NEWSLETTER
NDGS

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CONTENTS

DECEMBER, 1978

EDITOR'S NOTE--

The first article in this Newsletter was written by Dr. Lee Gerhard, State Geologist. It provides an appraisal of current North Dakota mineral industry activity. I've also included an article written by Erling Brostuen, Assistant to the State Geologist, on the formation and occurrence of oil and gas in North Dakota. It was excerpted from a soon-to-be released NDGS publication by Erling dealing with oil and gas in North Dakota, including information on such things as occurrence and mineral rights and some of the things people should be aware of before signing mineral leases, etc. I've written articles on next February's eclipse of the sun and another on the causes of the ice ages.

A clarification is also in order. An article in the June, 1978 Newsletter (titled: North Dakota Among Top Five States in Reserves Additions for 1977), should have credited the reserves figures to the Oil and Gas Journal (April 17, 1978 issue). The reserve figures used by the Oil and Gas Journal are different than those calculated by the North Dakota Geological Survey Engineering Branch. However, it is difficult to determine the quantities of crude oil that will ultimately be produced (reserves) and estimates will vary based on each evaluator's estimates of various factors such as reservoir volume, recovery factors, and future prices. Therefore, meaningful comparisons must use the same criteria so the Oil and Gas Journal's figures were used to compare North Dakota reserves to those of other states. The purpose was not to state precisely the number of barrels of new reserves, but to point out that North Dakota was not far behind such important producing states as Wyoming and Texas in adding additional reserves in 1977.

NORTH DAKOTA MINERAL INDUSTRY ACTIVITY--

It is difficult to assess the size and emphasis of future mineral exploration and development activities in North Dakota, but several trends are developing. Exploration and development activity continues in oil and gas, coal, and uranium; prospective development of a North Dakota potash industry remains dependent upon market conditions and Canadian governmental interactions with the potash industry.

Currently, coal exploration seems to be declining, a reflection of the now-accomplished mapping of coal resources by industry. Recent Environmental Protection Agency decisions regarding air-quality standards in the vicinity of coal-fired generating plants may have an effect on the demand for western coal. EPA standards have also made it necessary for the North Dakota Health Department to rule against construction of energy conversion plants in areas where the air quality of the Theodore Roosevelt National Park might be affected. Rules and regulations proposed by the Office of Surface Mining have also put a damper on former expectations of major coal mining activity in North Dakota. Even though some expansion of the coal industry in North Dakota should still be expected, hopes (or fears) of a major mining province developing here seem to have been overstated.

Uranium exploratory activity also seems to be declining, although several test drilling programs are still active. A significant discovery could, of course, cause an increase in exploratory activity.

Oil and gas activity has increased dramatically over the last four years, and it will probably continue to increase for several years to come. Much of the current drilling is exploratory and the wildcat success ratio has been high, generally over 25 percent. Furthermore, as new fields are blocked out, development drilling will continue to keep total activity high. The new North Dakota rig-count high of 57, which was reached last summer, is an indication of the high level of interest in our part of the Williston basin.

Geological Survey activity in oil and gas is also growing, not only because new wells are being drilled, but because declining production levels in old wells places stress upon proper plugging and abandonment procedures. Less prosperous leases are becoming harder to maintain and require ever-increasing amounts of attention by our field inspectors.

It is always a pleasure to report positive developments. One of these is that oil production in North Dakota has jumped again, marking a four-year continuous increase. This year we estimated total oil production at about 25,000,000 barrels. This compares with 1974 when North Dakota produced only 19,696,847 barrels, the low point of recent production. Gross production tax collections for fiscal 1977-1978 were up to $10,727,666, compared to $4,357,679 in 1974. The 1977-79 biennium estimate is $23,900,000.

Computer modeling of oil and gas exploration and development cash flow in North Dakota by the North Dakota State University Agricultural Economics Department suggests that, in 1978, approximately $800 million (0.8 billion dollars) flowed into North Dakota. The magnitude of the petroleum industry activity in North Dakota demands that one major North Dakota Geological Survey effort will be in petroleum geology and regulation over the next biennium.

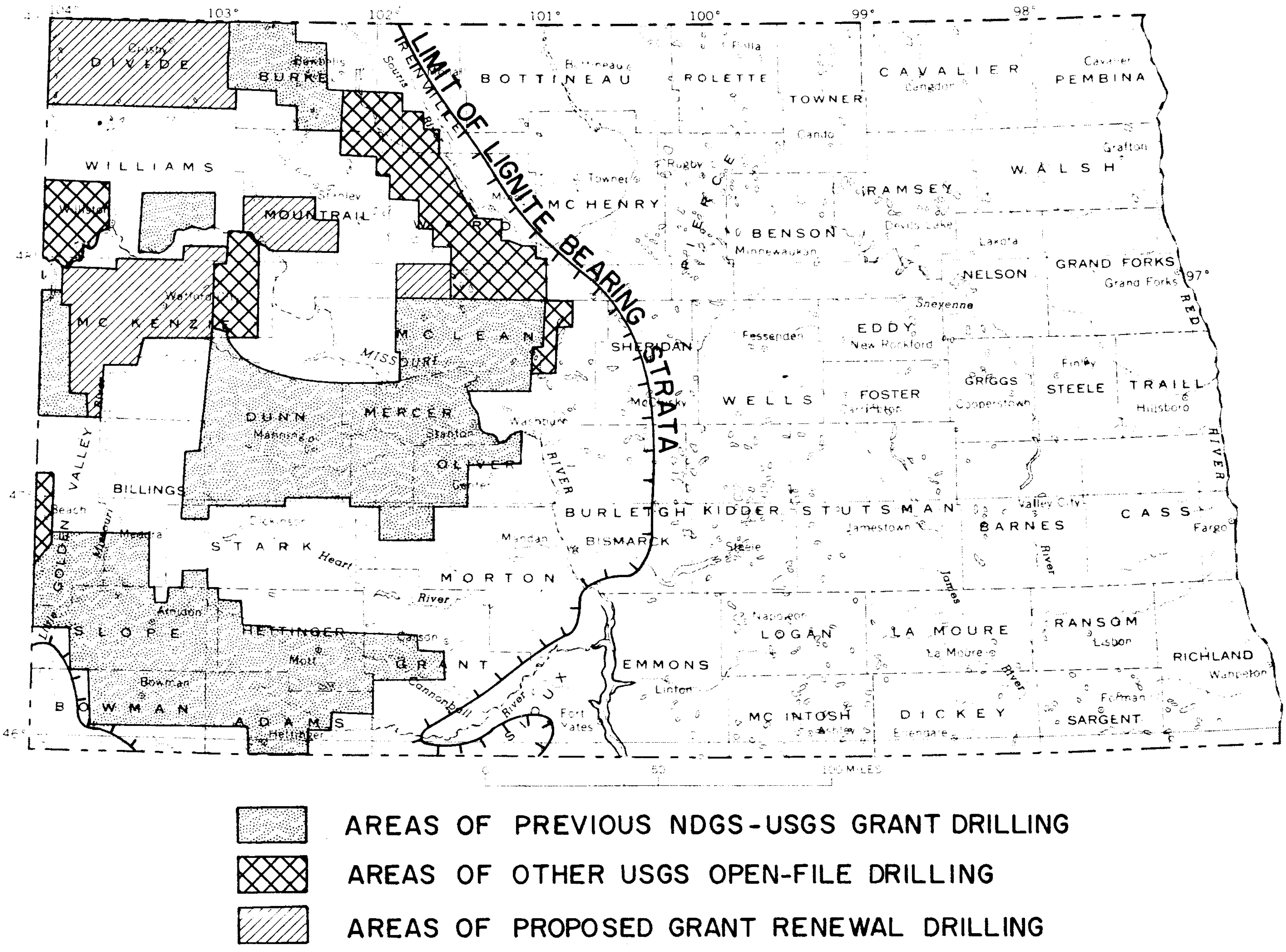
LIGNITE DRILLING PROGRAM--

Kelly Carlson, of the North Dakota Geological Survey, has been in charge of a cooperative drilling program with the Conservation Branch of the U.S. Geological Survey for the past four years. The 1978 drilling program was concentrated in Burke County, where 45 testholes were drilled; these included two coreholes with drilling amounting to 20,863 feet plus 11 feet of core. In McLean County, 42 testholes were drilled, including three coreholes with drilling amounting to 15,841 feet plus 39 feet of core. Other drilling was done in Hettinger, Adams, Bowman, Slope, and Golden Valley Counties to fill in gaps from drilling during previous years. The map that follows this article shows the areas of drilling during the past four seasons and the projected areas of investigation for the 1979 season if our renewal grant is approved. If it is approved, the primary study areas for 1979 will be Divide, Mountrail, Ward, and McKenzie Counties. Seven holes were drilled in McKenzie County this year, and the proposed drilling would be coordinated with the groundwater study now in progress in that area.

Since July 1, 1975, all lignite exploration in North Dakota has required permits from the North Dakota Geological Survey and the filing of logs from such exploration; however, the statute also provides for a confidentiality period of seven years beginning with the expiration of the permit (permits are issued for one-year periods), so this information from industry will probably not be available for public use until after July 1, 1983. The cooperative drilling project is designed to obtain information over as wide an area as possible and make it available to the public and to get maximum stratigraphic information with the available funds. Therefore, we have generally been drilling two or three testholes per township in the areas of study with depths ranging from about 100 to 800 feet depending upon depths of the lignite-bearing strata. Over the past four years, we have drilled about 550 testholes totaling about 180,000 feet of drilling. We have logs from nearly all of these holes and samples from most of the holes. Our intent has been to assess the lignite resources of the state rather than define strippable reserves.

Recent logging practice during the course of oil exploration drilling includes the running of gamma ray logs to the surface through the casing. This practice also provides a significant source of public information on the lignite resources of western North Dakota.

Continuation of the cooperative coal drilling project through the 1979 field season will provide a general coverage of most of the areas of lignite interest in North Dakota.


LIMIT OF LIGNITE BEARING STRATA
DIVIDE
BURKE
RENVILLE
BOTTINEAU
ROLETTE
TOWNER
CAVALIER
PEMBINA
WILLIAMS
MOUNTRAIL
WARD
MC HENRY
PIERCE
BENSON
RAMSEY
WALSH
NELSON
GRAND FORKS
MC KENZIE
MC LEAN
SHERIDAN
EDDY
WELLS
FOSTER
GRIGGS
STEELE
TRAILL
DUNN
MERCER
OLIVER
BILLINGS
GOLDEN VALLEY
STARK
MORTON
BURLEIGH
KIDDER
STUTSMAN
BARNES
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HETTINGER
GRANT
SIOUX
EMMONS
LOGAN
LA MOURE
RANSOM
RICHLAND
BOWMAN
ADAMS
MC INTOSH
DICKEY
SARGENT
MISSOURI
RIVER
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James
Heart
Cannonball
RED RIVER
104°
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50
100 MILES
AREAS OF PREVIOUS NDGS-USGS GRANT DRILLING
AREAS OF OTHER USGS OPEN-FILE DRILLING
AREAS OF PROPOSED GRANT RENEWAL DRILLING

QUATERNARY STUDIES--

During the past field season, Alan Kehew continued his geologic field mapping in Ward and Renville Counties, and Ken Harris mapped in Bottineau County. John Bluemle finished reports on the geology of Dickey and LaMoure Counties and on Ransom and Sargent Counties; both of these reports should be published within the next six months.

Dan Walker, UND geology student, completed the fieldwork for his senior thesis this autumn. Dan's thesis problem is an attempt to correlate the Pleistocene sediments from Lake Sakakawea, near Riverdale, to the Underwood area. His correlations will be based on seven power-auger holes, up to 80 feet deep, that were drilled and cored this summer. Dan's stratigraphy, a 6½-mile-long cross section, will link previous Master's thesis work in the Riverdale bluffs area with stratigraphic work currently being conducted in the Falkirk area by Gerald Groenewold of the NDGS.

In addition to Dan Walker's thesis-related drilling program, Dan Daly and Bernd Rehm cooperated with Dan Walker in drilling and coring 37 additional testholes in the Falkirk Mine study area. Information gained during the drilling this past summer, along with data from existing testholes, will be used to characterize the Pleistocene stratigraphy in the Underwood area.

Drilling began last spring on what is hoped will eventually be a north-south correlation cross section in the eastern part of North Dakota. The cross section will extend from Sargent County northward to Cavalier County, and tie together three separate areas where Pleistocene stratigraphic sections have already been developed. The drilling for this project was also a "shake-down cruise" for Dan Walker, Alan Kehew, and Ken Harris on the Mobile Drill unit and also an introduction to some new coring equipment that had been acquired for the unit.

The sediment samples collected in these, and other drilling programs, are currently being analyzed in the NDGS sediment lab by Dave Lechner. The information gained in these analyses will be summarized and entered in a master file of near-surface stratigraphic information. The "N-File" allows near-surface information that was used in the solution of a geologic problem to remain in a reference system so it will be available as needed for future projects.

Lee Clayton of the UND Geology Department has submitted the North Dakota portion of the Dakotas Quadrangle (1:1,000,000) to the USGS for comments. This is the first and largest of the four sections of North Dakota that will be submitted as parts of the USGS compilation of a new Quaternary Map of the United States.

REVISED NORTH DAKOTA STRATIGRAPHIC COLUMN--

The increased exploration activity has brought many new operators into the North Dakota portion of the Williston basin. Some of them have requested a stratigraphic column so that they may be familiar with terminology used in North Dakota. We also receive many other requests for a stratigraphic column.

It has been about 20 years since the Survey published a complete column. During the interim, many studies have been conducted. Some have proposed changes of portions of the column, and some of the changes have been accepted. So it seems that this is an appropriate time to publish a revised stratigraphic column that will accurately present our current understanding of Williston basin stratigraphy.

We tentatively plan to supplement the new stratigraphic column with examples of type logs, correlation charts, and portrayals of lignite coal stratigraphy and glacial stratigraphy. Lithologic descriptions of rock units will be considerably more detailed than the descriptions on earlier columns.

By publishing a new stratigraphic column at this time, we hope to provide a sort of standard basis for comparison throughout the North Dakota part of the Williston basin. We do not expect that everyone will choose to use our terminology. The column should, however, be valuable as a teaching aid and as a means of introducing the geology of the basin to newcomers.

We hope to be able to publish the column sometime in 1979.

NEW PUBLICATIONS--

Since the June, 1978 Newsletter was published, we have released one open-file report entitled "Lignite Drilling During 1977 in Western North Dakota: Adams, Billings, Bowman, Dunn, Golden Valley, Grant, Hettinger, Mercer, Oliver, Slope, Stark, and Williams Counties." It is a publication of the U.S. Geological Survey and is listed as Open-File Report 78-888. The report contains maps showing locations, logs (gamma ray, density, self-potential, and resistivity) and sample descriptions for 241 testholes. Analyses of 15 lignite cores are also included. The report is 541 pages long and is supplied in an unbound format. Copies are available from us at a cost of $30.00.

Bulletin 65, Part III was published since the last Newsletter was published. It is entitled "Ground-Water Resources of Adams and Bowman Counties, North Dakota," and it describes the general availability of groundwater and provides information on quantity and quality with an emphasis on the five major aquifers found in the two counties. Aquifer discussions include descriptions of the lithology and areal extent. The report also includes information on present groundwater use. The bulletin is supplied free of charge.

The Official Oil Production Statistics and Engineering Data for the First Half of 1977 were published in July of 1978. This report contains the oil and water production by individual wells as well as other pertinent information. The Official Oil Production Statistics and Engineering Data for the Second Half of 1977 and the First Half of 1978 have just been published. So, as you can see, we are getting caught up and more up-to-date on the production statistics reports. These reports are available from the Survey at $3.50 for 1977 and $4.00 for the First Half of 1978.

We published a report entitled "Late Paleocene Mammals of the Tongue River Formation, western North Dakota." This report was written by Richard C. Holtzman of the Minnesota Geological Survey.

Finally, we published a post card showing the geology of North Dakota. The post card is in color with a short explanation of the geologic units shown and a short statement concerning the State's mineral resources on the back. Counties are also shown on the post card as are the major cities and the major streams.

We are enclosing a post card with this issue of the Newsletter. Additional post cards are available from the North Dakota Geological Survey, Grand Forks, ND 58202. The post card is free in limited quantities.

GEOLOGY AND GEOHYDROLOGY OF THE KNIFE RIVER BASIN AND ADJACENT AREA OF WEST-CENTRAL NORTH DAKOTA--(THE REAP REPORT)--Groenewold, et al--

This report by Gerald Groenewold of the NDGS, and several assistants, deals with the surface and subsurface geology, regional groundwater-flow systems, chemistry, and chemical evolution of groundwater in the units overlying the Pierre Formation in west-central North Dakota. The study, which should be available from the NDGS in the near future, concentrated on the area within the Knife River basin, although additional study sites outside of the Knife River basin at Center and Falkirk were included. The report also includes a discussion of the groundwater-flow patterns, chemistry, and chemical evolution of water in the Fox Hills aquifer throughout southwestern North Dakota. Detailed mapping of surface and near-surface materials in the Beulah-Hazen area allowed for the generation of a series of land-use suitability maps for that area.

The study determined the regional stratigraphic framework of the units overlying the Pierre Formation with emphasis on detailed correlation of the Tertiary lignite-bearing strata. A series of detailed cross sections based on several hundred testholes has been constructed which demonstrates the correlation of the various lignite beds in the Sentinel Butte and Bullion Creek Formations across the study area. Each major lignite bed has been named, with type and reference testholes. The relationship between the present lignite-bed terminology and the terminology of previous workers has been discussed in detail. This study has demonstrated that individual lignite beds are traceable for many tens of miles and serve as convenient stratigraphic markers for subdividing the Sentinel Butte and Bullion Creek Formations.

The detailed stratigraphic framework, thus defined, has allowed for a specific designation of the intake zone for most of the farm and domestic wells in the study area. This information, in conjunction with previously published groundwater chemical data and additional selective sampling of wells as part of this study, has allowed for a detailed definition of the chemical characteristics of water within the various stratigraphic units. This, in turn, has allowed for the formulation of groundwater geochemical models for the various groundwater systems. The key processes which influence the evolution of groundwater in the Knife River basin are: pyrite oxidation, carbonate dissolution, gypsum precipitation and dissolution, cation exchange, and sulfate reduction. The hydrostratigraphy and hydrochemistry of five proposed and active lignite-mining sites have been discussed in detail. These include the Indian Head, Beulah-Hazen, and Dunn Center sites within the Knife River basin and the Center and Falkirk sites, which lie in close proximity to the Knife River basin.

The implications of the interpretive groundwater geochemical framework relative to the post-mining groundwater quality have been addressed in the report. Of major concern is the generation, in the post-mining landscapes, of waters characterized by adverse sulfate content generated by pyrite oxidation. Major differences between premining and post-mining landscapes include the large volumes of oxygen trapped within voids in the spoils and the lack of organic matter in the spoils relative to the premining landscape. The consumption of most of the entrapped oxygen by pyrite oxidation rather than organic-matter oxidation is therefore an anticipated eventuality and potentially could result in the generation of very high levels of sulfate in the post-mining groundwater. The sulfate concentration in a groundwater sample from spoils at one of the mine sites exceeded 9,400 mg/L. Sulfate concentrations in spoil waters commonly exceeded 2,500 mg/L. A detailed knowledge of the overburden in conjunction with proper placement of overburden during mining and contouring operations is necessary to assure acceptable post-mining groundwater quality.

CEMENT ROCK IN NORTH DAKOTA--

With all due respect to the title of this item, it is an unfortunate fact that, up to now at least, we haven't been able to find any economic deposits of cement rock. For this reason, cement has been expensive in North Dakota, and recently it has been in short supply. Cement I purchased last summer in Grand Forks, for example, came from Winnipeg; cement for our lignite drilling project came from Regina; and much of the cement used in western North Dakota is produced in Rapid City.

Last summer, several state legislators called for a new investigation into the problem, which has always been with us. Over the years, the North Dakota Geological Survey has conducted at least ten investigations, looking for a source of cement rock in the state. C.B. Folsom compiled a list of references to published studies conducted for cement in North Dakota. I have included the list at the end of this article. In addition to the listing of published study results, some private studies have also been conducted. For example, the Lehigh Portland Cement Company did some exploration for cement raw material in eastern North Dakota in the early 1960's.

A cement plant that was constructed by the Pembina Portland Cement Company in 1899 began operations near Concrete in northeastern North Dakota in the early 1900's. Their product was marketed as northern hydraulic cement, bricklayer's cement, and cement plaster. The plant was in operation only until 1909 and, since then, no other commercial cement developments have taken place in the state.

The raw material used by the Pembina Portland Cement Company plant was a calcareous (limy) shale zone mined from the Cretaceous Niobrara Formation, which is exposed in the Tongue River valley near the town of Concrete about 12 miles south of Walhalla. The low quality of the natural cement produced (not "portland-grade" cement, in spite of the company's name) coupled with poor market factors, kept the product from being a success.

The calcareous shale zone in the Niobrara Formation has since been investigated (1964) as a potential raw material for portland cement. Attempts at beneficiating (improving the quality by concentration techniques) this material, using simple sizing, differential settling, and conventional flotation methods have been unsuccessful and hopes for developing a successful beneficiation process seem to be slight since the material is so uniformly fine grained. The calcareous shale is probably suitable only as a raw material for a natural hydraulic or masonry cement and the market for such a product is limited. Nearly all construction contracts call for portland cement; in fact, 95 percent of all the cement used in the United States is portland hydraulic cement (hydraulic cements have the property of setting or hardening under water). Since portland cement is formed from properly proportioned mixtures of lime, alumina, silica, and iron oxides, it may be possible to use the calcareous shale as the source of alumina, silica, and iron oxide as a blend with a pure limestone as a raw material for portland cement. If such a blending process should become economically feasible, a near-surface deposit of about 55 million tons of suitable calcareous shale exists in the Shawnee-McCanna area of western Grand Forks County.

High-quality limestone could be shipped into the area and blended with the Niobrara shale, but it is questionable whether this would be economically practical as the costs of transporting the limestone would be high. An investigation was conducted (1967) to look for high-grade limestone in North Dakota as an alternative to importing limestone. It was thought that the best prospects of economic deposits are in Ordovician carbonates in Pembina and Grand Forks Counties where these rocks are present below the glacial deposits at depths of about 200 to 250 feet. Coreholes in these areas found the carbonate at expected depths, but analyses of the cores showed that the carbonates are generally dolomitic, that is, calcium, magnesium carbonates. Magnesium is a detrimental element in cement and the tolerance is only about 4 percent, although even less is preferred. The most promising testhole data in the 1967 program was from an area near Manvel where an interval at a depth of less than 250 feet averaged about 7.5 percent magnesium carbonate. Other testholes generally had higher magnesium contents. Since the Niobrara shale also contains some magnesium carbonate and blending would require approximately equal amounts of Niobrara and pure limestone to reach the proper lime percentage, it appears that something better than has yet been found will be required before we will see a portland cement plant in North Dakota.

The 1967 study did not rule out the possibility of finding a better zone at some other location, but the generally high magnesium content of the cored intervals is discouraging.

INVESTIGATIONS OF CEMENT ROCK IN NORTH DAKOTA--

1. Babcock, Earle J., Private investigation led to establishment of a plant at Pembina in 1899.

2. Berkey, Charles P., 1905, Economic Geology of the Pembina region of North Dakota: Am. Geol., v. 35, p. 142-152, illus. incl. geol. map (scale 1:187,500).

3. Eckel, Edwin C., 1905, Cement materials and industry of the United States: U.S. Geol. Survey Bull. 522, 401 p., illus.

4. Barry, Clyde M., and Melsted, V.J., 1908, The geology of northeastern North Dakota with special reference to cement materials: N. Dak. Geol. Survey 5th Bienn. Rept., p. 115-211, illus. incl. geol. map (scale 1:375,000).

5. Budge, W.E., 1937, School of Mines survey 1937: N. Dak. Engineer, v. 14, no. 1, p. 3-4, illus.

6. Burr, Alexander C., Fallgatter, W.S., and MacMillian, W.W., 1950, Raw materials for the manufacture of Portland Cement in North Dakota: N. Dak. Acad. Sci. Proc., v. 3, p. 15-18.

7. Hansen, Miller, 1952, Report on limestone deposits in Stark County and Hettinger County, North Dakota: N. Dak. Geol. Survey Report of Investigation 8, 71 p. At the request of the North Dakota Economic Development Commission, the Survey studied occurrences Oligocene limestone in southwestern North Dakota with special reference to usability of the limestone in cement manufacture.

8. Kohanowski, Nicholas H., 1959, Study of Limestones in North Dakota. Study funded by Lehigh Cement Co. as a private investigation.

9. Carlson, Clarence G., 1964, The Niobrara Formation of eastern North Dakota; its possibilities for use as a cement rock: N. Dak. Geol. Survey Report of Investigation 41, 56 p.

10. Anderson, Sidney B., Haraldson, Harald C., 1968, Investigation of limestones in northeastern North Dakota as a possible source of cement. Study funded by U.S. Department of Commerce, North Dakota Economic Development Commission, and North Dakota Resources Development Corporation: N. Dak. Geol. Survey Report of Investigation 48, 62 p.

ENVIRONMENTAL STUDIES--

Our study of waste disposal sites across the state is providing information on the danger of groundwater contamination from sanitary landfills. This study is being conducted in cooperation with the State Health Department. During the past field season, monitoring wells were installed at the Cavalier and Carrington landfills. The monitoring wells are scheduled to be sampled at regular intervals, and the water samples will be analyzed at the Health Department labs in Bismarck.

A new cooperative project that was initiated last fall involves evaluation of the groundwater pollution potential of surface impoundments throughout the state. The facilities to be evaluated include municipal sewage lagoons as well as waste impoundments used in agriculture and industry. The assessment is funded by a grant from the U.S. Environmental Protection Agency to the State Health Department. The North Dakota evaluation is part of an effort being made in each of the 50 states.

An environmental geologic study of the Minot area is also in progress. Last summer, mapping of the surficial geology was undertaken by Alan Kehew of the NDGS and Garth Anderson, a UND geology graduate student. Drilling also began last summer and it is expected to continue during the next field season. The purpose of the study is to provide information to help planners and developers evaluate the geologic conditions that affect the suitability of land for various types of development projects. The information will be useful in evaluating all types of construction projects, selecting waste disposal sites, and locating deposits of sand and gravel.

A REALLY BIG SOURIS RIVER FLOOD?--

An interesting preliminary result of Alan Kehew's Minot study has been his formulation of an hypothesis that a large flood of water inundated the Minot area sometime between 12,000 and 14,000 years ago, shortly after the glaciers retreated northward into Canada from north-central North Dakota. In contrast to modern floods, which may cover only the floor of the Souris River valley, this ancient flood filled the entire valley of the Souris River.

The path of the flood water can be traced to Minot from glacial Lake Regina, a large late Wisconsinan age lake located in central Saskatchewan. Glacial lakes such as Lake Regina formed in front of the glaciers because the existing east and northeastward drainage paths were blocked by glacial ice. At some time in late Wisconsinan time, Lake Regina drained rapidly into the Souris River valley near the town of Weyburn, Saskatchewan. South of Estevan, Saskatchewan, the flood water split into two branches.

Some of the water stayed in the Souris River valley while the remainder spilled over a divide into the Des Lacs River valley. Later, the two streams rejoined at the point where the Des Lacs River meets the Souris River near Burlington, North Dakota. So much water flowed through the two valleys that the flood broke out of the Souris River valley just east of Minot and eroded a maze of shallow channels in the Surrey area.

The exact route and effects of the flood downstream from Minot have not yet been thoroughly worked out, but it is likely that the flood water may have accumulated temporarily in the glacial Lake Souris basin, a low, flat area in McHenry, Bottineau, Rolette, and Pierce Counties. From glacial Lake Souris, much of the flood water eventually drained through the Sheyenne River valley into glacial Lake Agassiz in southeastern North Dakota.

Minot, of course, has been subjected to repeated flooding by the Souris River in recent years. None of the modern floods are in the same league as the one described above, as Alan envisions it. The worst flood on record, for example, was the 1904 flood, which had a discharge of 12,000 CFS (cubic feet per second). The second worst flood, in 1976, had a discharge of 9,350 CFS at Minot. The Pleistocene flood, on the other hand, may have had a discharge of several million CFS, perhaps four or five hundred times the magnitude of the worst historic floods.

THE ORIGIN OF OIL AND GAS--

Oil and gas are organic substances consisting of molecules composed of hydrogen and carbon atoms. These molecules are derived from the remains of living organisms such as plants and animals that thrived during prehistoric times. Materials composed of such hydrogen and carbon compounds are known as <u>hydrocarbons</u>. Because they are found in rock, they are known also as <u>petroleum</u>, a word derived from the Latin words for rock, <u>petra</u>, and for oil, <u>oleum</u>.

It is commonly believed that oil and gas result from the decomposition of organic matter consisting of primitive forms of plant and animal life. The organic matter contains natural oils and fats which, following putrification, bacterial action, and subjection to intense heat and pressure with the passage of time, are converted to gaseous and liquid hydrocarbons.

Oil and gas are usually found in sedimentary rocks. Sedimentary rock is formed from materials (sediments) resulting from the decomposition and weathering of pre-existing rocks which have been transported and deposited in seas or on land. It is generally believed that oil and gas originate within sedimentary rocks deposited in the sea. Such sedimentary rocks are known as source rocks because oil and gas have their source in them. Sedimentary rocks include a variety of rock types including shale, sandstone, carbonates, and evaporites. Typical carbonate rocks are limestone and dolomite. Evaporites include salt, potash, and anhydrite. Sedimentary rocks may contain void spaces--pores--and, if they do, they are said to have porosity. Connecting channels between the pore spaces allow fluid (oil and gas) that is present to pass from one pore space to another. When these connecting channels are present, the rock is said to have permeability.

Sandstone and carbonates have both porosity and permeability. If these properties have not been altered since the rocks were deposited, they are referred to as "primary." Commonly, carbonates are altered as a result of groundwater seeping through them and dissolving away some of the material, or due to chemical alteration of limestone to dolomite, improving their porosity. Porosity formed in this way is referred to as "secondary porosity," meaning it developed sometime after the rock was deposited.

Evaporites are composed of minerals that precipitated as the sea water evaporated and was therefore no longer able to hold dissolved minerals in solution. Evaporites generally lack porosity and permeability.

Shale is composed of fine-grained material of clay size. It generally has high porosity, but because of the small grain size, it has extremely low permeability.

Porosity and permeability are two qualities required to form a reservoir rock, which is any rock that can contain oil and gas. Oil, gas, and water may move through porous and permeable rock until the movement is halted by a trap or some kind of a trapping mechanism. Traps may result from the buckling, folding, and fracturing of the earth, or they may be due to variations in rock characteristics or lithology resulting from cyclic periods of deposition and erosion, limited development of secondary porosity, or the filling of pore spaces with non-porous material. Regardless of how they form, all traps consist of porous and permeable rock layers (carbonates and sandstones) covered by layers of nonpermeable rock (shales and evaporites).

Most North Dakota oil and gas traps fall into one of two categories. They may be either "structural" traps or "stratigraphic" traps, or they may be a combination of both. Structural traps include "anticlinal" traps or "anticlines" or they may be "fault" traps. Anticlinal traps formed when alternating layers of porous and permeable and non-permeable rock were folded or arched into the form of an inverted trough or bowl. Oil and gas can accumulate at the crest of such a structure and be prevented from escaping by the overlying nonpermeable rock layers. A fault trap forms when layers of rock fracture and the rock on one side of such a fracture moves up or down relative to the rock on the other side of the fracture. This can result in the up-tilting of a porous rock layer, which may be pushed into contact with (thrust against) a non-permeable rock layer.

Stratigraphic traps can occur in many ways. Oil and gas that accumulates in porous rock layers is prevented from escaping due to changes in porosity and permeability, either in the rock layer itself, or by confinement against a non-permeable rock layer. Typical stratigraphic traps may consist of ancient sand bars, beaches, or stream sediments enclosed within non-permeable shales or they may be up-tilted, porous rock layers, which at some point in geologic time were partially eroded and subsequently buried beneath non-permeable rock layers. Other stratigraphic traps may result from the partial filling or plugging of pore spaces within otherwise porous rock layers by non-porous materials such as salt and anhydrite. Still other stratigraphic traps may be due to the limited development of secondary porosity.

TOTAL ECLIPSE OF THE SUN WILL INCLUDE NORTHERN NORTH DAKOTA--

During the next couple of months, most of you will be hearing a great deal about the February 26, 1979 total eclipse of the sun that will be visible over a path that extends for a distance of more than 1,200 miles over the North American continent. Probably the best places to view the eclipse will be in North Dakota and Manitoba. This will be the last total solar eclipse visible from this area for 38 years and probably the only one many of us will ever have an opportunity to see. I'll include a summary of what to expect as well as some elementary astronomy for background.

As all our readers know, a solar eclipse is caused when the moon passes between the sun and the earth so that its shadow falls on the earth's surface. The width of the shadow where the eclipse is total is never more than 195 miles, although a partial eclipse will be visible over virtually all of North America.

The February 26 (Monday) eclipse will begin at sunrise in the North Pacific (47° North Latitude; 139° West Longitude) west of Washington state. As the moon's shadow sweeps rapidly eastward across the earth's surface at about 1,800 miles per hour, it touches land first over Oregon. The center line of the eclipse, which coincides with the period of longest totality (totality ranges up to almost three minutes), then passes over Walla Walla, Washington; Lewistown, Montana; Crosby, North Dakota; Brandon, Manitoba; Winnipeg, Manitoba; and on over Hudson Bay; the northernmost tip of Quebec; Baffin Island; and it ends at sunset in northern Greenland.

The area that will experience a total eclipse includes all of the northwestern corner of North Dakota (see the accompanying map). The central line of the eclipse, which passes through Divide County, will experience the longest duration of totality (when the sun is completely hidden) in North Dakota, about two and three-quarter minutes. The eclipse will become total at about 10:37 a.m. Central Standard Time at Williston; 10:40 a.m. at Minot; 10:43 at Brandon; 10:44 at Rock Lake; and 10:47 at Winnipeg (times were obtained from Circular 157 of the U.S. Naval Observatory).

The February 26 eclipse is one of a series of similar total solar eclipses, the last three of which occurred on January 24, 1925; February 4, 1943; and February 15, 1961. This pattern results from the fact that 223 new moons (lunations), amounting to 18 years, 11 1/3 days (or 10 1/3 days, depending on the number of intervening leap years), occur between eclipses in the series. After the lapse of this interval of time, called the <u>saros</u> (the term "saros" refers to the Babylonian lunar cycle of 6585.32 days, at the end of which the centers of the sun and moon return very nearly to the same relative positions they were at the beginning of the cycle).

A <u>saros cycle</u> (or eclipse series) is a series of eclipses that occur at intervals of 6585.32 days. A saros cycle consists of about 70 solar eclipses (eclipses of the sun) during a period of about 1,200 years. (A lunar saros cycle consists of about 50 eclipses of the moon during a period of about 870 years). Next February's event is the 58th in this saros cycle, which began on May 27 in the year 933 with a small partial eclipse visible from Antarctica. Starting with the August 11, 1059 eclipse, the eclipses in the current cycle were annular (during an annular solar eclipse, the apparent disk of the moon is slightly smaller than the sun's disk so that a thin outer ring of the sun's light continues to shine), and since June 8, 1564, the eclipses in this saros cycle have all been total. The last total eclipse of this cycle will be on March 30, 2033, followed by a succession of partial ones. Eventually, the 71st and last eclipse of this saros cycle will be an insignificant partial eclipse on July 7, 2195, seen only from Arctic regions.

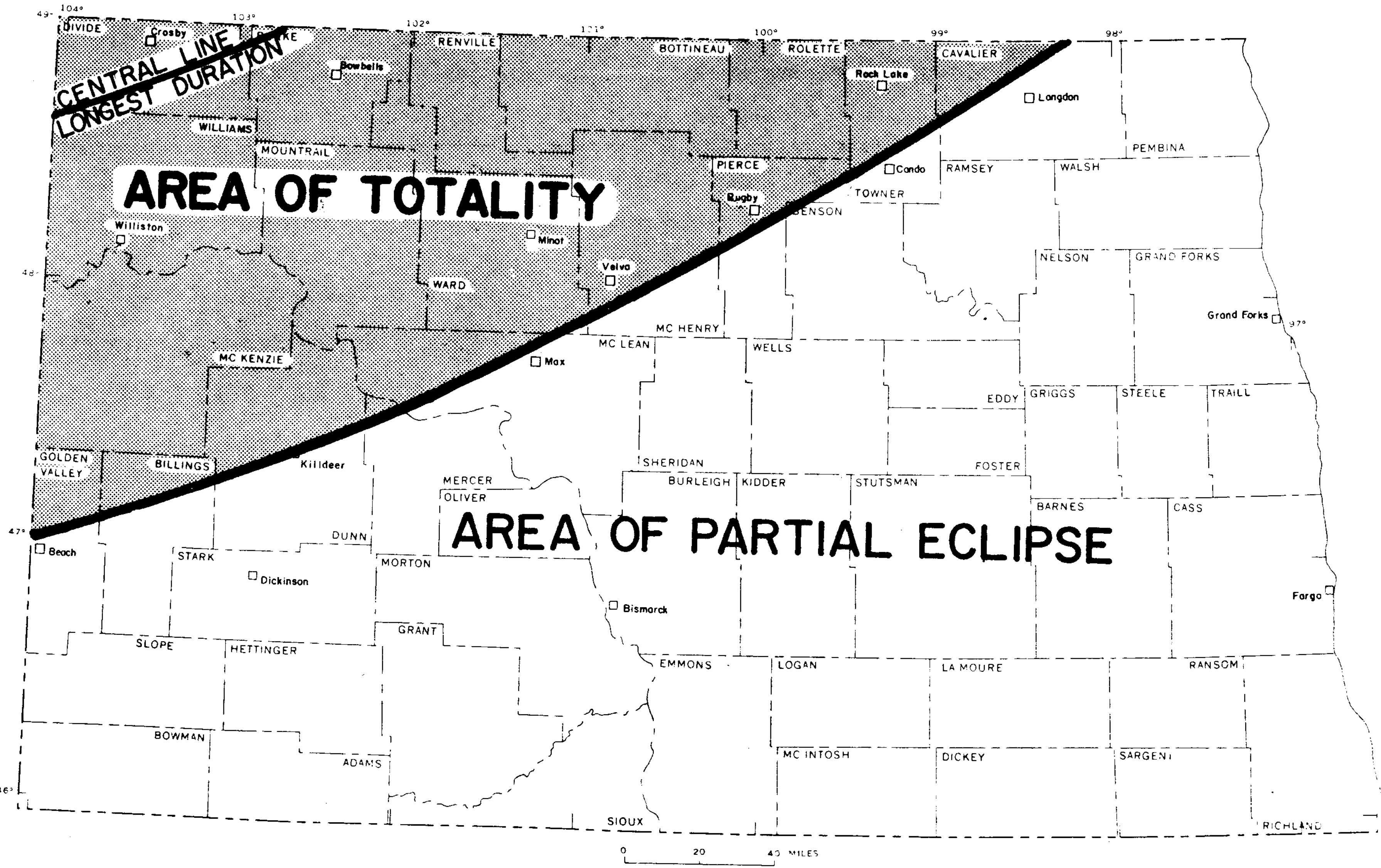
All eclipses of the saros cycle recur almost exactly as before, although approximately 120° west of the regions where they were visible in the previous saros. The 120° westward shift is due to the third-of-a-day excess in the saros. Thus, the 1925 eclipse was total in eastern North America and the Atlantic; the 1943 one in Alaska, and 1961 one in Europe. Successive eclipses in the series are also progressively farther north.

Incidentally, all solar eclipses are not necessarily part of this particular saros cycle. Total solar eclipses that occurred in 1937, 1955, and 1973 were part of another saros cycle (the 1991 eclipse in this series will not be visible in North America). Total solar eclipses also occurred in 1972 and 1976; in fact, at least two solar eclipses of some kind occur every year somewhere on the Earth's surface.

The brief and spectacular total eclipse should be watched only with proper eye protection. No eye protection is needed when the bright, dangerous surface of the sun is completely covered by the moon. However, during the partial phases, before and after the 2 to 3 minutes of totality, SAFE EYE PROTECTION must be used for even the briefest glance at the sun. Number 14 Welder's glass or special eclipse visors should be used. If binoculars or a telescope are used, they should be equipped with similar protection. Even a glimpse at the focused rays of the unshielded sun through a telescope can destroy the retina of the eye.

Some additional notes about the chances for good viewing conditions on eclipse day. The percentage of the sky that we might expect to be covered by clouds on February 26 is (statistically) about 70 percent at Minot at mid-eclipse. However, Canadian data indicate that (again, statistically) less than 50 percent of the sky just across the border in Manitoba and Saskatchewan might be expected to be covered by opaque cloudiness. The difference is a matter of definition and probably the Canadian approach is more realistic because high, thin cloudiness, although it wouldn't be an ideal situation, would still allow a good look at the eclipse. By contrast, Seattle, Washington can expect an 85 percent cloud cover at mid-eclipse.

In North Dakota, large daily deviations from the normal are the rule rather than the exception. And even if eclipse day dawns with exactly "normal" cloudiness, it may not be normal at the time of totality because of the one-hour interval of increasing partial eclipse that precedes totality. During that time, the reduced solar heating should tend to cause a decrease in cumulus cloudiness, but an increase in stratiform cloudiness. (This is theory; actually we probably won't have any cumulus clouds in North Dakota in February as such clouds are common only in summer. The reduced solar heating described above could, however, tend to cause an increase in stratiform cloudiness).


AREA OF TOTALITY
AREA OF PARTIAL ECLIPSE
CENTRAL LINE
LONGEST DURATION
104°
103°
102°
101°
100°
99°
98°
97°
49°
48°
47°
46°
DIVIDE
Crosby
WILLIAMS
MOUNTRAIL
Bowbells
RENVILLE
BOTTINEAU
ROLETTE
Rock Lake
CAVALIER
Langdon
PEMBINA
WALSH
RAMSEY
Cando
TOWNER
PIERCE
Rugby
BENSON
Williston
Minot
Velva
WARD
MC HENRY
MC LEAN
MC KENZIE
Max
WELLS
EDDY
NELSON
GRAND FORKS
Grand Forks
GRIGGS
STEELE
TRAILL
GOLDEN VALLEY
BILLINGS
Killdeer
SHERIDAN
FOSTER
MERCER
OLIVER
BURLEIGH
KIDDER
STUTSMAN
BARNES
CASS
Beach
DUNN
STARK
Dickinson
MORTON
Bismarck
Fargo
GRANT
SLOPE
HETTINGER
EMMONS
LOGAN
LA MOURE
RANSOM
BOWMAN
ADAMS
MC INTOSH
DICKEY
SARGENT
SIOUX
RICHLAND
0
20
40 MILES

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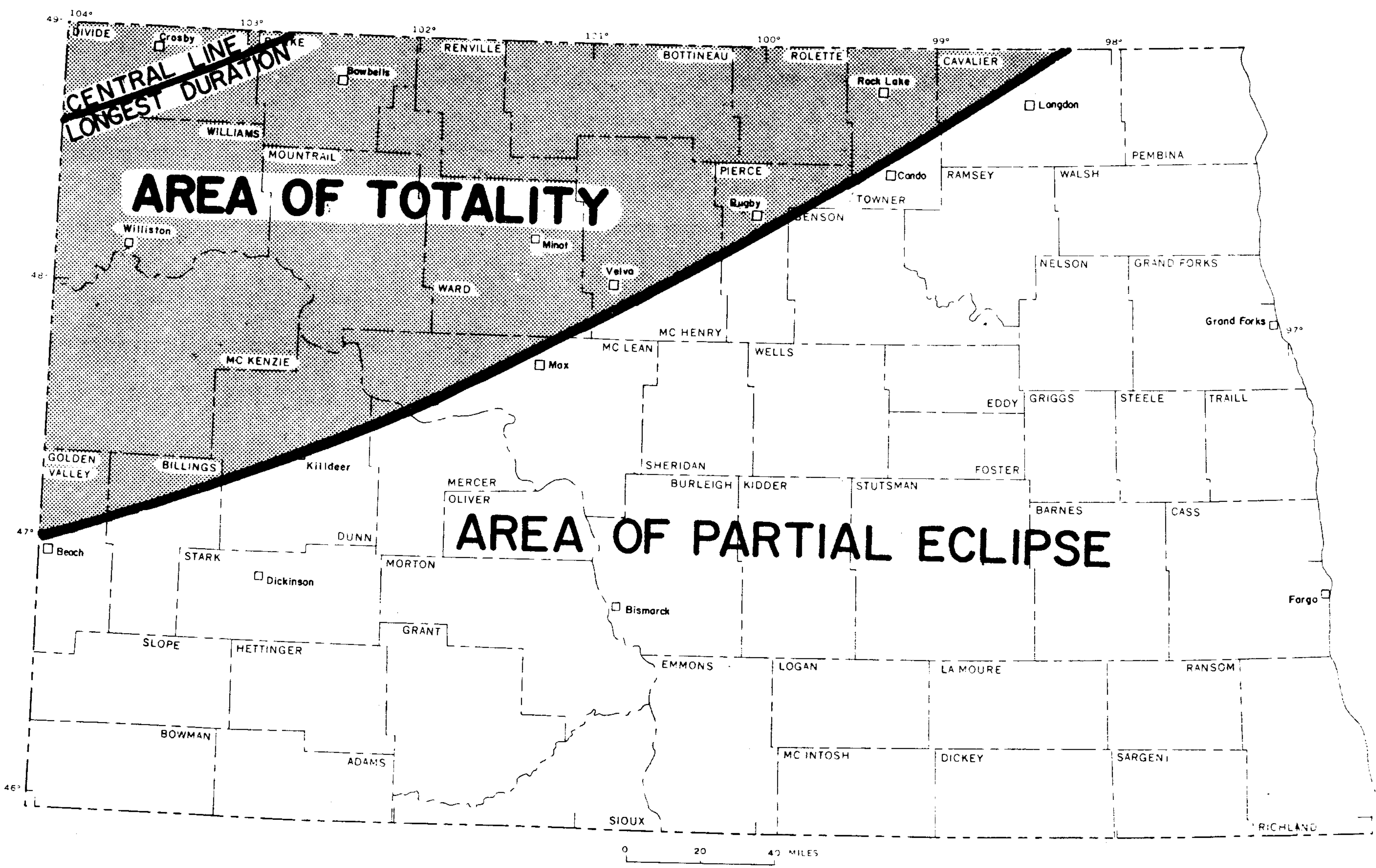

CENTRAL LINE
LONGEST DURATION
AREA OF TOTALITY
AREA OF PARTIAL ECLIPSE
DIVIDE
Crosby
WILLIAMS
MOUNTRAIL
Bowbells
RENVILLE
BOTTINEAU
ROLETTE
CAVALIER
Rock Lake
Langdon
PEMBINA
RAMSEY
WALSH
Cando
TOWNER
PIERCE
Rugby
BENSON
Williston
Minot
Velva
WARD
MC HENRY
MC LEAN
WELLS
Max
MC KENZIE
NELSON
GRAND FORKS
Grand Forks
EDDY
GRIGGS
STEELE
TRAILL
GOLDEN VALLEY
BILLINGS
Killdeer
SHERIDAN
FOSTER
MERCER
OLIVER
BURLEIGH
KIDDER
STUTSMAN
BARNES
CASS
Beach
STARK
DUNN
Dickinson
MORTON
Bismarck
Fargo
GRANT
SLOPE
HETTINGER
EMMONS
LOGAN
LA MOURE
RANSOM
BOWMAN
ADAMS
MC INTOSH
DICKEY
SARGENT
SIOUX
RICHLAND
49°
48°
47°
46°
104°
103°
102°
101°
100°
99°
98°
97°
0
20
40 MILES

For all of these reasons, if you plan to observe the total eclipse, it might be a good idea to equip yourself with immediate, last-minute mobility (jargon for "car") so you can drive a mile or so from under a cloud if it threatens to hide the precious two minutes of totality.

Realistically, I think we can probably expect either perfectly clear viewing weather with temperatures around zero degrees Fahrenheit or a little lower or we may be having a blizzard with temperatures around zero degrees Fahrenheit or a little lower. Then again, we may have a dust storm and 30 below. We'll just have to wait and see.

WHY DO WE HAVE ICE AGES?--

As a geologist, I guess two of the more common questions asked of me by people I talk to when they learn that I'm mapping the geology in their neighborhood or on their farm and by students on the field trips I lead, are: "Why do we have ice ages?" and "When will the next ice age start?" Usually, I try to give some sort of answer that gives the impression I might know something about it, but I'm certain I leave most of these people frustrated when they think back on what I (didn't) tell them. (Sometimes I just say "I don't know," but I'm not usually that candid). I've usually muttered something about "plate tectonics" and the "Antarctic continent being situated over a polar region and the effect this has on global climates" and how "climates don't really have to change a lot to cause the next glaciation" and maybe a few more ideas to be certain the issue is really confused so I can safely retreat.

Now, no one has really satisfactorily supplied all, or for all we know, even most of the correct answers to the question of why continental glaciations occur. I certainly don't intend to go into any great detail here about the causes of glaciation (mainly because I can't), but I think a sort of "layman's summary" might be useful.

To begin, I think most experts agree that the major continental glaciations were caused by the interaction of several factors. No single event, such as a cooling of the earth's climate, was solely responsible for the glaciations. We do know that glaciations have taken place (and are taking place) at times when the continents have been situated at high latitudes on the earth's surface. Only when they are located at high latitudes can large amounts of snow and ice accumulate on the continents. Furthermore, when the major land masses come to coincide with the polar climatic belts, the major seaways become blocked so that the earth's liquid heat-control mechanisms break down.

So, now I've written myself into a corner. No, to answer your next question, as a matter of fact, the continents have not always been in their present locations. In fact, they are moving over the surface of the earth in directions and at rates that have been calculated with considerable accuracy. For example, if you will look at a globe or map of the world, you'll see that the east coast of South America and the west coast of Africa look like the edges of two interlocking pieces of a jigsaw puzzle; these two continents have "drifted apart." Other continents have moved in different directions. The Indian subcontinent is moving northward into Asia and the two colliding land masses are causing a crumpling of the earth's crust that is forming the Himalayan mountain range. In the same way, the continent of Antartica, during Tertiary time (the past 65 million years) has gradually moved into its present position over the south polar region.

Probably the movement of continental land masses into areas of high latitude where it is possible to achieve the type of climate necessary to maintain glaciation is one of the most important single conditions required to cause ice ages. However, other factors need to interact too. Some of these may include variations in the earth's orbit around the sun; the heat output of the sun; the activity of volcanoes; the formation of mountains and the uplifting of the continents; changes in the albedo of the earth's surface (albedo is roughly equivalent to reflectivity--snow reflects much more light than does grass, for example); and maybe other as yet unsuspected factors such as the influence man may be having on the environment: disrupting the ozone layer perhaps, or adding heat and particulate matter to the atmosphere and oceans.

Some of the factors mentioned above are undoubtedly more important than others in causing continental glaciation to occur. A great deal has been written about the role of each of these factors. I doubt that mountain building or volcanic activity have, by themselves, been major contributing factors, because through geologic time, we see that many periods of volcanic activity do not coincide with glaciation and there seems to be no real correlation between mountain building and glaciation (mountain glaciers excepted, of course). Most changes in the oceans are ultimately caused by processes at work in the atmosphere. For this reason, I doubt that variations in salinity, etc., in the oceans are a direct cause of glaciations; rather, they are probably a result.

It is likely that, throughout the geologic past, fluctuations in climate have differed only in degree, not in kind, from the short-term variations of the present. A sudden, sustained increase in the earth's albedo could cause a drop in temperatures leading to atmospheric cooling (I'm quoting freely here from R. W. Fairbridge in a 1972 article in Quaternary Research). Such sudden variations do take place. In 1971, for example, a 12 percent increase in surface albedo (remember, we are referring to the amount of light, and hence heat, reflected from the earth's surface so it is not available for warmth) was measured by satellite photos.

Given all the other necessary conditions for glaciation, variations in the inclination of the earth's axis might help account for the cyclical pattern of repeated glaciations that have occurred during the ice age. That is, during the last three million years or so, we have experienced repeated episodes of glaciation, which have been separated by periods of remission, the so-called interglacial periods, such as the one we are now experiencing. The theory of changes in radiation is known as the Milankovitch theory and it depends upon the fact that systematic changes in the orientation and inclination of the earth's axis, coupled with long-term changes in the eccentricity of the earth's orbit, lead to variations in seasonal insolation (heat received) at any given latitude on a cyclic, recurring basis.

Recent studies of the changes in plants through Tertiary time (again, I am quoting freely, this time from a 1978 article by J. A. Wolfe in the American Scientist) support Milankovitch's theory and indicate that the major change in the inclination of the earth's axis, a sharp increase, actually took place at the end of the Eocene Epoch (about 40 million years ago). At that time, the inclination of the axis may have increased from between 5 and 10 degrees to about 25 degrees. It has since decreased again to its present inclination of 23½ degrees. The increase in the inclination of the earth's axis resulted in a marked drop in worldwide temperatures at the end of the Eocene. Even this dramatic change in climate--the mean annual temperature is thought to have dropped at least 20 degrees Fahrenheit at the end of the Eocene (again I am quoting freely from Wolfe)--was not enough to initiate widespread glaciation then. It did, however, "set the stage" for glaciation later, when other factors combined to create the necessary conditions.

In summary: given that the continents are properly located in polar regions as they are today, what else is required to cause an ice age? The surface albedo has to increase so cooling will result. Volcanic activity, with its increase in dust in the atmosphere, might cause this to happen or a decrease in solar radiation might cause it. And, as Milankovitch pointed out, changes in the eccentricity of the earth's orbit periodically would change the relative amounts of solar heat received in the northern and southern hemispheres. In about 8,000 years, the northern hemisphere will again be in a position of low insolation. Possibly, we might expect a return to glacial conditions then.

In summary then, given the proper controlling factors, the earth seems now to be locked into an ice-age condition, with orbital changes dictating repetition of the glacial-interglacial cycle as North America, Europe, Asia and Antarctica remain in comparatively high latitudes. The glaciations of our present ice age have probably, but not necessarily, been preceded by sudden, drastic drops in atmospheric temperatures; rather, they have produced such drops. The overall temperature of the earth has been significantly cooler since the end of the Eocene Epoch than it was throughout most of the earth's past, and the annual range of temperatures has been greatly increased, especially in higher latitudes.