GEOLOGY OF THE PEMBINA HILLS

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INTRODUCTION

PERHAPS some reading this article do not entirely understand just what geology is and would like to know more about the subject. Briefly, geology deals with the formation of rocks and minerals and their uses, the study of the origin and development of the earth, and the formation of the landscape of the earth's surface. In short, geology, is a historical study but deals with history in a more ancient sense than that about which we are commonly accustomed to thinking.

To understand properly many geologic ideas it is necessary to have an active but constructive imagination. In the course of this story you will be asked to imagine various geologic situations which may cause you to wonder, but be assured that in most cases the statements made are backed by facts. However, in a short article such as this there is not sufficient space to give all the data on which these statements are based.

Geologists have broken down the rocks into various divisions representing divisions of geologic time. We will not discuss all these in this article, but for purposes of reference, the main divisions of geologic time are given in Table I. The years given are approximate only, but are based on data derived from radioactivity studies. The part of the time table of interest to us in the Pembina Mountains starts only with the upper part of the Cretaceous, approximately 100,000,000 years ago.

Bed Rock Geology

In your mind cast away all that you know about the Pembina Mountains as you see them today and try to visualize the area as it was in Upper Cretaceous time. The seas as we know them now are different from what they were then and at the beginning of Upper Cretaceous time they were beginning to spread into the interior of the continent from both the Arctic and the Gulf. Before Cretaceous time ended, this seaway extended 3,000 miles north-south and from approximately central Minnesota to the Rockies.

This great seaway was bordered on the east by a relatively low land area and on the west by a fairly high land mass. Both land areas were undergoing erosion and were furnishing large amounts of sediment to the sea. This sediment makes the great masses of shale which we see in the Pembina Mountains today. The sea varied in depth from very shallow to deep—but how deep we do not know.

TABLE I.

	Years Ago
Cenozoic Era	
Recent Period	
Pleistocene Period	
Pliocene Period	
Miocene Period	
Oligocene Period	
Eocene Period	
Paleocene Period	
	70,000,000
Mesozoic Era	
Cretaceous Period	
Jurassic Period	
Triassic Period	
	190,000,000
Paleozoic Era	
Permian Period	
Pennsylvanian Period	
Mississippian Period	
Devonian Period	
Silurian Period	
Ordovician Period	
Cambrian Period	
	500,000,000
Cryptozoic Era	
Beginning of Earth	2,000,000,000 (?)

Now get your imagination working. You are in a position where you can watch geologic time unfold as far as this area is concerned. At the beginning of Upper Cretaceous time the sea began to lap eastward onto the old land area mentioned above. The shores of this sea were weedy and the water nearer the shore was so muddy and shallow that most sea animals were unable to live there. It was then an environment of brackish-water swamps similar in many respects to present day swamps along the Atlantic Coast. The sea continued to rise and spread eastward thus blanketing the area with a relatively thin layer of sand and mud containing plants which later became plant fossils. This layer forms the famous Dakota sandstone which yields so much artesian water in the southeastern part of the state. It is probably present below ground in the Pembina Mountain area but does not show at the surface.

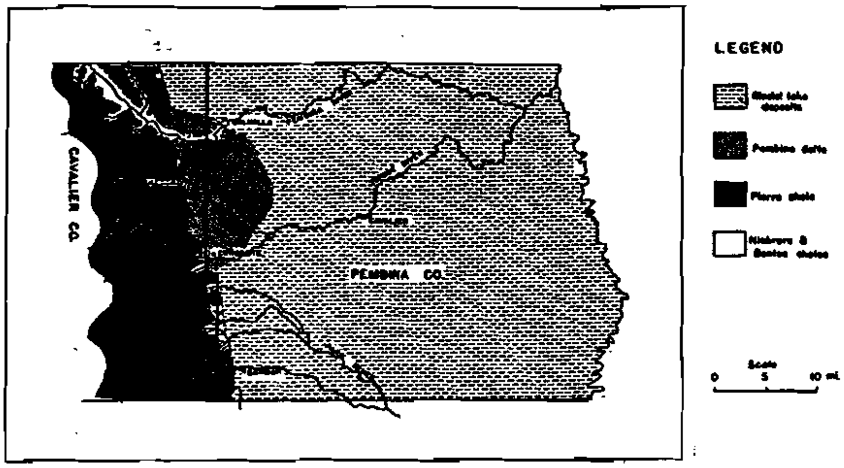
After the deposition of the Dakota, the sea apparently deepened, and only black carbonaceous clays of the Benton formation were deposited in the water. Later, the living conditions in the sea improved, and it was during this time that the gray clays making up the Niobrara formation were laid down. They are now gray limy shales which at the top are almost limestone because of the high lime content. This upper material is famous "cement" rock of the area which was, at one time, used in the manufacture of natural cement. (See Figures 1, Geologic Map of Pembina Mountain Area.)

During Niobrara time, life was much more abundant. Fish were apparently abundant in the sea, but interestingly enough, very few fish skeletons are found here. Fish scales, however, are abundant in some localities. The bones of a *Mososaur*, a prehistoric swimming reptile, have been found in the Niobrara rocks in the Pembina Mountains. Shell life which lived on the sea bottom is not so abundantly preserved as fossils.

One tiny animal fossil, microscopic in size, which is found abundantly in the upper part of the Niobrara formation is *Globigerina*. You can't see this fossil readily with the naked eye, so you need your magnifying glass. This tiny animal lived in great profusion in the surface waters and still lives in the sea today. When it died, its shell fell to the bottom and was buried in the clays accumulating there.

Following the deposition of the Niobrara shales, there occurred the deposition of other clays of a special nature. These are the "fullers earth" clays at the base of the overlying Pierre formation. These clays were apparently deposited in the sea, but their original sources may have been hundreds of miles away in a volcano. If these clays are volcanic in origin, they are what the geologist calls bentonite or altered volcanic ash. If they are not bentonites, the exact explanation for them is unknown to the writer. The "fullers earth" clays of the Pembina Mountains have been further altered by the leaching action of acids developed by weathering of certain iron sulfide (pyrite) minerals in the overlying beds. These clays are only 8-10 feet thick and are present mainly at the base of the Pierre formation.

The rest of the Pierre formation is a dark gray shale which locally contains abundant remains of the clam *Incoceramus*. Usually where these fossils are found, they occur in large masses cemented together, the masses sometimes being several feet across. These masses are called concretions, and their composition differs somewhat from the shale



enclosing them. What apparently happened was that living conditions were not good everywhere on the sea botton and seemingly the animals congregated in small groups. Their movements and life activities kept the water circulating to such an extent that the mud was not deposited so heavily on them and thus, they were not smothered to death.

After Pierre time, deposition of sediment in this area ceased until relatively recently during glacial time. After the deposition of the Pierre, the sea bottom was gradually uplifted, and erosion by running water began to take its toll. Imagine a flat muddy bottom emerging slowly above water with streams gradully forming on this surface. The streams began to cut valleys and eventually the area was worn down to a relatively flat surface which geologists call a peneplain. How many such surfaces were developed before the ice advanced over the area we do not know, but there are remnants of at least two such surfaces; the one represented by the top of the Pembina Mountains and the one below the lake deposits in the Red River Valley.

Physiographic Geology

By physiographic geology we mean the study of how the land surfaces and forms as we see them today came to be that way. Already, the development of erosion surfaces has been mentioned. Let's see how those surfaces looked before they were covered by the ice from the north.

Let us look first at the upper surface of the Pembina Mountains. We know that today they show a relatively level, slightly rolling surface. In other words the mountains are just the eroded eastern edge of a plateau surface. With slight modification, that is probably what they looked like before the ice covered them.

However, the area to the east of the mountains in the present Red River Valley probably looked considerably different from what it does now. It was a low area topographically, but it was not level as we see it today. The Red River drained north then as it does now, but it probably had many more tributaries which cut the land up into many river systems tributary to the Red. In the words of the geologist, it was probably a much dissected country.

Then came the glaciers. During some of the latter part of the time that the erosion described in the preceding paragraphs had been going on in the Pembina Mountains, the climatic conditions far to the north had been slowly changing. The average annual temperature had been falling and the snowfalls each winter had been greater with the result that each summer ended with some snow from the preceding winter still unmelted. Thus the snow accumulated year after year and finally began to compact into ice.

Finally, the ice accumulated to such thicknesses that it began to flow outward from the thickest areas, superficially much like the flow of asphalt. One of these tongues moved down over North Dakota and Minnesota—not once, but several times.

Now let us consider what geologic work this ice did. First by its very weight, it gouged and pried out the soil and rocks over which it was passing. This material became incorporated into the ice and was carried along. When the ice got far enough south or the climate warmed up enough, the southern edge of the ice began to melt and the rock material being carried began to drop out of the ice. This material was all mixed up with rocks of large size imbedded in clays. This type of deposit we call glacial till or glacial drift. Today it blankets almost three-fourths of North Dakota.

Now while the ice was doing all the work mentioned above, it was also having another important secondary effect. This was the damming of the northward flowing streams such as the Red River and the Souris River. Obviously, these streams could not use their old outlets to the Hudson Bay, so they were ponded, making large lakes. The lakes formed were called Lake Agassiz and Lake Souris, respectively. As the ice front receeded northward, new and lower outlets were progessively formed, this causing the lake to lower their levels. At the various levels beaches were formend and these beaches today are distinctive land marks in the Red River Valley.

Of special interest to the Pembina Mountains area is the effect that Lake Souris had on the region. As the ice front kept receding, a way was finally opened for Lake Souris to drain eastward into Lake Agassiz. When this happened, the water rushed out with great force and was able in a relatively short time to cut the gorge of the Pembina River in the Pembina Mountains much deeper. This is a fairly deep cut as it is about 400 feet deep.

The material cut from the gorge was deposited in Lake Agassiz in the form of a great delta, the east front of which today is locally called the "First Mountain" as it rises sharply from the level plain immediately to the east. This delta is the sandy area well shown along Route 5 east of Walhalla. In the gravel pits and sand pits along this road, large pebbles and cobbles of the Pierre and Niobrara shales cut from the gorge of the Pembina may be found.

After the ice disappeared entirely, the dominant agent in the formation of landscape has been running water. The streams are still downcutting in the mountain area, and thus the geologic story is brought up to date.

References for Further Reading

Barry, J. G. and Melsted, V. J., The geology of northeastern North Dakota with special reference to cement materials: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 115-225, 1908.

Leveritt, Frank, Quaternary geology of Minnesota and parts of adjacent states: U. S. Geol. Survey Prof. Paper 161, 149 pp., 1932.

Upham Warren, The Glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, 658 pp., 1895.

WAHPETON WILDLIFE FEDERATION ELECTS

Officers for the coming year elected by the Wahpeton Wildlife Federation are: Al Strong, President; Frank Rehm, Vice President; and Clifford Johnson, Secretary-Treasurer.