NEWSLETTER

NDGS

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North Dakota Geological Survey
University Station
Grand Forks, North Dakota 58202
Phone: (701)777-2231

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EDITOR'S NOTE--

Once again, I am including several articles on various aspects of North Dakota geology in the Newsletter. Reader response continues to be favorable to this kind of background information, so I'll keep including it as long as the demand continues. Incidentally, I'll appreciate suggestions from our readers for subjects for future essays.

I'd like to call attention to the item in this Newsletter titled "Geography Lesson." C. B. Folsom came across an old (1934) manuscript written by Andrew Alpha, and we all enjoyed Mr. Alpha's essay so much that I decided to share parts of it with you. Mr. Alpha's graphic descriptions of the harsh winters of the early 1930s "strike home," particularly in view of what so far seems to be shaping up as an unusual North Dakota winter.

DR. E. A. NOBLE TAKES YEAR'S LEAVE OF ABSENCE--

Dr. E. A. Noble, State Geologist and Chairman of the Department of Geology, is now on a one-year leave of absence as Deputy Chief of Uranium-Thorium branch in the Office of Energy Resources in Reston, Virginia. Replacing him as Acting State Geologist and Acting Chairman is Dr. Lee C. Gerhard. Dr. Gerhard came to the Survey in September 1975 as Assistant State Geologist. Prior to joining the North Dakota Geological Survey he worked for Sinclair Oil and Gas Company as an exploration geologist and region stratigrapher, taught geology at the University of Southern Colorado, and served Fairleigh Dickinson University both as a member of the faculty and as director of their marine station, the West Indies Laboratory on St. Croix, U.S. Virgin Islands. His academic training includes degrees from Syracuse University and the University of Kansas. Primarily trained as a structural geologist, paleontologist and stratigrapher, Dr. Gerhard developed an interest in carbonate sediments and rocks while exploring for oil in West Texas and New Mexico. Much of his recent research has been in application of carbonate studies to the exploration for oil and gas, studies he is continuing in the North Dakota Williston basin. His introduction to North Dakota was in 1962 as a summer employee of the Amerada Petroleum Corporation.

THE CHANGING ROLE OF THE NORTH DAKOTA GEOLOGICAL SURVEY--

Dr. Lee Gerhard provided the following comments about what the Survey can expect its role to be over the next decade.

The technical staff of the NDGS has been making projections of activities over the next two, five, and ten years, in an effort to provide a basis for budget and personnel efforts. It is quite clear that resource studies will occupy a high priority in Survey efforts over the next few years. While it is extremely encouraging to have the great increase in petroleum exploration and production in the State of North Dakota, that great increase, coupled with increases in uranium exploration and other resource exploration and development, has stressed the available manpower and budget for the Survey.

The carbonate studies program is making progress as part of the support effort for resource studies and research. Other studies of potash and uranium potential in North Dakota support our efforts to learn more about the mineral and hydrocarbon resources of the State.

At the same time, we anticipate that our level of activity in environmental geology, county studies, and the geology of coal reclamation will continue to be strong programs within the Survey and will sustain increased activity in the future as well as the resource studies program.

The North Dakota Geological Survey is fortunate to be able to participate in the mitigation of a national energy problem, no matter how small our role may really be. We are extremely pleased to be able to help the people of the State of North Dakota with the solution of problems dealing with their environmental quality, such as through our work in waste disposal, energy problems, and water studies. The results of our planning over the next decade indicate an ever-increasing role for the NDGS in the areas of environmental quality, resource development and management, and the solution of energy problems for North Dakota. It appears that North Dakota will play an increasingly important role within the nation as a major supplier of energy. This role will likely give the State of North Dakota a greater voice in the affairs of the nation.

SHORT-AND-LONG-RANGE SURVEY GOALS--

The following paragraphs are a summary of plans currently being formulated by Survey staff for future programs. In view of the rapidly expanding interest in "things geological" as a result of the tightening energy situation, we are, in a word, "swamped." Some of the short-and-long-range plans outlined here are still quite indefinite. We do invite your comments and suggestions regarding these activities and others that you think the State Geological Survey should be thinking about.

We intend to increase our studies of the geology of urban areas, identifying potential hazards and helping local planners to direct growth away from areas of valuable mineral resources. We intend to undertake detailed, instrumented studies of several existing sanitary landfills, hopefully enabling us to more fully understand the hydrologic characteristics of leachate in a variety of geologic situations.

We tentatively plan to inaugurate a new series of studies of 1°, 1° areas throughout North Dakota, providing geologic information of a more detailed, yet regional, nature than has been possible up to now under our county groundwater studies. We intend to include a series of derivative maps with each of these reports, showing such things as potential mineral resource availability, construction problems, suitability for various types of installations, and interpretations of geologic landforms, stratigraphy, and history.

Studies already underway by the Survey will require varying amounts of time to complete. Most of the county groundwater studies already underway should be finished in approximately five years. Coal evaluation studies are ongoing and may continue indefinitely, depending on funding and staff resources. Studies on surface mine reclamation procedures now underway will require several years to finish; we may go into greater detail on these studies.

Our geologic and engineering studies of oil- and gas-producing formations and exploration for these resources, as well as exploration for other mineral resources, are all ongoing concerns of all members of the Survey staff. The regulatory functions of the Conservation Division of the Survey can be expected to continue, increasing with the inauguration of uranium and possibly potash mining.

Generally, the inevitable growth in North Dakota's energy industry--oil and gas, uranium, but especially coal--will result in an increasing strain on the environment. This, in turn, is going to require greater attention by the Survey to environmental problems related to reclamation, engineering properties of materials, and other population growth-related problems. Depending on the scale at which it is undertaken, uranium mining may require the addition of several new regulatory personnel to the Survey staff.

Proposals by industry and Federal agencies to dispose of nuclear by-products in geologically-sound environments has resulted in interest being expressed in the vast northwestern North Dakota salt deposits and the bentonitic shales of the Pierre Formation in north-central North Dakota. Although disposal of such by-products may never occur in North Dakota, the Survey does, by virtue of its past studies, have considerable knowledge of the engineering properties of the two formations being considered for disposal purposes. We would, however, want to conduct more detailed studies if the plans to dispose of nuclear by-products continue to be pursued.

We expect our involvement in educational activities to continue. Our geologists are increasingly being called upon to lead field trips, speak to school and other groups, and participate in a variety of seminar situations. We plan to add to our series of Program Aids available to service clubs, school classes, and other groups.

We hope that, by providing both technical and nontechnical information on the geology of North Dakota during this period of increased awareness about our energy and environmental problems, we may help give North Dakotans--legislators, farmers, businessmen, teachers, students, or whoever--the basis they need for making sound decisions on how to best use our natural resources. We hope too, that by helping people understand the changes in rocks, soils, and landforms that can be seen across North Dakota, they may better appreciate our State.

NORTH DAKOTA OIL PRODUCTION--

Oil production in 1977 will show an increase over 1976 in North Dakota. Jack Wilborn, NDGS Petroleum Engineer, reports that production through October 31 was 19,434,047 barrels. Production during the comparable period of 1976 was 18,036,138 barrels. So far (Dec. 1) in 1977, sixteen new pools have been discovered; seventeen pools were discovered in 1976. North Dakota had 2,144 oil wells capable of production as of Dec. 1, 1977. On the same date last year we had 2,047 wells.

During the eleven-month period from January 1 to November 25, 1977, the Survey issued 315 drilling permits. A total of 246 permits were issued in all of 1976 (permits issued each month are listed in the Monthly Oil Production Report; anyone who wants this information should subscribe to that publication).

Uranium exploration has increased in recent months. We have issued five exploration permits since July 1, 1977. One company drilled over 3,000 test holes in 1977 and plans another 2,000 to 3,000 in 1978. Coal exploration has also increased. We have so far issued 76 coal exploration permits this year compared with 38 in 1976.

Some additional statistics of particular interest: Tiger Oil Company's Charlson Silurian discovery (#1 Slagten well) produced at the highest rate of any well in North Dakota history. In July it produced 73,736 barrels of oil in 31 days; 2,379 barrels of oil a day. The Shell Oil Co. #23x-9 Larson well in Renville County will give us our first recent production from the Deadwood Formation. The first production from the Deadwood Formation Formation in North Dakota was from a well on the Nesson anticline several years ago. It produced gas and condensate, but the Deadwood perforations are currently packed off. Probably the most important significance of Shell's Deadwood well is that it has sparked interest in this long-neglected target. And, in the Little Knife Field (Billings-Dunn-McKenzie Counties) Gulf Oil Corporation has completed 26 consecutive wells without a dry hole. Production in Little Knife is now being restricted because of concern over flaring of associated gas. A gas-producing plant is planned for the area in the near future.

CRACKS IN THE GROUND--

Last summer, geologists at the Survey investigated the occurrence of long cracks that formed in the ground at two locations in southern North Dakota, one in Dickey County and the other in Emmons County. In both instances, the fissures occurred in alfalfa meadows.

In Dickey County, the largest fissures occur near what is the topographically lowest part of the meadow, radiating outward toward the edges of the meadow and forming a pronounced rectilinear pattern in aerial view. The presence of the fissures made it difficult to harvest the alfalfa as machinery fell into the openings in the ground. Some of the Emmons County caverns were downright dangerous; a person would have difficulty getting out if he fell in.

The alfalfa fields in both locations had extensive root systems with some roots up to an inch or more in diameter and ten or twelve feet long. Plant growth was best along and over the fissures, especially in locations where the ground had not yet, but would soon, collapse. In fact, a study of the height of the alfalfa enabled us to predict where future collapse would occur, areas of better growth marking areas of future collapse. Apparently, plants with roots hanging into the humid caverns were able to extract more moisture from the air than were nearby solidly-rooted plants.

Open fissures in the Dickey County location were as much as four feet wide, but they averaged about two to three feet wide and ranged in depth to about four or five feet. The floors of the fissures consisted of topsoil that had dropped down. In areas where the topsoil had not yet fallen into the fissure, the bottom of the fissure appeared to be as much as ten feet below the ground surface.

The Emmons County fissures apparently had not yet reached as advanced a stage of development as had the Dickey County ones. Unconnected caverns were more common than were continuous fissures, but the caverns were as deep as eight or ten feet and some of them were partially filled with water.

The Survey augered several holes at both locations. At the Dickey County location, as much as eight or twelve feet of powder-dry silt, apparently slough sediment, overlay slightly moist glacial sediment. In Emmons County, moist silt overlay wet Pierre Formation shale. The Emmons County site is not really dry, but it is apparently much less wet than it was formerly.

It seems likely that, in both locations, the fissures formed due to dewatering of the sediments over the past several years. During the past two seasons, the area was even drier than during the 1930s, even though the spring and summer of 1977 saw some improvement in moisture conditions throughout the area. There was very little snow melt to add to the moisture supply in either 1976 or 1977. Recently, drought conditions in California made high pumping rates for irrigation necessary; the resultant excessive dewatering of aquifers caused fissuring and "sinking soil" similar to that at the two North Dakota locations. However, no unusual usage of groundwater has taken place at either North Dakota locations.

The main similarity of the two sites, aside from the fissures, seems to be that the crop was alfalfa. Is it possible that, during these dry years, the alfalfa was forced to go deeper than normal for water and it removed so much moisture from the soil that the sediment shrank, cracking much like mud does when it dries, and the material above fell into the voids that resulted?

Perhaps some of our readers may have some ideas why the fissures formed. We'd appreciate hearing from you if you have questions, a theory, or the answer to the problem.

HISTORICAL NOTES--

C. B. Folsom provided the following items of historical interest:

We had always assumed that the first oil and gas conservation act was passed in 1941. Not so! An act was passed in 1911. About 1910 some shallow gas had been discovered in Bottineau County and it was customary for the "promoters" to take prospective investors out to the wells and open them up. Although the pressures were only about 20 psi, the whistle of the gas bothered the neighboring farmers so the legislature decreed that wells could not be produced unless tied to a distribution system.

In 1929, another law was passed requiring that operators provide logs, and other data, to any interested party within a certain distance of an exploratory well. This was stoutly opposed by the oil industry and was repealed in 1937. The matter was academic anyway as the State Geologist was not given any appropriation with which to enforce the act.

Another point of interest: In the records of the NDGS, Dr. Frank C. Foley appears as State Geologist upon the death of Howard Simpson and disappears in 1941 without explanation. Upon inquiry it turns out that the reason for his disappearance is quite logical--U.S. Geological Survey offered him $2600 per year, $600 per year more than he was getting at the University of North Dakota.

Dr. Foley, who still lives in Lawrence, Kansas, recalls that he did not get any salary until July 1933, although he started work on the first of February. The State had been unable to meet its payroll til then.

LIGNITE DRILLING PROGRAM--

Kelly Carlson is in charge of our cooperative lignite drilling program, being conducted under a grant form the Conservation Branch of the U. S. Geological Survey. He reports that drilling was done in the following counties during the summer of 1977: Adams, Billings, Bowman, Dunn, Golden Valley, Grant, Hettinger, Mercer, Oliver, Slope, Stark, and Williams. A total of 241 test holes were drilled in 1977. This includes nine holes where the lignite was cored. Total footage was 62,562 plus core intervals. The open-file report on this drilling is in preparation and will be released when it is approved the the U.S. Geological Survey.

The open-file report for the 1976 cooperative drilling project has been released as Open File Report 77-857. It is titled: "Preliminary report of 1976 drilling of lignite in western North Dakota: Adams, Billings, Dunn, Hettinger, McKenzie, Mercer, Morton, Oliver, Slope, and Stark Counties. It contains maps showing locations, logs (gamma ray, density, self potential, and resistivity), and sample descriptions for the 115 test holes. The report may be purchased from the Grand Forks office of the North Dakota Geological Survey for $20.50.

KNIFE RIVER BASIN STUDY--

Survey geologist Dr. Gerald Groenewold reports that, as a result of his study of the geology and hydrology of the Knife River Basin and the Underwood area, he has arrived at a much clearer understanding of the coal stratigraphy there. A total of nine major coal beds occur in the Sentinel Butte Formation in the Knife River Basin. All nine of these beds are now well-defined and have been assigned names. Although our understanding of Bullion Creek Formation stratigraphy is not yet so detailed as is our knowledge of the Sentinel Butte, we have defined five major coal beds in the Bullion Creek. Using this new stratigraphic framework, it should now be possible to correlate the Knife River Basin coals with the coal beds in southwestern North Dakota.

This new, detailed knowledge of the coal stratigraphy will make it possible to develop much more accurate estimates of total strippable coal resources throughout the area. It should also lead to a detailed understanding of the hydrology of the area, enabling us to accurately predict the effect on water supplies as a result of present and future mining.

NORTH DAKOTA SANITARY LANDFILL INVENTORY--

During the past summer and fall, 76 sanitary landfill sites in North Dakota were evaluated with respect to their geologic setting. The landfill inventory was carried out by Dr. Alan Kehew of the Survey in cooperation with the North Dakota Department of Health. The objective of the inventory was to determine the geologic conditions at existing landfill sites throughout the State.

A sanitary landfill should be designed to prevent waste materials from coming in contact with surface water and groundwater supplies. Surface water contamination may occur when landfills are placed in flood-prone areas such as floodplains and long, narrow ravines; groundwater pollution is more difficult to predict and detect. A poorly-located landfill can produce a dark-colored, smelly liquid called "leachate," which forms either when the refuse is in direct contact with groundwater at or below the water table or by infiltration of rain and snow melt down through the landfill materials. Once leachate reaches the water table, it moves along with the groundwater flow systems. In some states, leachate from landfills has polluted domestic and public water supply wells resulting in the necessity for expensive corrective measures.

To evaluate a sanitary landfill site, it is necessary to consider the properties of both the surface and subsurface materials as well as the nature of the groundwater flow systems in the area. During the past summer's study, the surficial geology was examined at each site. The high cost of obtaining subsurface data made it necessary to infer subsurface conditions by referring to previously-published maps and reports and by a visual appraisal of local surface conditions. The Survey's County Groundwater Studies reports were particularly useful wherever they had been completed.

Each site was placed in one of four categories. These categories are: "Possible chemical waste site" (12 sites); "Acceptable for present use" (21 sites); "Not acceptable for present use" (27 sites); and "Not enough information to make determination" (16 sites).

The twelve "Possible chemical waste sites" are located in areas with the most favorable geological conditions, that is, they are underlain by sediments with high clay content through which leachate and groundwater move only very slowly. The "Acceptable for present use" sites are located in generally favorable settings in which the surface water and groundwater pollution potentials are low. The "Not acceptable for present use" sites occur in unfavorable geological settings. Although water pollution may not actually be occurring at these sites, a significant potential for pollution does exist. Most of these landfills are located in sand or gravel deposits, which are poor for landfills because they allow leachate to move rapidly to the water table. Many of our best aquifers are found in near-surface sand and gravel deposits and could be polluted if an improperly-constructed landfill were located in them. The "Not enough information to make determination" category was used wherever published information was lacking or where subsurface conditions are difficult to determine without additional detailed investigations.

Now that the inventory is nearing completion, detailed investigations are planned in some locations to insure that water pollution potential will be minimized at proposed new landfill sites. One study was completed by the Survey early this year at Langdon. Another investigation was begun this fall at Cavalier. Test wells (piezometers) were installed at these two landfills so that groundwater samples could be collected and analyzed. Detailed studies in representative types of materials throughout the State will give us the knowledge to locate and design landfills so that the danger from leachate pollution is at a minimum.

DATA STORAGE AND RETRIEVAL--

Many of the programs in which the Survey is involved are generating vast amounts of data and future programs can be expected to generate additional data. The large number of oil wells currently being drilled provides us with cores and samples; our Core and Sample Library, located on the University of North Dakota campus near the Survey offices, is rapidly becoming filled to its capacity. This is not "dead" storage; the samples and cores in the library are used almost daily by Survey staff in their studies and by consultants and University staff and students. Core is routinely shipped to oil companies for study by their geologists. The Carbonate Core and Sample Study Laboratory, located in the same building as the Survey, was established last year. It is designed for whole sample and petrographic study of Williston basin carbonate rocks; Survey and University geologists working in the Carbonate Core and Sample Study Laboratory, make continual use of the materials in the Core and Sample Library.

Our geophysical log files, located in the Survey offices, are similarly crowded and they, too, are used to their best advantage by geologists from the Survey, industry, and the University. The Survey now requires additional storage and office space to maintain existing data sources and files.

The large amount of data generated by the above-mentioned and other studies, can perhaps best be made accessible to the public by the expeditious use of computers. Ideally, much of our data should be stored in the North Dakota Regional Environmental Assessment Program (REAP) computer so it will be available to all users of the REAP system; the Survey should have terminals to the REAP computer in its Grand Forks and Bismarck offices.

Until now, the amount of data coming into the Survey has been manageable. It has been filed and subsequently used as the basis for technical reports. The value of these technical reports has become increasingly evident recently as industry geologists are using them in their search for North Dakota's mineral resources; planners have required derivative maps, studies, and reports and the only source of data for these has been our filed store of data and our existing technical reports. Our cooperation involving scientific input to agencies such as the local Regional Councils for Development, the State Health Department, and the Department of Public Instruction would have been impossible without our series of county groundwater bulletins, some of which were completed as long as 15 years ago.

We are repeatedly complimented on the quality, organization, and accessibility of our technical data; our log and core files; our open-file reports; and the wide variety of existing technical reports we have available. Continued efficiency will require ever-improving methods of data compilation, manipulation, and retrieval.

INTEREST INCREASES IN NORTH DAKOTA URANIUM--

The current energy rush in North Dakota is bringing explorationists and developers into the State at an accelerated rate. The greatly increased activity by oil and gas operators in the State is quite apparent to everyone due to news media accounts of drilling permits issued by the NDGS and coal development in North Dakota is almost constantly being discussed by the press. The increased interest in the uranium potential of the State is not so apparent however. The frequency of inquiries by industry and government agencies is increasing dramatically and we have a steady stream of visitors stopping by to examine logs, cores, and anything else pertinent to uranium.

The Survey is fortunate in already having considerable data on hand to assist explorationists in their search for economic deposits of uranium. These data are largely in the form of geophysical logs; cores and samples from exploratory holes drilled for oil, gas, and lignite; and in conjunction with the county geology and groundwater resources studies conducted by the NDGS, State Water Commission, and the USGS. The North Dakota Geological Survey has published several reports dealing with uranium potential in the State. In addition, Bendix Field Engineering Corporation, under contract to ERDA, has just completed a preliminary drilling program in the Red River Valley to assess uranium potential there.

The NDGS is directly involved in regulating the exploration and production of uranium and other subsurface minerals by virtue of Chapter 38-12 of the North Dakota Century Code, which designates the State Geologist as supervisor charged with the duty of enforcing the rules and regulations of the Industrial Commission applicable to the subsurface mineral resources of the State. In this capacity, the State Geologist issues all exploratory permits and collects and stores all required exploratory and production data.

The rules and regulations are currently being reviewed to determine their applicability to fulfill the requirements of the statute. If necessary, we will propose revisions and additions to the existing rules. Any proposed changes will be adapted only after public hearing by the Industrial Commission.

GEOGRAPHY LESSON--

I am printing a portion of an essay written in January of 1934 by Mr. Andrew G. Alpha when he was a student majoring in geology at the University of North Dakota. Mr. Alpha is currently a geologist in Denver, Colorado. The essay, titled "The Geography of My Home Town," was written for a course in Human Geography. The town Mr. Alpha wrote about was Adams, North Dakota in western Walsh County. The whole essay is about 20 pages long and I've chosen two exerpts dealing with the natural setting and climate of the area.

TOPOGRAPHY - NATURAL LIFE

It is high noon. The sun shines upon the virgin prairie over which the broom, the quack, and the buffalo grasses billow in green waves before the prairie wind. The heat waves shimmer and roll on the horizon. The buffalo feeds in quietude. The ground squirrels stand like sentinels atop their earthen mounds. It is the Dakota summer.

This green expance of grass land is near the eastern edge of the great rolling prairie which stretches 150 miles westward to the Coteau du Missouri. From a nearby hill can be seen a panoramic view for miles. There are great recessional moraines snaking, meandering, curving in a general northwest direction. These moraines are the footprints, the fossil remains of a great ice sheet. It is the evidence of a great plateau of moving ice which some thousands of years before had extended over the northern part of North America.

These recessional moraines and hills prove that this plateau retreated gradually and haltingly. There were a succession of pauses--a period of melting and then a stop long enough for it to accumulate debris along its margin. This repeated process left great moraines and scattered hills, an unmistakable evidence of a losing fight with a warmer climate.....

.....Today this green rolling prairie of the Indian and buffalo has long been turned over exposing the rootlets which once anchored an endless meadow of luxurious hay. Only here and there on a hill top or near a slough is to be found today any remnant of this once majestic and extensive prairie. The rock debris has long been cleared off and piled up and the black loam exposed to civilized, tamed and cultivated grasses, plants and grains.

The buffalo and Indian have been forced to retreat by the white man. The lowly prairie dog alone remains and prospers on the new diet of grains.....

.....The greater number of the sloughs have dried up leaving hay meadows and fields. Twenty-eight years ago one of these sloughs was purchased for a townsite because an ambitious farmer wanted too high a price for the adjacent dry prairie. This slough was surveyed and streets were mapped out. People moved in, and the railroad was built through the town. One block from Main Street there were still a few ducks floating about in the water.....

CLIMATE

This region has a continental climate. Extremes of temperature are the rule. From the parching, drying, stifling heat of July and August to the subzero cold and blizzards of January and February, there is a range in temperature of 140 degrees between extremes. Not only are there great seasonal and yearly variations, but there are variations within a week, and even within a day. A day may break clear and thawing, and before late afternoon a blizzard may be raging, and the temperature may drop to 20 degrees degrees below zero. All economic activities, all social habits of the people are influenced by the passage of seasons and the daily idiosyncracies of nature.....

.....The summer season is short but the days are long and very warm, and during the past few years the summers have been very dry. The summer season was formerly ideal for the growth of grain crops. It was wet during the earlier summer and dry, ripening weather during the later summer towards fall. The past few years, however, have been very dry. Due to the dryness of the soil, the winds have created great dust storms which darken the sky and limit the visibility to less than half a mile. These hot, dry, parching winds burn up and pre-ripen the grain crop and leave the withered stalks and leaves as silent crematory evidence of a might-have-been bumper crop.

This warm summer season brings with it swarms of insects, including grasshoppers, mosquitoes, crickets, flies and others which are more or less harmful.

The fall season gradually gets colder and blends into winter. The winters are long and cold.

During the long and cold winters, such as these occurring in 1932-33, and 1931-32, the community becomes isolated. No automobiles are seen, nor is there any traffic of that nature into or about town for three or four months. The town is snow-bound, and the main arteries of travel are blocked by drifts which are 15 to 40 feet high, especially near a bordering grove of trees.

Snowmobiles constructed from aeroplane propellers and motors of a pusher and puller type afford the only means of motor transportation. During the winter of 1931-32 there were 12 snowmobiles in operation within the village.

Aeroplanes equipped with skis are to be seen once or twice a day patrolling the high tension wire. Trains at times do not reach town for a period of two weeks. The result is that mail is held up, and only radio news is available. To open the roads huge rotary plows are employed.

In the spring the snow melts and the frost comes out of therground. This is locally called the "break up". During the two weeks or more of break up there is very little travel. When the frost begins to leave, the roads, including main street road, become seas of mud, two or three feet deep. The streets heave, until they resemble miniature anticlines and synclines, three feet high. These anticlines are like great sponges. When a vehicle is driven over them, they may break, and mud and water may spurt forth and the vehicle may be sucked into the mud. Automobiles become stuck in the mud even on Main Street. Many of the streets become impassable.

The roads leading into town from all directions are impassable to automobiles, and too muddy for wagons. Consequently during this period there is very little business transacted in the town. When a day does come when it is possible for people to come to town, all manner of vehicles may be seen--buggies, democrat wagons, lumber wagons, carts, automobiles--and there are even people mounted on horseback.

The effect of climate is the strongest factor in shaping the lives of these people. Their food, clothing, homes, work, transportation, mode of living--everything is the result of climate. It is climate that makes them work and save for a long winter. They must adjust their activities and habits to conform to climatic factors. Climate is the relentless dictator. Every season presents a new series of influences, problems, obstacles, which have to be conquered and which leave their scars, their influence, their environment stamp.

THE RED RIVER VALLEY--

The Red River Valley is not a true river valley in the traditional sense. The modern Red River of the North did not carve the Red River Valley the way a river usually carves a valley.

In fact, the Red River Valley of the North was already a major physiographic feature long before North Dakota was glaciated. The land that is the Red River Valley of North Dakota, Minnesota, and Manitoba was, prior to glaciation, a rolling area rather than the exceptionally flat surface we see today.

The Red River Valley began to form when a river flowing northward to Hudson Bay through northwestern Minnesota and Manitoba gradually carved a narrow, shallow valley. This river flowed through an area over which salty artesian water from the Cretaceous Dakota Formation sandstone was seeping to the surface. Artesian water that escapes from the Dakota Sandstone to the surface throughout parts of eastern North Dakota today results in numerous flowing water wells and areas of salty soil in places.

With time, the north-flowing river eroded its way downward to the hard, igneous granite rock of the Canadian Shield, which underlies all of eastern North Dakota and northern Minnesota. Rather than continuing to carve downward into this hard material, the river tended to shift its channel gradually westward where the granite is found at increasing depths. As its channel shifted westward, the river carved away the soft shale and sandstone that covered the granite, forming an east-facing escarpment. This escarpment, which formed the west wall of the valley, was probably always marked by numerous springs where the Dakota Sandstone was exposed. The seepage of the salty artesian water from the valley walls tended to remove sediment from the surface and transport it to the river. Eventually, a steep escarpment formed along the west side of the valley. This escarpment gradually migrated westward, becoming steeper and higher as erosion continued and the north-flowing river gradually became located farther and farther to the west. Today, this escarpment is known as the Pembina Escarpment in northeastern North Dakota; the Manitoba Escarpment farther north.

By the time the Pleistocene Ice Ages began, about three million years ago, the Red River Valley was a broad, rolling lowland bounded by a steep western side and a low, gentle rise to the east in Minnesota. The river that flowed in the valley, the ancestral Red River, followed a meandering course northward through eastern North Dakota into Manitoba to Hudson Bay.

With the coming of the glaciers, this north-flowing river was immediately dammed by the ice and a lake formed in the Red River Valley ahead of the advancing glacier. Similar lakes formed ahead of the glaciers when their margins receded northward from the Red River Valley at the end of each glaciation.

As the glaciers flowed southward through the Red River Valley and into the lake ahead of them, they eroded the face of the escarpment--the Pembina Escarpment--steepening it to its present shape. Layers of clay and silt that were deposited in the lake waters were overridden by the glaciers and glacial sediment was deposited on top of the lake sediment.

North Dakota was glaciated several times during the ice age, and it is likely that most of these glaciations began with ice moving southward through the Red River Valley, which is the lowest area in the State. Glaciers, like water, fill low areas first, spilling over onto higher areas as they become thicker and advance.

Any well drilled in the Red River Valley, especially within about ten miles of the Red River, will penetrate several layers of old, buried lake sediment. These layers of lake sediment are interbedded with layers of glacial sediment. The uppermost layer of lake sediment forms the modern, flat surface of the Red River Valley. This uppermost layer was deposited at the bottom of the glacial Lake Agassiz, the lake that formed ahead of the glacier as its margin receded northward into Canada at the end of the most recent ice age, about 13,500 years ago.

THE GLACIAL LAKE AGASSIZ--

Flat plains are found today in areas that were flooded by lakes of glacial melt water at the end of the Ice Age. Sediment deposited from the still, quiet lake waters formed smooth lake floors that we refer to as glacial lake plains. Several thousand lake plains that range in size from a few acres to several thousand square miles are found throughout the glaciated part of North Dakota. The larger glacial lakes formed when glaciers blocked the routes of major rivers and the largest such lake was glacial Lake Agassiz, which covered the Red River Valley of North Dakota as well as large parts of Manitoba, Saskatchewan, Ontario, and Minnesota. Other large glacial lakes in North Dakota included glacial Lake Souris in the north-central part of the State, glacial Lake Minnewaukan in the Devils Lake area, and glacial Lake Dakota in the southeast part of the State.

A river flowed northward through the Red River Valley long before North Dakota was glaciated (see the preceding article). At the end of the Ice Age, as the glacier was receding northward through the Red River Valley, the north-flowing runoff in the Valley contributed to a large, ice-dammed lake, Lake Agassiz, south of the receding ice.

As the glacier continued to shrink northward, the level of Lake Agassiz rose and fell, leaving an array of beaches along the old shorelines and thick accumulations of bedded silt and clay where the water had been deepest. Lake Agassiz drained southward through the Minnesota River Valley to the Mississippi River while it was at its higher levels, but as the water level dropped and the glacier continued to melt, lower, more northerly outlets to Lake Superior were opened.

Lake Agassiz began to form about 13,500 years ago when the glacier first receded far enough to open up part of the Red River Valley, the extreme southeast corner of North Dakota. Then, about 12,800 years ago, the glacier in the Red River Valley stopped receding or perhaps even readvanced a short distance, resulting in a stabilization of the lake level. The highest well-developed beaches, known as the Herman Beaches because they are well-developed near Herman, Minnesota, formed along the shore of the Lake Agassiz about this time.

About 11,000 years ago, the glacier ice receded into northern Minnesota, allowing Lake Agassiz to drain eastward into Lake Superior. While the lake was drained, until 9,900 years ago, a spruce forest grew in the Red River Valley. Then, about 9,900 years ago, the ice readvanced in northern Minnesota, blocking the drainage route to Lake Superior, causing Lake Agassiz to flood the Red River Valley once again. The spruce forest was drowned and covered by a few feet of silt and clay as the water rose once again. Finally, about 9,300 years ago, Lake Agassiz drained for the last time as the ice receded, allowing it to drain eastward to Lake Superior.

In the center of the Red River Valley, near Fargo and Grand Forks, the offshore sediment of Lake Agassiz is as much as 150 feet thick and can be subdivided into at least five separate units. Two, and perhaps three, glacial readvances of as much as 50 miles each left layers of glacial sediment interbedded with the lake sediments.

Over the part of the lake plain nearest the Red River, flat-bedded lake sediment consisting of clay, silt, and fine sand is found at the surface. In places, the horizontal bedding was disturbed by such things as mud-flows in the loose, wet lake sediment; by boulders dropped from icebergs floating on the surface of the lake; or by squeezing of the lake sediments between cakes of lake-surface ice that sank as the lake drained.

Near the edges of the glacial Lake Agassiz plain, bouldery, waveworn deposits of glacial sediment are common. Beach ridges are also found along the edges of the lake plain. Some of the beaches are hundreds of miles long, more prominent in some places than others, generally a few hundred feet across, and composed of from 5 to 25 feet of gravel and sand. In some places the beaches are absent and wave-cut scarps are found instead.

The beaches that formed along Lake Agassiz are developed best where wave action was concentrated. Larger beaches formed on the east side of the lake in Minnesota than on the west in North Dakota because prevailing westerly winds resulted in greater wave activity on the east shore of the lake. The action of the waves tended to sort the lake deposits into silt and clay, which were carried to deeper water, and sand and gravel, which were reworked along the shore and deposited as extensive beaches in places.

The levels of glacial lakes such as Lake Agassiz rose and fell often during the life of the lake. Well-defined beaches and scarps formed along the shore when the lake level remained stationary for a period of time. It is possible, however, that intense storms, events lasting only a matter of days, may have built large beaches in places, so the size of the beaches is not necessarily an indication of the relative length of time a lake level persisted.

The major river on the glacial Lake Agassiz plain, the Red River of the North, established its present route about 9,300 years ago, and except for minor changes such as a few meander cutoffs and oxbows that have formed, the route of the river has changed little since that time. Most of the meanders that were entrenched at the time the river first formed remain unchanged today.

Wherever large rivers flowed into glacial lakes, sandy deltas were built. Deltas that formed at the mouths of the Pembina and Sheyenne Rivers where they entered Lake Agassiz consist of extensive, irregular accumulations of sand. The surfaces of the deltas have been blown into dunes by the wind in places.