Discovery Heightens Interest In *North Dakota* Geology

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Part 1

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OIL IN NORTH DAKOTA was the encouraging word flashed around the state when Amerada Petroleum Corporation made a highly significant strike with Clarence Iverson 1 in SW SW 6-155n-95w, Williams County, further stimulating the already high interest in the state's geology. The well is considered North Dakota's first commercial oil discovery although it had not been completed as a producing well. The last test, before preparations to drill deeper were made, yielded 451 barrels of 53.4-gravity oil with 3.9 million cubic feet of gas in 16 hours through one-half-inch choke. At last report, drillers were trying to recover a lost bit from the hole before drilling deeper to evaluate lower horizons. Meantime, other locations have been rumored in this and nearby areas.

Putting even more emphasis on oil possibilities of this rarely explored state, are current reports of oil shows in a wildcat being drilled 155 miles southeast of Amerada's discovery. Although information is being closely held, several shows of oil have been reported from Phillips Petroleum Company and The Carter Oil Company's Patented 1, in NE NW 29-136n-81w, Morton County.

The Amerada producer was tested in what is believed to be beds of Devonian age, although there is some doubt as to the exact position in the Devonian. After drilling to 11,744 feet, casing was set and tubing run. Several tests were made near the bottom of the hole with some recovery before the zone 11,630-60 feet was perforated and acidized with a total of 10,000 gallons. It is through those perforations that production tests were made. The well was originally scheduled as a 10,000-foot basement test, and it was believed that Amerada intends to go to basement rocks in this venture before plugging back to the proven producing level.

A little more than a mile south of the discovery, a location for a test was announced by M. B. Rudman and Critchell Parsons of Dallas. This wildcat will probe Ordovician beds as well as the Devonian zone found by Amerada.

OIL PRODUCERS, influenced by successes in Western Canada, are taking a closer look at areas where similar conditions might be encountered. In North Dakota this interest is evidenced in large concentrations of leases taken during the past several years. It is obvious, from the present article, that the conditions necessary for oil accumulation (source rock, reservoir rock, and traps) are present in North Dakota. However, the main difficulty seems to be finding all three conditions suitable in one place. The writer is optimistic that such conditions can be encountered if enough wells are drilled.

The Phillips and Carter operation was reported drilling below 6490 feet toward a 9000-foot objective, and was said to have recovered oil on a test at the 5800-foot level. Another drill-stem test at about 6170 feet was also reported to have recovered 45-gravity oil.

Another encouraging show of oil was reported in Souris Valley Petroleum Company's J. H. Downey 1, in lsd. 11, Sect. 9, TWP. 1 n., R. 27 WPM., Province of Manitoba, Canada, just a few miles across the border from North Dakota. This show was logged in the Madison of Mississippian age. As will be noted below, Standard Oil Company of California's Daly 15-18 in lsd. 15, Sect. 18, TWP 10n., R. 27 W.P.M. has produced some oil from the Madison formation also. These wells, while not in North Dakota, are significant in that they are close to the state and the same geologic conditions which they indicate in Manitoba will almost of a certainty be found in North Dakota.

One pertinent reason why there is so much interest is that in the western part of the state is an extensive basin where approximately 14,000 feet of sedimentary rocks have been deposited. Several of these formations have been petroliferous in other parts of the U. S. and Canada, and there seems to be no reason why they should not be oil-bearing in North Dakota.

During 1950, four wells were drilled in North Dakota, all dry holes.

Because so few wells have been drilled in North Dakota, there is too little known concerning the subsurface stratigraphy of the state, particularly the Paleozoic. These rocks are known only from about 17 wells in the state proper and from the surface outcrops of the formations in Manitoba, Montana, and the Black Hills of South Dakota.

In view of the fact that the state consists of more than 70,000 square miles and that there have been only about 17 wells drilled, not all of these penetrating the entire sedimentary section, all present conclusions in regard to the stratigraphy of the Paleozoic particularly, must be regarded as tentative. Undoubtedly there will be many changes of opinion as more wells are drilled.

Structure of State

The general structure of North Dakota is that of a large basin called the Williston Basin. This is a general area of downsinking which apparently was active from Ordovician time up to and including the later part of the Tertiary. This basin of downsinking is one of several on the shelf area of the main geosynclinal trough which is now the present site of the Rocky Mountains in the U. S. and Canada. This basin is of interest because it has not always been in identically the same spot. During various periods it has migrated slightly, but in general its location is that outlined on the structure map, Figure 1, showing the contours drawn on the top of the Dakota sandstone.

On this general feature there are superimposed a number of smaller structures, some of which are still fairly large. One of these (the Nesson Anticline) is the largest known anticline in the state. It is located in the northern part of McKenzie County and the southern part of Williams County. It has been reported that a number of seismic highs are located on this main trend; however, the present writer has seen no seismic map which would confirm this. Another structure of some size is in the central part of Emmons County extending into Logan and McIntosh counties.

Numerous minor structures are in other parts of the state. There is some question, however, whether these are due to diastrophic movements or whether they might be compaction features. In either event they are of interest because they do show small amounts of closure.

From the standpoint of suitable traps for oil accumulation, it is the writer's opinion that most attention must be placed on stratigraphic type traps. In North Dakota the varieties of this type which are most likely to be found are unconformities, reefs, and various types of wedge-out conditions. Therefore, proper knowledge and interpretation of the stratigraphy is vital.

Stratigraphy

GENERAL: In general it can be said that all formations in North Dakota thin eastward out of the basin (Figure 2). They also thin to the southeast and northeast. Toward the west, however, they tend to thicken, but some thin shortly after passing into Montana. The relationships of the formations in North Dakota with those of Western Canada are not entirely clear. This is due to a lack of information, and as soon as more wells are drilled, the relationship will undoubtedly become clearer.

CAMBRIAN: So far as is known, the Cambrian extends only a short distance into the state. The only well in which there is positive evidence that it is present is Carter N. P. 1 in Fallon County, Montana. There it consists of ". . . interbedded green shale and dolomite overlying a basal glauconitic sandstone."[1] Some observers would place it also in a number of other wells in the state but no general agreement on this has been reached.

ORDOVICIAN: The Ordovician is one of the most extensive of the Paleozoic formations in the state. It is known in practically every well drilled deep enough to encounter it. In general it can be divided into three formations. These are, from the bottom up, the Winnipeg, Red River, and Stony Mountain. The exact age of these particular formations in terms of the standard section is not exactly known; but probably the Red River and Stony Mountain formations are Upper Ordovician, and the Winnipeg formation may be approximately equivalent to the Chazy. The Winnipeg is from 100 to 535 feet thick and consists largely of gray-green shale, some sandstone, sandy limestone, and gray sandstone.

In some wells, notably that of the E. L. Semling well in Oliver County, North Dakota, the Winnipeg is rather largely shale with relatively little sandstone. However, in the Northern Ordinance Franklin Investment Company 1 in Emmons County, North Dakota, there is a considerable sand section present which has excellent porosity. When this well was drilled, it was found that the sandstone carried abundant water under considerable pressure. This water was relatively fresh, having an analysis of 2607 parts per million total dissolved solids, but there might be some question here if some drilling water rather than formation water were not tested. This sandstone, if found under proper conditions, would make an excellent reservoir rock. Overlying the Winnipeg formation is the Red River formation consisting largely of gray to tan, dense to granular, dolomitic, and sandy limestones. These limestones

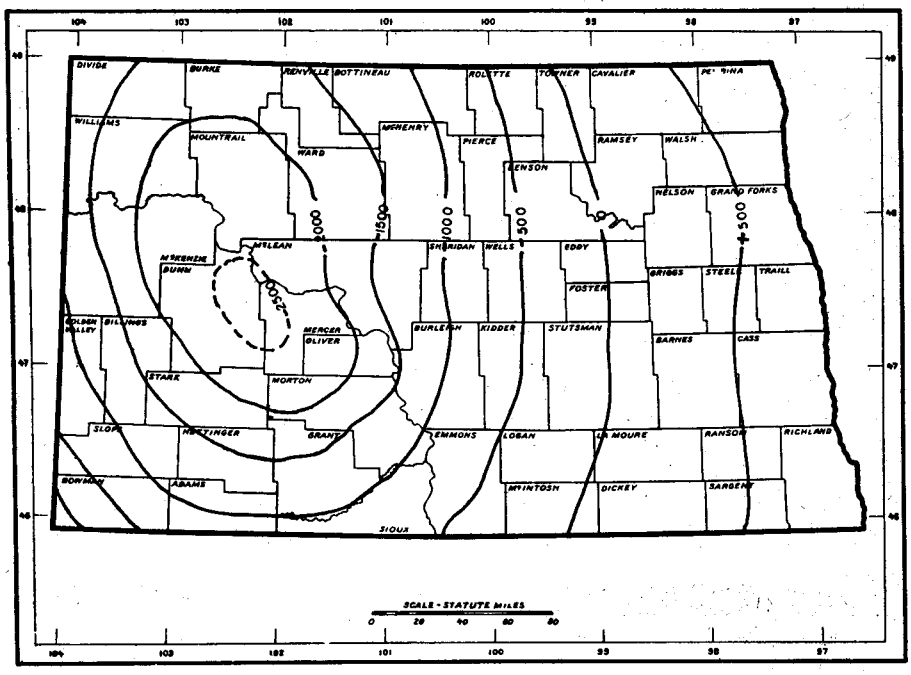

FIGURE 1. Structure map of the Dakota sandstone based on sea level datum.

frequently have in them zones of porosity which are of considerable interest although as yet no oil has been found in them. Overlying this is the Stony Mountain formation, from 100 to 500 feet thick, consisting of white dolomitic limestones and shale. On the outcrop in Manitoba this formation consists more of red and green shales and interbedded limestone.

SILURIAN: It was thought for some time that the Silurian was not present extensively except in the northern part of the state. However, reexamination of the cuttings from some of the deeper wells revealed that the Silurian probably is more extensive than was formerly thought. It is dense white dolomitic limestone with relatively little or no porosity in the wells that have been drilled to date. However, on the outcrop in Manitoba there are frequently biostromes in this formation, and also probably reefs of coral and associated organisms.

DEVONIAN: The Devonian in North Dakota is of considerable interest at the present time in view of the fact that it is one of the main petroliferous formations in the province of Alberta, Canada, and also, oil has been encountered in it in North Dakota, as stated earlier in this report. The Devonian in North Dakota apparently is most closely correlative with the surface outcrops of the Middle Devonian in Manitoba. In the latter locality the Devonian is apparently largely if not entirely Middle Devonian in age. Starting at the bottom, it consists of the Ashern formation which in North Dakota is estimated to be from 0 to 117 feet in thickness. It consists rather largely of red and variegated shales with some limestone. Some geologists place this unit in the Silurian; others classify it as Siluro-Devonian.

Overlying the Ashern is the Elm Point limestone, a rather thin formation totaling from 0 to 60 feet in thickness. It consists rather largely of a dense, mottled limestone which sometimes has a slightly saccharoidal texture.

The Winnipegosan formation overlies the Elm Point and varies from 0 to 660 feet in thickness. This is chiefly a dense to saccharoidal dolomite. It frequently has excellent porosity and unquestionably in some places reef-like beds have been encountered in this formation both at the surface and in the subsurface. Certainly at the outcrop, reefs have been found in this particular formation in southwestern Manitoba.

Manitoban Formation

Overlying the Winnipegosan formation is the Manitoban formation, which consists of buff and slightly pinkish, mottled limestone, some dolomite and anhydrite and varies from 0 to 250 feet in thickness. In the basal part of the section in the outcrop in Manitoba, the Manitoban sometimes has a red shale, dolomite and limestone interval.

The Manitoban is overlain by the Lyleton formation which has been named by Allan and Kerr.[2] It consists of calcareous red shales and some dolomites with a little sand and is 0 to 190 feet in thickness. This formation is regarded as probably being Upper Devonian in age.

As has been indicated, all the formations with the exception of the Lyleton are regarded Middle Devonian in age. It would appear, however, that in the western part of the state may be formations which are very similar in lithology to the Upper Devonian of Montana. In this part of the state the Devonian formations below the Lyleton consist of beds of dense to saccharoidal dark brown limestone and saccharoidal dolomites. Porosity of both a vugular and intergranular nature are present. These rocks, as has been indicated before, apparently are very close in their appearance lithologically to the Upper Devonian in Montana and may be the rough equivalents of the Potlatch interval of Montana. However, no positive fossil remains have yet been identified to place these rocks exactly in their proper stratigraphic position. Considerable amounts of salt and anhydrite also have been found associated with these beds. Whether or not the salt and anhydrite beds belong in the Devonian or in the underlying Silurian is as yet an unsolved problem. This age problem of the Devonian in North Dakota is an extremely interesting one, inasmuch as somewhere in the state probably the Upper Devonian overlies the Middle Devonian and, therefore, a wedge-out zone is possible within the state.

So far as is known to the writer, no beds of reef-like nature have as yet been encountered in beds which might be classified as Upper Devonian. However, Middle Devonian reef beds have been reported in several wells.

MISSISSIPPIAN: The Mississippian is also of great interest in view of the fact that shows have been found in beds of this age, notably the upper part of the Madison limestone. In general the Mississippian can be divided into several major groups. These are the Englewood or Kinder-

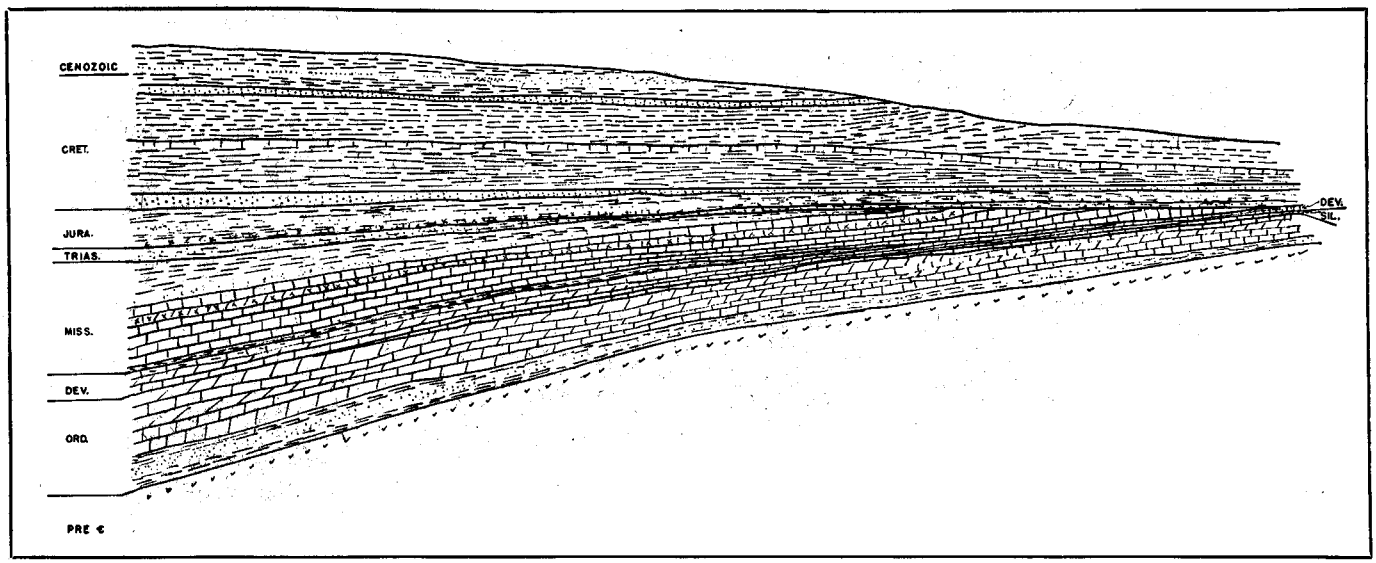

FIGURE 2. Diagrammatic east-west cross-section across North Dakota, based on the top of the Dakota sandstone.

hook beds, the Madison group, the Big Snowy group, and the Amsden formation.

The Englewood or Kinderhook formation consists of about 25 to 110 feet of rather dark carbonaceous shale, green-gray shale, some limestone, and gray siltstone or sandstone. This is apparently approximately equivalent with the black shale found at similar intervals practically everywhere in the U. S. It makes a fine marker bed and is present in the subsurface in most wells.

Overlying the Englewood is the Madison group, which can be divided into two formations, the Lodgepole below and the Mission Canyon above. In general the Lodgepole formation consists of 75 to 880 feet of gray to buff granular to dense limestone with considerable chert in some localities, especially in Montana. This is the thicker of the two formations in the Madison group. Overlying the Lodgepole is the Mission Canyon formation (80-530 feet thick) which consists of oolitic to fragmental, buff to light tan limestones which are sometimes cavernous at the surface. It is in the upper part of this formation where vugular porosity is frequently developed in which oil stain has been noted. Some free oil has been noted at this horizon in the J. H. Downey 1 of the Souris Valley Petroleum Company mentioned previously.

Overlying the Madison is the Big Snowy group, consisting of four formations, started from the base upward—the Charles, Kibbey, Otter, and Heath. The Charles is of considerable interest because it consists of a section of dolomitic limestones and considerable anhydrites and some variegated colored shales from 50 to 890 feet thick. There is considerable question as to whether or not the Charles should be separated from the underlying Madison, inasmuch as its lithology with the exception of the abundant anhydrites is similar. In fact, there is one large anhydrite, approximately 100 feet or so below the top of what is frequently called Madison. Some would include this anhydrite in the Charles; others include it in the Madison. There appears to be no clear-cut contact between the two formations. It has been suggested that the Charles may be the subsurface equivalent of the upper part of the Madison which does not show readily at the surface. Perhaps it has not been recognized due to the absence of the anhydrite at the surface. In any event, it was included originally in its definition by Seager in the basal part of the Big Snowy group.[3]

The Charles is overlain by the Kibbey formation, consisting of 60 to 300 feet of variegated shales with red and gray sandstones near the base. The sandstones are rather poorly sorted and therefore there is some question as to whether they would make a good oil-bearing horizon. However, oil has been found in the Kibbey in eastern Montana.

Overlying the Kibbey is the Otter, which in the outcrop is a bright green shale. In North Dakota, however, it is difficult if not impossible to separate the Otter from the overlying Heath. The Otter varies from 0 to 100 feet in thickness. Some anhydrite is noted in the Otter, and a limestone bed is sometimes present at the top.

Overlying the Otter is the Heath, which varies from 0 to 335 feet in thickness and consists of black carbonaceous shale, some gray to green shale, and dolomite, with some small lenticular sandstones occasionally present. These sandstones, which have produced oil in eastern Montana, appear to be in the nature of offshore bars.

Overlying the Heath is a controversial formation known as the Amsden. The Amsden varies from 0 to 250 feet in thickness in North Dakota, and consists of orange, red, purple dolomitic limestone, dolomite, and shale. The Amsden in North Dakota is herein being placed in the Mississippian, but there are several geologists who would place it in the Pennsylvanian. In any event, the lower part of the Amsden apparently is what is present in North Dakota, and if it is correlative with the lower part of the Amsden in Montana, it probably should be placed in the Mississippian. This, however, is an open question which must be solved when more data are available.

PENNSYLVANIAN: The writer does not believe the Pennsylvanian is present in North Dakota except perhaps in the southwestern corner of the state. There it is represented by the Minnelusa formation which varies from 0 to 200 feet in thickness. This formation consists rather largely of white anhydrite, sandstones and limestones and is not extensively developed.

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Part 2—CONCLUSION

CONCLUDING a discussion of oil possibilities in North Dakota, the author evaluates the Permian, Triassic, Jurassic, Cretaceous, The Cannonball-Ludlow and Pleistocene. He concludes that best prospects for oil and gas production are in Devonian beds, where abundant porosity has been found. Second in importance, he believes, are Mississippian beds, notably the upper part of the Madison formation.

PERMIAN: The Permian is also poorly represented in North Dakota. It is known largely from the Carter N. P. 1 well in Fallon County, Montana. There it consists of two formations. The Opeche formation is found at the base of the Permian and in the well mentioned it is 88 feet thick. The lithology consists of red shale and anhydrite. It is overlain by the Minnekahta formation which in the Carter well is 40 feet thick. This formation consists of purple dolomite and limestones.

TRIASSIC: The Triassic is represented by the Spearfish formation which consists rather largely of reddish, medium-to-fine-grain sandstones, and some red and gray silty shale. Some gray and black shales and anhydrites are also present. The thickness of the formation varies from 30 to 895 feet. There is some question as to the extension of the Spearfish this far from its type area in the northern part of the Black Hills. The difficulty is that the lithology of the Spearfish is very similar to parts of the lithology of the basal part of the Big Snowy group and also to the basal part of the overlying Jurassic. They might easily be misidentified if the upper part of the Big Snowy were missing.

JURASSIC: The Jurassic in North Dakota is represented by the Morrison formation and by what is frequently called the Sundance formation. The writer would prefer to call this the Ellis group. The Ellis group in Montana has been subdivided into three formations—the Sawtooth or Piper, the Rierdon, and the Swift, starting from the base upward. The Sawtooth is the thickest of the three and consists rather largely of evaporitic sequence which includes limestones, anhydrites, and some shale. At the top of the Sawtooth or the base of the Rierdon is an oolitic lime-

stone or microconglomerate which is quite consistent, making it an excellent marker bed. It is overlain by the Rierdon, largely a black and gray shale sequence with some oolitic and dense limestones. The Rierdon is overlain by the Swift formation which consists of glauconitic sandstones and some gray-green shale. The Swift is of some interest from the standpoint of oil development as it might provide a suitable reservoir rock. However, as the formation is traced eastward from its outcrop in Montana, it becomes increasingly more shaly with the result that it is very difficult in the subsurface to distinguish it from the underlying Rierdon. The total thickness of the Sundance or Ellis formation varies from 90 to 895 feet.

Overlying the Sundance or Ellis formation is the Morrison formation which consists of gray, green, and variegated shales and shaly sandstones. It varies from 0 to 260 feet in thickness in North Dakota. It is difficult to distinguish in the subsurface, but usually is identified as a shale interval present between the upper part of the Ellis on one hand and the basal part of the Dakota group on the other.

TABLE I
Geologic Formations in North Dakota

CENOZOIC	Olig.				White River formation 50–200′ clays, shales, limestone, sandstone.	
	Eocene	Wasatch Stage			Golden Valley formation 100–200′ light-colored clay, ash, sandstone.	
	Paleocene	Fort Union Stage			Tongue River formation 200–800′ light-colored and dark-colored calcareous shale and sandstone and lignite.	
					Cannonball-Ludlow formation 0–360′ marine sands, clays, Ludlow 0–250′ lignite, shale and sandstone.	
MESOZOIC	Cretaceous	Upper			Hell Creek formation 100–575′ grey bentonitic sandstone and shale, lignitic shale and concretions.	
			Montana Stage		Fox Hills 180–320′ brown to grey sandstone with ironstone concretions.	
					Pierre formation 930–2300′ grey shales and ironstone concretions.	
			Colorado Stage		Niobrara formation 80–100′ grey shale and "cement rock."	
					Benton formation 90–1360′ dark grey shale.	
					Dakota formation 10–300′ micaceous white sandstone with pyrite, gypsum and lignite.	
		Lower			Fuson formation 50–150′ grey shale, sandy shale and sandstone.	
					Lakota formation 20–190′ white sandstone with little shale.	
	Jurassic				Morrison formation 0–260′ grey and green shale and shaly sandstone.	
					Sundance formation 90–895′ glauconitic sandstone, green shale, sandstone and shaly limestone with gypsum.	
	Tris.				Spearfish formation 30–895′ red sandstone and red shale, brown sandstone, red shale and red evaporites.	
PALEOZOIC	Permian				Minnekahta formation 40′ purple dolomite and limestone. Not extensively developed in the state.	
					Opeche formation 88′ red shale and anhydrite. Not extensively developed in the state.	
	Pa.				Minnelusa formation 0–200′ white and reddish sandstone. Not extensively developed in the state.	
	Mississippian	Tennessean	Meramec-Chester		Amsden formation 0–250′ orange, red, purple dolomite limestone shale.	
				Big Snowy Group	Heath formation 0–335′ black carbonaceous shale, grey to green shale, dolomite.	
					Otter formation 0–100′ varicolored shale and anhydrite.	
					Kibbey formation 60–300′ varicolored shale and fine grey sandstone near base.	
					Charles formation 50–890′ brown buff dolomite limestone, grey and white anhydrite, varicolored shale.	
		Waverlyan	Osage	Madison Group	Mission Canyon formation 80–530′ granular and oolitic buff limestone.	
					Lodgepole formation 75–880′ grey to buff granular to finely crystalline limestone.	
			Kinderhook		Englewood formation 25–110′ carbonaceous shale, limestone, grey shale and siltstone.	
	Devonian				Lyleton formation 0–190′ calcareous red shale.	
					Manitoban formation 0–250′ granular buff limestone, dolomite and anhydrite.	
					Winnipegosan formation 0–660′ granular and dense grey to brown limestone and dolomite.	
					Elm Point 0–60′.	
					Ashern 0–117′.	
	Silurian system 0–150′.					
	Ordovician				Stony Mountain formation 100–500′ dense to granular buff to white dolomitic limestone and varicolored shale.	
					Red River formation 100–600′ grey to tan dense to granular dolomitic and sandy limestone.	
					Winnipeg formation 100–535′ green shale, conglomeratic sandstone.	
	Cambrian 60–220′ green shale, and dolomite, glauconitic sandstone.					
	Pre-Cambrian granite and amphibolite.					

CRETACEOUS: The Cretaceous is inaugurated by a group of sandstones and shales which have been called collectively the Dakota group. A recent author,[4] however, would term this group the Inyan Kara and would discard the term Dakota altogether apparently. His terminology would be, starting from the base, Dakota sandstone, Fuson shale, and Fall River standstone. It would appear that the formation herein called the Dakota sandstone formation would probably be correlative with his Fall River sandstone. He places the whole group plus part of the overlying sequence which is called herein the Banton formation, in the lower Cretaceous. Sufficient study of North Dakota Cretaceous stratigraphy has not been made as yet to pass an opinion as to the exact age of these formations. It would appear, however, that the Dakota sea was a transgressing one and therefore the formations in North Dakota might be somewhat younger than those present in the type area in South Dakota.

The Dakota group consists of a series of clean white to dirty gray sandstones and interbedded gray shale. It is difficult if not impossible in some wells to distinguish the three formations shown in Table 1. The Dakota is famous for the amount of artesian water it produces. Some small amounts of gas associated with water have been found in the southeastern part of North Dakota. An approximate correlative of the Dakota group, the Viking sand in Alberta and Saskatchewan, does produce some oil. It might conceivably produce some in North Dakota although little encouragement for this can be given.

Above the Dakota but separated from it by a shale interval, is a sand and shale sequence tentatively being correlated with the Muddy sand. It varies from 0 to perhaps 90 feet in thickness. It lenses out rapidly eastward from the center of the basin and quite possibly could contain oil. It deserves more consideration and thought than has thus far been given it, especially as it is relatively shallow.

Overlying the Dakota group is a large section of Cretaceous shales. In

North Dakota in general these shales are divided only into the larger headings, notably the Benton, Niobrara, and Pierre. The Benton formation is from 90 to 1360 feet thick and consists rather largely of a dark gray, usually non-calcareous shale. It is in turn overlain by the Niobrara formation varying in thickness from 80 to 800 feet of rather largely gray shale with "cement" rock, a very calcareous shale, at the top. At the top also are a number of fossils, notably the "Globigerina." These zones containing the Globigerina are sometimes called the white speckled zones and there seem to be several in the Niobrara. Just exactly whether or not these can be used as marker beds is not known at present.

The Pierre formation overlies the Niobrara and is from 930 to 2300 feet thick. This is largely an extensive gray shale sequence. At the base on the outcrop of the northeastern corner of North Dakota is a bed of the so-called "Fuller's earth" which appears to be a badly leached bentonitic shale. Whether or not this can be found in the subsurface is doubtful. In any event, it is a good marker at the surface.

Overlying the Pierre is the Fox Hills formation. This is the last great Cretaceous marine incursion into North Dakota. It consists rather largely of gray glauconitic sandstone and interbedded greenish-gray marine shale and varies in thickness from 180 to 320 feet. It outcrops in the central part of the state along the Missouri River and its tributaries not too far distant from the South Dakota border. It is also found at the surface in the southwestern corner of the state in Bowman County.

The uppermost Cretaceous formation is the Hell Creek. This is largely a continental formation consisting of fine-grained, argillaceous sandstone, lignitic shales, and some thin lignites. It is approximately 100 to 575 feet thick and contains at its base a small, thin marine bed which is fossiliferous. This member has been called the Brien sandstone for a town of that name in the southern part of Morton County, North Dakota. The Hell Creek formation is characterized by non-marine fossils, notably the remains of the dinosaur Triceratops.

TERTIARY: The Cannonball-Ludlow formations represent a transitional marine-non-marine sequence. From the Missouri River west for about 50 miles, the Cannonball formation is found well developed. It consists of fossiliferous marine sands interbedded with green-gray to black marine shales. It intergrades with the Ludlow formation which takes its place as the Cannonball disappears westward. The westernmost extent noted of the Cannonball is on the Little Missouri in Slope County. The Ludlow averages from 0 to 250 feet in thickness and is entirely a non-marine sequence consisting largely of lignite, shales, and sandstones.

Overlying the Cannonball-Ludlow is the Tongue River formation, averaging 200 to 800 feet in thickness. The top is seldom seen in view of the fact that a considerable erosional disconformity is found at its top. This formation consists of light- and dark-colored calcareous shales and sandstones and lignite. This formation is the main lignite-bearing formation of North Dakota.

The Tongue River is overlain by the Golden Valley, which varies from 100 to 200 feet in thickness. This consists of a light-colored clay, ash, and sandstone sequence in which the sands are fine-grained and micaceous. The amounts of clays and shales are minor, but in the basal part of the formation there is a sequence of hard, white to dark gray clays and local lignites which are frequently mottled with yellow upon weathering. This makes the bed an excellent barker bed where it is exposed.

About the Author

DR. WILSON M. LAIRD, state geologist of North Dakota, graduated from Muskingum College with a B.A. degree in 1936. He obtained his Master's degree from the University of North Carolina in 1938 and his Ph.D. from the University of Cincinnati in 1942. He was assistant professor of geology, University of North Dakota in 1940-42; associate professor in 1942-46; and was appointed state geologist in 1941 and professor in 1946. He also served on field and survey sessions for the Pennsylvania Geological Survey and the U. S. Geological Survey and has acted as consultant for various oil companies since 1948. In 1950 he was elected president of the Association of American State Geologists.

Overlying the Golden Valley formation of Eocene age is the White River formation of Oligocene age. This consists of an erratic-occurring formation from 50 to 200 feet in thickness of shales, clays, limestones, and sandstones. It caps only the higher buttes of the state, and is known from very local occurrences in the southwestern corner of North Dakota. It is not extensive and apparently represents river and local lake deposits in the latest part of the Cenozoic.

PLEISTOCENE: Most of the eastern and northern part of the state is overlain by a sequence of glacial materials largely of Wisconsin age. These formations are not of interest from the standpoint of oil geology except for the fact that they mask the beds which immediately underlie them. They also tend to make seismic prospecting somewhat difficult.

Oil and Gas Possibilities

It is the opinion of the writer that the best possibilities at present for oil and gas production lie in the beds of the Devonian. These beds of either Upper or Middle Devonian age apparently have abundant porosity, and the fact that they have produced oil, particularly in Alberta, makes them especially interesting.

Second in importance are those of the Mississippian beds, which contain a number of horizons which might produce. The most favorable of these from the standpoint of porosity is apparently the upper part of the Madison formation. Oil has been found in it in Souris Valley Petroleum Company's Downey 1 and there have been numerous shows in other wells. The Downey well recently was reported drilling at 4137 feet. At mid-April, some weeks after completion as a discovery well, Standard Oil Company of California's Daly 15-18 in Lsd 15, Sec. 18 twp., 10 n., r 27 w., p.m., near Virden, Manitoba, was pumping 7 barrels per day of 33 gravity dark brown oil and 16 barrels per day of water from a depth of 2200 to 2340 feet in beds which apparently are Madison equivalents.

Overlying the Madison is the Charles formation, which also has abundant porosity in its limestone. No oil has been found in this, but occasional oil stains have been noted.

Overlying the Charles is the Kibbey, a shale and standstone sequence, which might have sufficient porosity to produce oil. However, none has been noted in this formation in North Dakota. At the upper part of the Big Snowy group is the Heath formation. This formation is largely shale, but occasionally sand stringers are found

which in Montana have produced oil.

From the standpoint of secondary importance, the beds of the Ordovician offer a great deal from the standpoint of potential oil producers. Notably, attention should be called to the very porous zone in the upper part of the Red River formation. This zone has abundant porosity and should oil occur there, the wells should be large producers. In the basal part of the Ordovician in the Winnipeg sand section, excellent porosity has been noted in certain of the wells in the state, notably the Northern Ordinance Franklin Investment 1.

The Silurian is not extensively known in the state. As has been mentioned, however, it has biostromal lenses in the outcrop in Manitoba, and if such beds are found in the subsurface in North Dakota, they should certainly afford abundant porosity for the occurrence of oil.

The Dakota sandstone in North Dakota has been notable for its lack of petroleum. It has, however, produced in a number of other states, notably Wyoming, Montana, and as the Viking sands in Alberta and Saskatchewan. In North Dakota, however, it is abundantly supplied with water and so to date it has not given any indication that it would be an oil producer. However, in some of the old water wells in the southeastern part of the state, considerable amounts of gas have been encountered in this horizon.

The Muddy sand in the central and east-central part of North Dakota also shows significant porosity, which with its shallow depth should make it of interest.

The sands of the upper part of the Jurassic also might have some potential reservoir rock. However, these sands are erratic and do not appear to be too favorable from the standpoint of potential oil and gas horizons. The basal part of the Jurassic where numerous oolitic limestones are present might have some possibility as a potential oil producer.

REFERENCES

[1] Crowley, A. J., "Possible Lower Cretaceous Uplifting of Black Hills, Wyoming, and South Dakota," Amer. Assoc. of Petroleum Geologists Bull., Vol. 35, pp. 83-107, 1951.