2/

MASTER

GJBX-81(77)

**PRELIMINARY STUDY OF URANIUM IN
PENNSYLVANIAN AND LOWER PERMIAN
STRATA IN THE POWDER RIVER BASIN,
WYOMING AND MONTANA, AND THE
NORTHERN GREAT PLAINS**

BENDIX FIELD ENGINEERING CORPORATION
Grand Junction Operations
Grand Junction, Colorado 81501

November 1977

ISSUED BY THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE
UNDER CONTRACT NO. E(05-1)-1664

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

PRELIMINARY STUDY OF URANIUM IN PENNSYLVANIAN AND LOWER
PERMIAN STRATA IN THE POWDER RIVER BASIN, WYOMING
AND MONTANA, AND THE NORTHERN GREAT PLAINS

J. F. Dunagan, Jr., and K. A. Kadish

BENDIX FIELD ENGINEERING CORPORATION
Grand Junction Operations
Grand Junction, Colorado 81501

November 1977

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

PREPARED FOR THE U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
UNDER CONTRACT NO. EY-76-C-13-1664

ISSUED BY THE U.S. DEPARTMENT OF ENERGY, GRAND JUNCTION OFFICE

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

	<u>Page</u>
Summary	1
Introduction	2
Location	2
Previous work	2
Procedures	2
Literature study	2
Sampling and analytical procedures	4
Subsurface procedures	4
Geology	4
Stratigraphy	4
Minnelusa Formation	4
Fairbank and Hartville Formations	10
Amsden and Tensleep Formations	10
Amsden Group and Quadrant Formation	10
Fountain Formation and midcontinent Permian-Pennsylvanian strata	11
Structural features	11
Williston basin	11
Powder River Basin	12
Denver-Julesburg basin and Chadron arch	12
Central Montana uplift	12
Big Horn Mountains, Casper arch, and Black Hills	12
Hartville uplift and Laramie Mountains	13

CONTENTS (continued)

	<u>Page</u>
Results	13
Subsurface study	13
Sample study	15
Possible origins of uranium	15
Pennsylvanian and Lower Permian continental rocks	16
Conclusions	16
Selected bibliography	17
Appendix A. Location, description, and analyses of rock samples	25
Appendix B. Subsurface data reference points	31

ILLUSTRATIONS

	<u>Page</u>
Figure 1. Project area and major tectonic features of the northern Great Plains and bordering regions	3
2. Sample locations, subsurface control points, and extent of radiometric anomalies, northern Great Plains area	5
3. Correlation chart of Pennsylvanian and Lower Permian strata	6
4. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, South Dakota and North Dakota	7
5. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, Montana and South Dakota	8
6. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, South Dakota and Nebraska	9
7. Representative well logs showing radiometric anomalies . .	14

SUMMARY

Persistent and widespread radiometric anomalies occur in Pennsylvanian and Lower Permian strata in the subsurface of the northern Great Plains and the Powder River Basin. The primary host lithology of these anomalies is shale interbedded with sandstone, dolomite, and dolomitic sandstone. Samples from the project area indicate that uranium is responsible for some anomalies. In some samples there seems to be a correlation between high uranium content and high organic-carbon content, which possibly indicates that carbonaceous material acted as a trapping mechanism in some strata. The Pennsylvanian and Permian rocks studied are predominantly marine carbonates and clastics, but there are rocks of fluvial origin in the basal Pennsylvanian of Montana, North Dakota, and South Dakota and in the Pennsylvanian and Permian deposits on the east flank of the Laramie Mountains. Fine-grained clastic rocks that flank the Chadron arch in western Nebraska are possibly of continental origin. The trend of the Chadron arch approximately parallels the trend of radiometric anomalies in the subsurface Permian-Pennsylvanian section. Possible source areas for uranium in the sediments studied were pre-Pennsylvanian strata of the Canadian Shield and Precambrian igneous rocks of the Ancestral Rocky Mountains.

INTRODUCTION

Strata of Pennsylvanian and Early Permian age are found in the subsurface of the Powder River Basin of Wyoming and Montana and in much of the northern Great Plains area. These strata commonly contain radiometric anomalies, as indicated by radioactivity logs from petroleum test wells. The purpose of this project is to investigate the nature, distribution, and host lithology of these anomalies.

The project was initiated in January 1977 and concluded in March 1977. The study was conducted by personnel of Bendix Field Engineering Corporation under the auspices of the U.S. Energy Research and Development Administration.

LOCATION

The project area (Fig. 1) includes most of western North Dakota, all of western South Dakota, most of western Nebraska, and part of eastern Wyoming and Montana. The project boundary is between lats 41° N. and 49° N. and between longs. $99^{\circ}54'$ W. and $108^{\circ}54'$ W., and encompasses an area of approximately 169,000 sq mi (270,000 sq km). This area includes all of the Watford City, Dickinson, Bismarck, Alliance, Valentine, Scottsbluff, North Platte, Newcastle, Gillette, Ekalaka, Forsyth, and Miles City sheets of the National Topographic Map Series 2° maps, and parts of the Williston, Minot, McClusky, Jamestown, Cheyenne, Casper, Torrington, Arminto, Sheridan, Billings, Hardin, Roundup, Jordan, Glendive, and Wolf Point sheets.

PREVIOUS WORK

Numerous studies deal with the Pennsylvanian and Lower Permian strata in the project area. Darton (1909), Foster (1958), Condru and Reed (1935, 1940, 1950), and others have investigated the Permian-Pennsylvanian stratigraphy of the Black Hills, Hartville uplift, and Powder River Basin areas. The structure and stratigraphy of central Montana and the Williston basin have been discussed by Mundt (1956a, 1956b), Carlson and Anderson (1965), McCauley (1956), and others. Regional studies have been presented by Tranter and Petter (1963), Wilson (1962), and other workers.

Petroleum exploration in the project area has been extensive, and although Pennsylvanian and Lower Permian rocks are the target of few tests, these rocks have been penetrated by numerous wells. There are no indications that Permian-Pennsylvanian rocks in the project area have been explored for uranium deposits.

PROCEDURES

LITERATURE STUDY

Literature references pertinent to the project were assembled in the early stages of the study. Available publications were studied and used as

Figure 1. Project area and major tectonic features of the northern Great Plains and bordering regions.

references for further investigation. Literature was reviewed throughout the course of the project.

SAMPLING AND ANALYTICAL PROCEDURES

Samples were collected from cored intervals of four petroleum test wells to determine the source of radiometric anomalies noted on well logs. For three of the wells, sample depths were selected by correlating core intervals with radiometric anomalies on corresponding gamma-ray logs, and then by scanning the core with an Exploranium GR-410 portable four-channel gamma-ray spectrometer utilizing a 3 x 3 in. (7.6 X 7.6 cm) NaI(Tl) detection crystal. (This is not an endorsement of Exploranium instruments.) For the fourth well, the sample was selected by inspecting a cored interval with a recording gamma-ray core scanner.

The samples were analyzed by gamma-ray spectroscopy, full spectrum emission spectroscopy, chemical fluorometric assay for U_3O_8 content, colorimetric assay of thorium content, and determination of major elements and oxides by atomic absorption, colorimetric, and volumetric methods. Results of sample analyses are presented in Appendix A.

SUBSURFACE PROCEDURES

Geophysical logs from petroleum test wells in various parts of the project area were examined to provide data concerning thickness and general lithologic character of the Pennsylvanian and Lower Permian section. The logs provided data on thickness and magnitude of radiometric anomalies in the section. A total of 198 wells were studied by examination of 137 electric logs, 119 gamma-ray logs, and 36 Amstrat lithologic logs. The wells are tabulated in Appendix B, and location are shown in Figure 2.

GEOLOGY

STRATIGRAPHY

The rock units considered in this study are of Pennsylvanian and Early Permian (Wolfcamp) age. A number of formational names (including Minnelusa, Fairbank, Hartville, Amsden, Tensleep, Tyler, Alaska Bench, Devils Pocket, Quadrant, and Fountain) have been applied to these units by individual authors working in different areas. Each formation is briefly discussed below. A correlation chart of the approximate time equivalence of these formations and the areas in which each is recognized is presented in Figure 3. Generalized stratigraphic cross sections, drawn from well-log data, are shown in Figures 4, 5, and 6.

Minnelusa Formation

The name "Minnelusa Formation" is applied to a sequence of carbonate (predominantly dolomite), sandstone, shale, and anhydrite found on the surface in the Black Hills area of South Dakota and Wyoming, and in the subsurface of

Figure 2. Sample locations, subsurface control points, and extent of radiometric anomalies, northern Great Plains area.

Figure 3. Correlation chart of Pennsylvanian and Lower Permian strata.

Figure 4. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, South Dakota and North Dakota (see Fig. 2 for location).

Figure 5. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, Montana and South Dakota (see Fig. 2 for location).

Figure 6. Diagrammatic cross section of Pennsylvanian and Lower Permian strata, South Dakota and Nebraska (see Fig. 2 for location).

the Powder River Basin and part of western South Dakota. Foster (1958), in his stratigraphic summary of the Minnelusa Formation, indicated that the Minnelusa ranges from Morrowan to Wolfcampian in age and that it can be divided into three members which are separated by regional unconformities.

In the Williston basin area, "Minnelusa Formation" is applied to a marine carbonate and clastic sequence of approximately Desmoinesian and early Missourian age (Wishart and others, 1964), which conformably overlies the Amsden Formation and is unconformably overlain by the Opeche Formation of Permian age.

Fairbank and Hartville Formations

The Fairbank Formation (Condra and Reed, 1950, p. 3-5), consists of sandstone, siltstone, and shale of Morrowan age (Tenney, 1966, p. 233) that were deposited unconformably on the Guernsey Formation (Mississippian) in the Hartville uplift area. The Fairbank Formation is conformably overlain by the Hartville Formation, a sequence of limestone, dolomite, sandstone, and shale of Atokan through Wolfcampian age (Bates, 1955, p. 1987).

Amsden and Tensleep Formations

The Amsden Formation of the Big Horn Mountains and western Wyoming is Morrowan and Atokan in age (Williams, 1962, p. 165) and unconformably overlies the Madison Formation (Mississippian). The Amsden contains a basal sandstone (the Darwin Sandstone Member) overlain by a dolomite, limestone, and shale sequence. In the Williston basin area, the Amsden Formation is Atokan and late Morrowan in age and is conformable with the Minnelusa Formation above and the Tyler Formation below.

The Amsden is conformably overlain by the Tensleep Formation, a sequence of sandstone and dolomite with shale, limestone, and anhydrite. In much of the Big Horn Mountain area, the Tensleep is of lower and middle Desmoinesian age (Agatston, 1954, p. 528), but in the southern Big Horn Mountains, the Tensleep may range in age from Atokan to Wolfcampian (Williams, 1962, p. 168). The Tensleep was partially eroded prior to deposition of the Phosphoria Formation (Permian).

Amsden Group and Quadrant Formation

The following stratigraphic summary is based on the description of Pennsylvanian stratigraphy of central Montana by Maughan and Roberts (1967).

The Tyler Formation of Morrowan age consists of fluvial shales and sandstones, which unconformably overlie the Big Snowy Group (Mississippian), and of marine shales, thin limestones, and sandstones. Limestone, dolomite, and mudstone of the Alaska Bench Limestone (Morrowan and Atokan) conformably overlie the Tyler Formation. The formational name "Devils Pocket" is applied to a sequence of dolomite, mudstone, and sandstone of Atokan and Desmoinesian age that unconformably overlies the Alaska Bench Limestone. The Tyler, Alaska Bench, and Devils Pocket formations compose the Amsden Group.

The Quadrant Formation is a middle Desmoinesian sandstone or quartzite equivalent of the Tensleep Formation and conformably overlies the Amsden Group in parts of central and south-central Montana. Most of the Quadrant has been removed by erosion.

In the Williston basin area of North Dakota, the Alaska Bench Limestone may not be present, but the Tyler Formation is represented by a sequence of varicolored shale and mudstone interbedded with sandstone and limestone, and is probably Early Pennsylvanian (Morrowan?) in age (Ziebarth, 1964).

Fountain Formation and Midcontinent Permian-Pennsylvanian Strata

In the Front Range of Colorado and in the Laramie Mountains in southeastern Wyoming, the Fountain Formation consists of coarse fluvial arkosic sediments with siltstone and minor carbonate (Maughan and Wilson, 1960, p. 34), and ranges in age from Morrowan (Mallory, 1972b, p. 131) to Virgilian (Maughan and Wilson, 1960, p. 41). In the subsurface, coarse Fountain clastics grade eastward into the marine section of the Denver-Julesberg basin (Taylor, 1958, p. 64). Pennsylvanian and early Permian strata of this area are predominantly carbonates and shales and are Morrowan to Wolfcampian in age. These strata are usually referred to by group names of the midcontinent region (Tranter and Petter, 1963, p. 48), but some authors (for example, Condra and Reed, 1950, p. 40) have applied the names of correlative members of the Hartville Formation.

STRUCTURAL FEATURES

Detailed structural geology of the study area is beyond the scope of this project, but there are several major tectonic features in the area that should be recognized, including the Williston, Powder River, and Denver-Julesberg basins; the Chadron arch; the Big Horn and Laramie Mountains; and the Black Hills, Hartville, and Central Montana uplifts. Figure 1 depicts the approximate geographic relationships of these structural elements, which are briefly discussed below.

Williston Basin

The Williston basin is a structural and stratigraphic intracratonic basin that includes within its boundaries most of North Dakota and parts of eastern Montana, western South Dakota, southern Saskatchewan, and southwestern Manitoba. Sedimentary rocks in the Williston basin range from Cambrian through Tertiary in age (Carlson and Anderson, 1965). Development of the basin began in Middle Ordovician time, and intermittent subsidence and uplift continued throughout the Paleozoic and Mesozoic eras. Structural features, such as the Nesson and Cedar Creek anticlines, were initiated in Precambrian time and were reactivated intermittently throughout the growth of the basin. The Laramide orogeny of latest Cretaceous and early Tertiary time reactivated the Cedar Creek anticline and shaped the Williston basin as a whole (Sandberg, 1964).

The Cedar Creek anticline is an asymmetric northwest-trending fold situated on the southwest flank of the Williston basin. The anticline extends for approximately 100 mi (161 km) from northwestern South Dakota and southwestern North Dakota to the Yellowstone River in Montana. It is about 10 mi (16 km) wide and is steeper on the west flank than on the east (Davis and Hunt, 1956). The Nesson anticline is a north-trending structural high in northwestern North Dakota, about 100 mi (161 km) long by 12 mi (19 km) wide, and plunges gently to the south (Middleton and Kennedy, 1956).

Powder River Basin

The Powder River Basin is an asymmetric, roughly north-trending structural and stratigraphic basin located in northeastern Wyoming and southeastern Montana. It is bordered on the west by the Big Horn Mountains, on the southwest by the Casper arch, on the south by the Laramie Mountains and the Hartville uplift, and on the east by the Black Hills. Subsidence and westward tilting of the Powder River Basin and uplift of the bordering mountains resulted from Laramide orogenesis in Paleocene and Eocene time (Wyo. Geol. Assoc., 1965).

Denver-Julesberg Basin and Chadron Arch

The Denver-Julesberg basin is situated in northeastern Colorado, northwestern Kansas, western Nebraska, and southeastern Wyoming. In the project area, the basin is bordered by the Chadron arch on the northeast, the Black Hills on the north, the Hartville uplift on the northwest, and the Laramie Mountains on the west. The basin is asymmetric with a gently dipping east flank and a steep west flank. It was formed in Eocene time by Laramide orogenic forces (Martin, 1965).

The Chadron arch, part of a northwest-trending basement high (Muehlberger and others, 1967, p. 2360), is located in northwestern Nebraska. It was a positive area during part of Pennsylvanian time (Mallory, 1972a) and was active in Late Cretaceous time (Fuenning, 1942, p. 1535) and also in early Tertiary time (Stanley, 1971, p. 69).

Central Montana Uplift

West-northwest-trending anticlines, synclines, and fault zones characterize the Central Montana uplift (Sonnenberg, 1956, p. 73). This area was occupied by a depositional trough in Precambrian and Cambrian time, was uplifted in post-Silurian time, and was formed again as a depositional trough in Mississippian time. The present deformation is the result of Laramide tectonics imposed on the older structural features (Norwood, 1965).

Big Horn Mountains, Casper Arch, and Black Hills

The Big Horn Mountains are located in north-central Wyoming and trend generally northwest, separating the Bighorn Basin on the west from the Powder River Basin on the east. These mountains consist of an exposed core of

Precambrian igneous and metamorphic rocks flanked by Paleozoic and younger sediments. The Big Horn Mountains were uplifted in Paleocene and Eocene time in response to Laramide orogenic events.

The Casper arch is a structural saddle between the northwestern end of the Laramie Mountains and the southern end of the Big Horn Mountains (Hooper, 1961, p. 1523). Uplift of the Casper arch in early Eocene time along a reverse fault (Keefer, 1965, p. 1889) separated the eastern Wind River basin from the southwestern Powder River Basin.

The Black Hills uplift, located in western South Dakota and northeastern Wyoming, is an arcuate, northwest-trending anticlinal uplift. Major deformation occurred during the Laramide orogeny, beginning in Late Cretaceous (Bartram, 1940, p. 113) or in Paleocene time (Wyo. Geol. Assoc., 1965).

Hartville Uplift and Laramie Mountains

Condra and Reed (1950, p. 17) described the Hartville uplift as follows: "The Hartville Uplift is 15 to 23 miles in width and 35 to 40 miles in length.... Its general structural trend is north-northeast. The main part of this area is composed of two roughly parallel anticlinal folds separated by a broad, shallow syncline, and is bordered on the east and west by small outlying synclines and folds." Deformation and uplift of this area occurred in Late Cretaceous time (Smith, 1903, p. 3).

The Laramie Mountains of southeastern Wyoming trend north-northwest and form an extension of the Colorado Front Range. The Laramie Range is an asymmetric anticlinal uplift, steeper on the east flank than on the west. Precambrian rocks are exposed in the core and on the northwestern end of the uplift, and Paleozoic and younger sediments flank the core (Sears and Sims, 1954, p. 27). The Laramie Mountains were deformed during the Laramide orogeny.

RESULTS

SUBSURFACE STUDY

Subsurface cross sections of the Powder River Basin (Foster, 1958, Figs. 5, 6, 7) indicate persistent radiometric anomalies (Fig. 2) in shaly intervals of the Minnelusa Formation (Fig. 7, log A). Most of these anomalies are in the middle Minnelusa, although some are in the lower and upper Minnelusa. Powder River Basin well logs, examined in this study, are commonly incomplete and represent only part of the upper Minnelusa Formation. However, they show a radiometric anomaly in the upper 100 ft (30 m) of the section that is moderately persistent in the north-central and northeastern parts of the basin.

In the Williston basin area, the Tyler Formation commonly contains a group of three to six radiometric anomalies in shaly and sandy intervals (Fig. 7, log B). The aggregate thickness of these anomalies is about 35 ft (11 m). Anomalies in the Minnelusa-Amsden section of this area are less persistent. There are few anomalies in the wells around the northern and eastern border of the subject area.

THE TEXAS CO.

Adon Unit No. 1

Sec. 2, 52N-72W

Campbell Co., Wyoming

Elev. 4358 K.B.

A.

Powder River Basin
(after Footer, 1938)

STANOLIND OIL & GAS CO.

Northwestern Improvement No. 1

Sec. 17, 143N-100W

Billings Co., North Dakota

Elev. 2815 K.B.

B.

Williston basin

Vertical Scale 1:2400

Figure 7. Representative well logs showing radiometric anomalies.

There are few radiometric anomalies in the Permian-Pennsylvanian section of western Nebraska. Logs that show anomalies have an average of four or five anomalies per well, with an aggregate thickness of about 10 ft (3m), and display a southeasterly trend that roughly parallels the Chadron arch. This arch may have influenced accumulation of radioactive material in the sediments flanking it. Mallory's (1972a) Pennsylvanian series maps showed the Chadron arch area as a positive element in Early and Middle Pennsylvanian time, and Condra and Reed (1950, p. 57) reported thinning of Pennsylvanian strata over the arch.

SAMPLE STUDY

Samples were collected from cored intervals of the Tyler Formation in three petroleum test wells in Stark County, southwestern North Dakota. Sample analysis indicates that uranium, or a combination of uranium and thorium, is the source of the radiometric anomalies in samples 22818 and 22819. It is probable that thorium is responsible for the anomaly noted in the depth interval represented by sample 22820. Higher uranium content was noted in samples 22818 and 22819, both of which contained more organic carbon than sample 22820. Sample 23074, collected from a cored interval of the Minnelusa Formation in a petroleum test well in Campbell County, Wyoming, contained 79 ppm (parts per million) U_3O_8 and 9 ppm Th. Sample locations, descriptions, and analytical results are presented in Appendix A.

POSSIBLE ORIGINS OF URANIUM

Sample data are not conclusive but indicate that some radiometric anomalies in the project area were caused by anomalous uranium concentration in the sediments. In view of the widespread nature of the anomalies in the project area, potential source areas should be considered. The two primary possibilities are the Canadian Shield area and the Ancestral Rocky Mountains.

The Canadian Shield or cratonic area may have contributed clastic material to the Williston basin. Sources of clastics deposited in the northern Great Plains and Williston basin were to the north and northeast of these areas (Sloss, 1956, p. 8). Macauley (1964, p. 30) stated that uplifted Mississippian rocks on the craton in northern Canada supplied detritus to Montana and North Dakota.

The Ancestral Rocky Mountains, primarily the Frontrange and Pathfinder uplifts, supplied thick arkosic clastics to bordering areas, represented in the project area by the Fountain Formation. These uplifts remained positive areas throughout Pennsylvanian time (Mallory, 1972a).

Precambrian igneous rocks, proposed as the source of uranium for some deposits (Rosholt and others, 1973, p. 1001), were exposed in the cores of the Ancestral Rocky Mountains during Pennsylvanian time (Tenney, 1966, p. 229) and could have supplied uranium to Pennsylvanian and Permian sediments. However, no indications were found that Precambrian igneous or metamorphic rocks were exposed in the Canadian Shield during Permian and Pennsylvanian times. If such rocks were not exposed, then uranium that accumulated in Pennsylvanian rock of the northern Great Plains-Williston basin area must have been derived from other sources, such as deposits or accumulations in older strata, which may have provided clastics during Pennsylvanian deposition.

PENNSYLVANIAN AND LOWER PERMIAN CONTINENTAL ROCKS

Mesozoic and Cenozoic sandstones of fluvial origin are hosts for many commercial uranium deposits. Consequently, sediments deposited in continental environments are considered favorable for investigation as potential host rocks. In the project area, continental rocks of Pennsylvanian and Early Permian age are limited in extent.

The Tyler Formation of Montana and the Dakotas consists of continental mudstones and channel sandstones, with some limestone and shale that represent brief marine incursions. The Tyler Formation is exposed in the Central Montana uplift but elsewhere is found only in the subsurface. It is several thousand feet below surface in the Williston basin.

The Fountain Formation or its equivalent consists of fluvial fan deposits that flanked the ancestral Frontrange uplift (Mallory, 1972b). There may be some fine-grained continental clastics flanking the Chadron arch. The Fountain is exposed on the flanks of the Laramie Mountains and in the Front Range of Colorado, but it grades eastward into fine-grained clastics and carbonates in the subsurface. Pennsylvanian sediments occur a few thousand feet below surface on the Chadron arch.

CONCLUSIONS

Radiometric anomalies are widespread in subsurface Pennsylvanian and Lower Permian rocks in the project area. Many of these anomalies may result from the uranium content of the sediments. Samples with higher uranium content also have higher organic carbon content, which possibly indicates that carbonaceous material acted as a trapping mechanism in some strata. Possible sources of uranium are pre-Pennsylvanian strata of the Canadian Shield area and Precambrian igneous rocks in the Ancestral Rocky Mountains. The Tyler Formation of Montana and the Dakotas and the Fountain Formation of the western Denver-Julesburg basin and the Laramie Mountains are of continental origin and, therefore, are potentially favorable as host rocks for uranium deposits. Most of these sediments are at considerable depth, with limited surface exposures. Fine-grained continental clastic rocks may flank the Chadron arch, and there seems to be an approximate parallelism of subsurface radiometric anomalies with the trend of this arch (Fig 1).

SELECTED BIBLIOGRAPHY

- Agatston, R. S., 1954, Pennsylvanian and Lower Permian of northern and eastern Wyoming: *Am Assoc. Petroleum Geologists Bull.*, v. 38, p. 508-583.
- 1957, Pennsylvanian of the Wind River Basin, *in* Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf., South Wind River Basin, 1957: p. 29-33.
- Agnew, A. F., and Tychsen, P. C., 1965, A guide to the stratigraphy of South Dakota: *South Dakota Geol. Survey Bull.* 14, 195 p., 2 figs.
- Anderson, S. B., 1974, Pre-Mesozoic paleogeologic map of North Dakota: *North Dakota Geol. Survey Misc. Map* 17, scale 1:1,000,000.
- Ballard, F. V., 1963, Structural and stratigraphic relationships in the Paleozoic rocks of eastern North Dakota: *North Dakota Geol. Survey Bull.* 40, 42 p.
- Ballard, Norval, 1942, Regional geology of Dakota Basin: *Am. Assoc. Petroleum Geologists Bull.*, v. 26, p. 1557-1584.
- Bartram, J. G., 1940, The stratigraphy and structure of eastern Wyoming and the Black Hills area, *in* Kansas Geol. Soc. Guidebook 14th Ann. Field Conf., Western South Dakota and Eastern Wyoming, 1940: p. 113-120.
- Bates, R. L., 1955, Permo-Pennsylvanian formations between Laramie Mountains, Wyoming, and Black Hills, South Dakota: *Am. Assoc. Petroleum Geologists Bull.*, v. 39, p. 1979-2002.
- Bowles, C. G., and Braddock, W. A., 1963, Solution breccias of the Minnelusa Formation in the Black Hills, South Dakota and Wyoming, *in* Geological Survey Research, 1963: *U.S. Geol. Survey Prof. Paper* 475-C, p. C91-C99.
- Brady, F. H., 1931, Minnelusa Formation of Beulah District, northwestern Black Hills, Wyoming: *Am. Assoc. Petroleum Geologists Bull.*, v. 15, p. 183-188.
- 1958, Evaporite deposits in the Minnelusa Formation in the Sundance-Beulah area, Crook County, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin, 1958: p. 45-47.
- Branson, C. C., 1939, Pennsylvanian formations of central Wyoming: *Geol. Soc. America Bull.*, v. 40, p. 1199-1226.
- Carlson, C. G., 1967, Cross-section of Paleozoic rocks of western North Dakota: *North Dakota Geol. Survey Misc. Ser.* 34, p. 12-15.
- comp., 1969, Bedrock geologic map of North Dakota: *North Dakota Geol. Survey Misc. Map* 10, scale 1:1,000,000.

SELECTED BIBLIOGRAPHY (continued)

- Carlson, C. G., and Anderson, S. B., 1965, Sedimentary and tectonic history of North Dakota part of Williston Basin: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1833-1846.
- Chuman, Dick, 1956, Melstone oil field, Musselshell County, Montana, in Billings Geol. Soc. 7th Ann. Field Conf. Guidebook, Central Montana, 1956: p. 110-112.
- Condra, G. E., 1927, The stratigraphy of the Pennsylvanian System in Nebraska: Nebraska Geol. Survey Bull. 1, 2nd Ser., 292 p.
- Condra, G. E., and Reed, E. C., 1935, Permo-Pennsylvanian section of the Hartville area of Wyoming: Nebraska Geol. Survey Paper 9, 46 p.
- _____, 1940, Correlation of the Carboniferous and Permian horizons in the Black Hills and the Hartville Uplift, in Kansas Geol. Soc. Guidebook 14th Ann. Field Conf., Western South Dakota and Eastern Wyoming, 1940: p. 127-139.
- _____, 1950, Correlation of the formations of the Laramie Range, Hartville Uplift, Black Hills, and western Nebraska [rev. ed.]: Nebraska Geol. Survey Bull. 13-A, 52 p.
- Cooper, G. G., 1956, The Tyler Formation and basement faulting, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 28-85.
- Darton, N. H., 1909, Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey Prof. Paper 65, 105 p.
- Darton, N. H., and Paige, Sidney, 1925, Central Black Hills, South Dakota: U.S. Geol. Survey Atlas, Folio 219.
- Davis, W. E., and Hunt, R. E., 1956, Geology and oil production on the northern portion of the Cedar Creek Anticline, Dawson County, Montana, in 1st Internat. Williston Basin Symposium: Bismarck, North Dakota, North Dakota Geol. Soc.-Saskatchewan Geol. Soc., 1956, p. 121-129.
- Denson, N. M., and Botinelly, Theodore, 1949, Geology of the Hartville Uplift, eastern Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 102, scale 1:48,000.
- Dillé, G. S., 1930, Minnelusa of Black Hills of South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 14, p. 619-623.
- Easton, W. H., 1962, Carboniferous formations and faunas of central Montana: U.S. Geol. Survey Prof. Paper 348, 126 p.

SELECTED BIBLIOGRAPHY (continued)

- Faulkner, G. L., 1956, Subsurface stratigraphy of the pre-Niobrara formations along the western margin of the Powder River Basin, Wyoming, in Wyoming stratigraphy: Wyoming Geol. Assoc., p. 35-41.
- Fisher, J. H., 1963, Tensleep Sandstone of the eastern Big Horn Mountains, Wyoming, in Wyoming Geol. Assoc.-Billings Geol. Soc. Guidebook Joint Field Conf., Northern Powder River Basin, 1963: p. 54-60.
- Foster, D. I., 1956, Northwest Sumatra Field, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 117-123.
- _____, 1958, Summary of the stratigraphy of the Minnelusa Formation, Powder River Basin, Wyoming, in Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin, Wyoming, 1958: p. 39-44.
- Fuening, Paul, 1942, Thickness and structural study of major divisions of Cretaceous System in Nebraska: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 1517-1536.
- Gorman, D. R., 1963, Stratigraphic-sedimentational aspects of the Amsden Formation: Big Horn Mountains, in Wyoming Geol. Assoc.-Billings Geol. Soc. Guidebook Joint Field Conf., Northern Powder River Basin, 1963: p. 67-70.
- Gott, G. B., Wolcott, D. E., and Bowles, C. G., 1974, Stratigraphy of the Inyan Kara Group and localization of uranium deposits, southern Black Hills, South Dakota and Wyoming: U.S. Geol. Survey Prof. Paper 763, 57 p., 4 pl.
- Hainer, J. L., 1956, The geology of North Dakota: North Dakota Geol. Survey Bull. 31, 46 p., 3 pl.
- Henbest, L. G., 1954, Pennsylvanian foraminifera in Amsden Formation and Tensleep Sandstone, Montana and Wyoming, in Billings Geol. Soc. Guidebook 5th Ann. Field Conf., Pryor Mountains-Northern Bighorn Basin, Montana, 1954: p. 50-53.
- Hooper, W. F., 1961, Lower Cretaceous of Casper Arch, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 1523-1544.
- Jennings, T. V., 1959, Faunal zonation of the Minnelusa Formation, Black Hills, South Dakota: Jour. Paleontology, v. 33, p. 986-1000.
- Jensen, J. S., and Carlson, K. P., 1972, The Tyler Formation in the subsurface, central Montana, in Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region: Rocky Mountain Assoc. of Geologists, p. 128-130.

SELECTED BIBLIOGRAPHY (continued)

- Jones, C. T., 1940, Subsurface section from Big Muddy Field, Converse County, Wyoming, through Nebraska, to central Kansas Uplift, Ellis County, Kansas, in Kansas Geol. Soc. Guidebook 14th Ann. Field Conf., Western South Dakota and Eastern Wyoming, 1940: p. 140-141.
- Keefer, W. R., 1965, Geologic history of Wind River Basin, central Wyoming: Am Assoc. Petroleum Geologists Bull., v. 49, p. 1878-1892.
- Keefer, W. R., and Van Lieu, J. A., 1966, Paleozoic formations in the Wind River Basin, Wyoming: U.S. Geol. Survey Prof. Paper 495-B, 64 p., 6 pl.
- Kunkel, R. P., 1954, Structure contour map of the base of Mississippian rocks in the Williston Basin and adjoining areas of Montana, North Dakota, South Dakota, and Wyoming: U.S. Geol. Survey Oil and Gas Inv. Map OM 165, scale 1:1,000,000.
- Love, J. D., 1954, Tentative diagrammatic correlation of Tensleep, Amsden, Casper and Hartville Formations of Wyoming, in Wyoming Geol. Assoc. Guidebook 9th Ann. Field Conf., Casper Area, Wyoming, 1954: chart in pocket.
- Love, J. D., and Weitz, J. L., 1951, Geologic map of the Powder River Basin and adjacent areas, Wyoming: U.S. Geol. Survey Oil and Gas Inv. Map OM 122, scale 1:316,800.
- Love, J. D., Denson, N. M., and Botinelly, Theodore, 1949, Geology of the Glendo area, Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 92, scale 1:48,000.
- Love, J. D., Henbest, L. G., and Denson, N. M., 1953, Stratigraphy and paleontology of Paleozoic rocks, Hartville area, eastern Wyoming: U.S. Geol. Survey Oil and Gas Inv. Chart OC 44, vert. scale 1:480.
- Macauley, G., 1964, Regional framework of Paleozoic sedimentation in western Canada and northwestern United States, in Leskela, Willard, Brindle, John, and Harris, S. H., eds., 3rd Internat. Williston Basin Symposium: Billings, Montana, Billings Geol. Soc., North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1964, p. 119-126.
- Mallory, W. W., 1958, Pennsylvanian coarse arkosic redbeds and associated mountains in Colorado, in Curtis, Bruce, ed., Rocky Mtn. Assoc. of Geologists Symposium on Pennsylvanian Rocks of Colorado and Adjacent Areas, 1958: p. 17-20.
- _____, 1960, Outline of Pennsylvanian stratigraphy of Colorado, in Weimer, R. J., and Haun, J. D., eds., Guide to the geology of Colorado: Denver, Colo., Geol. Soc. America, Rocky Mtn. Assoc. of Geologists, Colorado Sci. Soc., p. 23-33.

SELECTED BIBLIOGRAPHY (continued)

- Mallory, W. W., comp., 1972a, Regional synthesis of the Pennsylvanian System, in Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region, 1972: Rocky Mtn. Assoc. of Geologists, p. 131-132.
- _____, 1972b, Pennsylvanian arkose and the ancestral Rocky Mountains, in Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region, 1972: Rocky Mtn. Assoc. of Geologists, p. 131-132.
- Martin, C. A., 1965, Denver basin: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1908-1925.
- Maughan, E. K., and Roberts, A. E., 1967, Big Snowy and Amsden Groups and the Mississippian-Pennsylvanian boundary in Montana: U.S. Geol. Survey Prof. Paper 554-B, 27 p., 4 pl.
- Maughan, E. K., and Wilson, R. F., 1960, Pennsylvanian and Permian strata in southern Wyoming and northern Colorado, in Weimer, R. J., and Haun, J. D., Guide to the geology of Colorado: Denver, Colo., Geol. Soc. America, Rocky Mtn. Assoc. of Geologists, Colorado Sci. Soc., p. 34-42.
- McCauley, V. T., 1956, Pennsylvanian and Lower Permian of the Williston Basin, in 1st Internat. Williston Basin Symposium: Bismarck, North Dakota, North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1956, p. 150-164.
- Middleton, H. F., and Kennedy, G. O., 1956, Stratigraphy of the Nesson Anticline, in 1st Internat. Williston Basin Symposium: Bismarck, North Dakota, North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1956, p. 53-60.
- Muehlberger, W. R., Denison, R. E., and Lidiak, E. G., 1967, Basement rocks in continental interior of United States: Am. Assoc. Petroleum Geologists Bull., v. 51, p. 2351-2380.
- Mundt, P. A., 1956a, Heath-Amsden strata in central Montana: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 1915-1934.
- _____, 1956b, The Tyler and Alaska Bench Formations, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 46-51.
- North Dakota Geological Society, 1954, Stratigraphy of the Williston Basin: North Dakota Geol. Soc., 70 p.
- Norton, C. H., 1956, Evidences of unconformity in rocks of Carboniferous age in central Montana, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 52-66.
- Norwood, E. E., 1965, Geological history of central and south-central Montana: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1824-1832.

SELECTED BIBLIOGRAPHY (continued)

- Pye, W. D., 1958, Northern Great Plains paleogeology and inter-stratigraphic relationships, in 2nd Internat. Williston Basin Symposium: Regina, Saskatchewan, Saskatchewan Geol. Soc., North Dakota Geol. Soc., 1958: p. 8-16.
- Rascoe, Bailey, Jr., and Baars, D. L., 1972, Permian System, in Mallory, W. W., ed., Geologic atlas of the Rocky Mountain region: Rocky Mtn. Assoc. of Geologists, p. 143-165.
- Reed, E. C., 1955, Correlation of the Permo-Pennsylvanian rocks of the Black Hills with the northern midcontinent region, in North Dakota Geol. Soc. Guidebook South Dakota-Black Hills Field Conf., 1955: p. 44-47.
- _____, 1959, The geological section of Nebraska [rev. ed.]: Nebraska Geol. Survey Bull. 14A, p. 22-58.
- Rosholt, J. N., Zartman, R. E., and Nkomo, I. T., 1973, Lead isotope systematics and uranium depletion in the Granite Mountains, Wyoming: Geol. Soc. America Bull., v. 84, p. 989-1002.
- Sandberg, C. A., 1964, Precambrian to Mississippian paleotectonics of the southern Williston Basin, in Leskela, Willard, Brindle, John, and Harris, S. H., eds., 3rd Internat. Williston Basin Symposium: Billings, Montana, Billings Geol. Soc., North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1964, p. 37-38.
- Schoon, R. A., 1974, Generalized stratigraphic column of central and north-western South Dakota: South Dakota Geol. Survey Educational Ser. Map 6, 1 sheet.
- Sears, W. A., and Sims, F. C., 1954, Structural geology of the Casper Mountain area, in Wyoming Geol. Assoc. Guidebook 9th Ann. Field Conf., Casper area, 1954: p. 27-31.
- Shelton, J. W., and Al-Shaieb, Zuhair, 1976, Summary of the stratigraphy, sedimentology, and mineralogy of Pennsylvanian and Permian rocks of Oklahoma in relation to uranium-resource potential: U.S. Energy Research and Devel. Adm., GJBX-20(76), Open-File Rept; 156 p.
- Sloss, L. L., 1956, Geologic comparison of Williston Basin and other productive basins, in 1st Internat. Williston Basin Symposium: Bismarck, North Dakota, North Dakota Geol. Soc., Saskatchewan Geol. Soc. 1956, p. 6-13.
- Smith, Russell, and Burchett, Raymond, 1967, Stratigraphic cross section of Paleozoic rocks of Nebraska: Am. Assoc. Petroleum Geologists (Reprinted from Stratigraphic cross section of Paleozoic rocks Oklahoma to Saskatchewan), p. 7-9, 1 pl.

SELECTED BIBLIOGRAPHY (continued)

- Smith, W.S.T., 1903, Hartville, Wyoming: U.S. Geol. Survey Atlas, Folio 91.
- Sonnenberg, F. P., 1956, Tectonic patterns of central Montana, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 73-81.
- South Dakota Geological Survey, 1953, Panel diagram, subsurface formations of South Dakota [rev.]: South Dakota Geol. Survey, scale 1:105,600.
- Stanley, K. O., 1971, Tectonic implications of Tertiary sediment dispersal on the Great Plains east of the Laramie Range, in Wyoming Geol. Assoc. Guidebook 23rd Ann. Field Conf., Wyoming tectonics, 1971: p. 65-70.
- Stevenson, R. E., 1952, Structures and stratigraphy of southwestern Butte County: South Dakota Geol. Survey Rept. of Inv. 69: p. 17-31.
- Taylor, J. R., 1958, Pennsylvanian stratigraphy and history of northern Denver Basin, in Curtis, Bruce, ed., Rocky Mtn. Assoc. of Geologists Symposium on Pennsylvanian Rocks of Colorado and Adjacent Areas, 1958: p. 64-68.
- Tenney, C. S., 1966, Pennsylvanian and Lower Permian deposition in Wyoming and adjacent areas: Am. Assoc. Petroleum Geologists Bull., v. 50, p. 227-250.
- _____, 1968, Heavy oil in Minnelusa in northern Black Hills, in Wyoming Geol. Assoc. Guidebook 20th Ann. Field Conf., Black Hills Area, South Dakota, Montana, Wyoming, 1968: p. 95-99.
- Thomas, H. D., 1940, Pennsylvanian and Permian stratigraphy of central and southeastern Wyoming, in Kansas Geol. Soc. Guidebook 14th Ann. Field Conf., Western South Dakota and Eastern Wyoming, 1940: p. 121-126.
- _____, 1949, Summary of Paleozoic stratigraphy of the Powder River Basin, in Wyoming Geol. Assoc. Guidebook 4th Ann. Field Conf., Powder River Basin, Wyoming, 1949: p. 43-45.
- Thompson, W. O., and Kirby, J. M., 1940, Cross sections from Colorado Springs to Black Hills showing correlation of Paleozoic stratigraphy, in Kansas Geol. Soc. Guidebook 14th Ann. Field Conf., Western South Dakota and Eastern Wyoming, 1940: p. 142-147.
- Towse, Donald, 1952, Subsurface geology of south-central North Dakota: North Dakota Geol. Survey Bull. 27, 23 p.
- Tranter, C. E., and Petter, C. K., 1963, Lower Permian and Pennsylvanian stratigraphy of the northern Rocky Mountains, in Wyoming Geol. Assoc. - Billings Geol. Soc. Guidebook Joint Field Conf., Northern Powder River Basin, 1963: p. 45-53.

SELECTED BIBLIOGRAPHY (continued)

- Varland, R. O., 1956, Big Wall Field, in Billings Geol. Soc. Guidebook 7th Ann. Field Conf., Central Montana, 1956: p. 113-115.
- Verville, G. J., and Momper, J. A., 1960, Pennsylvanian fusulinids and preliminary series correlation in southwestern Wyoming, in Wyoming Geol. Assoc. Guidebook 15th Ann. Field Conf., Overthrust Belt of southwest Wyoming, 1960: p. 127-128.
- Verville, G. J., and Thompson, E. E., 1963, Desmoinesian fusulinids from the Minnelusa Formation in the southern Black Hills, South Dakota, in Wyoming Geol. Assoc., Billings Geol. Soc. Guidebook Joint Field Conf., Northern Powder River Basin, 1963: p. 61-66.
- Williams, J. S., 1962, Pennsylvanian System in central and northern Rocky Mountains, in Branson, C. C., ed., The Pennsylvanian System in the United States, a Symposium: Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 159-187.
- Wilmarth, M. G., comp., 1936, Modern classifications of the Pennsylvanian rocks of eastern Kansas and southeastern Nebraska: U.S. Geol. Survey, 1 pl.
- _____, comp., 1936, Modern classifications of the Permian rocks of Kansas and Nebraska: U.S. Geol. Survey, 1 pl.
- Wilson, P. C., 1962, Pennsylvanian stratigraphy of Powder River Basin and adjoining areas, in Branson, C. C., ed., The Pennsylvanian System in the United States, a Symposium: Tulsa, Okla., Am. Assoc. Petroleum Geologists, p. 117-158.
- Wishart, John, Kent, Donald, and Scott, Jim, comps., 1964, Stratigraphic correlation chart, in Leskela, Willard, Brindle, John, and Harris, S. H., eds., 3rd Internat. Williston Basin Symposium: Billings, Montana, Billings Geol. Soc., North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1964, p. 6.
- Wyoming Geological Association Technical Studies Committee, 1965, Geologic history of Powder River Basin: Am. Assoc. Petroleum Geologists Bull., v. 49, p. 1893-1907.
- Ziebarth, H. C., 1964, The Tyler Formation of southwestern North Dakota, in Leskela, Willard, Brindle, John, and Harris, S. H., eds., 3rd Internat. Williston Basin Symposium: Billings, Montana, Billings Geol. Soc., North Dakota Geol. Soc., Saskatchewan Geol. Soc., 1964, p. 119-126.

APPENDIX A

LOCATION, DESCRIPTION, AND ANALYSES OF ROCK SAMPLES

TABLE A1. LOCATION AND DESCRIPTION OF ROCK SAMPLES

Sample no.	Legal location	Formation/ Age	Depth (ft)	Lithology
22818 (composite sample)	SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 25, T. 146 N., R. 97 W. (North Dakota)	Tyler Formation/ Pennsylvanian	8,036	Limestone pebble conglomerate in black graphitic shale, pebbles appear fossiliferous.
			8,041-8,044	Shale, gray, calcareous, calcite vein, some iron in carbonate or iron carbonate.
			8,051-8,052	Shale, gray, calcareous, calcite vein, some iron in carbonate or iron carbonate.
			8,082	Shale, gray and black, carbonaceous, calcareous, fossiliferous, some limonite stains on gray shale.
22819	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 10, T. 139 N., R. 98 W. (North Dakota)	Tyler Formation/ Pennsylvanian	8,035	Shale, black, carbonaceous, slightly calcareous and pyritic, fossiliferous.
22820 (composite sample)	NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 16, T. 139 N., R. 99 W. (North Dakota)	Tyler Formation/ Pennsylvanian	8,213-3,216	Claystone, red, dark-gray, black claystone, red, slightly calcareous, with non-calcareous gray patches.
			8,216.5	Claystone, red and gray.
			8,217	Sandstone, red oxidized, fine to medium grained, quartzose, slightly calcareous. Small reduced gray-green patches. Red portion more porous than gray-green patches.

TABLE A1. (continued)

Sample no.	Legal location	Formation/ Age	Depth (ft)	Lithology
23074	NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 12 T. 53 N., R. 70 W. (Wyoming)	Minnelusa Formation/ Pennsylvanian	7,359-7,360	Sandstone, dense, light to dark gray, fine-grained, with intercalated pink or light red bands; some claystone noted; central part of interval dis- plays pinpoint porosity, bleeding oil.

TABLE A2. RAPID ROCK ANALYSIS
(Results in percent)

Oxide or element	Sample no. 22818	Sample no. 22819	Sample no. 22820	Sample no. 23074
SiO ₂	31.3	39.4	66.3	52.95
Al ₂ O ₃	11.7	15.7	16.1	5.55
TiO ₂	0.55	0.63	0.87	0.17
MnO	0.16	0.15	0.01	0.09
MgO	1.12	0.72	0.67	8.07
Na ₂ O	0.66	0.76	0.90	0.20
K ₂ O	1.81	1.53	2.51	1.77
CaO	21.99	13.39	0.77	8.40
CO ₂	14.1	9.77	0.27	19.6
P ₂ O ₅	0.31	0.56	0.15	0.08
S	1.35	3.89	0.15	0.10
SO ₄	0.52	0.24	0.22	0.04
FeO	2.10	1.01	1.49	2.62
Fe ₂ O ₃	1.94	4.65	8.59	0.10
Organic C	7.37	9.39	3.91	12.88

TABLE A3. GAMMA-RAY SPECTROSCOPIC AND CHEMICAL URANIUM
AND THORIUM ANALYSES

Sample no.	cU ₃ O ₈ (ppm)	cU (ppm)	eU (ppm)	cTh (ppm)	eTh (ppm)
22818	13	11	13.4	11	9.3
22819	19	16.1	20.5	11	9.3
22820	3	2.5	4.2	7	13.8
23074	79	67	61.3	9	2.8

c: chemical.

e: equivalent.

TABLE A4. SEMIQUANTITATIVE EMISSION SPECTROGRAPHIC ANALYSIS
(Element concentration in percent)

Element	Sample no. 22818	Sample no. 22819	Sample no. 22820	Sample no. 23074
Al	8.0000	9.0000	>10	4.0000
B	0.0080	0.0100	0.0080	0.0100
Ba	0.0100	<0.0005	0.0800	0.0200
Be	0.0004	0.0004	0.0004	0.0003
Ca	>10	10.0000	1.0000	8.0000
Cr	0.0100	0.0100	0.0200	0.0020
Cu	0.0010	0.0030	0.0001	0.0070
Fe	1.0000	1.5000	5.0000	1.5000
Ga	0.0001	0.0005	0.0003	0.0001
K	1.0000	0.8000	0.8000	1.0000
Li	0.0020	0.0020	0.0030	0.0005
Mg	0.4000	0.3000	0.4000	5.0000
Mn	0.1000	0.2500	0.0070	0.0400
Mo	<0.0005	0.0080	0.0005	<0.0005
Na	0.1000	0.1000	0.1000	<0.0100
Ni	0.0040	0.0080	0.0040	0.0080
P	0.2000	0.0500	<0.05	<0.05
Pb	0.0005	0.0100	0.0020	0.0010
Si	>10	>10	>10	>10
Sr	0.0400	0.0050	0.0900	0.0400
Ti	0.1500	0.2000	0.4000	0.1000
V	0.0100	0.0200	0.0100	0.0200
Y	<0.001	0.0020	0.0020	0.0010
Zn	<0.01	0.0100	<0.01	0.0100
Zr	0.0080	0.0060	0.0200	0.0070

> x: Concentration greater than x percent.

< x: Concentration below detection limit.

APPENDIX B
SUBSURFACE DATA REFERENCE POINTS

APPENDIX B. SUBSURFACE DATA REFERENCE POINTS

Well ref. no.	Location	State	Operator and well no.	Elevation (ft) KB
WO-				
04843	sec. 22, T. 48 N., R. 82 W., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Mobil Oil F-13-22P	4,851
04861	sec. 3, T. 50 N., R. 72 W., SE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Samedan Oil Caplan #1	4,431
04863	sec. 12, T. 50 N., R. 71 W., NW $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Cardinal Oil Derington #1	4,595
04868	sec. 12, T. 49 N., R. 83 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Texaco Inc. #1 Johnson L&C	5,615
04878	sec. 9, T. 52 N., R. 82 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Austral Oil Buell #1	4,688
04881	sec. 5, T. 54 N., R. 77 W., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Trigood Oil Petrich #1	3,803
04882	sec. 10, T. 54 N., R. 77 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Apache Explor. #1-10 U.S. Wildhorse	3,751
04889	sec. 31, T. 53 N., R. 74 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Ashland Oil Federal #1-31	4,593
04910	sec. 29, T. 58 N., R. 81 W., NE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Mountain Min. #14-29 Fed.-Fordyce	4,124
04921	sec. 28, T. 58 N., R. 71 W., SE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Davis Oil Fed. Rogers #1	3,718
04936	sec. 33, T. 51 N., R. 69 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	C. E. Brehm Stewart #1	4,251
04939	sec. 35, T. 51 N., R. 70 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Prenalta Corp. 35-2 Govt.	4,337
04940	sec. 2, T. 7 S., R. 39 E., SE $\frac{1}{4}$ NE $\frac{1}{4}$	Montana	States Oil Govt.-Cabot #1	4,662
04947	sec. 4, T. 51 N., R. 72 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Carter Oil #1 Govt.-Oedekoven	4,296
04955	sec. 17, T. 51 N., R. 71 W., SW $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Woods Pet. Stephenson #1	4,264
04957	sec. 15, T. 51 N., R. 71 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Andrikopoulos #1-15 Federal	4,460
04958	sec. 20, T. 51 N., R. 70 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	True Oil McPherson #1	4,221
04959	sec. 27, T. 51 N., R. 70 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Prenalta-Echo #27-1 Govt.	4,347
04961	sec. 35, T. 51 N., R. 70 W., SW $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Davis Oil C-W #1	4,218
04963	sec. 32, T. 51 N., R. 69 W., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	W. B. Osborn U.S.A. #26-1	4,317
04965	sec. 35, T. 51 N., R. 69 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	U. S. SRM Co. #1 Larsen-A	4,486
04974	sec. 28, T. 50 N., R. 68 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Nat. Assoc. Pet. Hall #1	4,242
04976	sec. 14, T. 47 N., R. 78 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Publishers Pet. Federal #1-14	4,332
04988	sec. 35, T. 58 N., R. 70 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Exeter Drilling #1 Atlantic-Govt.	3,600
05005	sec. 30, T. 6 S., R. 50 E., NE $\frac{1}{4}$ NW $\frac{1}{4}$	Montana	Shell Oil Govt. #21-30	3,292
05021	sec. 2, T. 7 S., R. 36 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Montana	Amerada Pet. #1 Crow Tribal	3,753
05053	sec. 35, T. 50 N., R. 72 W., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Internat. Nuclear Edwards #1	4,520
05055	sec. 22, T. 50 N., R. 71 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	McCulloch Oil Homestake Mining #1	4,492

APPENDIX B. (continued)

Well ref. no. WO-	Location	State	Operator and well no.	Elevation (ft) KB
05056	sec. 30, T. 50 N., R. 70 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Superior Oil Govt. #1	4,581
05057	sec. 33, T. 50 N., R. 70 W., NE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Sinclair Oil & Gas Pulaski #1	4,423 GL
05077	sec. 29, T. 57 N., R. 78 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Shell Oil #1 Clear Creek	4,159
05084	sec. 10, T. 5 S., R. 49 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Montana	Shell Oil #14-10 Govt.	3,653
05095	sec. 19, T. 2 S., R. 40 E., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Montana	Superior Oil #22-19 Cheyenne	3,546
05109	sec. 10, T. 1 S., R. 36 E., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Montana	Mobil Prod. #T-44-10 "1"	3,444
05112	sec. 34, T. 1 S., R. 37 E., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Montana	McAlester-Wilco Tribal 4-34	3,461
05113	sec. 29, T. 1 S., R. 39 E., SW $\frac{1}{4}$ NE $\frac{1}{4}$	Montana	Southland Royalty #1 NPRR Sup.	3,938
05118	sec. 32, T. 1 N., R. 35 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Montana	Great North. Trailways Kendrick #1	3,388
05120	sec. 12, T. 1 N., R. 37 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Montana	Forest Oil #12-1 Alderson	3,558
05141	sec. 20, T. 2 N., R. 52 E., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Montana	Garfield & Pasternak #1 Govt.	3,285
05144	sec. 26, T. 3 N., R. 35 E., C SW $\frac{1}{4}$	Montana	Glenn McCarthy Kendricks #2	3,094
05145	sec. 23, T. 3 N., R. 40 E., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Montana	Carter Oil #1 NPRR	3,365
05152	sec. 20, T. 5 N., R. 40 E., NE $\frac{1}{4}$ SE $\frac{1}{4}$	Montana	Carter Oil #1 Schenk	3,000 GL
05159	sec. 8, T. 6 N., R. 47 E., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Montana	Brown-Barker #1 Govt.	2,725
05162	sec. 16, T. 47 N., R. 70 W., NE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Calif. Oil #1 State 0-19293	4,425
05163	sec. 36, T. 47 N., R. 71 W., NE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Ambassador Oil Wyo. State #1	4,629
05164	sec. 14, T. 47 N., R. 72 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Reading & Bates Lynde #1	4,591
05170	sec. 23, T. 48 N., R. 71 W., SE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Southland Royalty Cayce #1	4,505
05171	sec. 21, T. 48 N., R. 72 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Davis Oil Lynde #1	4,629
05176	sec. 20, T. 49 N., R. 71 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	True Oil Wolff #44-20	4,723
05177	sec. 27, T. 49 N., R. 72 W., SE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Sam Gray Rohan #27-1	4,787
05178	sec. 14, T. 49 N., R. 74 W., SW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Reading & Bates Mohawk State #1	4,675
05183	sec. 24, T. 53 N., R. 72 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Davis Oil Walker-Fed. #1	4,200
05192	sec. 18, T. 56 N., R. 75 W., NE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Glenn A. Dow Govt. Kirby #1	3,878
05256	sec. 25, T. 55 N., R. 74 W., SE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Amarillo Oil Dow-State #1	4,183
05257	sec. 34, T. 50 N., R. 74 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Union Oil #1-E-34 Fed.	4,665

APPENDIX B (continued)

Well ref. no.	Location	State	Operator and well no.	Elevation (ft) KB
05260	sec. 16, T. 50 N., R. 73 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Shell Oil #16-1 State	4,636
05262	sec. 4, T. 51 N., R. 83 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	G. L. Reasor Tarbet #1	5,331
05263	sec. 30, T. 58 N., R. 84 W., NE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Shell Oil Buszkieswic #1	4,035 DF
05264	sec. 27, T. 52 N., R. 73 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Pubco Pet. #27-6 Federal	4,455
05265	sec. 21, T. 47 N., R. 81 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Davis Oil #1 Signal-Govt.	4,772
05267	sec. 30, T. 52 N., R. 71 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Shamrock Oil #1 Stephenson	4,237
05268	sec. 19, T. 55 N., R. 79 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Amerada Pet. #1 USA Boland	4,333
05269	sec. 35, T. 51 N., R. 72 W., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Tenneco Oil #1 Marshall A	4,436
05272	sec. 34, T. 49 N., R. 76 W., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Chevron Oil #1 Chevron-Fed.	4,409
05273	sec. 7, T. 47 N., R. 71 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Davis Oil #1-B Dunlap	4,654
05274	sec. 9, T. 47 N., R. 71 W., NW $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Davis Oil #1 Floyd	4,616
05276	sec. 16, T. 48 N., R. 72 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Risco Oil #1 State-Grigsby	4,621
05277	sec. 33, T. 57 N., R. 74 W., SE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Phillips Pet. #4 Greenough-A	4,068
05278	sec. 13, T. 57 N., R. 75 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Glenn A. Dow #1 Govt.-Parker	4,142
05282	sec. 24, T. 50 N., R. 77 W., NE $\frac{1}{4}$ NE $\frac{1}{4}$	Wyoming	Devon Corp. #1 Unit	4,284
05283	sec. 3, T. 55 N., R. 75 W., SE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	True Oil #24-3 T-S-C	4,027
05285	sec. 19, T. 51 N., R. 70 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Trigood Oil #1 Munoz-Govt.	4,396
05286	sec. 17, T. 57 N., R. 79 W., NE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Amerada Pet. #1 Govt.-Cranston	3,948
05289	sec. 33, T. 54 N., R. 73 W., NE $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Cranlyn Expl. Govt. #1	4,119 GL
05290	sec. 24, T. 54 N., R. 74 W., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	MKM Exploration #1-A Parnell	4,186
05291	sec. 15, T. 5 S., R. 46 E., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Montana	Miami Oil #1-15 Fed.	3,739
05292	sec. 11, T. 9 S., R. 45 E., NE $\frac{1}{4}$ NW $\frac{1}{4}$	Montana	Gulf Oil #1 Bales	3,883
05331	sec. 16, T. 36 N., R. 74 W., NW $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Humble Oil #1 Hornbeck Unit	5,798
05480	sec. 17, T. 40 N., R. 76 W., SE $\frac{1}{4}$ SW $\frac{1}{4}$	Wyoming	Sinclair #1 Wind Creek	5,532
05577	sec. 12, T. 45 N., R. 81 W., NE $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Shell Oil Govt. 43X-12	4,776
05579	sec. 8, T. 46 N., R. 81 W., SW $\frac{1}{4}$ NW $\frac{1}{4}$	Wyoming	Skyline Oil S Crazy Woman Creek #1	5,005

APPENDIX B (continued)

Well ref. no.	Location	State	Operator and well no.	Elevation (ft) KB
WO-12-				
000	sec. 9, T. 129 N., R. 106 W., C NW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Carter Oil #1 L. L. Johnson	2,953
001	sec. 29, T. 131 N., R. 80 W., C NE $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Ohio Oil #1 Standing Rock Sioux	1,731
002	sec. 13, T. 132 N., R. 102 W., C NW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Western Nat. Gas Truax-Traier #1	3,074
003	sec. 26, T. 133 N., R. 83 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Youngblood & Youngblood Kelstrom #1	1,997
004	sec. 24, T. 134 N., R. 96 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Socony Vacuum Jacobs #F-14-24	2,616
005	sec. 20, T. 135 N., R. 98 W., SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Worley, Harrell & Feldman Benz #1	2,964
006	sec. 32, T. 137 N., R. 76 W., NW $\frac{1}{4}$ NW $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Continental Oil McCay #1	1,869
007	sec. 15, T. 137 N., R. 100 W., C SE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Pan American #1 Fritz	2,854
008	sec. 11, T. 139 N., R. 82 W., C SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Signal Drilling #1 Boehm	1,861
009	sec. 30, T. 139 N., R. 86 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Deep Rock Oil Johnson "A" #1	2,204
010	sec. 9, T. 139 N., R. 100 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Amerada Pet. May #1	2,774
011	sec. 3, T. 140 N., R. 77 W., C NW $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Continental Oil Duemeland #1	1,981
012	sec. 23, T. 140 N., R. 79 W., C NW $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Hunt Trust #1 Ryberg	2,007
013	sec. 32, T. 140 N., R. 96 W., C SW $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Leach Oil #1 Kalanek	2,516
014	sec. 15, T. 140 N., R. 105 W., C NE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Blackwood & Nichols #1 Gilman	2,876
015	sec. 3, T. 141 N., R. 81 W., C SE $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Youngblood & Youngblood #1 Wachter	1,924
016	sec. 34, T. 141 N., R. 85 W., C NW $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Signal Drilling #1 Bueligen	2,173
017	sec. 6, T. 141 N., R. 94 W., C SE $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Socony Vacuum Dvorak #F-42-60	2,296
018	sec. 32, T. 142 N., R. 74 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Hunt Trust #1 Sauter	1,848
019	sec. 14, T. 142 N., R. 85 W., NE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Sunray DX Oil #1 Henke	2,193
020	sec. 28, T. 142 N., R. 89 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Plymouth Oil Co. #1 Lentz	2,284 DF
021	sec. 17, T. 143 N., R. 100 W., C SE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Stanolind Oil & Gas N.W. Improv. #2	2,815
022	sec. 3, T. 143 N., R. 103 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Gulf Oil #1 Federal	2,365
023	sec. 10, T. 144 N., R. 88 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Williston Oil & Gas Boeckel #1	2,059
024	sec. 10, T. 144 N., R. 94 W., C NE $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Argo Oil #1 Larson	2,410
025	sec. 31, T. 144 N., R. 100 W., C SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Texas Co. #1 Govt.-Pace	2,463
026	sec. 15, T. 145 N., R. 101 W., SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Shell Oil #32-15 N.P.	2,294
027	sec. 19, T. 146 N., R. 76 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Hunt Trust #1 Bauer	1,984
028	sec. 11, T. 146 N., R. 91 W., C NW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Stanolind Oil & Gas #1 Unit	2,291

APPENDIX B (continued)

Well ref. no.	Location	State	Operator and well no.	Elevation (ft) KB
WO-12-				
029	sec. 36, T. 147 N., R. 96 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Continental Oil #1 State	2,647
030	sec. 13, T. 148 N., R. 98 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	California Co. #1 Rough Creek Unit	2,472
031	sec. 28, T. 148 N., R. 104 W., C NW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Gulf Oil & Sun Oil #1 Pierre	2,339
032	sec. 22, T. 149 N., R. 91 W., C SE $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Mobil Producing #F22-22-1	2,092
033	sec. 12, T. 149 N., R. 96 W., C SW $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Amerada Pet. #1 Risser	2,438
034	sec. 21, T. 152 N., R. 94 W., C SW $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Stanolind Oil & Gas Woodrow Star #1	2,140
035	sec. 1, T. 152 N., R. 95 W., C SE $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Amerada Pet. Norby #1	2,148
036	sec. 34, T. 152 N., R. 96 W., NE $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Skelly Oil Tank #1	2,328
037	sec. 13, T. 152 N., R. 102 W., C NE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Phillips Pet. #1 Hoehn	2,278
038	sec. 2, T. 153 N., R. 85 W., C SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Stanolind Oil & Gas Waswick #1	2,175
039	sec. 10, T. 153 N., R. 96 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Amerada Pet. #1 Mogen Tract	2,017
040	sec. 23, T. 154 N., R. 100 W., C SW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Texas #1 Donahue	2,253
041	sec. 6, T. 155 N., R. 95 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Amerada Pet. #1 Iverson	2,390
042	sec. 12, T. 155 N., R. 96 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Amerada Pet. Nelson #1	2,359
043	sec. 14, T. 156 N., R. 92 W., C SE $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Hunt Horne #1	2,322
044	sec. 7, T. 156 N., R. 96 W., C NE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Champlin Refining Tank #1	2,311
045	sec. 25, T. 157 N., R. 89 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Hunt #1 Anderson	2,271
046	sec. 21, T. 158 N., R. 95 W., C NE $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Amerad Pet. #Pederson-Cotter Unit	2,473
047	sec. 10, T. 160 N., R. 91 W., C SW $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Lion Oil Co. #1 Swenson	2,327
048	sec. 23, T. 160 N., R. 93 W., SE $\frac{1}{4}$ SE $\frac{1}{4}$	North Dakota	Wilhite Co. #1 Pixley	2,372
049	sec. 36, T. 160 N., R. 95 W., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Hodge #1 State	2,366
050	sec. 13, T. 161 N., R. 92 W., C SE $\frac{1}{4}$ SW $\frac{1}{4}$	North Dakota	Pan Am Pet. #1 Owings	2,171
051	sec. 22, T. 161 N., R. 94 W., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	North Dakota	Hunt Oil #1 Cooksley	2,419
052	sec. 29, T. 162 N., R. 95 W., C NE $\frac{1}{4}$ NW $\frac{1}{4}$	North Dakota	Phillips Pet. #1 Braathen	2,233
053	sec. 34, T. 47 N., R. 71 W., NW $\frac{1}{4}$ SE $\frac{1}{4}$	Wyoming	Miles #1 Hayden	4,596
054	sec. 16, T. 2 N., R. 16 E., C SW $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Atlantic Refining #1 Knoll State	2,867
055	sec. 5, T. 3 N., R. 22 E., C SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Carter Oil Danielson #1	2,466

APPENDIX B (continued)

Well ref no. WO-12-	Location	State	Operator and well no.	Elevation (ft) KB
056	sec. 9, T. 4 N., R. 11 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$ NE $\frac{1}{4}$	South Dakota	Lion Oil Govt. Libertin #1	2,595
057	sec. 21, T. 4 N., R. 18 E., SE $\frac{1}{4}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$	South Dakota	F. E. Pohle #1 May	2,568
058	sec. 13, T. 5 N., R. 29 E., NW $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Cities Service Oil Wagner #1	1,814
059	sec. 34, T. 6 S., R. 2 E., SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Ozark Coffing Estate #2	4,231
060	sec. 18, T. 7 N., R. 28 E.,	South Dakota	Cities Service Oil Barrick Triple #1	2,082
061	sec. 26, T. 8 N., R. 13 E., C SE $\frac{1}{4}$ SE $\frac{1}{4}$	South Dakota	Herndon Drilling #1 Shinost	2,932
062	sec. 7, T. 9 N., R. 9 E., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	South Dakota	Mobil Oil Mickelson F41-7-P	2,860
063	sec. 30, T. 10 S., R. 8 E., C SE $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Interior Drilling Putnam #1	3,389
064	sec. 6, T. 12 S., R. 1 E.,	South Dakota	Pan American Pet. USA Dorough #1	4,009
065	sec. 33, T. 13 N., R. 10 E., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	South Dakota	Mule Creek Oil #41-33 State	2,808
066	sec. 20, T. 13 N., R. 20 E., SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Kerr McGee Oil Brammer #1	2,546
067	sec. 27, T. 14 N., R. 2 E., SW $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Pure Oil #1 Govt.	3,337
068	sec. 7, T. 15 N., R. 16 E., C SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Shell Oil Bastian #22-7	2,470
069	sec. 13, T. 15 N., R. 23 E., C SE $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Herndon Drilling #1-A O'Leary	2,236
070	sec. 16, T. 17 N., R. 4 E., SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Richfield Oil #1 State	3,133 DF
071	sec. 27, T. 17 N., R. 27 E., C SE $\frac{1}{4}$ SE $\frac{1}{4}$	South Dakota	Herndon Drilling #1 Merkel	1,909
072	sec. 23, T. 18 N., R. 8 E., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	South Dakota	Shell Oil #41-23 State	3,040
073	sec. 12, T. 18 N., R. 19 E., C SE $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Shell Oil #22-12 Everidge	2,231
074	sec. 23, T. 19 N., R. 18 E., C NW $\frac{1}{4}$ NW $\frac{1}{4}$	South Dakota	Shell Oil #11-23 Govt.	2,385
075	sec. 5, T. 21 N., R. 4 E., SW $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Phillips Pet. #2 Thune	3,048
076	sec. 26, T. 21 N., R. 14 E., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	South Dakota	Younblood & Youngblood Anderson #1	2,628
077	sec. 8, T. 22 N., R. 11 E., C NW $\frac{1}{4}$ SE $\frac{1}{4}$	South Dakota	Hunt & Brooks Federal #1	2,690
078	sec. 11, T. 22 N., R. 19 E., C NW $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Shell Oil Winter #1	2,489 DF
079	sec. 11, T. 102 N., R. 78 W., SW $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Gulf Oil Swedlund #1	1,951
080	sec. 4, T. 2 S., R. 23 E., NW $\frac{1}{4}$ SW $\frac{1}{4}$	South Dakota	Cities Service Oil Phipps A-1	2,326

APPENDIX B (continued)

Well ref. no. WO-12-	Location	State	Operator and well no.	Elevation (ft) KB
081	sec. 12, T. 12 N., R. 25 W., C NE $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Placid Oil Cyriacks #1	2,690
082	sec. 23, T. 12 N., R. 30 W., C NW $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Fisher Gamble #1	3,048
083	sec. 19, T. 12 N., R. 36 W., C NW $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Pan Am. #1 Perlinger	3,362
084	sec. 25, T. 13 N., R. 43 W., C NW $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Stoddard Zimmerman #1	3,633
085	sec. 5, T. 14 N., R. 32 W., C SW $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Wallace Enterprises, Inc. Hoatson #1	2,913.6
086	sec. 26, T. 14 N., R. 35 W., C NW $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Pan Am. Humphrey #1	3,013
087	sec. 35, T. 14 N., R. 53 W., S $\frac{1}{2}$ SW $\frac{1}{2}$ SW $\frac{1}{2}$	Nebraska	Magnolia Pet. Herboldsheimer #1	4,641 DF
088	sec. 11, T. 15 N., R. 49 W., NE $\frac{1}{2}$ NE $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Ohio Oil #1 Egging	4,217
089	sec. 26, T. 15 N., R. 24 W., C SE $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Hamilton Arnold #1	2,740
090	sec. 12, T. 15 N., R. 54 W., C NE $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Shell Oil #1-B Schmid	4,764
091	sec. 14, T. 17 N., R. 34 W., SW $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Placid Oil Ellerty Et Al #1	3,293
092	sec. 21, T. 18 N., R. 55 W., W $\frac{1}{2}$ NW $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Stanolind Oil #3 Lovercheck	4,920
093	sec. 15, T. 19 N., R. 31 W., C SW $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Placid Oil Connell #1	3,248
094	sec. 13, T. 19 N., R. 34 W., C SE $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Placid Oil Huffman #1	3,377
095	sec. 27, T. 19 N., R. 52 W., C SE $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Shell Oil #1 Rice	3,892
096	sec. 33, T. 20 N., R. 36 W., C SE $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Volentine #1 Mildale	3,548
097	sec. 36, T. 20 N., R. 39 W., C NW $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Hamilton State #1	3,731
098	sec. 27, T. 22 N., R. 34 W., C NW $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Thomas Producing Vinton #1	3,436
099	sec. 8, T. 22 N., R. 36 W., SW $\frac{1}{2}$ SW $\frac{1}{2}$	Nebraska	Thomas Producing #1 Egan	3,600
100	sec. 5, T. 22 N., R. 39 W., SW $\frac{1}{2}$ SW $\frac{1}{2}$	Nebraska	Thomas Producing Minor #1	3,845
101	sec. 23, T. 24 N., R. 23 W., C SE $\frac{1}{2}$	Nebraska	Kingwood Oil #1 Schneiderit	2,606 DF
102	sec. 13, T. 24 N., R. 28 W., C SE $\frac{1}{2}$ SW $\frac{1}{2}$	Nebraska	Muir & Thompsin #1 Beckhoff	3,058 GL
103	sec. 20, T. 24 N., R. 41 W., C SW $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Tucker Drilling Finegan #1	3,923
104	sec. 34, T. 26 N., R. 32 W., C SW $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Belco Pet. #1 Starr	3,294
105	sec. 10, T. 26 N., R. 42 W., N $\frac{1}{2}$ NW $\frac{1}{2}$ SE $\frac{1}{2}$	Nebraska	Texaco-Seaboard, Inc. #1 Musser-Mos.	3,948
106	sec. 20, T. 26 N., R. 44 W., SE $\frac{1}{2}$ NW $\frac{1}{2}$	Nebraska	Texaco, Inc. #1 Caldwell	3,859
107	sec. 13, T. 27 N., R. 57 W., C SE $\frac{1}{2}$ NE $\frac{1}{2}$	Nebraska	Continental Oil Hatch #1	4,720
108	sec. 12, T. 29 N., R. 37 W., SE $\frac{1}{2}$ SE $\frac{1}{2}$ SW $\frac{1}{2}$	Nebraska	Motex Oil #1 Saults	3,487

APPENDIX B (continued)

Well ref. no.	Location	State	Operator and well no.	Elevation (ft) KB
WO-12-				
109	sec. 22, T. 30 N., R. 47 W., C NW $\frac{1}{4}$ NE $\frac{1}{4}$	Nebraska	Blair #1 Kudrna	4,081
110	sec. 2, T. 30 N., R. 51 W., C SE $\frac{1}{4}$ NE $\frac{1}{4}$	Nebraska	Potter Drilling #1 Soester	4,519
111	sec. 28, T. 31 N., R. 49 W., C SW $\frac{1}{4}$ SE $\frac{1}{4}$	Nebraska	California Co. #1 Deans	4,416
112	sec. 23, T. 31 N., R. 54 W., C NE $\frac{1}{4}$ NE $\frac{1}{4}$	Nebraska	San Jacinto Pet. Oldaker #1.	4,584
113	sec. 4, T. 32 N., R. 43 W., C NW $\frac{1}{4}$ SE $\frac{1}{4}$	Nebraska	Badgett Hess #1	3,798
114	sec. 5, T. 33 N., R. 27 W., NE $\frac{1}{4}$ NW $\frac{1}{4}$ SW $\frac{1}{4}$	Nebraska	Sund Hills Drilling #1 Borman	2,564
115	sec. 12, T. 33 N., R. 37 W., C SW $\frac{1}{4}$ NW $\frac{1}{4}$	Nebraska	British American #1 Cole	3,225
116	sec. 27, T. 33 N., R. 47 W., C SW $\frac{1}{4}$ NE $\frac{1}{4}$	Nebraska	Tucker Drilling Augustine #1	3,640