North Dakota Geological Survey

WILSON M. LAIRD, *State Geologist*

Report of Investigation Number 31

Study Reveals . . .

MISSISSIPPIAN POSSIBILITIES

Report on Upper Madison group facies in northwestern North Dakota may improve correlation tasks.

By

SIDNEY B. ANDERSON, Head

Subsurface Division

Reprinted from

December, 1958, WORLD OIL

Grand Forks, North Dakota, 1958

Study Reveals . . .

Mississippian possibilities

Report on Upper Madison group facies in northwestern North Dakota may improve correlation tasks.

By Sidney B. Anderson
North Dakota Geological Survey, Grand Forks, N. D.

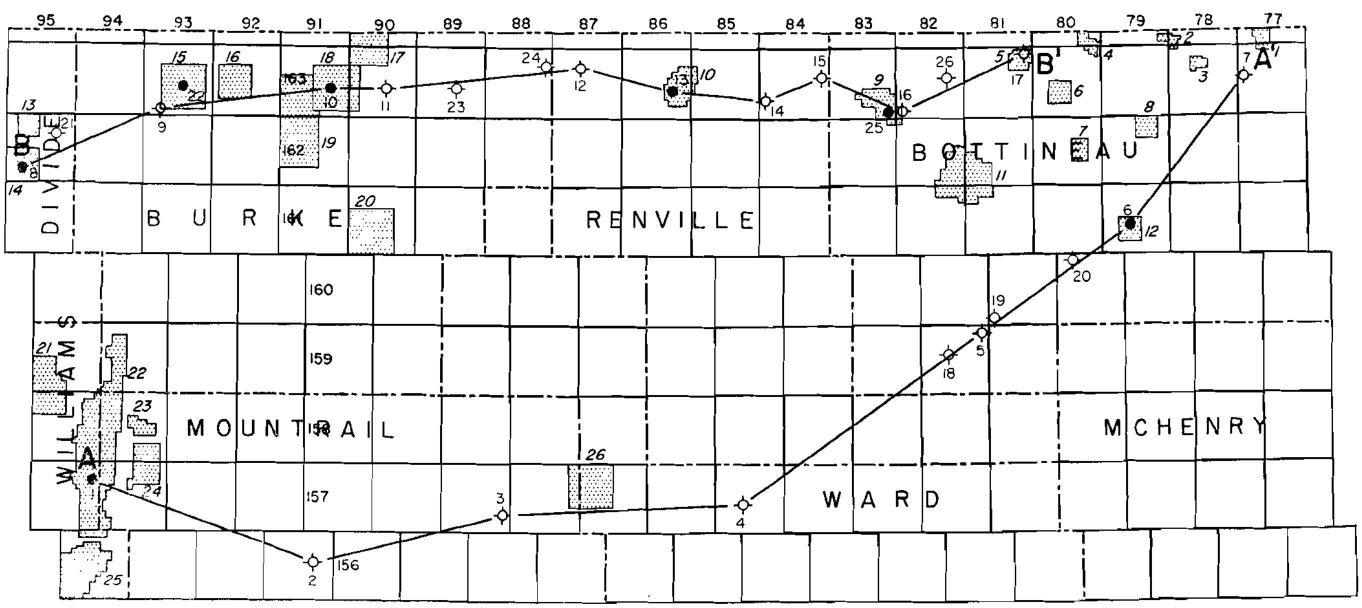
FACIES PROBLEMS of the Upper Madison group of Mississippian age in northwestern North Dakota long have been responsible for the confusion existing in correlation of the Mississippian system.

Names, definitions, correlations, occurrence, lithology and thickness of Madison group formations are offered in an effort to eliminate some of this confusion.

Description. Thickness of the Mississippian system is governed by regional thinning and post-Mississippian-pre-Triassic erosion. In the eastern half of the area, the Big Snowy group—which overlies the Madison group deeper in the Williston Basin—is missing; the Madison is unconformably overlain by the Spearfish "red beds" of Triassic or Jurassic age.

A secondary anhydrite cap has been deposited over most of the post-Mis-

FIGURE 1—Facies change in the Upper Madison group discussed extend from the northwestern to the northcentral portion of North Dakota in Townships 156 through 164 to the International Boundary within Ranges 77 through 95.



LEGEND

A — A' = LINES OF CROSS SECTION & WELL NUMBERS

5 = FIELDS & FIELD NUMBERS

1. NORTH SOURIS
2. NORTHEAST LANDA
3. SCANDIA
4. NORTH WESTHOPE
5. KUROKI
6. WESTHOPE
7. SOUTH WESTHOPE
8. LANDA
9. HAAS
10. BLUELL
11. WAYNE
12. NEWBURG
13. BAUKOL-NOONAN
14. NOONAN
15. COLUMBUS
16. RIVAL
17. ENTRY
18. FLAXTON
19. LIGNITE
20. COTEAU
21. McGREGOR
22. TIOGA
23. EAST TIOGA
24. WHITE EARTH
25. BEAVER LODGE
26. SOUTHWEST AURELIA

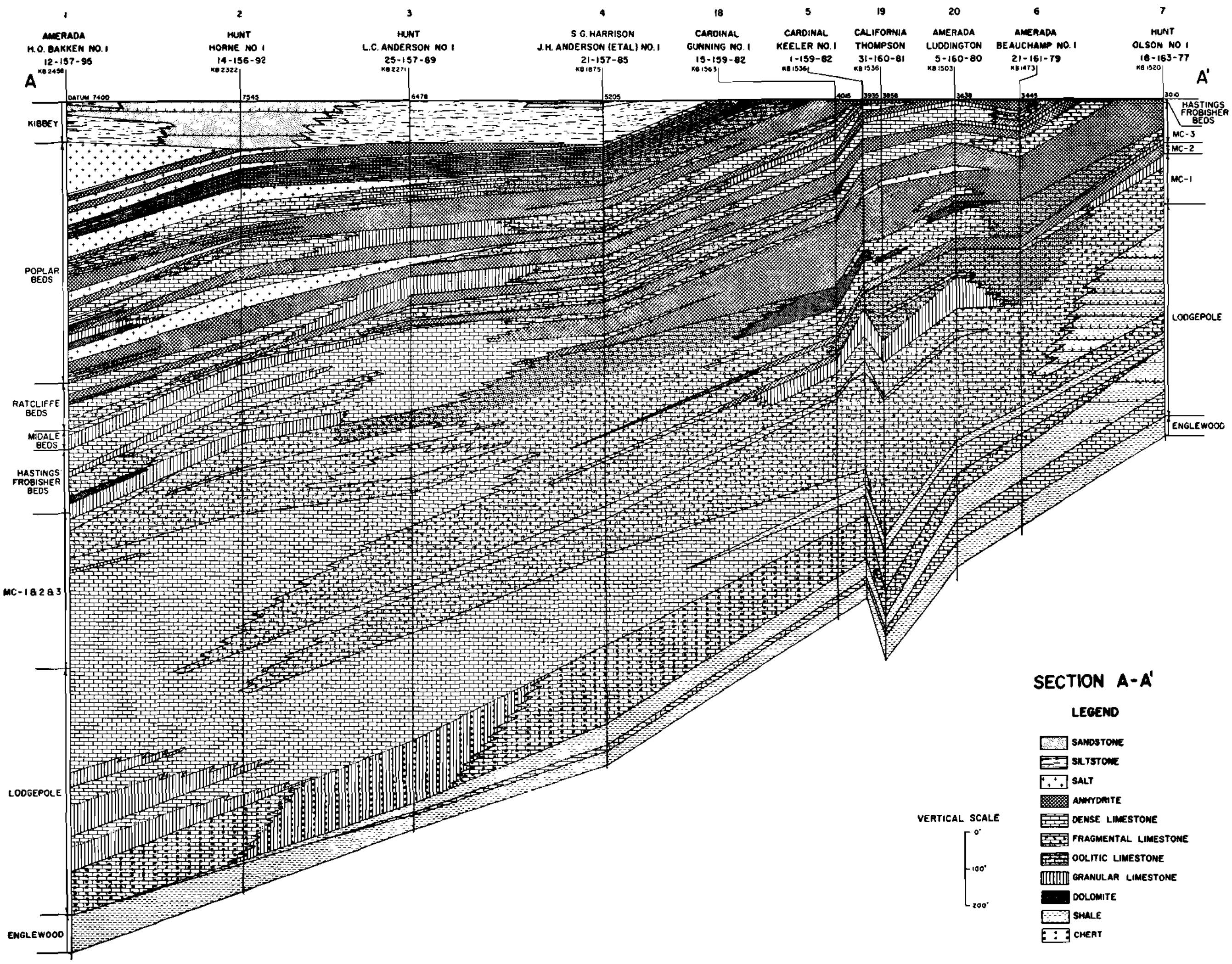


FIGURE 2—This geologic east-west cross section (A-A') extends from Amerada Petroleum Corporation's H. O. Bakken 1, Sec. 12-157-95, Williams County, to Hunt Oil Company's Oliver Olson 1, Sec. 18-163-77, Bottineau County. This line of cross-section was selected as the area to demonstrate a number of facies changes, and more of the deeper wells necessary for control have been drilled along the line of this section. Datum for this cross-section is the base of the Kibbey limestone, or, where the Kibbey has been removed by erosion, the post-Mississippian unconformity is used as a datum.

The most striking facies change occurring on this cross-section is between the Wm. H. Hunt-L. C. Anderson 1, Sec. 25-157-89, and the S. G. Harrison-J. H. Anderson et al 1, Sec. 21-157-85. A large limestone section in the Hunt-Anderson well changes to anhydrite in the Harrison-Anderson well in a distance of 20 miles. This may be due to a barrier which impeded the circulation of water and caused deposition of anhydrite on the east, or shoreward, side.

Several good possibilities for stratigraphic traps are shown at the unconformity—between the Cardinal-Gunning 1, Sec. 15-159-82, and the California-Thompson 1, Sec. 31-160-81.

This illustration indicates an anomalous feature in the east part of the cross-section, which shows the California Company's Blanche Thompson 1 located in Sec. 31-160-81 to be structurally low on the Englewood and Lodgepole, with a thickening in the upper Lodgepole and lower Mission Canyon. This appears to have been caused by salt solution in the Devonian Prairie Evaporite section with a subsequent collapse of overlying beds.

The Thompson well had no salt in the Prairie Evaporite section, while Cardinal Drilling Company's Keeler 1, Sec. 1-159-82, about two miles distant, had 160 feet of salt in the section. The salt collapse apparently occurred during late Lodgepole and early Mission Canyon time, as evidenced by thickening of these parts of the formations.

The extent of this area of salt collapse is unknown, but it may have formed structural traps, particularly in the upper Devonian and Mississippian Lodgepole. At any rate, it effected Mississippian sedimentation in the area of collapse. (Anderson and Hansen, 1957.)[2]

sissippian erosional surface. This anhydrite may form an effective seal over some of the porous beds that have been truncated by erosion, thereby forming excellent stratigraphic traps.

Several facies changes exist in the area under discussion, notably changes from a limestone facies to an anhydrite facies or from porous limestone to dense limestone. The latter also may form excellent stratigraphic traps.

These porous horizons may provide excellent oil and gas reservoirs if they meet one or more combinations of the following conditions:

- If they contain permeability barriers
- If they are associated with structure
- If they are truncated by the Mississippian unconformity and overlain by a secondary anhydrite acting as a seal.

Obviously, the easiest to find are the porous horizons associated with structure. The other conditions are

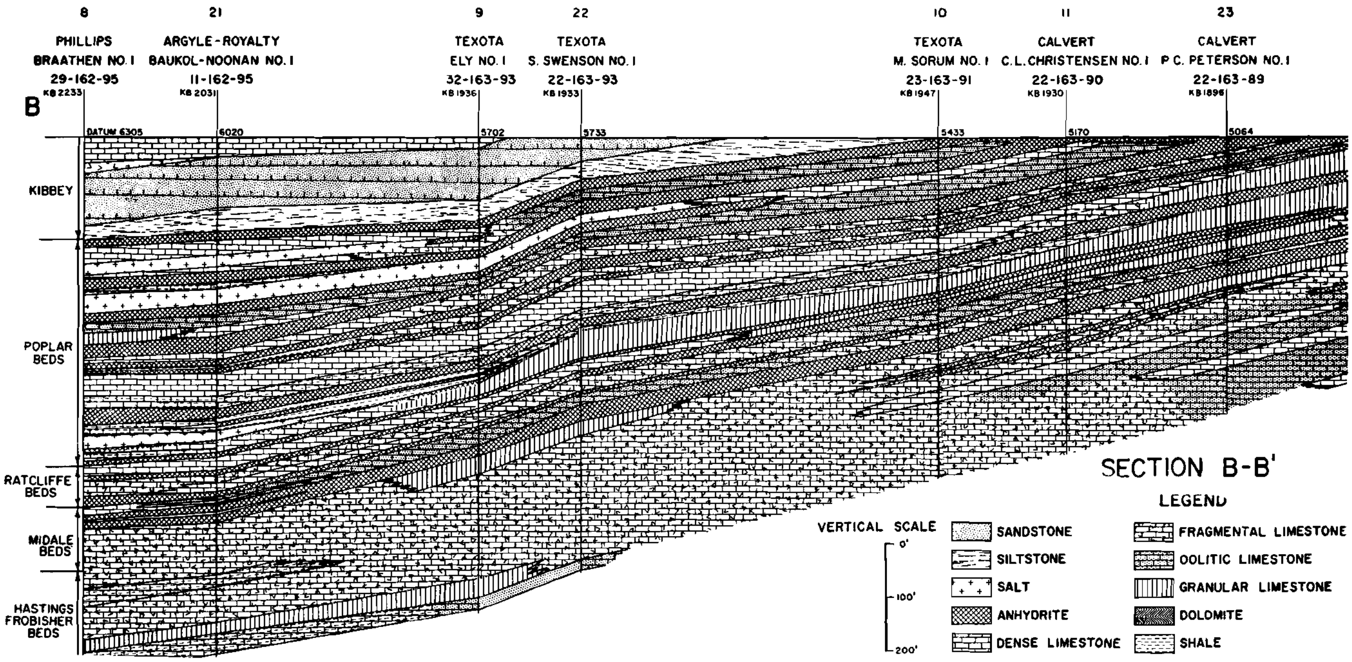


FIGURE 3—This cross-section B-B's is a geologic east-west cross-section extending from Phillips Petroleum Company's Braathen 1, Sec. 29-162-95, to Cardinal Drilling Company—U.C.L.I. 1, Sec. 1-163-81. Datum for this cross-section is the top

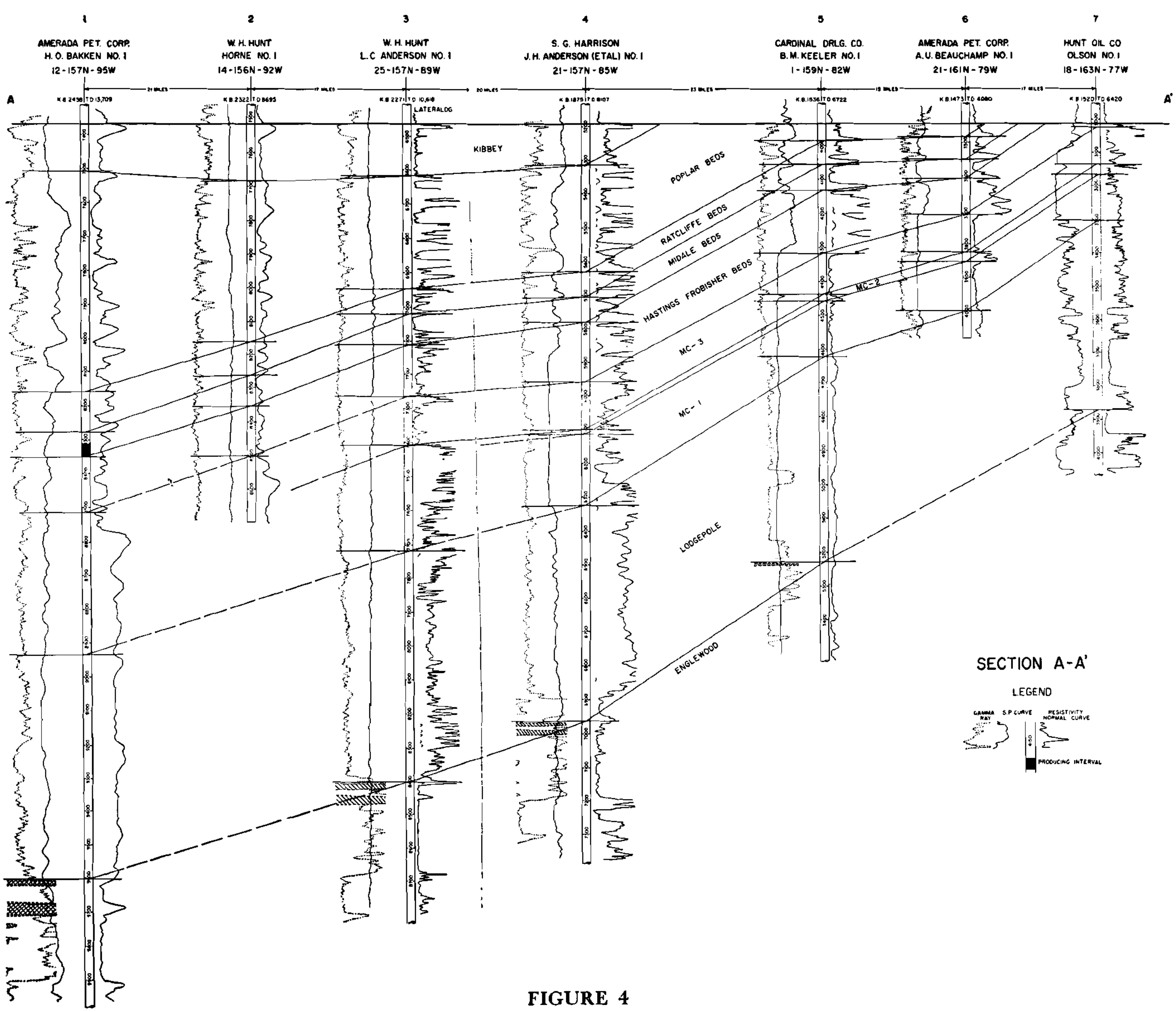
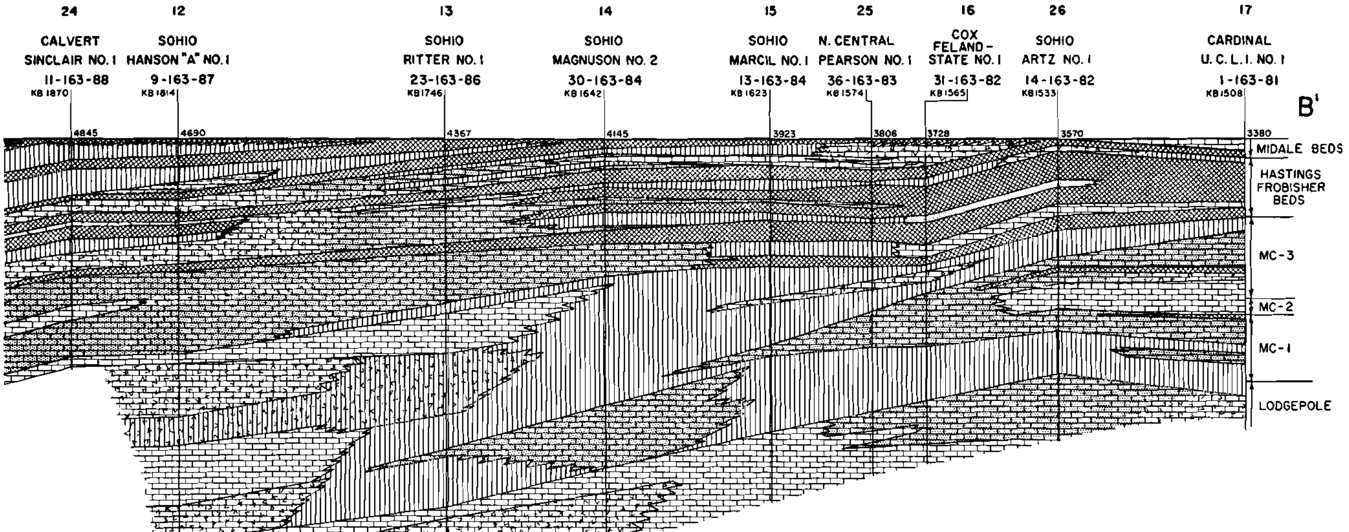


FIGURE 4



Several good possibilities for stratigraphic traps are shown along the top of the cross-section at the unconformity—between the Texota-M. Sorum 1, Sec. 23-163-91, and the Sohio Petroleum Corporation-Magnuson 2, Sec. 30-163-84.

of the Kibbey limestone as far east as the limestone extends, and from that point eastward the post-Mississippian unconformity is used for a datum.

A secondary anhydrite appears to have been developed over the erosional surface. The secondary anhydrite may form an effective seal over the truncated limestone beds which could create excellent stratigraphic traps.

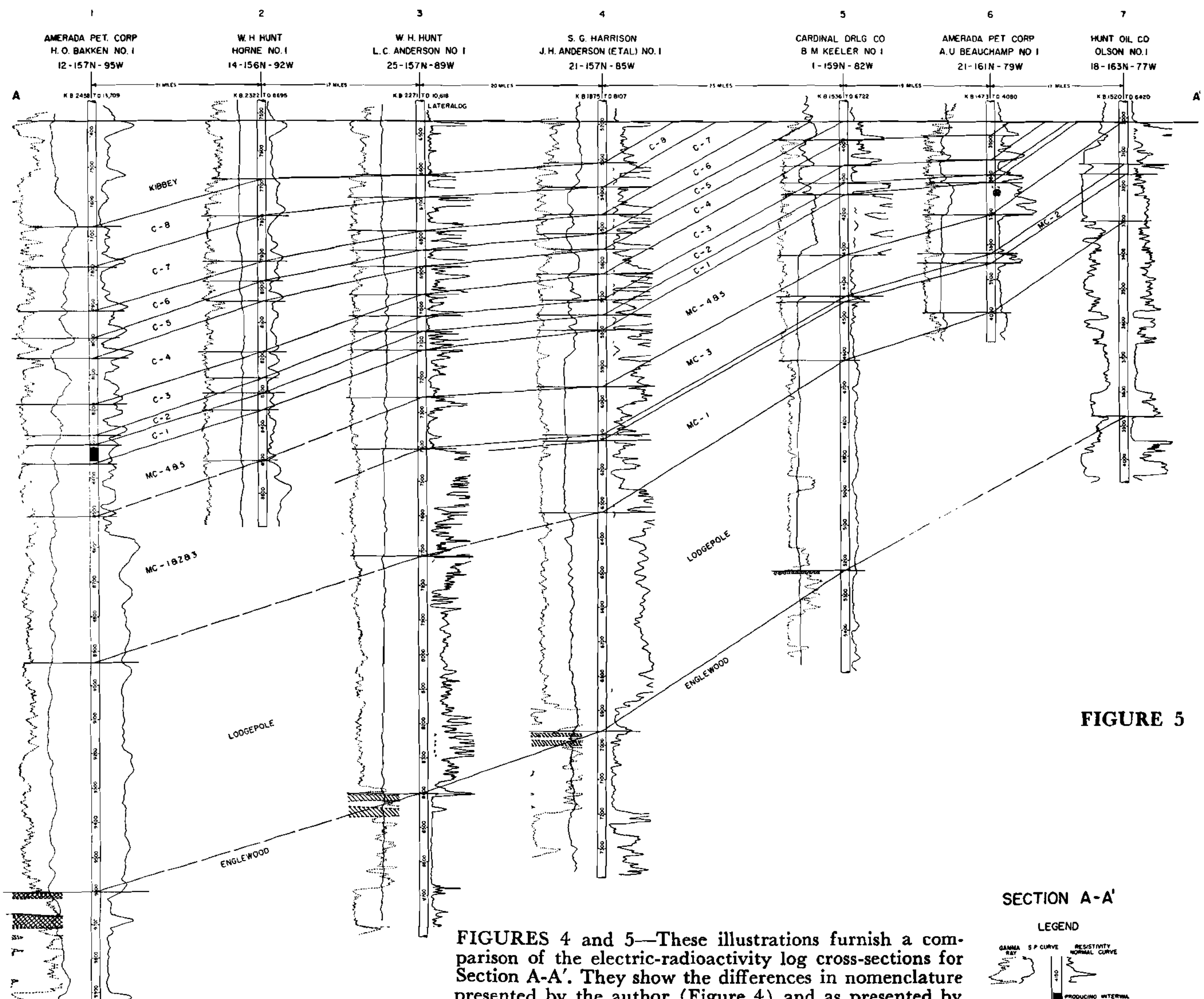
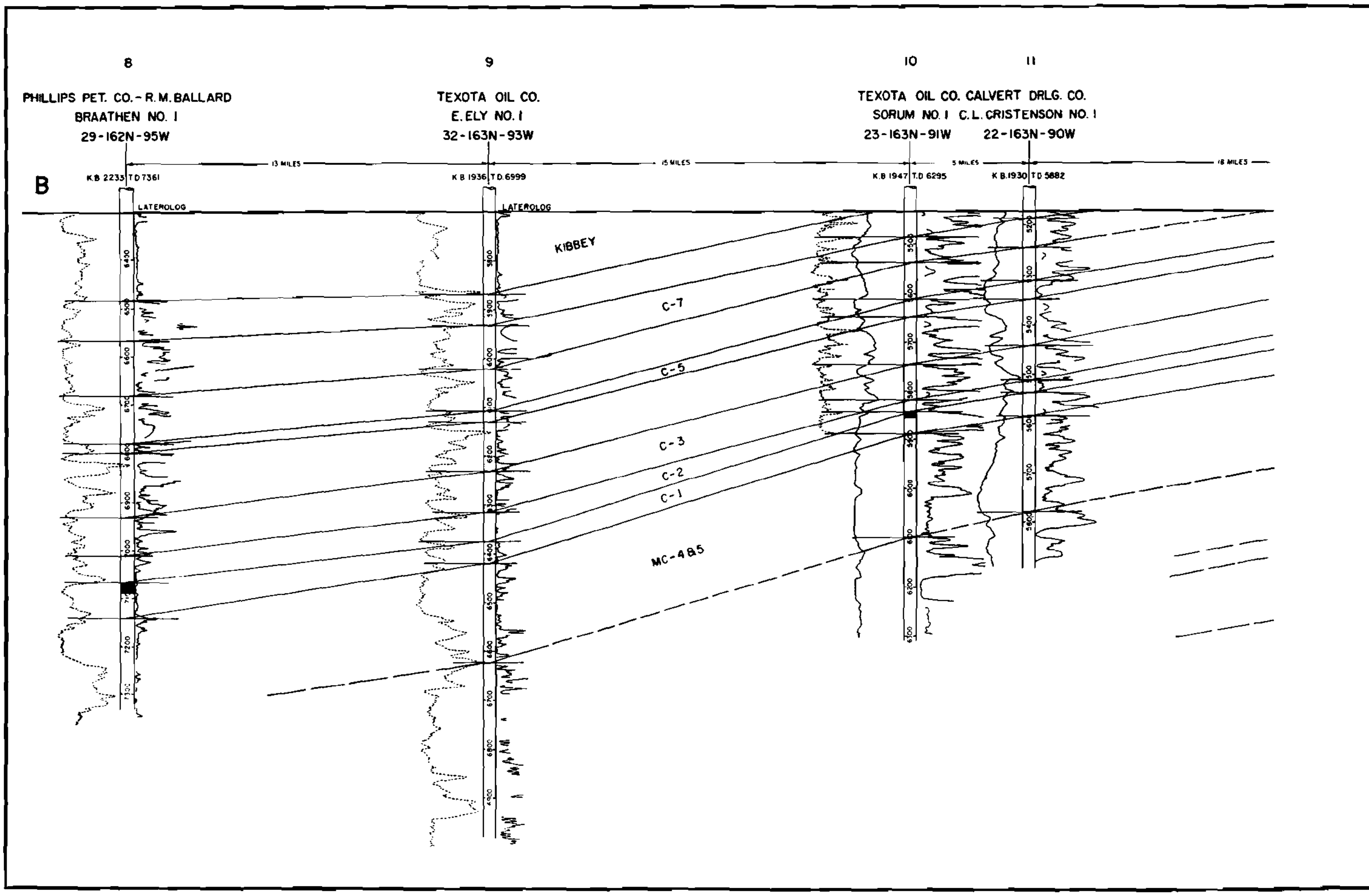
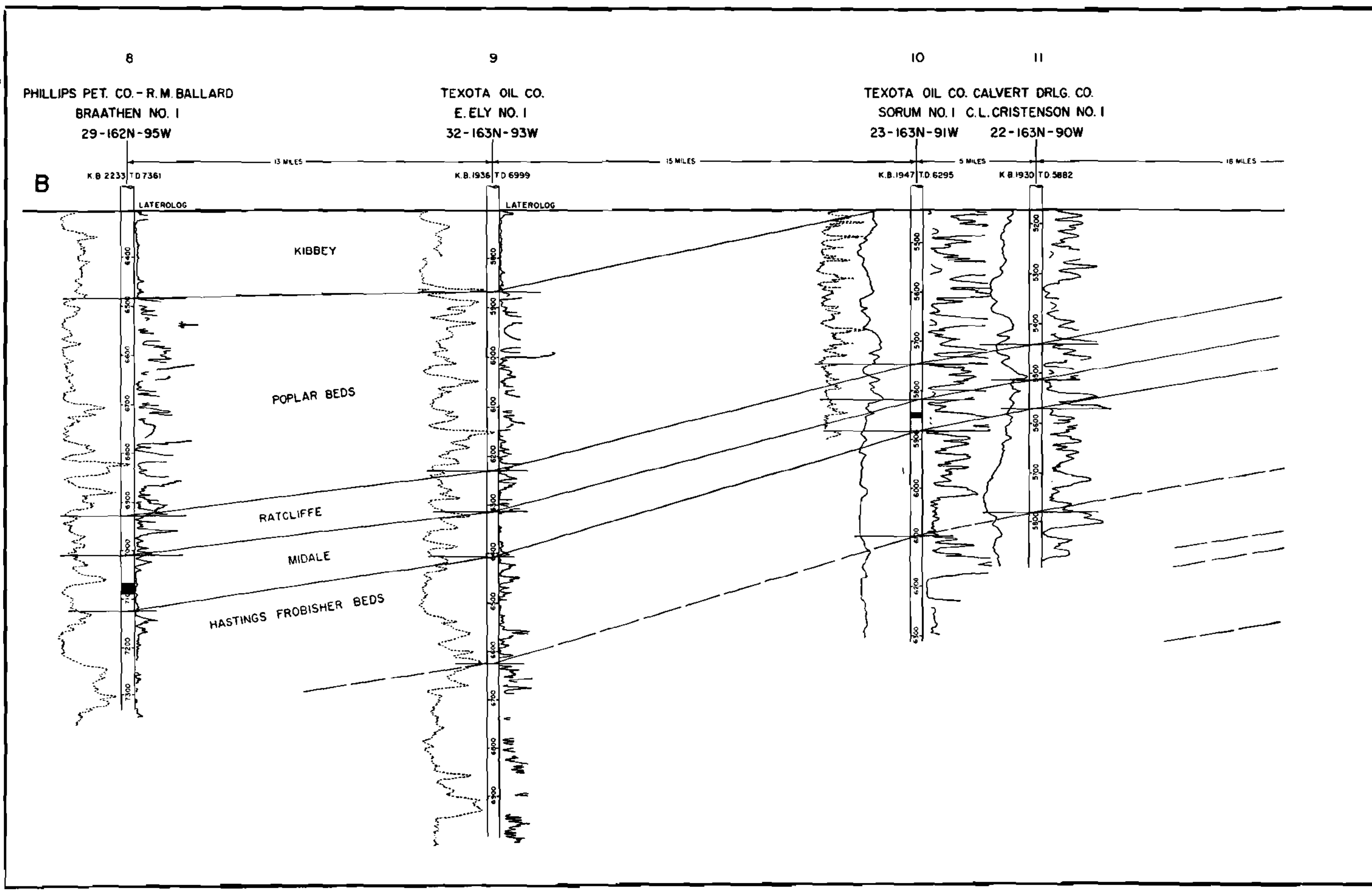


FIGURE 5

FIGURES 4 and 5—These illustrations furnish a comparison of the electric-radioactivity log cross-sections for Section A-A'. They show the differences in nomenclature presented by the author (Figure 4) and as presented by Harrison and Flood (Figure 5) in 1957.



8
PHILLIPS PET. CO.- R.M. BALLARD
BRAATHEN NO. 1
29-162N-95W
9
TEXOTA OIL CO.
E. ELY NO. 1
32-163N-93W
10
TEXOTA OIL CO.
SORUM NO. 1
23-163N-91W
11
CALVERT DRLG. CO.
C.L. CRISTENSON NO. 1
22-163N-90W
13 MILES
15 MILES
5 MILES
18 MILES
B
K.B 2233 T.D 7361
K.B 1936 T.D 6999
K.B 1947 T.D 6295
K.B 1930 T.D 5882
LATEROLOG
LATEROLOG
KIBBEY
C-7
C-5
C-3
C-2
C-1
MC-485



8
PHILLIPS PET. CO.- R.M. BALLARD
BRAATHEN NO. 1
29-162N-95W
9
TEXOTA OIL CO.
E. ELY NO. 1
32-163N-93W
10
TEXOTA OIL CO.
SORUM NO. 1
23-163N-91W
11
CALVERT DRLG. CO.
C.L. CRISTENSON NO. 1
22-163N-90W
13 MILES
15 MILES
5 MILES
18 MILES
B
K.B 2233 T.D 7361
K.B. 1936 T.D 6999
K.B. 1947 T.D 6295
K.B 1930 T.D 5882
LATEROLOG
LATEROLOG
KIBBEY
POPLAR BEDS
RATCLIFFE
MIDALE
HASTINGS FROBISHER BEDS

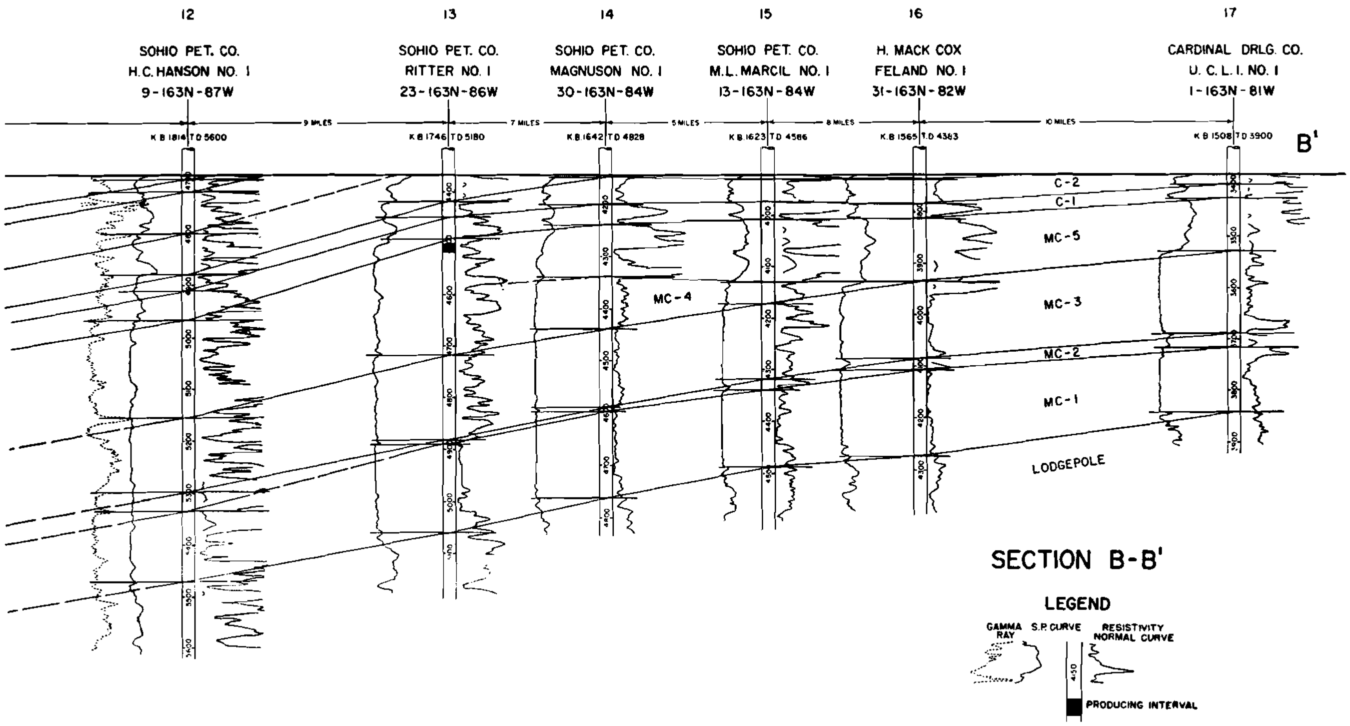


FIGURE 6

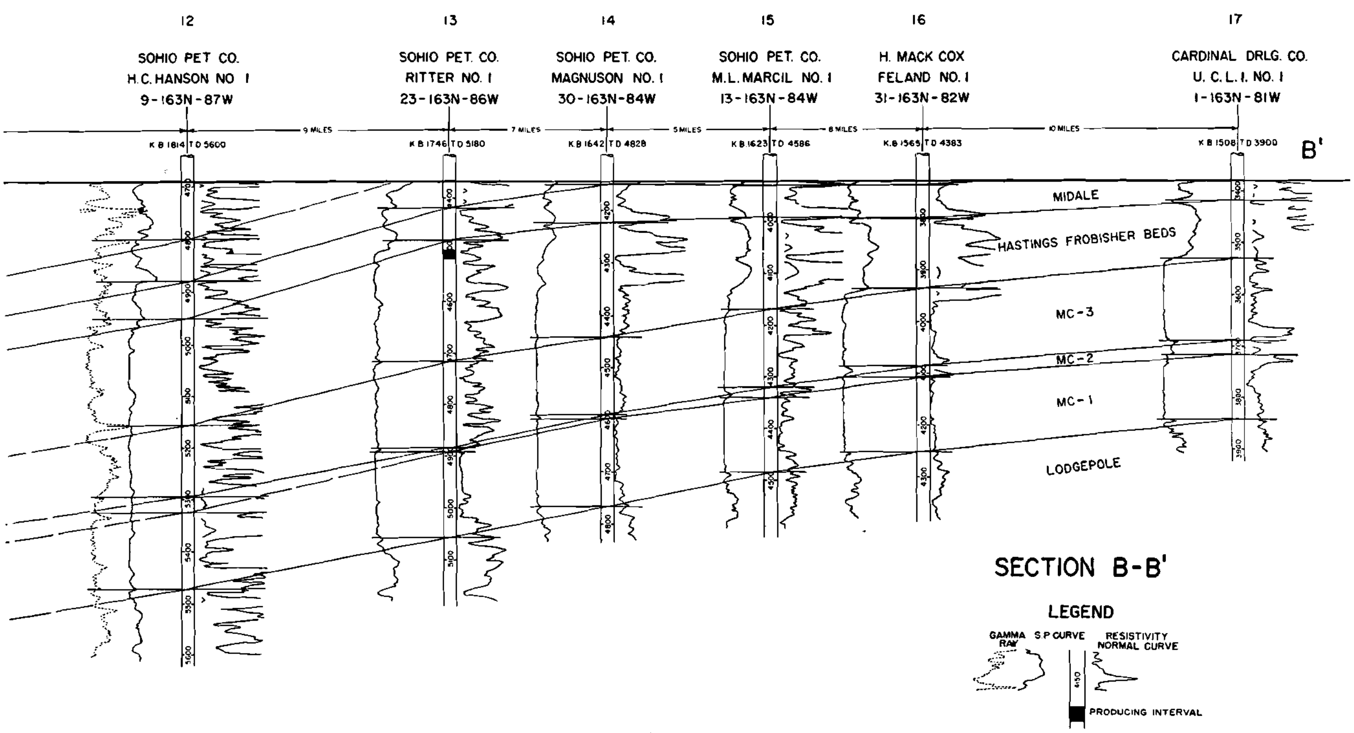


FIGURE 7

FIGURES 6 and 7—These illustrations compare electric-radioactivity log cross-sections for Section B-B'. They show the differences in nomenclature as presented by the author (Figure 4) and as presented by Harrison and Flood (Figure 6) in 1957.

much more difficult to find, and finding them will require detailed subsurface studies.

Formations considered. Facies changes in the Upper Madison group discussed lie under an area as shown in Figure 1. Formations included are:

- Englewood formation
- Madison group
- Lodgepole formation
- Mission Canyon formation
- Charles formation

Data selection. Control data include sample logs, which were prepared by North Dakota Geological Survey geologists, as well as electrical and radio-activity logs from NDGS files.

For clarification of correlation work of the Mississippian series, the following illustrations have been included:

- Two geologic cross-sections (Figures 2 and 3)
- Four electric and radioactivity log cross-sections (Figures 4, 5, 6, and 7)
- A nomenclature chart (Figure 8)
- A facies diagram (Figure 9)

Lithologies illustrated in Figures 1 and 2 include limestone, dolomite, salt, anhydrite, shales, siltstone and sandstone. Limestone textural terms used on the cross-sections are oolitic, fragmental, granular and dense, as defined in Table 1.

Englewood formation. In the portion of the Englewood formation covered by this report, as in a large part of the Williston Basin, the Englewood consists of two thin bedded, carbonaceous, hard, dark gray to black shales, separated by a light gray siltstone, very fine grained sandstone or a thin limestone.

The Englewood in North Dakota rests unconformably on the Devonian Lyleton formation and is conformably overlain by the Mississippian Lodgepole formation.

From outcrops in the Black Hills,[7] Darton in 1901 described outcrops as being composed of a pink slabby limestone, 20 to 30 feet thick, underlying the Pahasapa limestone and overlying the Cambrian Deadwood formation. Later, the formation was described as being composed of varicolored shales with intercalated beds of reddish brown limestone and buff colored dolomite underlying the Pahasapa limestone.[4]

From samples obtained in Amerada Petroleum Corporation's H. O. Bakken 1, Sec. 12-157-95,[11] the black shale and sandstone at the base of the Mississippian in North Dakota was named the Bakken formation. However, in the opinion of the NDGS, the Englewood of North Dakota correlates reasonably closely with the Englewood of the Black Hills. Therefore, there is no apparent need to use the term "Bakken," unless further study indicates the need.

TABLE 1

Constituents	Type of Limestone
Spherical or subspherical grains without regard to internal structure....	Oolitic
Aggregates of fossil or rock fragments	Fragmental
Non-interlocking crystals with few rock or fossil fragments..........	Granular
Interlocking crystals—virtually no porosity..........................	Dense

Madison group. The NDGS defines the Madison group as consisting of the Lodgepole, Mission Canyon and Charles formations.

The Madison group was described in 1893 by Peale, who divided it into three units: laminated limestones, massive limestones and jaspery limestones.[12] He described laminated limestones as dark, fine-grained, compact limestones occurring in laminated beds; massive limestones as light bluish-gray and massively bedded; and jaspery limestones as massively bedded with the upper 300 or 400 feet being generally yellowish white, light colored beds containing jasper and chert.

These formations are time-honored terms which still have some validity in parts of the Williston Basin. However, the facies situation is such that if lithologies only are used, these formations would intergrade with each other, particularly the Mission Canyon and Charles.

The Bakken was included in the Madison group by Fuller (1956), who placed the Lodgepole and Mission Canyon formations in a unit termed Madison limestone.[8] Considerable confusion has existed in the nomenclature in this part of the geologic column, as can be seen in Figure 8.

Lodgepole formation. This formation was named for exposures in Lodgepole Canyon in the Little Rocky Mountains of Eastern Montana by Collier and Cathcart (1922),[6] who described it as consisting of fossiliferous thin-bedded limestones and shales having a thickness of 800 feet.

Texture of the Lodgepole in the portion of the Williston Basin under discussion varies from fine-grained dense to granular and fragmental limestone. There appears to be more granular and fragmental limestone toward the eastern part of the area. The lower part of the Lodgepole often is argillaceous with a cherty limestone section immediately underlying it. The color varies from medium gray to light gray becoming pale reddish to pale orange toward the edge of the basin.

In the section of North Dakota covered by this report, the Lodgepole conformably overlies the Englewood formation, and is conformably overlain by the Mission Canyon formation. Thickness of the Lodgepole in this area varies from about 560 feet in the east to about 650 feet on the Nesson anticline.

As yet, no production has come from the Lodgepole in North Dakota. However, the formation does produce in the Lulu Lake and Virden areas of Manitoba.

Mission Canyon formation. Collier and Cathcart (1922) named this formation for exposures of 500 feet of massively bedded white limestone in Mission Canyon in the Little Rocky Mountains.[6]

The Mission Canyon, in the east and central portions covered by this report, consists largely of pale red to pale orange oolitic and fragmental limestone having a thickness of about 280 feet, grading into yellow gray and yellow brown fine grained, dense limestone about 650 feet thick in the west part.

The Mission Canyon contains several excellent zones of porosity, particularly in the central and eastern portion, where the formation becomes largely oolitic [see Anderson and Nelson (1956) and Figures 1 and 2].[3] In the east part, Mission Canyon contains an anhydrite bed which has been called the Middle Anhydrite by Anderson and Nelson. Others have termed this the M. C. 2 bed (Figure 8), which points to the fact that it is an excellent marker bed. This marker bed ranges from about 10 to 30 feet in thickness and occurs in about the center of the formation. To the west, this anhydrite marker becomes shaly or dolomitic and eventually changes to limestone.

The Mission Canyon rests conformably on the Lodgepole formation, and is overlain conformably by the Mississippian Charles formation, although the typical Charles lithology in the east appears in part to be the time equivalent of the Mission Canyon lithology in the west.

In the eastermost part of the area of this report, the Charles has been eroded and the Spearfish red beds overlie the Mission Canyon unconformably.

Charles formation. Seager (1942) named the Charles formation from the Arro Oil and California Company's 4, SE NW 21-15N-30E, Garfield County, Montana.[14] He described the Charles as a sequence of anhydrite, limestone, brown to red shales, siltstones, and dolomite lying between the Kibbey and Mission Canyon limestone. Seager placed the Charles in the Big Snowy group, but did not designate the interval; however, Nordquist (1953)[11] put the Charles in the Madison group and designated the interval in the type well as being from 3,195 to 3,800 feet. Anderson (1954)[1] also put the Charles in the Madison group. Thickness of the Charles is governed both by regional thinning eastward and pre-Mesozoic erosion.

In the western section of the area under discussion, the Charles consists largely of salt, anhydrite and limestone. In the east part, it consists largely of anhydrite and limestone with only one minor salt which is stratigraphically lower than the salts to the west as shown on Figure 1. Massive salt beds in the west part thin to the east and eventually are replaced by anhydrite.

The limestone of the Charles grades from a pale brown and light gray in the west to a yellowish gray in the east part of the area. The anhydrites vary from a light gray and bluish white to a pale red, becoming more reddish to the east. The formation varies in thickness from about 820 feet in the Amerada H. O. Bakken 1, 12-157-95, to being absent in the east part of the report area, where the formation has been removed by erosion.

From present studies, the contact between the Charles and Mission Canyon apparently is conformable and transitional, and, in part, the two formations are time equivalents. In this area, the Charles is overlain un-

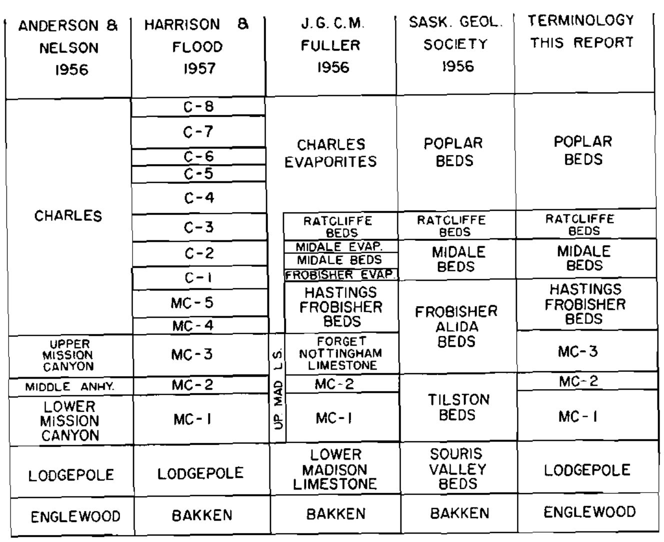


FIGURE 8—Four of the various nomenclature systems used to correlate the Mississippian system in the Williston Basin—in addition to the one used in the accompanying report—are shown on this chart. While all the systems have advantages, correlation becomes difficult with many different usages. For clarification, this combined system is used. For comparison with this combined system, Harrison and Flood's terminology appears in Figures 5 and 6.

It appears that the term "Souris Valley Beds" used in the Saskatchewan Geological Society's stratigraphic cross-sections (1956)[13] may be confused with the previously named Devonian Souris River formation. Therefore, the term "Lodgepole" is retained for the sequence below the M. C. 1 (Tilston Beds) and above the Englewood (Bakken). This usage is in line with the original and well-known definition of the Lodgepole formation.

Due to lack of paleontological information, certain marker beds selected from electric and radioactivity logs are used as time lines. The wide regional consistency of electric log characteristics, thickness and dip into the basin of these beds lends credence to this supposition.

The Mission Canyon has been described as massive marine limestone, and the Charles as largely an evaporitic sequence. If these descriptions are followed, it will be noted on the cross sections (Figures 1, 2 and 9) that the base of the Charles is stratigraphically lower towards the east while the top of the Mission Canyon is stratigraphically higher toward the west in the deeper part of the basin. (Similar conditions of integradation appear to exist at the Lodgepole-Mission Canyon contact farther east outside the area of this report.

As a result, such expressions as "Lodgepole formation in Mission Canyon facies," meaning "Mission Canyon formation of Lodgepole age," are used (Moore, 1955)[10].

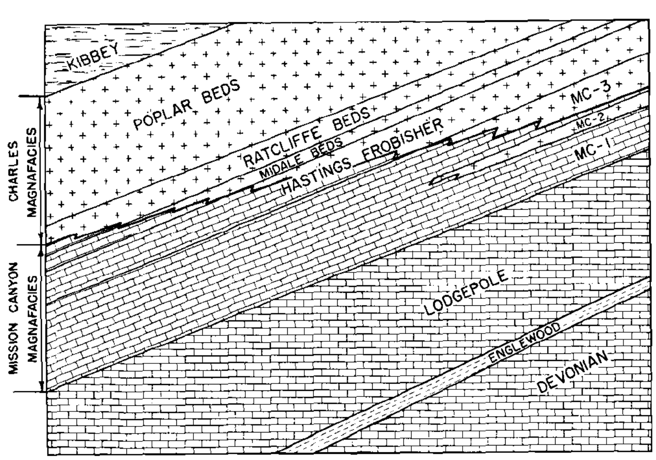


FIGURE 9—On the basis of the descriptions found in Figure 8, "formations" of the Madison group are stripped of their original connotation and become ingrading belts of lithology, which are seen to cross time lines within the Williston Basin. Gross lithologic belts which transgress time (although in a dissimilar tectonic setting) originally were defined by Caster (1934) as magnafacies.[5]

Thus, the massive marine limestone facies of the Williston Basin might be more correctly called the Mission Canyon magnafacies and the evaporitic facies could be termed the Charles magnafacies, divesting these "formations" of the time connotation, which has led to correlation confusion in the Williston Basin.

About the Author

Sidney B. Anderson is head of the subsurface division for the North Dakota Geological Survey. He received a B.S. degree from the University of North Dakota in 1951. He was employed by the ground water division of the U. S. Geological Survey at Grand Forks from June of 1951 until January of 1952 when he joined the North Dakota Geological Survey. He is a member of AAPG, Sigma Xi, North Dakota Geological Society, North Dakota Academy of Science and Sigma Gamma Epsilon.

conformably by the Spearfish of Triassic or Jurassic age.

REFERENCES

[1] Anderson, S. B., 1954, Stratigraphic Sections of the Mississippian System in North Dakota: North Dakota Geol. Survey Rept. Invest. 16.

[2] Anderson, S. B., and Hansen, D. E., 1957 Halite Deposits in North Dakota: North Dakota Geol. Survey Rept. Invest. 28.

[3] Anderson, S. B., and Nelson, L. B., 1956, Mississippian Stratigraphic Studies, Bottineau County, North Dakota: North Dakota Geol. Survey Rept. Invest. 24.

[4] Butler, R. V., et al., 1955, Lithologic Correlation of the Middle and Lower Paleozoic Rocks: North Dakota Geol. Soc. Guidebook, Field Conference, p. 38-42.

[5] Caster, K. E., 1934, The Stratigraphy and Paleontology of Northwestern Pennsylvania, Part I, Stratigraphy: Bull. Amer. Paleontology, Vol. 21, No. 71.

[6] Collier, A. J., and Cathcart, S. H., 1922, Possibility of Finding Oil in Laccolithic Domes South of the Little Rocky Mountains, Montana: U. S. Geol. Survey Bull. 736 F.

[7] Darton, N. H., 1901, Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming: U. S. Geol. Survey 21st Annual Report, Part 4, p. 497-594.

[8] Fuller, J. G. C. M., 1956, Mississippian Rocks and Oilfields in Southeastern Saskatchewan: Saskatchewan Dept. Min. Res. Rept. 19.

[9] Harrison, R. L., and Flood, A. L., 1957, Mississippian Correlations in the International Boundary Areas: First International Williston Basin Symposium, 1956, Conrad Publishing Company, Bismarck, North Dakota, p. 36-51.

[10] Moore, P. F., 1955, Discussion of previous Mississippian Symposium Committee correlations: Jour. Alberta Soc. Petrol. Geol., Vol. 3, p. 207-210.

[11] Nordquist, J. W., 1953, Mississippian Stratigraphy of Northern Montana: Billings Geol. Soc. Guidebook, 4th Annual Field Conference, p. 68-82.

[12] Peale, A. C., 1893, The Paleozoic Section in the Vicinity of Three Forks, Montana: U. S. Geol. Survey Bull. 110.

[13] Saskatchewan Geological Society, 1956, Stratigraphic Cross-Sections of Mississippian Rocks (Exclusive of the Bakken formation) in the Northeastern Part of the Williston Basin: Mississippian Names and Correlations Committee, Regina, Saskatchewan, Canada.

[14] Seager, O. A., 1942, A Test on the Cedar Creek Anticline, Southeastern Montana: Amer. Assoc. Petrol. Geol. Bull., Vol. 26, p. 861-864.