# Uranium in Black Shale Deposits, Northern Rocky Mountains and Great Plains

GEOLOGICAL SURVEY BULLETIN 1030-H

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*By* W. J. MAPEL

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

# URANIUM IN BLACK SHALE DEPOSITS, NORTHERN ROCKY MOUNTAINS AND GREAT PLAINS

By W. J. MAPEL

ABSTRACT

Reconnaissance examinations for uranium in 22 formations containing black shale were made in parts of Montana, North Dakota, Utah, Idaho, and Oregon in 1953. About 150 samples from 80 outcrop localities and 5 oil and gas wells were submitted for uranium determinations. Most of the black shale deposits examined contain less than 0.003 percent of uranium; however, thin beds of black shale at the base of the Mississippian system contain 0.005 percent of uranium at 2 outcrop localities in southwestern Montana and as much as 0.007 percent of uranium in a well in northeastern Montana. An 8-foot bed of phosphatic black shale at the base of the Brazer limestone of middle and late Mississippian age in Rich County, Utah, contains as much as 0.009 percent of uranium.

Commercial gamma-ray logs of oil and gas wells drilled in Montana and adjacent parts of the Dakotas indicate that locally the Heath shale of late Mississippian age contains as much as 0.01 percent of equivalent uranium, and black shales of Late Cretaceous age contain as much as 0.008 percent of equivalent uranium.

## INTRODUCTION

### PURPOSE AND LOCATION

A reconnaissance search for uranium in black shale in the northern Rocky Mountains and Great Plains regions was carried out during the summer of 1953 by the U. S. Geological Survey on behalf of the Division of Raw Materials, U. S. Atomic Energy Commission. The work is part of a continuing program to investigate the uranium possibility of untested or incompletely tested black shale deposits in the Western States. Most of the localities visited are in southwestern and central Montana, central and southeastern Idaho, and northwestern Utah. About 150 gamma-ray logs from wells drilled for oil and gas in Montana and adjacent parts of North and South

*Relative stratigraphic relations of formations examined*

| Age | Eastern Oregon | Northern Idaho | Central Idaho | Southeastern Idaho | Northwestern Utah | Central and southwestern Montana | Eastern Montana |
|---|---|---|---|---|---|---|---|
| Cretaceous | | | | | | Colorado shale | |
| Triassic | Unnamed argillite | | | | | | |
| Mississippian | | | Unnamed shale<br>Milligen formation | Brazer limestone | Brazer limestone<br>Madison limestone<br>Leatham formation (of Holland, 1952) | So-called Amsden formation of local usage (lower part)<br>Big Snowy group:<br>Heath shale<br>Otter formation<br>Kibbey sandstone [2]<br>Madison limestone<br>Sappington sandstone (as used by Holland, 1952) | Heath shale [1]<br>Lodgepole limestone<br>Bakken formation (as used by Nordquist, 1953)[1] |
| Ordovician | | | Saturday Mountain formation<br>Ramshorn slate<br>Phi Kappa formation | | Swan Peak formation | | Winnipeg formation [1] |
| Cambrian | | | Garden Creek phyllite | Spence shale member of Ute limestone | Spence shale | Wolsey shale | |
| Precambrian | | Prichard formation | | | | Spokane shale<br>Greyson shale | |

[1] Not exposed, drill cuttings or cores sampled.
[2] Not examined.

Dakota were scanned for anomalous radioactivity, and samples of drill cores or cuttings from 5 of the wells were submitted for uranium determinations. Plate 14, the index map, shows the localities visited, and the table above shows the formations examined.

Previous work by Duncan (1953) indicated that the Heath shale of late Mississippian age and a thin black shale sequence of early Mississippian age—called variously the Bakken formation (as used by Nordquist, 1953), the shale of Kinderhook age, or the Exshaw formation (Warren, 1937)—at some places contain abnormally large amounts of uranium. Particular attention was given to a systematic sampling of these formations in an attempt to define areas of maximum or minimum radioactivity which might then be related to facies changes, source areas, thickness, or other factors that reflect environments of deposition.

Black shale of the Phosphoria formation of Permian age is known to contain uranium in the northern Rocky Mountains region, but it was excluded from the study because it has been sampled extensively as part of a separate investigation by the Geological Survey.

### ACKNOWLEDGMENTS

The present investigation is a continuation of previous reconnaissance studies made at various times since 1951 in the Rocky Mountains region, as reported by Duncan (1953).

D. C. Duncan, R. J. Ross, J. E. Smedley, R. P. Kunkel, P. W. Richards, and H. D. Hadley supplied samples of black shale or guided the writer to exposures of shale in Utah and Montana. W. J. Hail, Jr., compiled information from the gamma-ray logs and assisted in interpreting the results of this work. Radiometric and chemical analyses listed in this report were made in Geological Survey laboratories.

## FIELD WORK AND USE AND INTERPRETATION OF THE GAMMA-RAY LOGS

Outcrops of black shale described in the geologic literature or in unpublished reports available to the writer were examined for radioactivity at about 80 localities. Estimates of radioactivity were made in the field using a portable scintillation detector or a Geiger counter. At most of the localities, representative samples of the formation were collected for uranium determinations regardless of the observed radioactivity. At a few localities, however, only those parts of the formation which showed appreciable radioactivity were sampled.

Roads between outcrops were traversed with a car-mounted scintillation counter, and those areas with higher than average background were examined on foot with the portable instruments.

The examination of gamma-ray logs of wells drilled for oil or gas provides a convenient means of evaluating the uranium possibilities of many black shale formations which otherwise might be difficult to test because of poor natural exposures or broad outcrop areas. Gott and Hill (1953), in a study of commercial gamma-ray logs of uncased wells drilled in the Rangely field, northeastern Utah, found that, on the average, a 1-inch deflection of the Lane Wells gamma-ray curve at a 10-inch sensitivity scale is caused by about 0.0007 percent of equivalent uranium. They pointed out that variations in this value might be caused by such factors as the ratio of thickness to grade of the bed tested, the fluid content of the well, the shielding effect of casing in cased wells, differences in individual logging instruments, and the rate of movement of the ionization chamber. The calibration, therefore, is only approximate, but it gives some measure of the order of magnitude of radioactivity of the formations penetrated, and it is useful in comparing the radioactivity of the rocks from place to place.

Tables 1 and 2 list 15 wells drilled in Montana and the Dakotas and indicate the average and maximum deflections on the gamma-ray logs of formations containing significant amounts of black shale. The locations of these wells are given in figure 51. Gamma-ray logs of

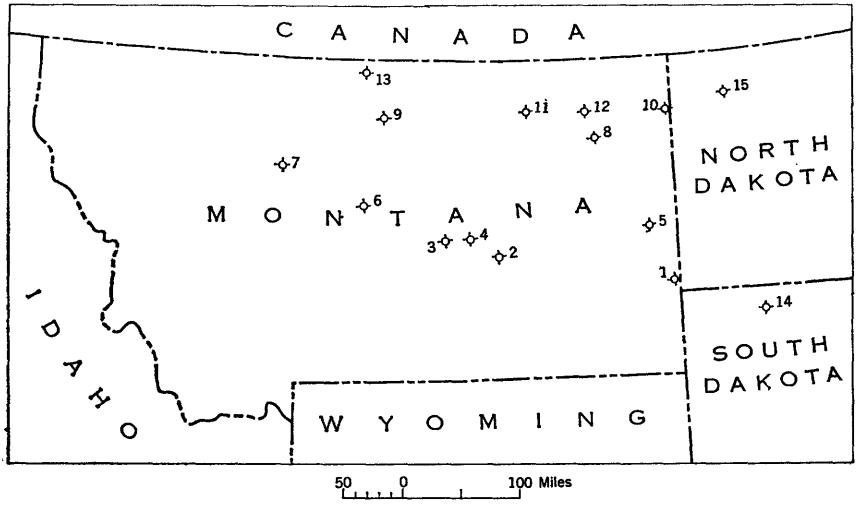


FIGURE 51.—Locations of selected wells for which gamma-ray logs were studied (table 1).

other wells examined but not listed in tables 1 and 2 show comparable radioactivity values.

## SUMMARY OF THE RESULTS OF THE INVESTIGATION

Uraniferous deposits of black shale thus far found in the northern Rocky Mountains and Great Plains regions are either deeply buried and inaccessible, or they are too thin or of too low grade to be of value at this time as a source for uranium. Only a few of the deposits contain more than 0.003 percent of uranium. Of these few, beds of black shale at the base of the Madison limestone of early Mississippian age contain 0.005 to 0.007 percent of uranium at three localities in Montana and one in North Dakota (locs. 43, 44, 82, and 85, pl. 14), and 4 feet of a bed of black shale 8 feet thick at the base of the Brazer limestone of middle and late Mississippian age contains 0.009 percent of uranium at one locality in Rich County, Utah (loc. 30). The analyses of samples collected at these and other localities are listed in table 3.

The evaluation of gamma-ray logs of oil and gas wells, as shown by table 2, suggests that the Heath shale of late Mississippian age locally contains 0.009 percent of equivalent uranium or more in Musselshell and McCone Counties, Mont., and that the Colorado and Pierre shales of Cretaceous age contain as much as 0.008 percent of equivalent uranium in Blaine County, Mont., and in Perkins County, S. Dak., respectively. No drill cores or cuttings from these wells were available for analyses, and so the actual uranium content of the shale is unknown.

TABLE 1.—*Selected wells in northern Great Plains for which gamma-ray logs were studied*

| Well no. (fig. 51) | Name of well | Location | Gamma-ray log available— | | Deepest formation logged | Source of information on formation boundaries |
|---|---|---|---|---|---|---|
| | | Sec., T., R., county, and State | From (feet) | To (feet) | | |
| 1 | Shell-Little Beaver 21-24 | Central part NE¼NW¼-24-4N-61E, Fallon, Mont. | 0 | 8,873 | Stoney Mountain shale (Ordovician). | Oil scout reports. |
| 2 | Farmers Union Central Exchange-Bunge 1. | Central part NE¼NE¼-31-9N-35E, Rosebud, Mont. | 24 | 4,353 | Otter formation (Mississippian) | Do. |
| 3 | Texas-Nebraska Feed Co. 1 | Central part SE¼NE¼-22-11N-27E, Musselshell, Mont. | 3,550 | 3,800 | Heath shale (Mississippian) | Do. |
| 4 | Farmers Union Central Exchange-Thompson 1. | SW part SW¼SW¼-7-11N-31E, Musselshell, Mont. | 0 | 5,035 | Kibbey sandstone (Mississippian) | Do. |
| 5 | Shell-Pine Unit 1 | SW part SW¼NE¼-30-12N-57E, Wibaux, Mont. | 0 | 9,746 | Winnipeg formation (Ordovician) | Sonnenberg, Rader, and Clement, 1952. |
| 6 | Cities Service-K. E. Huffine 1 | Central part SW¼SE¼-27-17N-15E, Fergus, Mont. | 0 | 6,014 | Cambrian, undifferentiated | Oil scout reports. |
| 7 | United Petroleum-Good 1 | Central part NE¼NE¼-18-23N-4E, Chouteau, Mont. | 0 | 3,606 | do | Do. |
| 8 | Marigold Oil, Ltd.-Farnham 1 | Central part SW¼SW¼-14-25N-48E, McCone, Mont. | 5,000 | 8,953 | Silurian, undifferentiated | Do. |
| 9 | Texas-Davis Ranch 1 | Central part SE¼SW¼-4-29N-18E, Blaine, Mont. | 0 | 4,921 | Cambrian, undifferentiated | Do. |
| 10 | Deep Rock Oil Corporation-Picard 1. | Central part NW¼NE¼-6-29N-58E, Roosevelt, Mont. | 5,600 | 9,028 | Mission Canyon limestone (Mississippian). | Do. |
| 11 | Gulf-R. L. Cornwell 1 | Central part SW¼NE¼-14-30N-38E, Valley, Mont. | 0 | 7,037 | Cambrian, undifferentiated | Do. |
| 12 | Continental-Fast 1 | Central part NE¼SE¼-14-30N-46E, Roosevelt, Mont. | 50 | 6,312 | Mission Canyon limestone (Mississippian). | Do. |
| 13 | General Petroleum-Erickson 36-12P. | SW part NE¼SW¼-12-36N-15E, Hill, Mont. | 0 | 6,312 | Winnipeg formation (Ordovician). | Do. |
| 14 | Shell-H. D. Veal 1 | Central part SE¼SE¼-7-17N-15E, Perkins, S. Dak. | 0 | 8,315 | do | Do. |
| 15 | Amerada-Harry Bakken 1 | Central part SW¼NE¼-12-157N-95W, Williams, N. Dak. | 6,100 | 13,715 | do | Baillie, 1953; Anderson, 1954. |

TABLE 2.—*Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains*

| Well no. (fig. 51) | Rock unit | Depth (feet) | | Thickness of unit (feet) | Gamma-ray deflection, converted to sensitivity of 10 (inches) | | Depth in well of maximum deflection (feet) | Estimated maximum eU [1] (percent) |
|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Average | Maximum | | |
| | **Cretaceous rocks** | | | | | | | |
| 1 | Pierre | 200 | 2,160 | 1,960 | 3.0 | 4.8 | 1,899 | 0.003 |
| | Niobrara | 2,160 | 2,788 | 628 | 3.7 | 5.7 | 2,210 | .004 |
| | Greenhorn | 2,788 | 2,915 | 127 | 3.6 | 4.7 | 2,860 | .003 |
| | Belle Fourche | 2,915 | 3,460 | 545 | 3.7 | 5.7 | 3,335 | .004 |
| | Mowry | 3,460 | 3,680 | 220 | 3.1 | 4.9 | 3,540 | .003 |
| | Skull Creek | 3,710 | 3,850 | 140 | 3.4 | 4.0 | 3,811 | .003 |
| | Cloverly | 3,850 | 4,100 | 250 | 2.6 | 3.7 | 3,908 | .003 |
| 2 | Colorado | 1,117 | 2,952 | 1,835 | 4.8 | 7.3 | 2,161 | .005 |
| | Kootenai | 3,032 | 3,273 | 241 | 2.3 | 8.0 | 3,151 | .006 |
| 4 | Claggett | 0 | 396 | 396 | 3.0 | 5.1 | 319 | .004 |
| | Eagle | 396 | 807 | 411 | 4.1 | 5.7 | 805 | .004 |
| | Colorado | 807 | 2,472 | 1,665 | 4.9 | 8.0 | 1,629 | .006 |
| | Kootenai | 2,577 | 2,903 | 326 | 3.1 | 5.0 | 2,738 | .004 |
| 5 | Pierre | 1,135 | 2,368 | 1,233 | 2.2 | 3.4 | 2,255 | .002 |
| | Niobrara | 2,368 | 2,928 | 560 | 3.0 | 4.5 | 2,900 | .003 |
| | Greenhorn, Carlile, Belle Fourche, Mowry | 2,928 | 3,705 | 777 | 3.3 | 5.8 | 3,469 | .004 |
| | Muddy and Skull Creek, undivided | 3,705 | 3,945 | 240 | 3.0 | 4.0 | 3,935 | .003 |
| | Cloverly | 3,945 | 4,365 | 420 | 2.4 | 4.3 | 3,955 | .003 |
| 6 | Colorado | 200 | 1,426 | 1,226 | 5.0 | 8.2 | 6412 | .006 |
| | Kootenai | 1,484 | 1,990 | 506 | 3.2 | 6.0 | 1,890 | .004 |
| 7 | Colorado | 0 | 1,030 | 1,030+ | 2.7 | 4.5 | 200 | .003 |
| | Kootenai | 1,030 | 1,602 | 572 | 2.2 | 4.5 | 1,331 | .003 |
| 9 | Colorado | 0 | 2,449 | 2,449+ | 6.0 | 10.9 | 1,183 | .008 |
| | Kootenai | 2,449 | 2,724 | 275 | 4.4 | 6.7 | 2,498 | .005 |
| 11 | Claggett and younger | 0 | 955 | 955+ | 2.0 | 3.3 | | .002 |
| | Eagle | 955 | 1,390 | 435 | 3.5 | 4.2 | 1,319 | .003 |
| | Niobrara | 1,390 | 1,842 | 452 | 4.0 | 6.7 | 1,405 | .004 |
| | Frontier and Mowry, undivided | 1,842 | 2,585 | 743 | 3.3 | 5.9 | 2,029 | .004 |
| | Skull Creek | 2,617 | 2,764 | 147 | 3.5 | 4.2 | 2,699 | .003 |
| | Kootenai | 2,764 | 3,148 | 384 | 3.0 | 5.7 | 2,881 | .004 |
| 12 | Claggett | 1,525 | 1,950 | 425 | 2.7 | 5.1 | 1,858 | .004 |
| | Eagle | 1,950 | 2,150 | 200 | 3.0 | 3.6 | 2,019 | .003 |
| | Niobrara | 2,150 | 3,050 | 900 | 3.4 | 5.7 | 3,038 | .004 |
| | Greenhorn | 3,050 | 3,250 | 200 | 3.7 | 5.8 | 3,246 | .004 |
| | Belle Fourche | 3,250 | 3,430 | 180 | 4.1 | 6.6 | 3,348 | .005 |
| | Mowry | 3,430 | 3,590 | 160 | 3.7 | 5.4 | 3,525 | .004 |
| | Kootenai | 3,900 | 4,094 | 194 | 3.4 | 4.4 | 3,929 | .003 |
| 13 | Claggett | 880 | 1,550 | 670 | 3.4 | 4.6 | 1,388 | .003 |
| | Eagle | 1,550 | 2,020 | 470 | 4.6 | 6.5 | 2,460 | .005 |
| | Niobrara | 2,020 | 2,503 | 483 | 5.1 | 7.7 | 2,760 | .005 |
| | Greenhorn and Belle Fourche | 2,503 | 3,105 | 602 | 5.1 | 7.4 | 2,800 | .005 |
| | Bow Island (of Perry, 1937) | 3,105 | 3,737 | 632 | 4.2 | 6.0 | 3,488 | .004 |
| 14 | Pierre | 600 | 2,560 | 1,960 | 4.8 | 11.0 | 2,212 | .008 |
| | Niobrara | 2,560 | 3,044 | 484 | 5.0 | 8.5 | 2,560 | .006 |
| | Greenhorn, Belle Fourche, and Mowry | 3,044 | 3,605 | 561 | 6.2 | 10.0 | 3,480 | .007 |
| | Skull Creek | 3,605 | 3,853 | 248 | 0.8 | 9.2 | 3,610 | .006 |
| | Kootenai | 3,853 | 4,037 | 184 | 4.7 | 6.7 | 3,872, 3,895 | .003 |

[1] 1-inch deflection=0.0007 percent eU on 10-inch sensitivity scale.

TABLE 2.—*Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains*—Continued

| Well no. (fig. 51) | Rock unit | Depth (feet) | | Thickness of unit (feet) | Gamma-ray deflection, converted to sensitivity of 10 (inches) | | Depth in well of maximum deflection (feet) | Estimated maximum eU [1] (percent) |
|---|---|---|---|---|---|---|---|---|
| | | From— | To— | | Average | Maximum | | |
| | **Jurassic rocks** | | | | | | | |
| 1 | Morrison | 4,100 | 4,180 | 80 | 3.6 | 6.6 | 4,118 | .005 |
| 2 | do | 3,273 | 3,473 | 200 | 3.3 | 8.5 | 3,400 | .006 |
| 4 | do | 2,903 | 3,120 | 217 | 3.1 | 4.7 | 2,922 | .003 |
| 5 | do | 1,990 | 2,245 | 255 | 3.8 | 6.4 | 2,239 | .004 |
| 6 | do | 4,365 | 4,405 | 40 | 1.8 | 2.4 | 4,400 | .002 |
| 10 | do | 5,600 | 6,002 | 402 | 3.4 | 4.1 | 5,661 | .003 |
| 11 | do | 3,148 | 3,162 | 14 | 3.3 | 3.7 | 3,155 | .003 |
| 12 | do | 4,315 | 4,655 | 340 | 3.7 | 3.9 | 4,491 | .003 |
| 13 | do | 3,737 | 3,760 | 23 | 2.7 | 3.1 | 3,738 | .002 |
| 14 | do | 4,037 | 4,116 | 79 | 5.3 | 6.2 | 4,088 | .004 |
| | **Mississippian and Pennsylvanian rocks** | | | | | | | |
| 1 | Minnelusa | 5,700 | 5,870 | 170 | 3.1 | 7.1 | 5,870 | .005 |
| | Amsden | 5,870 | 6,070 | 200 | 2.7 | 5.3 | 5,903 | .004 |
| | Big Snowy group | 6,070 | 6,372 | 302 | 2.9 | 4.0 | 6,118 | .003 |
| 2 | Amsden of local usage | 4,017 | 4,233 | 216 | 1.3 | 4.8 | 4,136 | .003 |
| | Heath | 4,233 | 4,325 | 92 | 2.7 | 4.7 | 9,280 | .003 |
| 3 | Amsden of local usage | 3,550 | 3,747 | 197 | 2.2 | 4.3 | 3,558 | .003 |
| | Heath | 3,747 | 3,800+ | 53+ | 3.2 | 5.9 | 3,750 | .004 |
| 4 | Amsden of local usage | 3,604 | 3,976 | 372 | 2.4 | 8.5 | 3,930 | .006 |
| | Heath | 3,976 | 4,622 | 646 | 3.0 | 12.7 | 4,045 | .009 |
| 5 | Minnelusa | 5,820 | 6,230 | 410 | 1.8 | 3.6 | 6,227 | .003 |
| | Amsden | 6,230 | 6,374 | 144 | 1.8 | 3.6 | 6,356 | .003 |
| | Big Snowy group | 6,374 | 7,118 | 744 | 2.7 | 7.5 | 6,550 | .005 |
| 6 | Heath | 2,817 | 3,050 | 233 | 3.0 | 6.6 | 2,940 | .005 |
| | Otter | 3,050 | 3,395 | 345 | 3.0 | 8.4 | 3,169 | .006 |
| 8 | Amsden | 5,650 | 5,755 | 105 | 2.3 | 4.7 | 5,745 | .003 |
| | Heath and Otter formations, undivided | 5,755 | 5,990 | 235 | 2.5 | 15+ | 5,767, 5,775 | .010+ |
| 11 | Amsden | 6,996 | 7,437 | 441 | 2.3 | 5.7 | 7,304 | .004 |
| | Heath and Otter formations, undivided | 7,437 | 7,929 | 492 | 2.9 | 9.5 | 7,529 | .007 |
| 13 | Bakken (as used by Nordquist, 1953) | 4,940 | 4,976 | 36 | 5.8 | 8.9 | 4,971 | .006 |
| 14 | Big Snowy group | 5,182 | 5,432 | 250 | 5.8 | 9.0 | 5,358 | .006 |
| | Englewood | 6,495 | 6,570 | 75 | 6.0 | 8.8 | 6,504 | .006 |
| 15 | Heath and Otter formations, undivided | 6,900 | 7,340 | 440 | 4.6 | 7.8 | 7,005 | .006 |
| | Bakken (as used by Nordquist, 1953) | 9,613 | 9,721 | 108 | 9.0 | 13+ | 9,625, 9,700 | .009+ |
| | **Devonian rocks** | | | | | | | |
| 7 | Three Forks | 2,780 | 3,130 | 350 | 1.5 | 6.3 | 3,006 | .004 |
| 8 | do | 7,930 | 8,030 | 100 | 4.8 | 6.2 | 7,972 | .004 |
| 13 | do | 4,976 | 5,030 | 54 | 5.1 | 6.9 | 5,008 | .005 |
| 14 | Devonian, undifferentiated | 6,570 | 6,822 | 252 | 3.7 | 8.0 | 6,715 | .005 |
| 15 | Qu'appelle group (of Baillie, 1953) | 9,724 | 9,916 | 192 | 3.7 | 6.0 | 9,798 | .004 |
| | **Ordovician rocks** | | | | | | | |
| 5 | Winnipeg (upper part) | 9,520 | 9,662 | 142 | 7.8 | 10.6 | 9,535 | .007 |
| 13 | do | 6,285 | 6,312 | 25+ | 9.2 | 10.0 | 6,309 | .007 |
| 14 | do | 9,527 | 9,666 | 139 | 6.6 | 10.4 | 9,635 | .007 |
| 15 | do | 13,395 | 13,562 | 167 | 6.3 | 8.0 | 13,453, 13,466 | .004 |

[1] 1-inch deflection = 0.0007 percent eU on 10-inch sensitivity scale.

## DESCRIPTIONS OF SELECTED BLACK SHALE DEPOSITS

### BLACK SHALE AT THE BASE OF THE MADISON LIMESTONE AND EQUIVALENTS

A black shale sequence of early Mississippian (Kinderhook) age, which ranges in thickness from a few inches to as much as 100 feet, occurs locally at the base of the Madison limestone or its equivalents in southwestern and central Montana and in the Williston basin of Saskatchewan, Manitoba, Montana, and the Dakotas. The term "Bakken formation" has been used to identify this unit in the subsurface in the Williston basin, where it is described by Nordquist (1953, p. 72) as mainly "two thin highly radioactive black shales separated by a grey calcareous sandstone, siltstone, or dolomite." According to Nordquist, the upper shale unit may be correlative with a bed of black shale, a few inches to 30 feet thick, which occurs at the base of the Madison or Lodgepole limestones in various parts of southwestern Montana and Utah. The lower shale and medial sandstone-dolomite units may correlate with the Sappington sandstone as used by Holland (1952), a shale and sandstone sequence as much as 60 feet thick, which occurs below the Madison limestone in parts of southwestern Montana. In southern Canada, equivalents of the basal shale unit and medial sandstone-dolomite unit of the Bakken formation, as used by Nordquist (1953), are regarded by him to correlate respectively with the Exshaw shale (of Warren, 1937) and the basal sandstone of the overlying Banff formation (of McConnell, 1887). In most parts of the northern Rocky Mountains region, the Bakken formation (as used by Nordquist, 1953) and its equivalents unconformably overlie the Three Forks or Jefferson formations of Late Devonian age, and they are conformably overlain by limestone of the Madison or Lodgepole formations, or McConnell's Banff formation, all of early Mississippian age.

TABLE 3.—*Analytical data and outcrops examined*

[n. d. c., not determined chemically]

| Locality no. (pl. 14) | Location (Sec., T., R.) | Rock unit | Laboratory sample no. | Equivalent uranium (percent) | Uranium (percent) | Description |
|---|---|---|---|---|---|---|
| | | **Precambrian rocks: Idaho** | | | | |
| 4 | Benewah County 25-46N-2W. | Prichard formation | 98503 | 0.001 | (n. d. c.) | Grab sample, 300-ft exposure of dark-gray argillite. |
| 5 | Kootenai County 27-48N-2W. | do | | (1) | | 50-ft exposure of dark-greenish-gray argillite. |
| 6 | 21-49N-1W | do | | (1) | | 100-ft exposure of dark-greenish-gray argillite. |
| 7 | Shoshone County 3 and 4-48N-3E. | do | | (1) | | 150-ft exposure of dark-gray argillite. |
| 8 | 12-49N-4E | do | 98506 | .002 | (n. d. c.) | Grab sample, dark-gray argillite, in road cuts. |
| 9 | 14-49N-5E | do | | (1) | | Dark-gray thin-bedded argillite, in road cuts. |
| | | **Precambrian rocks: Montana** | | | | |
| 32 | Lewis and Clark County 22-14N-4W. | Spokane shale | 94788 | 0.002 | (n. d. c.) | Grab sample, dark-reddish-gray argillite, in road cuts. |
| 33 | 36-13N-6W | do | 94150 | .001 | (n. d. c.) | Grab sample, dark-greenish-gray silty shale, in road cuts. |
| 48 | Broadwater County 30-7N-4E. | Greyson shale | 94161 | .002 | (n. d. c.) | Grab sample, 200-ft exposure of dark-gray argillite. |
| 49 | 20-7N-5E | do | 94162 | .004 | 0.003 | Selected sample, 50-ft exposure of dark-gray argillite. |
| | | **Cambrian rocks: Idaho** | | | | |
| 10 | Custer County SW¼-16-13N-18E. | Garden Creek phyllite | 97044 | 0.003 | (n. d. c.) | Channel sample, 2-ft bed of dark-gray to black phyllite near middle of 120-ft exposure. |
| 11 | NE¼-3-12N-18E | do | 97045 | .003 | (n. d. c.) | Grab sample, black phyllite containing disseminated pyrite and chalcopyrite, collected from mine dump. |
| 23 | Bear Lake County 12-13S-42E. | Spence shale | 97024<br>97023 | .002<br>.002 | (n. d. c.)<br>(n. d. c.) | Grab samples, upper and lower parts of 60-ft exposure of dark-greenish-gray shale. |
| 24 | Oneida County 35-14S-36E. | do | 97042<br>97043 | .003<br>.003 | (n. d. c.)<br>(n. d. c.) | Grab samples, upper and middle parts of 30-ft exposure of dark-greenish-gray argillite. |

**Cambrian rocks: Utah**

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 | Cache County, 10-14N-2E. | Spence shale | 97039 | 0.003 | (n. d. c.) | Grab samples, middle and lower parts of 200-ft exposure of dark-greenish-gray shale. |
| | | | 97040 | .001 | (n. d. c.) | |
| | | | 97041 | .002 | (n. d. c.) | |
| 28 | SW¼-4-11N-4E. | do | 97038 | .005 | 0.003 | Channel sample, 5-ft bed of greenish-tan micaceous silty shale, lower part of 10-ft exposure. |

**Cambrian rocks: Montana**

| | | | | | | |
|---|---|---|---|---|---|---|
| 39 | Madison County, NW¼-14-3S-5W. | Wolsey(?) shale | 97012 | 0.005 | 0.001 | Grab sample, near middle of 50-ft exposure of greenish-black silty shale. |
| 46 | Broadwater County, 22-5N-1W. | Unidentified | 94790 | .002 | (n. d. c.) | Channel sample, 6-ft bed of black shale, upper part of 50-ft exposure. |

**Ordovican rocks: Idaho**

| | | | | | | |
|---|---|---|---|---|---|---|
| 12 | Custer County, NE¼-28-11N-17E. | Saturday Mountain formation | 97046 | 0.003 | (n. d. c.) | Chip sample, middle 10 ft of 30-ft bed of dark-gray shale. |
| 13 | 5-11N-17E | do | | (1) | | Thin-bedded black dolomite and interbedded black shale exposed in main adit of the Redbird mine for a distance of 1,000 ft. |
| 14 | Custer County, SW¼-24-10N-17E. | Ramshorn slate | 97047 | .003 | (n. d. c.) | Grab sample, lower part of 200-ft exposure of dark-gray to black thin-bedded argillite. |
| 15 | Unsurveyed—15 miles northeast of Ketchum. | Phi Kappa formation | 97052 | .003 | (n. d. c.) | Chip sample, top 25-ft of 1,700-ft exposure of black argillite. |
| | | | 97053 | .003 | (n. d. c.) | Chip sample, 10-ft bed near middle of 1,700-ft exposure of black argillite. |

**Ordovician rocks: Utah**

| | | | | | | |
|---|---|---|---|---|---|---|
| 26 | Cache County, NW¼-5-14N-4E. | Swan Peak formation | 97026 | 0.004 | 0.003 | Grab samples, upper and lower parts of 45-ft exposure of very dark gray noncalcareous shale. |
| | | | 97024 | .004 | .003 | |
| 27 | NE¼-18-12N-3E. | do | 97031 | .003 | .003 | Channel sample, 3-ft bed of noncalcareous dark-gray shale. |
| | | | 97030 | .003 | (n. d. c.) | Channel sample, 6-ft bed of noncalcareous dark-greenish-gray shale. |
| | | | 97029 | .003 | (n. d. c.) | Grab sample, 15-ft bed of dark-greenish-gray shale. |
| | | | 97028 | .003 | (n. d. c.) | Grab sample, upper part of 10-ft bed of dark-gray shale. |

[1] Not sampled.

TABLE 3.—*Analytical data and outcrops examined*—Continued

[n. d. c., not determined chemically]

| Locality no. (pl. 14) | Location (Sec., T., R.) | Rock unit | Laboratory sample no. | Equivalent uranium (percent) | Uranium (percent) | Description |
|---|---|---|---|---|---|---|
| | | **Ordovician rocks: Montana** | | | | |
| 84 | Wibaux County, NE¼-30-12N-57E (Shell-Pine Unit well 1). | Winnipeg formation | 207794 | 0.005 | 0.001 | Drill core, noncalcareous black shale, depth 9,532-ft. |
| | | | 207795 | .004 | .001 | Same as above, depth 9,525–9,535 ft. |
| | | **Mississippian rocks: Idaho** | | | | |
| 16 | Blaine County 19, 20-7N-15E. | Milligen formation | | (1) | | Black fissile shale, examined at several outcrops on north side of Pole Creek, no appreciable radioactivity. |
| 17 | 6-4N-18E | do | 97049 | .001 | (n. d. c.) | Grab samples, black graphitic shale on mine dumps, north side of Trail Creek. |
| 18 | 10-4N-18E | do | 97050 | .001 | (n. d. c.) | |
| | | | 97056 | .002 | (n. d. c.) | Channel sample, 2-ft bed of black graphitic shale at the portal of the Quaker City mine. Black shale of the Milligen formation examined on several mine dumps in this vicinity; no appreciable radioactivity. |
| 19 | Clark County 27-8N-29E. | Unnamed black shale | | (1) | | Flinty black shale examined on talus piles; no appreciable radioactivity. |
| 20 | Butte County 34-7N-29E. | do | | (1) | | Same as above. |
| | | **Lower Mississippian rocks: Utah** | | | | |
| 29 | Cache County NW¼-34-11N-2E. | Madison limestone | | | | Channel samples, 30-ft bed of dark-brownish-gray shale: |
| | | | 97032 | 0.002 | (n. d. c.) | Top 6 ft. |
| | | | 97033 | .004 | 0.003 | Next 5 ft. |
| | | | 97034 | .002 | (n. d. c.) | Next 6 ft. |
| | | | 97035 | .003 | (n. d. c.) | Next 6 ft. |
| | | | 97036 | .003 | (n. d. c.) | Bottom 7 ft. |
| 29 | do | Leatham formation (of Holland, 1952). | 97037 | .005 | .003 | Channel sample, top 2 ft of 8 ft bed of dark-brownish-black shale. |
| | | **Lower Mississippian rocks: Montana** | | | | |
| 34 | Lewis and Clark County SW¼-28-13N-1W. | Madison limestone | 94789 | 0.006 | 0.003 | Channel sample, 2½-ft bed of noncalcareous black shale. |
| 35 | Granite County NE¼-31-8N-12W. | Madison(?) limestone | | | | Channel samples, 20-ft bed of noncalcareous black shale: |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 94153 | .002 | (n. d. c.) | Top 4½ ft. |
| | | | 94154 | .003 | (n. d. c.) | Bottom 6 ft. |
| 36 | NE¼-5-7N-12W | do | 94151 | .001 | (n. d. c.) | Grab sample, 6-ft bed of black shale, no. 4 adit of Brooklyn mine. |
| 37 | SW¼-4-7N-12W | do | 94152 | .002 | (n. d. c.) | Channel sample, 2-ft bed of black graphitic shale. |
| 38 | Beaverhead County NE¼-34-9S-8W. | Madison limestone | 97015 | .005 | .003 | Grab samples, upper and lower parts of 15-ft bed of noncalcareous black shale. |
| | | | 97016 | .004 | .003 | |
| 40 | Madison County NE¼-13-3S-5W. | do | 97013 | .004 | .001 | Chip sample, 5-ft bed of dark-gray to black shale. |
| 41 | Jefferson County NW¼-16-1N-2W. | do | 94148 | .002 | (n. d. c.) | Grab sample, partings of black shale interbedded with gray limestone, 5-ft exposure. |
| | | | 94147 | .003 | (n. d. c.) | Channel sample, top 1½-ft of 20-ft bed of dark-gray shale and brown shaly siltstone. |
| 42 | Gallatin County 11-11S-3E. | do | 97011 | .002 | (n. d. c.) | Grab sample, black shale partings interbedded with gray limestone, 3-ft exposure. |
| 43 | SW¼-25-2N-2E | do | | | | Channel samples, 2½-ft bed of noncalcareous black shale: |
| | | | 94139 | .004 | .002 | Top 1 ft. |
| | | | 94140 | .004 | .005 | Bottom 1½ ft. |
| 43 | do | Sappington sandstone (as used by Holland, 1953). | | | | Channel samples, 7½-ft bed of black silty shale: |
| | | | 94141 | .003 | (n. d. c.) | Top 2 ft. |
| | | | 94142 | .002 | (n. d. c.) | Next 2 ft. |
| | | | 94143 | .003 | (n. d. c.) | Next 2 ft. |
| | | | 94144 | .002 | (n. d. c.) | Bottom 1½ ft. |
| | | | 94145 | .006 | .002 | Channel sample, 1-ft bed of dark-brownish-black shale, base of Sappington sandstone. |
| 44 | SE¼-2-2N-2E | do | | | | Channel samples, 10-ft bed of brownish-black shale: |
| | | | 94155 | .006 | .002 | Top 3 ft. |
| | | | 94156 | .007 | .001 | Next 2 ft. |
| | | | 94157 | .008 | .003 | Next 2 ft. |
| | | | 94158 | .006 | .001 | Next 2 ft. |
| | | | 94159 | .004 | .005 | Bottom 1 ft. |
| 61 | Fergus County 9-13N-17E. | Madison limestone | 201460 | .004 | .002 | Grab sample, noncalcareous black shale. |
| 64 | SW¼-8-12N-18E | do | 94176 | .004 | .002 | Channel sample, 1-ft bed of black shale. |
| 65 | 32-12N-19E | do | 94764 | .004 | .002 | Channel sample, 3-ft bed of noncalcareous black shale. |
| 78 | Blaine County 5-25N-24E. | Lodgepole limestone | 201457 | .003 | (n. d. c.) | Grab sample, noncalcareous black shale. |
| 79 | 2-26N-24E | do | 201458 | .004 | .002 | Grab sample, 1-ft bed of noncalcareous black shale. |
| 80 | 22-26N-25E | do | 201459 | .003 | (n. d. c.) | Grab sample, noncalcareous gray shale. |
| 81 | Daniels County, SW¼-12-36N-47E (Carter-Danielson well 1). | Bakken formation (as used by Nordquist, 1953). | 204065 | .006 | .002 | Depth 6,964 ft. |
| | | | 204066 | .005 | .002 | Depth 6,966 ft. |
| | | | 204067 | .010 | .003 | Depth 6,968 ft. |
| | | | 204068 | .007 | .004 | Depth 6,970 ft, pyritic. |
| | | | 204069 | .008 | .004 | Depth 6,971 ft, pyritic. |
| | | | 204070 | .003 | .002 | Depth 6,974 ft, some light-gray calcareous laminae. |
| 82 | Roosevelt County, NE¼-2-28N-51E, (Murphy and others-East Poplar well 1). | do | | | | Drill cores, noncalcareous black shale: |
| | | | 98518 | .006 | .006 | Depth 7,165–7,175 ft. |
| | | | 98519 | .004 | .002 | Depth 7,190–7,200 ft. |

[1] Not sampled.

TABLE 3.—*Analytical data and outcrops examined*—Continued

[n. d. c., not determined chemically]

| Locality no. (pl. 14) | Location (Sec., T., R.) | Rock unit | Laboratory sample no. | Equivalent uranium (percent) | Uranium (percent) | Description |
|---|---|---|---|---|---|---|
| **Lower Mississippian rocks: North Dakota** | | | | | | |
| 85 | Williams County, NW¼-12-157N-95W (Amerada-Harry Bakken well 1). | Bakken formation (as used by Nordquist, 1953). | 98520 | 0.004 | 0.005 | Drill cuttings, noncalcareous black shale: Depth 9,620–9,630 ft. |
| | | | 98521 | .008 | .007 | Depth 9,700–9,710 ft. |
| | | | 98522 | .009 | .006 | Depth 9,710–9,720 ft. |
| **Upper Mississippian rocks: Idaho** | | | | | | |
| 21 | Caribou County SE¼-33-7S-40E. | Brazer limestone | 94767 | 0.003 | (n. d. c.) | Grab sample, black cherty shale. |
| 22 | Bear Lake County NE¼-23-12S-44E. | do | 97017 | .001 | (n. d. c.) | Grab sample, 3-ft bed of calcareous black shale. |
| **Upper Mississippian rocks: Utah** | | | | | | |
| 30 | Rich County 32-13N-6E. | Brazer limestone | 97018 | 0.001 | (n. d. c.) | Chip sample, 10½-ft bed of calcareous black shale, containing thin lenses of black chert. |
| | | | 97019 | .004 | 0.006 | Channel sample, middle 2 ft of 14-ft bed of dark-brown shale and shaly black limestone. |
| | | | 97020 | .004 | .003 | Channel sample, 2½-ft bed of noncalcareous dark-brown shale. |
| | | | 97021 | .004 | .001 | Channel sample, 2-ft bed of noncalcareous dark-brown shale. |
| | | | 97022 | .004 | .009 | Chip sample, upper half of 8-ft bed of dark-brownish-black shale. |
| **Upper Mississippian rocks: Montana** | | | | | | |
| 45 | Broadwater County SE¼-29-3N-2E. | Heath shale | 94791 | 0.002 | (n. d. c.) | Grab sample, 1-ft bed of calcareous black shale. |
| 47 | Broadwater County 5, 7-4N-3E. | do | 94160 | .003 | (n. d. c.) | Grab sample, 10-ft bed of calcareous black shale. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 50 | Meagher County 14-9N-10E. | do | 94163 | .002 | (n. d. c.) | Channel sample, 3-ft bed of fossiliferous black shale. |
| 51 | Judith Basin County | do | 94778 | .002 | (n. d. c.) | Channel sample, 2½-ft bed of gypsiferous black shale. |
| | SW¼-3-16N-10E. | do | 94779 | .002 | (n. d. c.) | Chip sample, 12-ft bed of calcareous black shale. |
| 52 | NE¼-2-16N-10E | do | 94780 | .004 | 0.002 | Chip sample, 20-ft bed of noncalcareous black shale. |
| 54 | 6-15N-12E | do | 94781 | .001 | (n. d. c.) | Grab sample, 30-ft bed of black shale. |
| 55 | NE¼-11-14N-11E | do | 94773 | .003 | .002 | Chip sample, calcareous black shale interbedded with gray limestone, 30-ft exposure. |
| 56 | NW¼-19-14N-12E | do | 94771 | .002 | (n. d. c.) | Chip samples, top 6 ft of 60-ft exposure of black shale. |
| | | | 94772 | .001 | (n. d. c.) | Bottom 6 ft of unit above. |
| 57 | 29-12N-14E | do | 94766 | .001 | (n. d. c.) | Channel sample, 2-ft bed of calcareous black shale. |
| 58 | 21-11N-15E | do | 94765 | .003 | .002 | Grab sample, middle of 40-ft bed of black shale. |
| 59 | Wheatland County 5-10N-13E. | Otter formation | 94783 | .001 | (n. d. c.) | Grab sample, 6-ft bed of black shale. |
| 60 | 7-10N-13E | Heath shale | 94785 | .002 | (n. d. c.) | Grab sample, 5-ft bed of noncalcareous black shale. |
| 60 | do | Otter formation | 94784 | .003 | .002 | Grab sample, 4-ft bed of noncalcareous black shale. |
| 62 | Fergus County 7-13N-18E. | Heath shale | 94177 | .002 | (n. d. c.) | Grab sample, 5-ft bed of calcareous black shale. |
| 63 | NW¼-23-13N-17E | do | 94173 | .003 | (n. d. c.) | Channel sample, 5½-ft bed of calcareous black shale. |
| | | | 94174 | .004 | .003 | Channel sample, 4-ft bed of calcareous black shale. |
| 63 | do | Otter formation | 94175 | .004 | .003 | Grab sample, 2-ft bed of noncalcareous black shale. |
| 66 | 6-12N-20E | So-called Amsden formation of local usage. | 94755 | .001 | (n. d. c.) | Grab sample, 20-ft bed of maroon shale. |
| 66 | do | Heath shale | 94756 | .001 | (n. d. c.) | Channel sample, top 4 ft of 5-ft bed of noncalcareous black shale. |
| | | | 94757 | .001 | (n. d. c.) | Channel sample, top 4 ft of 30-ft bed of noncalcareous black shale. |
| | | | 94758 | .002 | (n. d. c.) | Channel sample, middle 4 ft of same unit as above. |
| | | | 94759 | .001 | (n. d. c.) | Channel sample, bottom 4 ft of same unit as above. |
| | | | 94760 | .003 | .002 | Channel sample, top 3 ft of 25-ft bed of calcareous silty black shale. |
| | | | 94761 | .003 | .003 | Grab sample, middle part of unit above. |
| | | | 94762 | .006 | .003 | Channel sample, top 6 ft of 70-ft bed of calcareous silty black shale. |
| 67 | SW¼-30-16N-19E | do | 94786 | .001 | (n. d. c.) | Grab sample, dark-gray noncalcareous shale from mine dump. |
| 68 | SW¼-14-15N-19E | do | 94169 | .004 | .003 | Grab sample, 3-ft bed of black shale. |
| 69 | 17-14N-21E | do | | | | Channel samples, 15-ft bed of noncalcareous black shale: |
| | | | 94178 | .003 | (n. d. c.) | Top 1½ ft. |
| | | | 94179 | .002 | (n. d. c.) | Next 1 ft. |
| 70 | SE¼-30-14N-21E | do | | | | Channel samples, 15-ft bed of calcareous black shale: |
| | | | 94182 | .002 | (n. d. c.) | Top 2½ ft. |
| | | | 94183 | .002 | (n. d. c.) | Next 2½ ft. |
| | | | 94184 | .003 | (n. d. c.) | Bottom 6 ft. |
| 71 | NE¼-8-13N-21E | Heath shale or Otter formation | 94185 | .001 | (n. d. c.) | Grab sample, 10-ft bed of black noncalcareous shale. |
| 72 | SW¼-17-14N-21E | Heath shale | 94180 | .003 | (n. d. c.) | Channel sample, bottom 2 ft of 3-ft bed of calcareous black shale. |
| 73 | SW¼-16-14N-22E | So-called Amsden formation of local usage. | 94192 | .002 | (n. d. c.) | Grab sample, 4-ft bed of noncalcareous black shale. |

TABLE 3.—*Analytical data and outcrops examined*—Continued

[n. d. c., not determined chemically]

| Locality no. (pl. 14) | Location (Sec., T., R.) | Rock unit | Laboratory sample no. | Equivalent uranium (percent) | Uranium (percent) | Description |
|---|---|---|---|---|---|---|
| | | **Upper Mississippian rocks: Montana—Continued** | | | | |
| | Fergus County—Continued | | | | | |
| 75 | SE¼13-12N-22E | Heath shale | 94187 | 0.002 | (n. d. c.) | Grab sample, upper part of 15-ft bed of noncalcareous black shale. |
| | | | 94188 | .002 | (n. d. c.) | Grab sample, lower part of 15-ft bed of noncalcareous black shale. |
| 76 | NW¼-20-14N-24E | do | 94190 | .002 | (n. d. c.) | Grab sample, black shale partings in 40-ft bed of light-gray sandstone. |
| 77 | Golden Valley County, 30-11N-21E | do | | (1) | | Scattered outcrops of black shale examined; no appreciable radioactivity. |
| 83 | Roosevelt County, SE¼-13-28N-50E (Carter-Lowe well 1). | do | | | | Drill core, dark-gray to black shale: |
| | | | 207572 | .002 | (n. d. c.) | Depth 4,925 ft. |
| | | | 207573 | .003 | (n. d. c.) | Depth 4,930 ft. |
| | | | 207574 | .003 | (n. d. c.) | Depth 4,933 ft. |
| | | **Triassic(?) rocks: Oregon** | | | | |
| 1 | Baker County 31-12S-46E. | Unnamed formation | | (1) | | Dark-gray and dark-greenish-gray argillite examined in road cuts and at natural exposures; no appreciable radioactivity. |
| 2 | 32-11S-45E | do | | (1) | | Same as above. |
| 3 | 33-9S-46E | do | | (1) | | Same as above. |
| | | **Cretaceous rocks: Montana** | | | | |
| 31 | Teton County 9-24N-8W. | Colorado shale | 98508 | 0.002 | (n. d. c.) | Grab sample, near middle of 60-ft bed of dark-gray bituminous shale (top of the sequence). |
| | | | 98509 | .002 | (n. d. c.) | Channel sample, bottom 1½ ft of same unit as above. |
| | | | 98510 | .001 | (n. d. c.) | Grab sample, ½-ft bed of dark-gray bituminous limestone. |
| | | | 98511 | .004 | 0.002 | Channel sample, 1-ft bed of light-yellow bentonite. |
| | | | 98512 | .003 | .001 | Chip sample, 4-ft bed of black bituminous shale. |
| | | | 98513 | .001 | (n. d. c.) | Channel sample, top 3 ft of 25 ft bed of dark-gray bituminous shale (base of the sequence). |

| | | | | | | |
|---|---|---|---|---|---|---|
| 53 | Judith Basin County 1-16N-11E. | do | 94777 | .005 | .003 | Grab sample, silicified limestone concretions in the upper part of 25-ft bed of yellowish-gray bentonite. |
| | | | 94776 | .002 | (n. d. c.) | Channel sample, bottom 1½ ft of 25-ft bed of yellowish-gray bentonite. |
| | | | 94775 | .002 | (n. d. c.) | Grab sample, ½-ft bed of gray silicified shale, underlying bed of bentonite described above. |
| | | | 94774 | .002 | (n. d. c.) | Channel sample, 4-ft bed of dark-gray shale, underlying unit above. |
| 74 | Fergus County NW¼-20-14N-24E. | do | 94189 | .002 | (n. d. c.) | Channel sample, 4-ft bed of silty black shale near middle of a 30-ft exposure of interbedded shale and yellowish-gray silty sandstone, base of the Colorado shale. |

[1] Not sampled.

The black shale sequence at the base of the Madison limestone was sampled at 17 localities in the mountainous parts of southwestern and central Montana and northwestern Utah. Sections at 10 of these localities are shown in figure 52. The maximum observed uranium content of the sequence is 0.005 percent, in the lower half of a 2½-foot-thick bed of black shale near Three Forks, Mont. (loc. 43), and 0.005 percent in the basal part of a 10-foot bed of brownish-black shale nearby (loc. 44).

The Bakken formation (as used by Nordquist, 1953) was sampled in three wells, two of them in northeastern Montana and the third in northwestern North Dakota. Drill cuttings representing 30 feet of black shale from one of the wells, Amerada Petroleum Corporation–Harry Bakken well 1, Williams County, N. Dak. (well 15, table 1), contain 0.005 to 0.007 percent of uranium. A sample of drill core from a 10-foot-thick bed of black shale in the C. H. Murphy, Jr., and others–East Poplar well 1, Roosevelt County, Mont., sec. 2, T. 28 N., R. 51 E., contains 0.006 percent of uranium. One of six samples of drill core from a 10-foot-thick bed of black shale in the Carter Oil Company–S. W. Danielson well 1, Daniels County, Mont., sec. 12, T. 36 N., R. 47 E., contains 0.004 percent of uranium. The samples from this well are anomalous in that they are decidedly out of balance in favor of equivalent uranium, as indicated in the following table:

*Descriptions of samples: Carter Oil Company–S. W. Danielson well 1, Daniels County, Mont.*

| Sample no. | Depth (feet) | Description | eU (percent) | U (percent) |
|---|---|---|---|---|
| 204065 | 6964 | Core chip, noncalcareous black shale | 0.006 | 0.002 |
| 204066 | 6966 | do | .005 | .002 |
| 204067 [1] | 6968 | do | .010 | .003 |
| 204068 | 6970 | Same as above, some disseminated pyrite | .007 | .004 |
| 204069 | 6971 | do | .008 | .004 |
| 204070 | 6974 | Core chip, dark-gray shale with light-gray calcareous laminae. | .003 | .002 |

[1] J. N. Rosholt, Jr., U. S. Geological Survey Trace Elements Laboratory, investigated the source of the high radioactivity in sample 204067, with the following result:

| | |
|---|---|
| Equivalent uranium (percent) | 0.010 |
| Uranium (percent) | .003 |
| $Th^{232}$ (radio-chemical) (percent) | .003 |
| $Th^{230}$ (ionium) (percent equivalent) | .009 |
| Radium (percent equivalent) | .006 |

The analysis above indicates that $Th^{230}$ and radium, both daughter products of uranium, are the principal contributors of excess radioactivity. The relatively high concentrations of these elements in comparison to uranium suggest that leaching of uranium or addition of $Th^{230}$ and radium has occurred in this deeply buried shale in comparatively recent time.

The thickness and the areal distribution of radioactivity in the Bakken formation (as used by Nordquist, 1953) as determined from

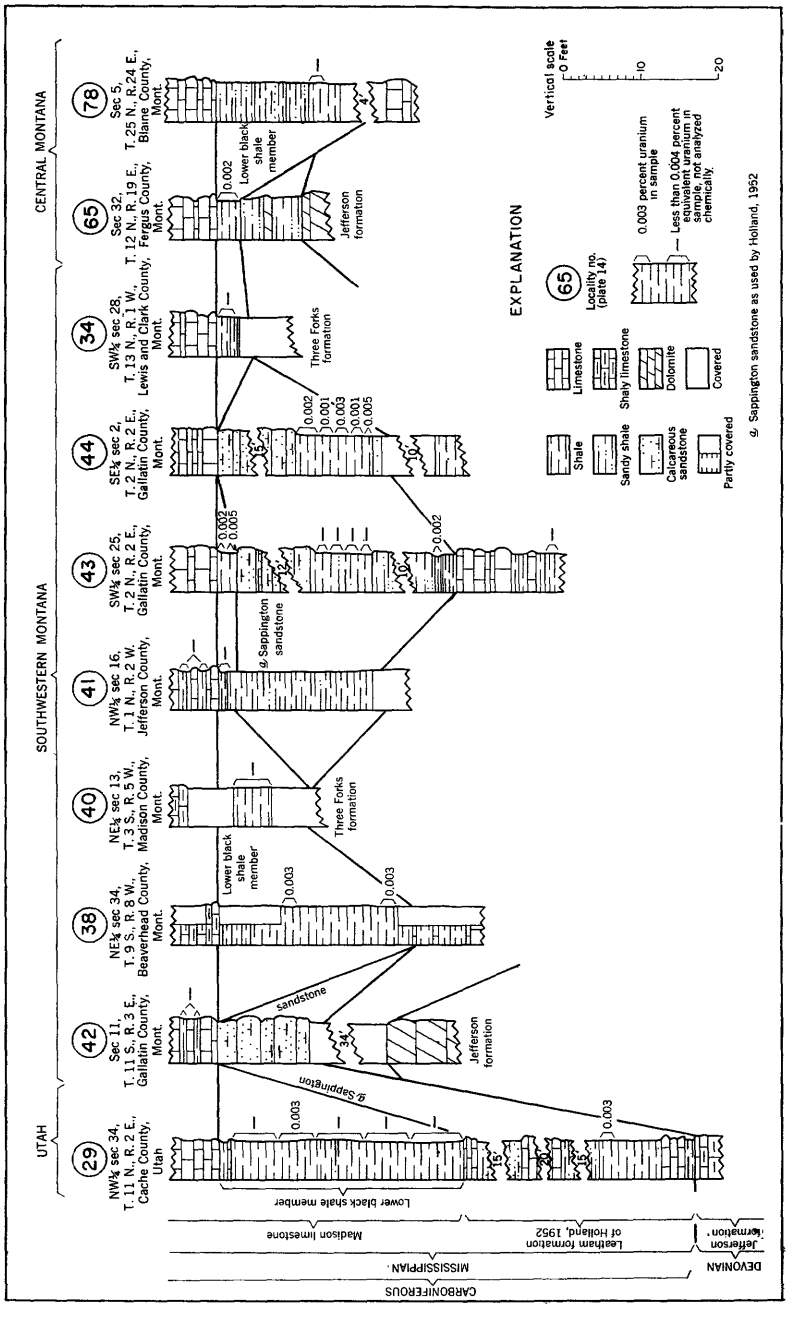


FIGURE 52.—Uranium content of basal black shale of Mississippian age at outcrops in the northern Rocky Mountains region.

published sample descriptions and gamma-ray logs, are shown in plate 15. These maps suggest that black shale in the Bakken formation (as used by Nordquist, 1953) is thickest in the northwestern corner of North Dakota and that the formation is most radioactive slightly east of this area, near the northeastern corner of Montana. It seems evident that radioactivity in the Bakken formation (as used by Nordquist, 1953) varies appreciably from place to place with a definite pattern. Recognition of the pattern will help in outlining areas in which maximum concentrations of uranium in the formation may be expected.

### BLACK SHALE AT THE BASE OF THE BRAZER LIMESTONE

In parts of Utah and Idaho the basal part of the Brazer limestone of middle and late Mississippian age consists of a black phosphatic shale sequence ranging in thickness from a few inches to about 75 feet. Exposures of this zone were tested at two places in southeastern Idaho (locs. 21 and 22), and at one place in northwestern Utah (loc. 30). Beds of black shale at the two Idaho localities are mostly nonuraniferous, but in Rich County, Utah, a bed of shale 14 feet thick in the upper part of the sequence contains as much as 0.006 percent of uranium, and a bed of shale 8 feet thick in the lower part contains as much as 0.009 percent of uranium. The measured sections and uranium content of the black shale at the three localities are shown in figure 53.

Black shale at the base of the Brazer limestone was examined by Duncan (1953) in Ogden Canyon, Weber County, Utah, about 45 miles southwest of the Rich County locality described above. In Ogden Canyon, Duncan reported, beds of phosphatic shale about 1 foot thick contain as much as 0.005 percent of uranium, 0.18 percent of vanadium oxide, and 17.3 percent of phosphate.

### HEATH SHALE

The Heath shale of late Mississippian age crops out along the margins of the Little Belt and Big Snowy Mountains in central Montana, and it has been penetrated in drill holes throughout a large area in eastern Montana and western North Dakota. The formation consists mainly of black shale, with subordinate amounts of gray limestone and fine- to coarse-grained sandstone. It is as much as 650 feet thick in the subsurface in the northeastern corner of Musselshell County, Mont., and it is as much as 400 feet thick where it is exposed on the flanks of the Little Belt and Big Snowy Mountains to the west. (See fig. 54.) The Heath is underlain by the Otter forma-

tion of late Mississippian age, which consists of green and black shale and gray limestone; it is overlain by the Amsden formation of local usage of late Mississippian and Pennsylvanian age, which consists mostly of red shale and sandstone and gray limestone and dolomite.

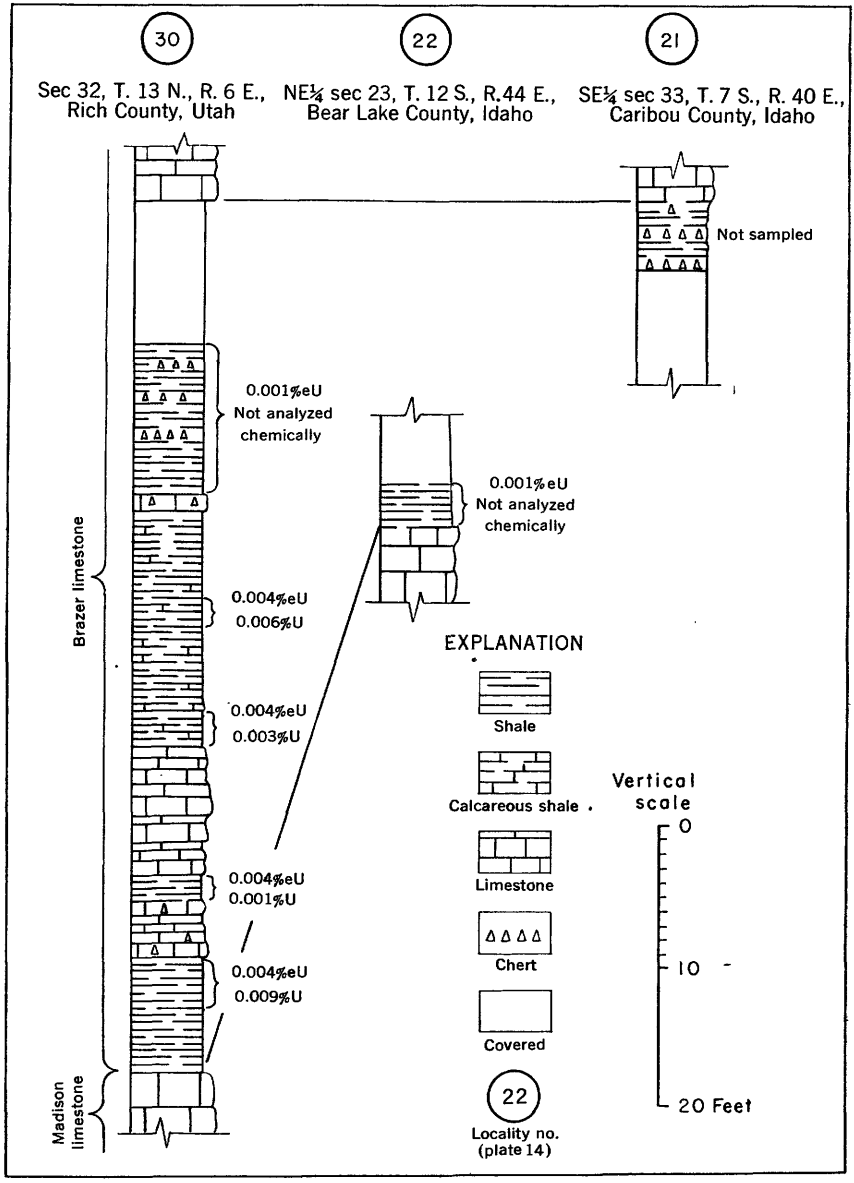


FIGURE 53.—Uranium content of black shale at the base of the Brazer limestone, Utah and Idaho.

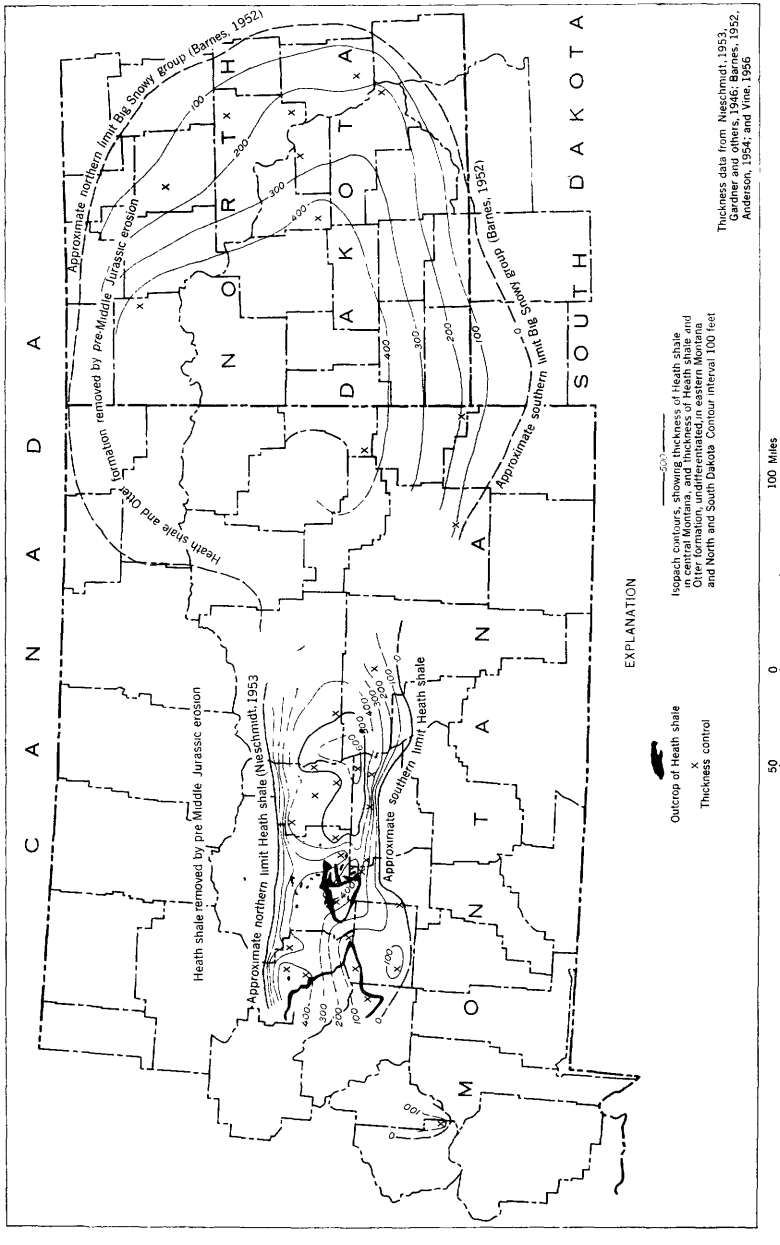


FIGURE 54.—Thickness and distribution of the Heath shale in central Montana and the Heath shale and Otter formation in eastern Montana and adjacent parts of North and South Dakota.

Outcrops of the Heath shale were examined for radioactivity at 8 places by W. J. Hail and J. R. Gill in 1951 (*in* Duncan, 1953), and outcrops of the Heath shale were examined at 24 places by the writer in 1953. The most highly uraniferous black shale thus far found in the formation was discovered by Hail and Gill 3 miles southeast of Forestgrove, Mont., in the NW¼ sec. 24, T. 14 N., R. 20 E., Fergus County. At this locality, the upper 4 feet of a bed of black shale 6 feet thick near the top of the formation contains 0.006 percent of uranium. Samples of black shale from the Heath shale elsewhere in central Montana contain a maximum of 0.003 percent of uranium.

A sample of water from a seep in the upper part of the Heath shale on the north flank of the Big Snowy Mountains (loc. 66) contains 7 parts per billion of uranium.

The Heath shale is characterized locally by large deflections on gamma-ray logs of oil and gas wells. A bed 10 feet thick in the Heath shale penetrated by the Marigold Oil, Ltd.–Farnham well 1, McCone County, Mont. (well 3, table 1), may contain more than 0.01 percent of equivalent uranium; and gamma-ray logs show some parts of the formation in Musselshell County, Mont., to be almost as radioactive. Not enough information is available so far to attempt to analyze the distribution of radioactivity in relation to the variations in thickness and lithology of the Heath.

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