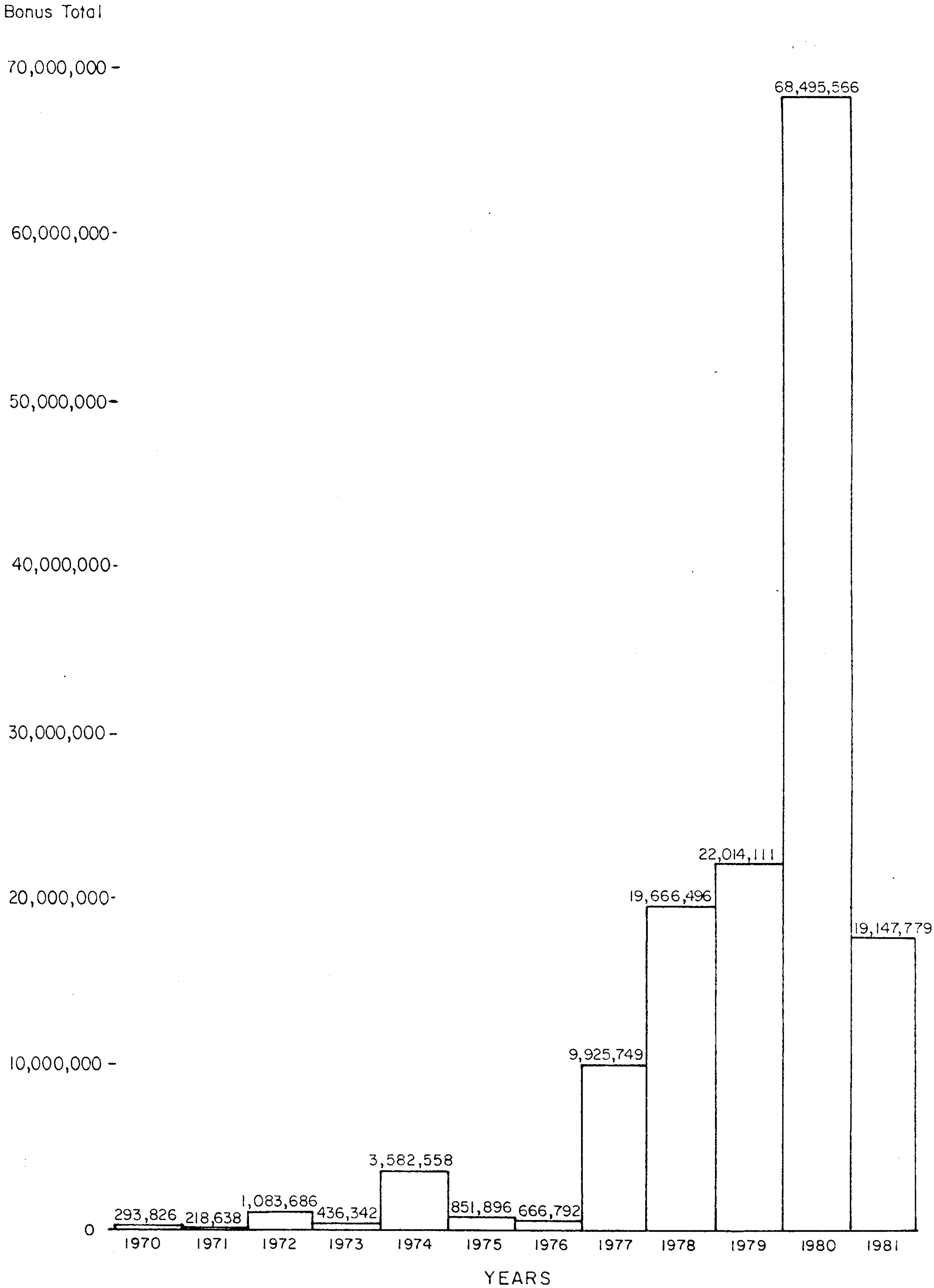


Figure 6. Oil and gas lease bonus income from state lands.

PRODUCTION PERFORMANCE CURVES

--Marvin Rygh

Recently, I have constructed production decline curves of various oil fields in Burke County. This study has been done to provide a data base for the possible deunitizing of these oil fields. Evidently, the operators feel that unitization and full-scale water injection are no longer economical or effective in this area. Tentatively, hearings will be held in Bismarck to consider deunitizing the fields and the production decline curves will be used at the proceedings.

Production performance curves are graphic representations of the production statistics over the life of a field or single well. These performance curves are generally referred to as decline curves because, in most cases, the production of oil declines with time.

Up until 1976, decline curves were published in the semi-annual production statistics report issued by the North Dakota Geological Survey. Since then, decline curves have not been included in the production reports, but we are tentatively planning to update the decline curves and make a separate publication available.

Performance curves are extremely useful in the petroleum industry. The phrase "a picture is worth a thousand words," applies perfectly in this case. A quick glance at a performance curve for an oil field (or a single well) can provide such information as past and present rate of oil production, cumulative oil and water production, gas-oil ratios, and reservoir pressure changes. By extrapolating the oil-production curve, projections can be made about the future economic life of the field. In most cases, these extrapolations are best guesses, but they can be surprisingly accurate. Making projections from the decline curves is one method an operator can employ to determine total recoverable reserves and future profits.

Quite often, a decline curve is used to evaluate secondary recovery or enhanced oil recovery (EOR) projects. Any substantial increase in oil production will show up readily on the graph as an upward movement of the oil production curve or a change in the slope of the curve corresponding to the time the EOR project was initiated. Along with increased oil production, the reservoir pressure should increase or at least stabilize somewhat. Of course, this occurs only if the EOR technique is successful.

A straight-line decline is the easiest type of curve to extrapolate. To obtain this straight-line relationship, the data are plotted on various types of graph paper. Three common types are used: Cartesian coordinates, semi-log, and log-log. In most cases, semi-log graph paper is used. In any case, the type of decline obtained, whether it is a straight line, constant percentage decrease, or hyperbolic, is a reflection of all of the factors influencing the production rate. Some factors may be definitely known, but many may be unknown. Surface conditions (workovers, proration, unitization, etc.), and reservoir conditions are major factors affecting the shape of the curve.

The example decline curve included with this article (fig. 1) is of the Glenburn Field in Renville and Bottineau Counties. This field is assumed to be an active water-drive reservoir. In other words, it is an oil field in which the natural energy for production is derived from bottom-water or edge-water in the reservoir. Pressured formation water drives the oil out of the pore spaces into the wellbore.

Ideally, if a replenishable head (fluid pressure) is available, the reservoir pressure should remain constant as long as the production of oil does not exceed the rate of infilling formation water. The example decline curve reveals that the Glenburn pool is not the ideal case and that the reservoir pressure has dropped from 1950 psi in 1960 to 460 psi in 1971. From this decline curve, one can also note the relationship

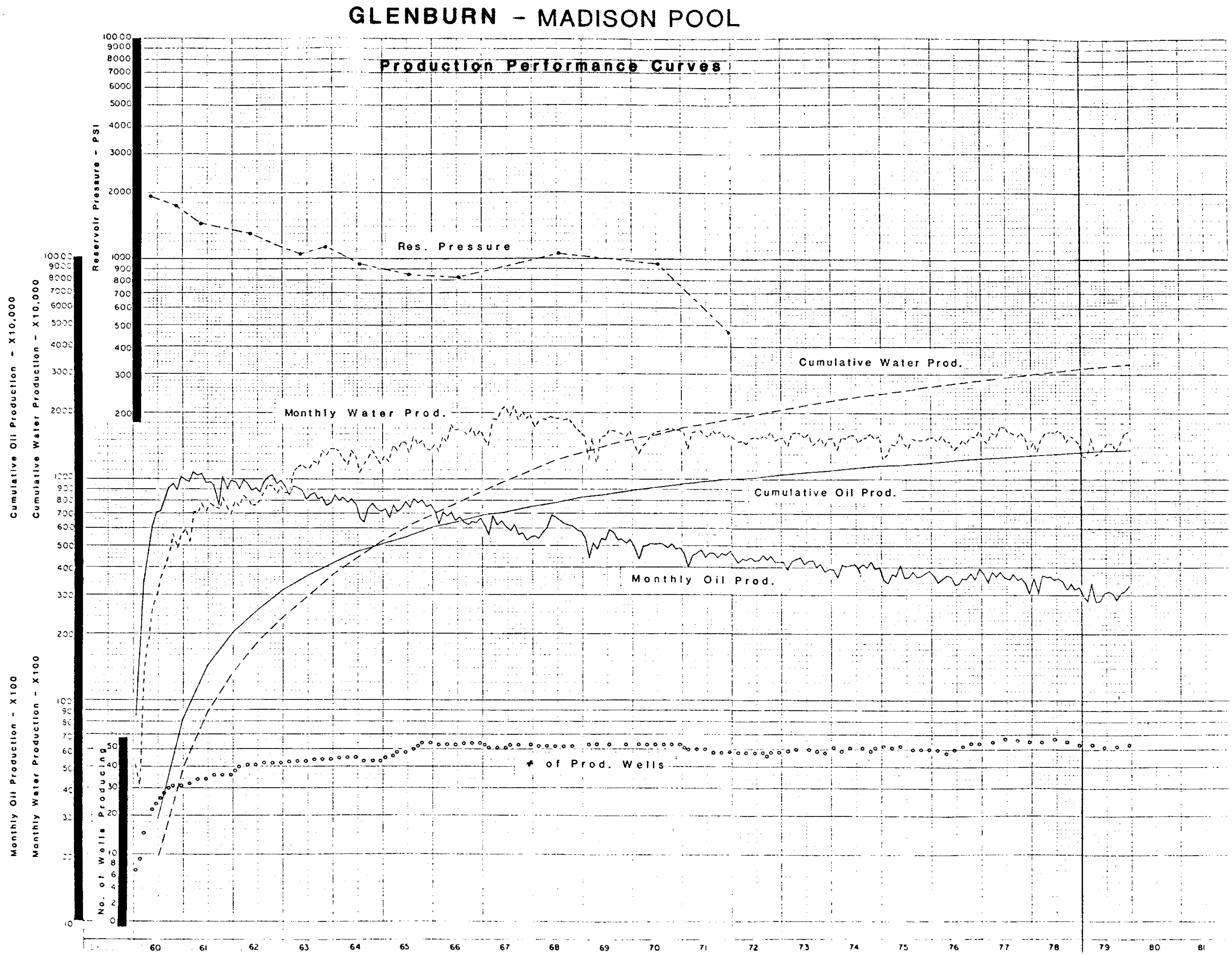


Figure 1. Decline curve fc the Glenburn-Madison Pool, Bottineau and Renville Counties, North

of water to oil produced. As oil production has progressed, the water-oil ratio (WOR) has increased and the cumulative water production has surpassed the cumulative oil production. This is a common occurrence because, over the life of a field, the oil-water contact in the reservoir becomes higher, hence more water is produced with every barrel of oil. An immediate way to minimize water encroachment is to slow down production, but there must be a compromise between the WOR and the production rate for the field to be profitable. A good operator knows the optimum rate of production for a given field.

Many more reservoir conditions can be plotted on these graphs. This was just a brief glance at one particular decline curve, but it should give an idea of what type of information can be obtained from production performance curves.

OIL PRODUCTION FROM KASKASKIA ROCKS IN NORTH DAKOTA'S WILLISTON BASIN

--Randy Burke and Gary Stefanovsky

The major hydrocarbon-producing formations in North Dakota are included in the Kaskaskia Sequence, which includes rocks of Devonian and Mississippian age (see table accompanying this article). Over 80 percent of the 652,461,547 barrels of oil produced in North Dakota (as of March 1, 1982) is from strata in the Madison and Jefferson Groups. The Madison Group is the major reservoir in the Kaskaskia Sequence. It has produced over 467,000,000 barrels of oil. All of the formations included in the Madison (Charles, Mission Canyon, and Lodgepole) are oil producing. Because the stratigraphy of the Madison wasn't worked out until a large amount of Madison oil was produced, the cumulative production figure has not been broken down by formation.

The Devonian portion of the Kaskaskia Sequence has produced a total of 73,709,847 barrels of oil. However, most of the Devonian production, 67,329,787 barrels, is from undifferentiated horizons. Only 6,380,060 barrels is known to have come from specific formations; perhaps it is logical to assume that, generally, the undifferentiated Devonian production was distributed in about the same proportion as is the known Devonian production. The Duperow Formation, with 5,389,870 barrels of known production, has been the most prolific Devonian producer (of the undifferentiated Devonian production, perhaps 57 million barrels was from the Duperow, if the known proportions hold).

With 541,510,250 barrels of produced oil, the Kaskaskia Sequence rocks have accounted for 83 percent of total North Dakota Williston Basin oil production since 1951.

KASKASKIA PRODUCTION

SEQUENCE	PERIOD	GROUP	FORMATION	CUMULATIVE OIL PRODUCTION (in barrels of oil)	% KASKASKIA	% NORTH DAKOTA OIL PRODUCTION
KASKASKIA	MISSISSIPPIAN	BIG SNOWY	Otter			
			Kibbey*			
		MADISON	Charles*			
			Mission* Canyon	467,800,403 (Undifferentiated Mississippian)	86.39	72
			Lodgepole*			
	DEVONIAN		Bakken*	— 843,424	.16	
			Three Forks*			
		JEFFERSON	Birdbear*	— 27,706	.005	
			Duperow*	— 5,389,870	0.995	
		MANITOBA	Souris River*	67,329,787 (Undifferentiated Devonian)	12.43	11
			Dawson Bay*			
		ELK POINT	Prairie			
			Winnipegosis*	— 119,060	.02	
TOTAL				541,510,250	100%	83%

*Producing Formations

GROUNDWATER HEAT PUMPS

In our last Newsletter we reported on the release of a study of North Dakota's hydrothermal resources and a new Geothermal Resources map. The Geothermal Resources map is available free of charge from the North Dakota Geological Survey. One of the practical applications of North Dakota's geothermal resources is in the installation of groundwater heat pumps for heating and cooling homes or other, larger buildings. Although this application does not, perhaps, utilize geothermal heat in the sense most people think of it--no geysers or hot springs are involved or anything like that--it does extract natural heat from the water and, in that sense, the earth's natural heat is being used. Almost any groundwater that is available can be used.

By now, most people in this part of the country have become aware of many of the applications of heat pumps and many people have installed air-to-air heat pumps to provide all or a portion of their home heating needs (I did it last year and I figure I saved about $500 on my heating bill compared to fuel oil as well as adding air conditioning to my home; I might have saved even more, but the electric company discontinued its policy of giving a preferential rate to all-electric customers shortly after I switched to all-electric). Air-to-air heat pumps have been common in the states farther south for a long time. Until now, however, only a very few people have installed groundwater (water-to-air or water-to-water) heat pumps.

A heat pump operates in a manner similar to a household refrigerator, which pumps heat from inside the refrigerator to the outside. The major difference between a heat pump and a refrigerator is that a heat pump can either deliver heat to or remove it from a space, simply by reversing the flow direction of the refrigerant. For this reason, heat pumps are sometimes called "reversed-cycle refrigerators." A groundwater heat pump extracts heat energy from groundwater that is pumped from a well into your home. After the heat has been extracted, the slightly cooled groundwater is pumped out of your home and discharged back into a second well drilled some distance from the source well (fig. 1). The extracted heat is used to heat the home. When the heat pump is operating as an air conditioner, the heat energy is removed from your home, carried away in the slightly warmed groundwater, and discharged into the ground again.

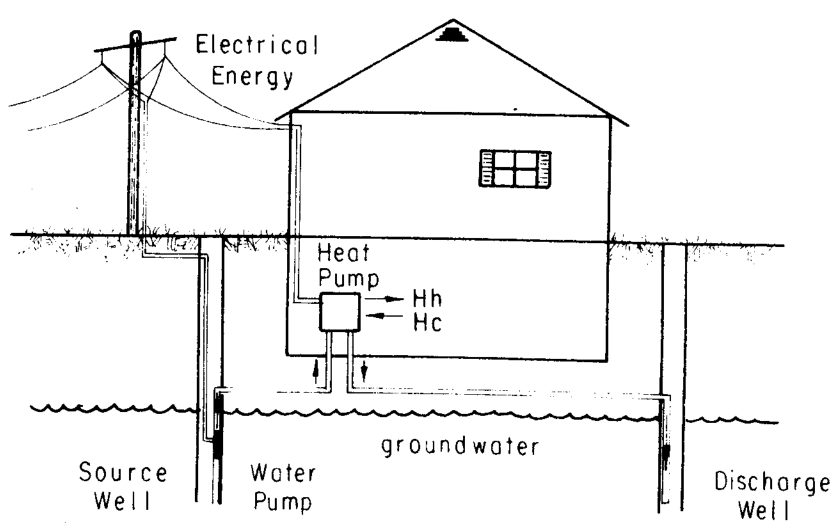


Figure 1. House with a groundwater heat pump installation. The heat pump can either extract heat from the water (Hh) and deliver it to the house, or extract it from the water (Hc) so that the water will take it down the discharge well.

Groundwater heat pumps have two basic advantages over heat pumps that use air as the heat source. First, water has the highest specific heat of any common substance. Its specific heat is four times greater than that of air. In other words, a given mass of water can store four times as much heat energy as an equal mass of air, and the water occupies a much smaller space. Second, groundwater temperatures in North Dakota are fairly constant the year around, with annual temperature changes from 10° to 20° F in shallow groundwater. The temperature variation for deep groundwater is less. Air temperatures, however, are often too low for economical use in the coldest part of the winter when heat is needed most and too high in the summer when cooling is needed. When an air-to-air heat pump operates in these extreme temperatures, its efficiency is reduced and a greater quantity of electricity is consumed.

A major portion of the cost of installing a groundwater heat pump system lies in drilling and completing the wells necessary to provide the groundwater supply and to return it to the ground after the heat has been extracted. This cost can vary depending on the depth required to obtain sufficient quantities of water. The permeability of the aquifer, which governs the rate at which water can be pumped into the ground as well as out, is also an important factor. In parts of North Dakota, suitable groundwater supplies are present near the surface, but in some places it is necessary to drill several hundred feet to obtain water. In some places, groundwater is unavailable at any depth. Table 1 lists and compares the initial costs of installing several types of heating systems. Obviously, a groundwater heat pump is not the cheapest type of system to install. I've assumed a $15 per foot drilling cost in calculating the cost of the wells required for a groundwater heat pump installation.

Table 1. Average Initial Costs for Heating and Cooling Systems

	Groundwater Heat Pump	Air-to-Air Heat Pump	Natural Gas Furnace	Electric Resistance	Electric Furnace	Propane
Heating and Cooling	$3000	$3000				
Heating			$1000	$ 500	$1000	$ 800
Cooling			1300	1100	1100	1300
Ductwork	400	400	300		400	300
Chimney			100			75
Storage Tank						150
Water Well	1600					
Plumbing	300					
TOTAL	$5,300	$3,400	$2,700	$1,600	$2,500	$2,625

Table 2 shows seasonal heating costs for given energy rates. In this table, columns A and B illustrate a sample situation where the respective seasonal heating costs are determined for given energy costs. Figure 2 shows the annual costs of heating a typical North Dakota home with various types of energy. Using figure 2 as a reference, similar relative cost comparisons may be made for any location once the local energy costs have been obtained from the local utilities and fuel suppliers. For this particular example--a situation characteristic of much of the state of North Dakota--the groundwater heat pump has no close competitor.

Table 2. Seasonal Heating Costs for Sample Energy Prices

Heating System	A Energy Cost	B Sample Seasonal Heating Cost
Fuel Oil	$1.20/gal	$1407/yr
Natural Gas	$ .40/ccf	610
Propane	$ .75/gal	1250
Electric Resistance	$ .04/kw-hr	843
Air-to-Air Heat Pump	$ .04/kw-hr	527
Groundwater Heat Pump	$ .04/kw-hr	285

Recently, two of us from the NDGS spent a day with Pat Falk of Hankinson, North Dakota, examining several groundwater heat pumps that Mr. Falk has installed in homes, shops, hospitals and churches in the Hankinson-Wahpeton area. A typical installation consists of two wells, separated by at least 50 feet (either vertically or horizontally or a combination of the two--the total separation between the intake and discharge points is generally 50 feet or more; greater distances are required in poor aquifers, less in good ones), a pump to deliver the water to and from the building being heated or cooled, and one or more heat pumps, depending on the size of the building. Supplemental electric resistance heating may be installed as well.

Mr. Falk provided us with the actual costs of heating several of the structures in which groundwater heat pump systems have been installed, compared with the conventional fossil fuel heating costs. His own older, 2,300-square-foot home, which has been insulated with foam in the walls and 8 inches of poured insulation in the ceilings, cost $306 to heat last winter (fig. 3). To produce the same amount of heat, Mr. Falk calculated that $1540 worth of fuel oil would have been required (that's off the scale of Figure 2 of this article, but if you want to compare it with Figure 2, we are using a fuel oil price of $1.20/gal for the Hankinson area). Two more examples Mr. Falk showed us were for new homes. One, a 1,700-square-foot home, cost $186 to heat last winter with the groundwater heat

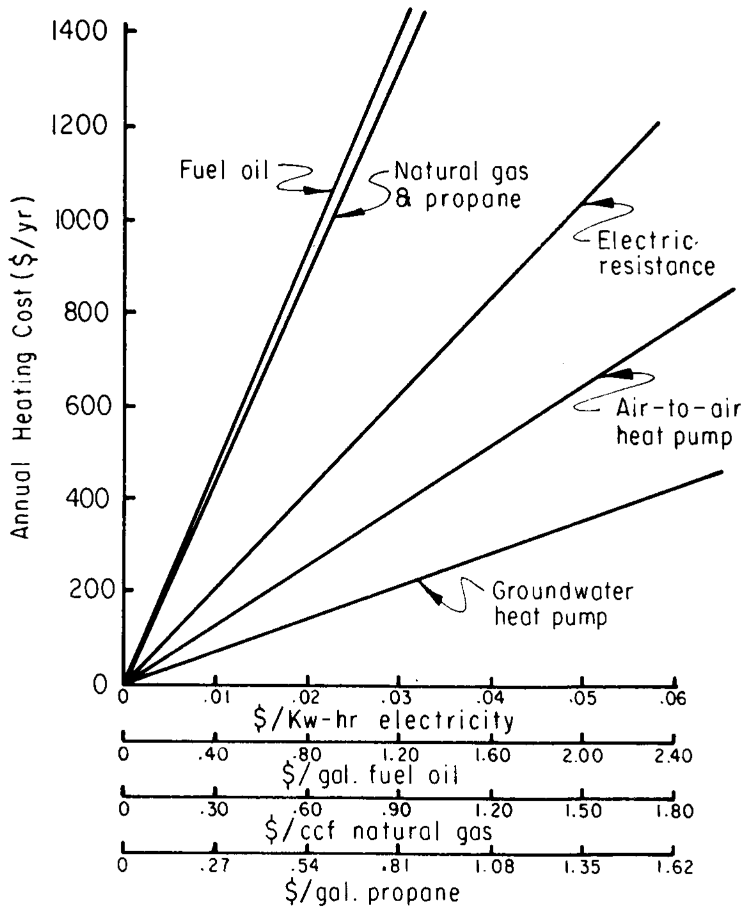


Figure 2. Annual heating costs for a typical North Dakota home using various energy systems. Costs of heating vary, depending on the price of the type of energy used in heating.

Figure 3. Pat Falk's home in Hankinson, North Dakota. Note the two well installations in the yard. As noted in the article, this home cost $306 to heat last winter, using the groundwater heat pump system Mr. Falk installed. It's hard to imagine a cheaper way to heat a 2300-square-foot home in North Dakota.

pump. A new, 2800-square-foot home cost $61 to heat during January, Hankinson's coldest month last winter (I don't have degree-day figures). Finally, Mr. Falk's shop, which covers 5000 square feet and has 16-foot ceilings, cost $1200 to heat last winter using the groundwater heat pump he installed. A comparable amount of heat derived from fuel oil would have cost about $4700. These figures were supplied to us by Mr. Falk and they seem to be consistent with research that has been done elsewhere (see Table 2 and Figure 2).

If you would like more detailed information on groundwater heat pumps, the following 28-page booklet, published in 1981, will be of interest:

> Geothermal Groundwater Heat Pump--Equipment Selection Procedures for Architects, Designers, & Contractors

It is available either from us (North Dakota Geological Survey) or from the North Dakota State Geothermal Energy Office, State Capitol Building, Bismarck, ND 58505 (phone 701/224-2107).

The following sources can also provide technical information about groundwater heat pumps:

For groundwater aquifer data:

> Kenneth Harris, North Dakota Geological Survey, University Station, Grand Forks, ND 58202 Phone: 701/777-2231

For information on terrestrial heat flow:

> Francis Howell, Physics Department, University of North Dakota, Grand Forks, ND 58202 Phone: 701/777-3516

For information on heat pump design, technical specifications, etc.:

> Don V. Mathsen, Engineering Experiment Station, University of North Dakota, Grand Forks, ND 58202 Phone: 701/777-3120

For additional general information:

> North Dakota State Energy Office, Geothermal Program, Federal Aid Coordinator's Office, State Capitol Building, Bismarck, ND 58505 Phone: 701/224-2107

ABSTRACTS OF TALKS GIVEN BY NDGS GEOLOGISTS

In addition to the papers presented at the AAPG meeting in Calgary (please see the first article in this Newsletter), some of our geologists presented papers at other meetings this spring. Two of the abstracts that follow represent papers delivered at the Annual meeting of the Geological Association of Canada in Winnipeg in May. The third is a sort of expanded abstract (a "communication") for a paper I gave at a symposium (on Potential Natural Vegetation in North Dakota--it's just a background paper; not original research) at the annual meeting of the North Dakota Academy of Science in Bismarck.

THE SHEYENNE RIVER BASIN: ITS GEOLOGY AND EFFECTS ON LAKE AGASSIZ

Brophy, J. A., North Dakota State University, Fargo, North Dakota 58105 and Bluemle, J. P., North Dakota Geological Survey, Grand Forks, North Dakota 58202

The Sheyenne River, the major North Dakota tributary to the southern Lake Agassiz basin, contributed large volumes of water and sediment to the lake. In its earliest phase, about 12,000 years B.P., the river was a broad, shallow, ice-marginal stream that carried meltwater from glacial lobes in central North Dakota. At that time, the river flowed southward past Ft. Ransom into Lake Dakota. With retreat of the west flank of the glacier into the Red River Valley lowland, the Sheyenne switched to the Minnesota River basin. At the same time, retreat of the glacier from central North Dakota allowed Lakes Souris and Minnewaukan to form. Large volumes of outlet water from these lakes passed into the Sheyenne River causing the erosion of a deep trench. Further dissipation of the ice in the Red River lowland created the first small segment of Lake Agassiz about 11,500 years B.P., and the Sheyenne became its tributary. As the lake expanded, coarse clastics built a delta at the river point of entry while finer sediments continued lakeward, building a large turbidite fan. As Lake Agassiz's southern outlet was cut downward, the Sheyenne trenched its delta and fan deposits, stabilizing at the Campbell level, which is marked by a terrace in the trench. Opening of the northern (Lake Superior) outlet of Lake Agassiz about 10,900 years B.P. drained the southern part of the basin and the Sheyenne further trenched the delta/fan and extended its course northeastward across the lake floor. Closing of the Lake Superior outlet resulted in reflooding of the southern basin, making an estuary of the lower Sheyenne trench in which fine-grained sediments were deposited. Final drainage of the southern lake basin when lower, northern outlets were opened led to trenching of the estuarine deposits and extension of the Sheyenne River in its present location across the lake floor.

GEOLOGICAL SETTING OF THE LAKE AGASSIZ REGION

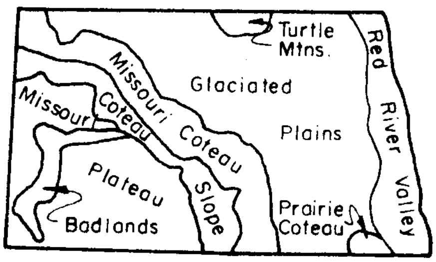
Teller, J. T., Department of Earth Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2, and Bluemle, J. P., North Dakota Geological Survey, Grand Forks, North Dakota 58202

The bedrock of the Lake Agassiz region can be subdivided into four major geological provinces: 1) A Precambrian granitic basement complex underlying the northern and eastern parts of the basin in Manitoba, Ontario, and Minnesota, 2) a Paleozoic carbonate-dominated area extending along the axis of the Red River valley in North Dakota and Minnesota through the Interlake region of Manitoba, 3) a second Paleozoic carbonate area underlying the Hudson Bay Lowland, and 4) a Mesozoic shale region that underlies the western side of the basin and forms a western marginal escarpment. Although strata dip southwestward into the Williston Basin, erosion during Tertiary and Quaternary time resulted in an overall northeasterly slope toward Hudson Bay on the preglacial bedrock surface. Only the magnitude of this slope was affected by glacially-induced isostatic depression and rebound, and whenever ice invaded the Hudson Bay Lowland water was dammed southward (upslope) in the Lake Agassiz region. The western margin of the Lake Agassiz basin (Manitoba Escarpment) rises abruptly by as much as 300 m, and is mainly the result of preglacial erosion of relatively soft Cretaceous and Jurassic shales. The floor of the main southern basin, which at one time lay more than 200 m below the surface of Lake Agassiz, is a bedrock trough between the Escarpment and the higher Precambrian rocks to the east, and has been repeatedly scoured by glaciation. Glacial, interglacial, and postglacial erosion and deposition have only modified the details of this surface, and Lake Agassiz sediment now overlies variable thicknesses of Cenozoic sediment. The Lake Agassiz watershed once extended west to the Rocky Mountains of Alberta, north to the Arctic, east to the Lake Superior basin, and south to the divide into the Mississippi River watershed at Brown's Valley, South Dakota--an area of more than 1.5 million km^2.

LANDFORMS OF NORTH DAKOTA

John P. Bluemle, North Dakota Geological Survey, University Station, Grand Forks, ND 58202

North Dakota's landforms can be broadly grouped into two categories: erosional and depositional. Most of the topography in the southwestern part of the state is the result of erosional processes that operated apart from the action of glaciers or processes directly related to glaciation. Conversely, most of the topographic features throughout northern and eastern North Dakota result directly from glaciation.



The map of North Dakota (at left) identifies several distinct physiographic or geomorphic regions. Although great individual variations characterize the landforms in each region, overall internal similarities make it possible to generalize about the geomorphic processes that operated to shape each region.

The area southwest of the Missouri River in North Dakota is referred to as the Missouri Plateau. Although some parts of the Missouri Plateau near the Missouri River were glaciated, in most instances an occasional erratic boulder or patch of glacial sediment is the only evidence of that glaciation. The Missouri Plateau is an extension of the Great Plains, which slope eastward away from the Rocky Mountains in Montana and Wyoming. The landscape throughout this vast region is the result of erosion, during Late Tertiary time, of flat-lying beds of sandstone, shale, and lignite (primarily the Fort Union Group deposits). These sediments have been modified by the formation of natural brick, baked by burning underground coal seams, and by mineral-rich groundwater, which formed layers of silcrete, petrified wood, concretions, and nodules of varying sizes and shapes. Secondary processes such as these resulted in great differences in lithification and durability of the sediments to erosion and weathering. The shapes of individual landforms of the Missouri Plateau are most notably the result of the differences in resistance of the near-surface materials to erosion by wind and running water.

The carving of the Little Missouri River badlands began in Pleistocene time when the river was diverted by glaciers from its northerly route into Saskatchewan. As a result of its diversion, the Little Missouri River was forced to flow eastward over a shorter, steeper route, resulting in a cycle of vigorous erosion that continues today.

In eastern and northern parts of North Dakota, depositional glacial landforms predominate. The overall aspect there is one of closely spaced hills and valleys, which have lower relief than landforms in the unglaciated "wide-open spaces," where large buttes and gently sloping areas are found. The unglaciated areas are also well drained. This contrasts with the glaciated parts of the state, where drainage ranges from completely unintegrated to areas with only poorly developed stream systems. Landforms in the glaciated parts of North Dakota are the result of depositional processes that operated over a drastically shorter period of time than did the erosional processes in unglaciated areas. Although some important erosional features, such as certain melt water trenches, are found in the glaciated areas, most of the topography is the result of relatively small-scale reshuffling by the ice of the materials it was flowing over. A layer of reworked sediment, some of it transported great distances by the glaciers, but most of it locally derived, completely changed the overall aspect of the landscape during Quaternary time. This layer of glacial sediment, which reaches thicknesses as great as 220 metres in central North Dakota, contains a broad mix of minerals, making possible extremely rich soils, in contrast to the poorer soils developed on some of the Cretaceous and Tertiary marine formations found farther west in unglaciated areas.

The glaciated part of North Dakota can be logically subdivided into four major physiographic units. These are 1) the Coteau Slope, and area adjacent to the Missouri River where glacial deposits are thin and the preglacial topography was only slightly modified by glacial processes; 2) the Missouri Coteau (along with the Turtle Mountains and Prairie Coteau), where glacial stagnation processes predominated; 3) the Glaciated Plains, an area where large-scale glacial thrusting, coupled with deposition due to ablation by the glacier, resulted in an intricate glacial landscape; and 4) the Red River Valley, an exceptionally flat area that is largely the surface expression of glacial Lake Agassiz.

To some degree, geologic factors such as slope angles, composition and texture of the subsoil materials, and groundwater conditions, all helped determine the type of soils that developed on North Dakota's landforms. However, changes in the climate since the end of the glacial epoch were undoubtedly the single most important factor governing the character of vegetation (and resulting soils) that developed on the landforms. This can be most readily illustrated by considering a modern analog: the Turtle Mountains and the Missouri Coteau have landforms that are essentially identical in all respects. Yet, the slight differences in climate that exist between the two areas results in strikingly differing types of natural vegetation in the two areas. Similarly, areas in central Minnesota, which have landforms identical, both in shape and composition, to those found on the Missouri Coteau in North Dakota, also have entirely different vegetation and soils.

RECENT EVENTS

--Don Halvorson

Along with our ongoing program of research, the Survey has been involved during the past six months in a number of changes in both our physical plant and personnel, as a result of the engineering division's move to Bismarck and the retirement or resignation of members of the Survey staff. We have increased the size of the publications library and shipping room, and are working to better utilize our available space. The space previously occupied by the engineering division has been partitioned into areas for processing of oil and gas data, and for housing our computer system and System 6. We are now sharing an IBM 34 computer with the UND Medical School. This allows us rapid retrieval of WELLFILE, WATERCAT, geothermal data, and other business and data management systems employed by the Survey.

The process of "settling into" the new core and sample library is progressing well. Approximately 90,000 boxes of core and well cuttings have been removed from the old facility which is now being dismantled and reassembled for University use in the plant services area. Space will be available in this building for storage of the Survey's two drilling rigs and logging van, and also for water well samples.

Most of the core samples have been organized in the new facility. We expect to have the remaining cores organized and the core study laboratory completed by September 1. This laboratory includes a sample preparation area, a microscope study area, and x-ray and photographic facilities.

The new core library will soon be filled to capacity, so we are pursuing additional funding for the construction of a mezzanine in the receiving room and for additional shelving for storage of lighter weight well cuttings. We are pleased that the core and sample library is very much in use and that we are receiving very positive feedback from the companies taking advantage of this facility.

Three additions to the Survey's professional staff have recently been made. Marvin Rygh has joined the subsurface division as our Petroleum Engineer. He is working with oil field statistics and reservoir analysis, and is responsible for maintaining and publishing oil field decline curves.

David Brekke is our mineralogist and microscopist. He will be doing potash research and SEM studies of fabric and porosity of Williston Basin reservoir rocks. He will serve as clay mineralogist and sedimentary-petrologist, aiding the surficial and geotechnical staff.

Robert Seidel has recently joined the Survey's surficial division and will work in the area of glacial geology. He will help to complete our county studies and will be involved in creating one-degree geologic and geotechnic maps of North Dakota, an open-file system which will contain all available information on each area.