ENVIRONMENTAL GEOLOGY & NORTH DAKOTA

BY

B. MICHAEL ARNDT

NORTH DAKOTA GEOLOGICAL SURVEY

MISCELLANEOUS SERIES NO. 48

1972

E. A. Noble, State Geologist

A brief note: Environmental geology had its beginnings in the large urban areas of our country where the problems are acute. We here in North Dakota have not yet had these problems. We are, however, in the unique position of being able to take someone else's lessons and prepare for the situations before they arise. Environmental geology can be an effective and powerful tool in keeping our state a pleasant and healthy place to live and work.

CONTENTS

PHOTO CREDITS

Figure 2--Lee Clayton

Figure 3--Nordlund, R. L., and Deere, D. U., 1970, Collapse of the Fargo grain elevator: ASCE, Proc., Jour. Soil Mechanics and Foundations Division, v. 96, No. SM2, fig. 7, p. 590.

Figures 7,8,11--Carlson, C. G., and Laird, Wilson M., 1964, Study of the Spoil Banks Assoc. with Lignite Strip Mining in North Dakota: N. Dak. Geological Survey Misc. Series 24, 27 p.

INTRODUCTION

Only recently has there developed widespread concern about the environment in which we live. No longer are we able to exploit the resources of vast areas of our land, use them up, move on to new areas, and start over again. We realize that in order to save something for the future, we must put our resources to wise use today. That our environment has limitations has long been realized by the geologist. Other people, too, are becoming aware of this situation. The result has been for geologists to show people how they can best use the resources available to them.

Traditionally, the geologist has directed his energies toward two goals: (1) to decipher the history of the earth which is hidden in its rocks, and (2) to use that knowledge to retrieve valuable minerals and fuels. Modern technology has brought about changes in the problems that concern geologists. People concentrating in urban complexes make excessive demands on the natural resources of those small areas. For this reason, the geologist has taken a new approach to the study of available mineral and water resources, landforms, and the geologic processes affecting them. This has brought about the advent of a new concept in geology - applying geologic techniques and principles to improve man's environment - that is, *Environmental Geology.*

WHAT IS ENVIRONMENTAL GEOLOGY?

The term "environmental geology" is rather new and no clear and concise definition has been developed. The improvement of man's environment by the application of geologic knowledge, as stated above, is probably satisfactory.

One of the consequences of population growth, especially in urban areas, has been to increase demands on our resources. To satisfy this growing need, new sources of raw materials must be found. From a geologist's point of view, these raw materials include sand and gravel, clay, building stone, natural fuels, and, possibly most important, *water.*

The duty of the geologist does not end in locating these materials. He may help to determine how these resources can be put to their best use. With his knowledge of the geology of an area, the geologist can help cities plan growth patterns. In this way, mineral resources located around cities may be used effectively before unchecked growth covers these deposits, making them unavailable for further use.

The information supplied by a geologist may also be necessary in other areas. Geological knowledge is essential in controlling certain types of pollution of water supplies. Effective disposal of wastes and an understanding of the engineering characteristics of the material on which a city is built may also require geological information.

The geologist and the science of geology thus play an important role in improving our environment in at least four ways: (1) physical planning, (2) disposal of wastes, (3) development of water resources, and (4) development of mineral resources.

PHYSICAL PLANNING

How many times have we heard of a building that collapsed because of an unstable foundation, or of a dam that does not hold water because of the porous nature of the materials in which it was built (Fig. 1). Too often this has been true, and too often failures such as these can be traced back to a planner or an engineer who was not aware of some

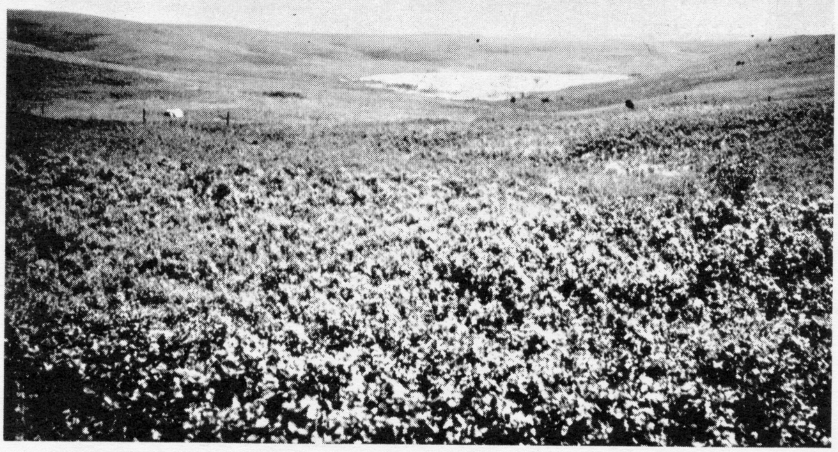

FIGURE 1. A dry cattle dam in western North Dakota. One of the reasons for its failure is the porous nature of the underlying sediments.

geologic condition peculiar to his project site. Had there been an awareness of local geologic conditions, costly and possibly dangerous situations could have been avoided (Fig. 2).

Such a situation occurred a few years ago at Fargo, North Dakota, where a grain storage facility collapsed (Fig. 3). The elevator was built on glacial Lake Agassiz silts and clays. Shifting and settling of the structure was expected, but certainly not complete failure. Error in loading the grain was partially to blame for the collapse. Foundation conditions may be highly unstable in these lake deposits because of a combination of high water table conditions and sediments with relatively low bearing strengths. The failure to recognize these geologic and hydrologic factors was a major reason for the disaster.

Factors Involved in Planning

Many factors, economic, cultural, engineering, topographic, and aesthetic, are involved in the selection and development of a given site for a particular structure. Geologic factors, too, must be considered before construction begins. All the above factors are interrelated and all need to be considered; none can be ignored.

A sand and gravel deposit or an ore body can't be moved. If a building is located over the deposit or a residential area has been built up near it, that deposit is lost. The geologist, by warning planners that such deposits exist in areas under consideration for development, can preserve these materials for future use.

Topography in many ways dictates the planning and construction of certain features. When wind is not a factor, an airport runway is more easily built parallel to the trend of the topography rather than across it. Less cutting and filling is required and certain drainage problems can be avoided. Topographic considerations, which may be of importance in the western part of the state, are of little consequence in eastern North Dakota, where the flat

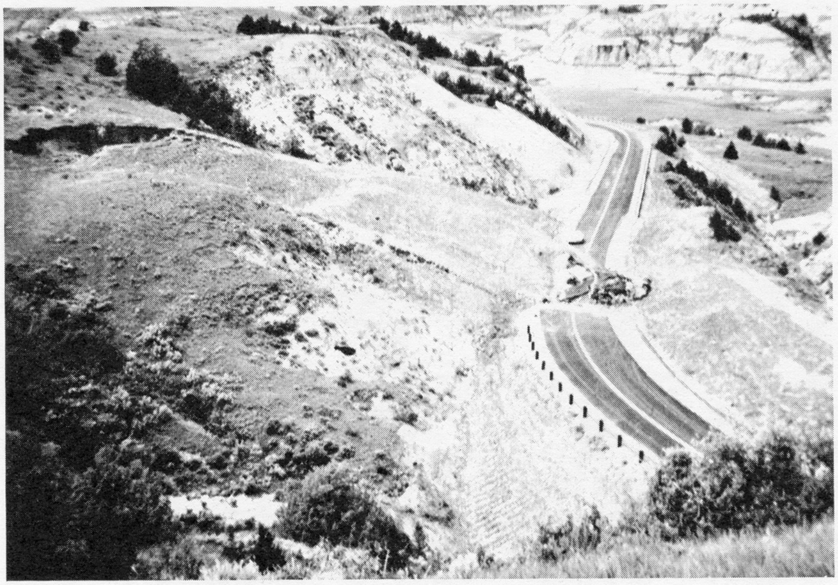

FIGURE 2. Landslides in South Roosevelt Park caused by inadequate understanding of geologic factors involved in construction in this area.

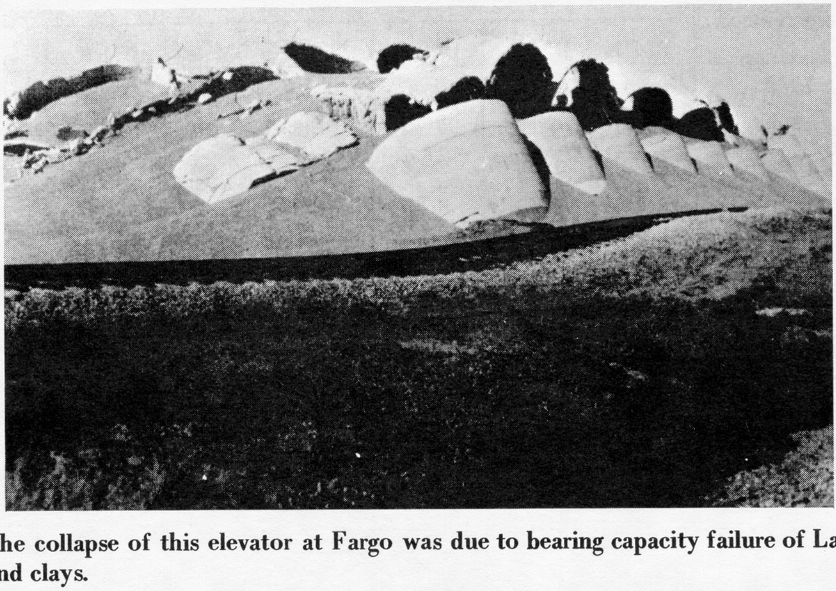

FIGURE 3. The collapse of this elevator at Fargo was due to bearing capacity failure of Lake Agassiz silts and clays.

topography poses its own special problems. High water table conditions play havoc with the construction of highways and airports because they make the creation of stable, strong foundations very difficult or expensive.

The engineering characteristics of geologic features are of prime concern (Fig. 4). Foundation stability is greatly affected by the rate of percolation of water through the materials on which the structure rests. It isn't much of a dam if water leaks through the underlying materials. Swell-shrink characteristics of clays must be taken into account so that they don't produce adverse effects (Fig. 5). Mineralogy and water content are important in slope stabilities. A steep slope in one area may be much more stable than a gentle slope in another area because of minute mineralogical differences or groundwater conditions.

Failure to recognize an unusual geologic feature delayed construction of the I-94 underpass near Fargo (Fig. 6). Part of the highway was to be built over a feature known as the Fargo Ridge. This ridge, which is the topographic expression of an old channel of the Sheyenne River, consists of saturated sand overlain by Lake Agassiz clays and silts. These saturated sands can produce a "quicksand" condition resulting in an unstable base. As a result, construction had to be halted until adequate geological study indicated how to best overcome this "quick" condition. Had a geologist been consulted prior to beginning construction, time and money could have been saved.

Aesthetic considerations are also important in development. A gravel pit or quarry, for example, near a residential area is not pleasing to look at. Another example is the lignite spoil banks in western North Dakota which are unsightly (Fig. 7). Proper reclamation techniques, including tree planting, may provide a welcome relief from the flatness and treelessness of certain areas. Added benefits include providing such areas with habitats for deer and game birds (Fig. 8). As the rest of the land undergoes more intense use, these areas will become more valuable. Natural geologic features might provide focal points for parklands, residential areas, or for the enhancement of public facilities. The geologist can go a long way in helping planners to utilize these features, be they natural or man made.

In summary, geologic investigations should always be included in the planning stages of construction and regional development.

DISPOSAL OF WASTES

Waste products are derived from a variety of sources: mining, manufacturing, processing, and human occupancy. These products may be disposed of into the atmosphere, into the ground, onto the ground, or into surface waters. In North Dakota atmospheric disposal resulting in polluted air is not yet the major problem it is in more industrial states. The same, however, cannot be said for the other types of disposal.

In order to develop and police waste disposal projects, a knowledge of geologic and hydrogeologic factors is essential. A geologist can help to determine whether natural conditions at the disposal sites are adequate to protect the groundwater resources from becoming contaminated. Some of the things a geologist considers in finding a satisfactory disposal site to prevent pollution are (1) the type of contaminants, (2) permeability of the materials at the disposal site, (3) flooding susceptibility, (4) depth to bedrock and/or water table, (5) extent of surface erosion, and (6) direction and rate of groundwater movement.

The oil industry in North Dakota has considered geologic and hydrogeologic conditions to avoid what might have become one of the state's worst disposal problems. Large quantities of natural brines are produced along with crude petroleum products from oil wells (Fig. 9). The most desirable solution to this disposal problem is to dispose of this salt water in an economical way that will produce the least environmental damage. Basically there are two techniques of brine disposal: (1) dump it into surface pits or, (2) inject it back into the ground.

FIGURE 4. **Grand Forks Air Force Base. Misunderstanding of the geology here resulted in both legal and construction complications.**

FIGURE 5. **This golf course is situated on a scenic site along the Pembina River. It overlies a bentonite-rich unit of the Pierre shale which is highly susceptible to slumping. As a consequence, several of the greens undergo nearly continuous disruption.**

FIGURE 6. Construction of this railroad underpass was delayed because of failure to recognize a unique geologic situation.

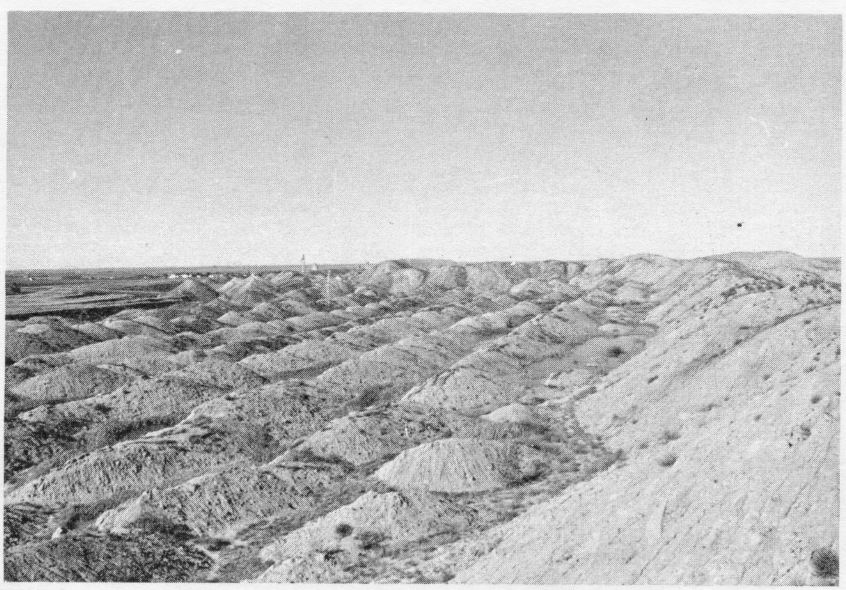

FIGURE 7. Spoil piles of an abandoned dragline operation in Divide County. Reclamation of such an unsightly area may result in a scene similar to Figure 8.

FIGURE 8. Trees planted at the Custer Mine in McLean County. This scene is more attractive than Figure 7. An added benefit is the cover that is provided for game.

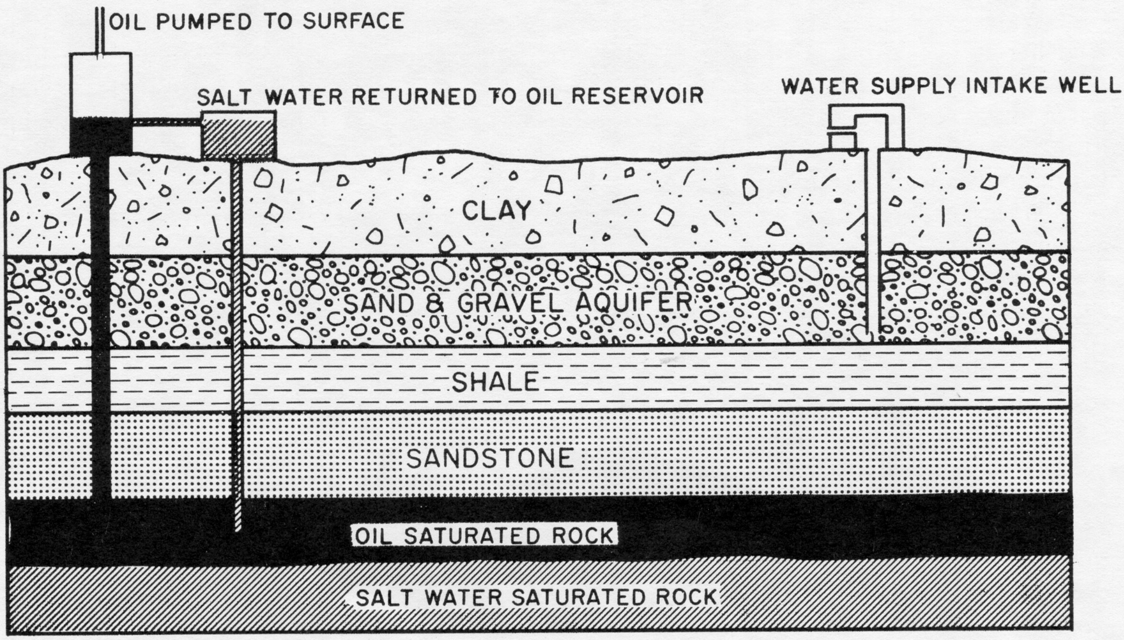

FIGURE 9. Brine that is produced along with the oil is forced back into the ground in such a manner as to prevent contamination of groundwater and surface water supplies.

Dumping the salt water into an excavated pit near the producing oil well would seem to be the most practical method. There are, however, some other considerations. First, we must find out if the proposed pit consists of suitable material which will prevent leakage. This leakage can go horizontally and affect nearby cropland, or, it can go vertically and pollute the groundwater supply. If there is a possibility that such a pit might leak, then it must be lined in such a manner as to insure proper control. Such a step increases the cost of this type of disposal, and it may be that another method would be more feasible. There is also an aesthetic factor involved here. An open excavation with big piles of barren dirt near the edges is very unattractive. This too is a problem that must be dealt with when using surface pit disposal methods.

The second method of brine disposal, injection into a selected subsurface formation, is the better solution in most cases. However, the problem of contamination here can be just as real and, in the long run, more serious than the contamination of surface waters. Aquifers, beds that are capable of producing groundwater, tend to accumulate contaminants in great amounts before the effects become apparent in water wells (Fig. 10). This sort of contamination is generally not reversible, and once these effects begin to show up in groundwater supplies, the contamination is so far advanced that the aquifer cannot be saved, except at considerable cost.

Safe and economical disposal can be attained under a carefully regulated program of brine injection that takes geologic factors into consideration. In North Dakota we have such a program administered by the State Geological Survey. By knowing the rates and direction of groundwater movement, and whether surface streams are gaining from or losing to groundwater supplies, effective disposal has been achieved.

We have mentioned the problems of pollution associated with the production of oil. In developing a sewage lagoon for community or industrial wastes the same kind of factors need to be considered.

WATER RESOURCES MANAGEMENT

Water is one of man's most important resources. There is hardly a daily activity, whether it be simply washing our hands or helping to produce our food and clothing, in which water does not play a role. Because North Dakota is an agricultural state, water is particularly important. Without adequate supplies our state's economy would rapidly disintegrate. As a result of our great dependence on adequate water supplies, it is necessary for us to know all we can about water.

Water occurs at the surface of the earth in rivers and lakes and beneath the surface as groundwater in underground aquifers. There is little practical difference between surface water and groundwater, as they depend on one another. Where there is an abundant water supply, the excess surface water is absorbed and becomes part of the groundwater system. In areas of low water supply, groundwater feeds the surface water supply which may deplete the groundwater supply. In this latter situation it is possible that both sources of water may be depleted. Geologists study these relationships and are able to develop effective and safe water supplies for individuals, industries, or communities.

Geologic and hydrologic factors should be considered in the development of a farm pond. If the geologic setting of an area is sand, the water may leak out as fast as it is put in. The rate of sedimentation in the pond or reservoir is controlled by such geologic factors as the steepness of neighboring slopes, the material of which these slopes are composed, and the type of ground cover in the area. All ponds and lakes are eventually filled up as debris is carried in by both natural processes and the activities of man. When a pond is filled too rapidly with debris, its water-holding capacity is diminished, making its cost unjustified. Pollution is another factor that enters into the development of a farm pond. The nature and

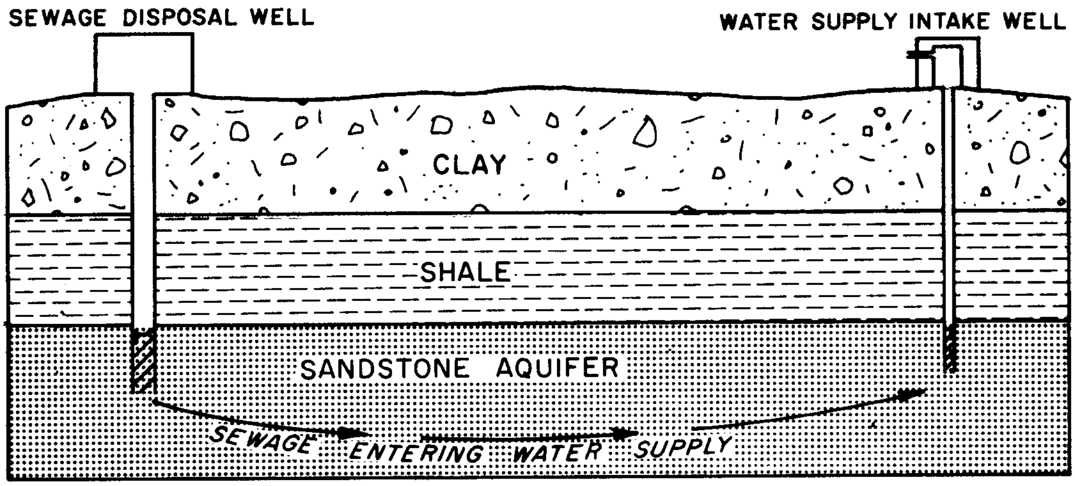

FIGURE 10. Situation in a small town in western North Dakota in which an abandoned well is used for sewage disposal. The sewage is entering the aquifer from which the town receives its water supply.

type of possible pollutants (i.e., pollution from a nearby feedlot) and the use for which the pond is intended must be considered. If the pond is primarily intended for stock use, the problem of pollution by animal wastes is less serious than if it is intended for human consumption. Such possible contaminants as nitrates and phosphates from chemical fertilizers, and insecticides and herbicides may be carried into the pond by slopewash or wind action. If this water is used for irrigation, some of these contaminants could possibly be detrimental to plants. There is, of course, always the possibility that these pollutants may migrate into the groundwater supply and contaminate nearby wells.

A commonly ignored situation is the possibility of contamination of the surface water supply by the groundwater. If the groundwater has a particularly high salt concentration, for example, and it is adding to the pond, the resulting salt contamination may make this water supply useless for irrigation, domestic, or stock use. The relationship between the groundwater and the water in the pond must be known. As in the case of waste disposal, we must be concerned with direction and rate of groundwater flow. Whether a pond is located in a groundwater discharge or recharge area will have much to do with water level stability, as well as determining whether it will hold water at all.

We have mentioned how geology and hydrogeology affect the location of a farm pond. The same principles used in developing this water supply are used in developing a community water supply, although the scale of the problem is larger. The relationship between surface water and groundwater is of particular importance, because most communities use either a combination of the two to supply their water needs or they use large reservoirs. As in the example of the pond, the rate and direction of groundwater flow must be considered for larger reservoirs. Contamination of the water supply is much more critical because there are greater possibilities and types of pollution. Disposal of sewage and industrial wastes and their effects on the water supply must be controlled. The other considerations relating to groundwater in such situations have already been mentioned.

There is another area of water resources management about which nothing has been said, and that is in the area of flood prediction and prevention. Though prevention may be largely an engineering problem, knowledge of geologic factors enables us to predict where possible flooding may occur, and possibly be prevented. The floodplains of rivers are susceptible to frequent flooding, as we well know in North Dakota. Certain farming practices which strip the land of its vegetative cover help to increase runoff, forcing streams to carry greater amounts of water. Urbanization, too, has had its effects in this respect. When we cover the land with streets and houses, we decrease the amount of land available to absorb the water that falls as rain or snow. This water, then, has no place to go but into a homeowner's basement or through sewer systems into rivers and streams. This also increases the amount of water that a stream must carry, thereby greatly increasing the chances for flooding to occur. With the help of the geologist, areas where groundwater recharge takes place can be located. By leaving these areas open, much of the precipitation that falls can be added to the groundwater system rather than to surface runoff.

MINERAL RESOURCES DEVELOPMENT

We have now looked briefly at three of the areas in which geology helps to improve our environment. This brings us to the last and certainly one of the most complicated aspects of environmental geology, the problem of mineral resources development.

When we hear the term "mineral resources" we immediately conjure up visions of gold and silver mines or oil wells. This is understandable, for these kinds of deposits have an air of romance about them and certainly represent great amounts of wealth. There are, however, other kinds of mineral resources which don't seem very romantic or particularly valuable but are nonetheless just as important. These are what are sometimes called the "growth minerals."

Growth minerals include sand, gravel, shale, clay, cement rock, and crushed stone. They are called growth minerals because as a population expands, so does the need for these types of minerals. These minerals are the basic units in building our highways, streets, homes, and schools, just to mention a few examples. Without them or at least without adequate supplies, construction costs would be astronomical. As a result, area development, especially urban development, would occur with difficulty and only at considerable expense.

In the search for new minerals, the role of the geologist today is the same as it has always been. He continues to pursue his traditional role of exploration for commercially usable resources, evaluation of geology for engineering purposes, and the location of groundwater supplies. However, as the population expands and our cities grow larger, his role has become more exacting. Not only does he have to find the raw resources, but he must recommend development of these in such a manner that they are of maximum benefit.

Mineral production and processing installations, such as gravel pits or rock quarries, generally have a poor public image. In the past it has been the practice of producers to remove all the commercially usable rock and then move on when the supply was exhausted or the cost-profit ratio was no longer satisfactory. The result has been to produce both eyesores and potentially hazardous situations. As a result, people try to prevent producers from developing these mineral deposits near urban areas, and the potentially usable resources nearby are no longer available for exploitation. The problem is then compounded by the fact that as producers have to go farther for their raw materials, shipping costs go up. This cost increase is, of course, ultimately passed on to the consumer.

In many places, urban development has occurred on top of deposits that could be a source for building materials. Restrictive zoning ordinances further prevent the removal and use of these materials. A prime example of this is Denver, Colorado, where almost one-third of its 925 million tons of sand and gravel reserves are no longer available because of construction built on them. Such a condition could very easily arise in North Dakota. The cities of Bismarck, Mandan, Minot, Jamestown, Valley City, and Williston are all built, at least partly, over sand and gravel deposits. Although, in most instances, adequate additional resources exist to assure future growth needs, care must be taken as these cities expand to protect the gravel supplies so these sources are not cut off.

The problems related to growth minerals production didn't arise overnight, nor are they going to be solved any faster. Industrial minerals producers are becoming increasingly aware of the need to educate the public about their proper and useful role, not only in the community's economy, but also in the wise sequential use of land in the community. Attitudes of the communities involved have also taken a different outlook. Not only does good planning hold down construction costs in the area, it also provides employment and a source for local tax revenue. The impetus in this change of community attitudes has been derived from a concept of land use that has emerged only in recent years--the *multiple land use concept* (Fig. 11).

The concept of multiple land use means just what it says - use of a specific area of land for more than one purpose. For example, a former gravel pit can be used as a sanitary land fill, covered up, and eventually used as a park or playground or even a homesite. A college in Missouri used an abandoned limestone quarry as a site for its football stadium. Open pit quarries have also been used for locating shopping centers, drive-in theaters, or petroleum storage tanks. Some have been developed as fishing and recreation lakes.

The geologist has an important role in multiple land use practices. His duties in such programs begin with the exploration for mineral deposits and continue through the planning and exploitation of that deposit. All through this process the geologist is concerned with finding another use for the land after the mineral producer is gone. It is the geologic setting that helps to determine to what subsequent use this land can be put.

FIGURE 11. An abandoned dragline pit in Burleigh County shows the effects of multiple land use. The pond and associated vegetation add beauty and utility to an area in which such features are not common.

IN SUMMARY . . .

Environmental geology is a relatively new and challenging field. The geologist is primarily concerned with four broad areas of study: (1) physical planning, (2) management and disposal of wastes, (3) water resources development, and (4) mineral resources development. This is not meant to imply that the environmental geologist works exclusively within one area; environmental geology is much too complex for that. It is almost impossible to work in one area without at least touching upon the other three. Environmental geology is not just concerned with urban areas but can and should also be applied to rural areas.

We have taken only a brief look at the role of environmental geology in modern society. Each situation has its unique set of circumstances, and the environmental geologist has to approach each problem differently. Examples of such problems are endless and so are the solutions.

SELECTED REFERENCES

1. Bell, G. L., 1968, Engineering geology of Interstate Highway 94 underpass at Northern Pacific Railway, Fargo, North Dakota: Eng. Geol. Case Hist. No. 6, Kiersch, G. A., Editor, p. 49-53.

2. Bergstrom, R. E., 1968, Disposal of wastes: scientific and administrative considerations: Ill. State Geol. Survey Env. Geol. Notes No. 20, 12 p.

3. Flawn, P. T., and Burket, J. M., 1965, Urban geology of greater Waco, Pt. I: Geology: Baylor Univ. Press; Waco, Texas, 45 p.

4. Frye, J. C., 1967, Geological information for managing the environment: Ill. State Geol. Survey Env. Notes No. 18, 12 p.

5. Hackett, J. E., 1966, An application of geologic information to land use in the Chicago metropolitan region: Ill. State Geol. Survey Env. Geol. Notes No. 8, 6 p.

6. Hackett, J. E., 1968, Geologic factors in community development at Naperville, Illinois: Ill. State Geol. Survey Env. Geol. Notes No. 22, 16 p.

7. Hayes, W. C., 1969, Environmental geology in town and country: Missouri Geol. Survey Ed. Ser. No. 2, 42 p.

8. Hughes, G. M., 1967, Selection of refuse disposal sites in northeastern Illinois: Ill. State Geol. Survey Eng. Geol. Notes No. 17, 26 p.

9. Risser, H. E., 1965, Problems in providing minerals for an expanding population: Ill. State Geol. Survey Env. Geol. Notes No. 5, 6 p.

10. Risser, H. E., and Major, R. L., 1967, Urban expansion - an opportunity and a challenge to industrial mineral producers: Ill. State Geol. Survey Env. Geol. Notes No. 16, 19 p.

11. Scott, G. R., 1969, General and engineering geology of the northern part of Pueblo, Colorado: U. S. G. S. Bull. 1262, 131 p.