# Reconnaissance for Uranium in Black Shale, Northern Rocky Mountains and Great Plains, 1953

By W. J. Mapel



*Trace Elements Investigations Report 464*

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By

W. J. Mapel

August 1954

Trace Elements Investigations Report 464

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*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

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# RECONNAISSANCE FOR URANIUM IN BLACK SHALE, NORTHERN ROCKY MOUNTAINS AND GREAT PLAINS, 1953

By W. J. Mapel

## ABSTRACT

Reconnaissance examinations for uranium in 22 formations containing black shale were conducted in parts of Montana, North Dakota, Utah, Idaho, and Oregon during 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 uranium; however, thin beds of black shale at the base of the Mississippian system contain 0.005 percent uranium at 2 outcrop localities in southwestern Montana and as much as 0.007 percent uranium in a well in northeastern Montana. An eight-foot bed of phosphatic black shale at the base of the Brazer limestone of Late Mississippian age in Rich County, Utah, contains as much as 0.009 percent 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 equivalent uranium, and black shales of Late Cretaceous age contain as much as 0.008 percent equivalent uranium.

## INTRODUCTION

A reconnaissance search for uranium in black shale in the northern Rocky Mountain region was carried out during July, August, and September, 1953, by

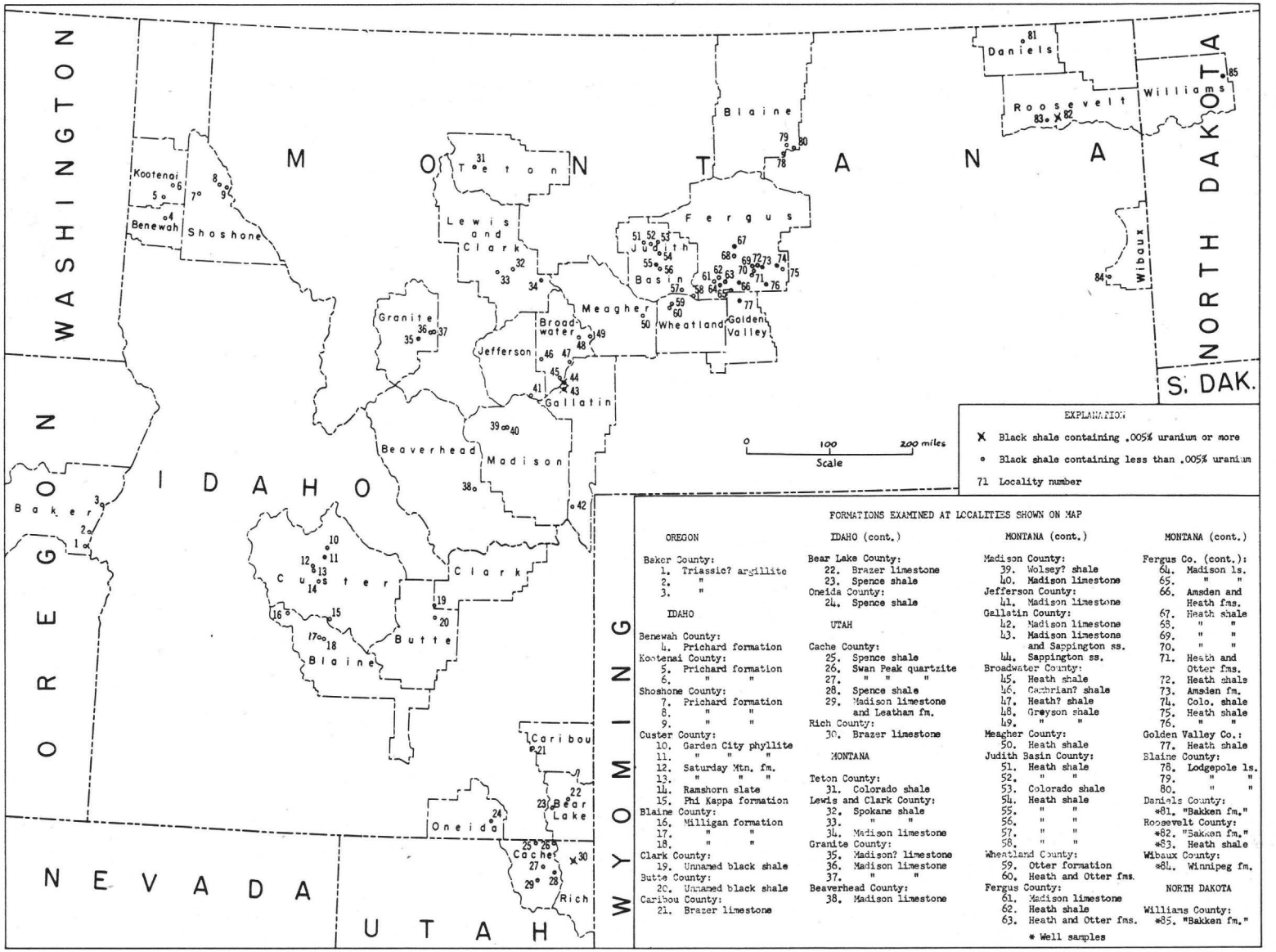
the U. S. Geological Survey on behalf of the Division of Raw Materials, U. S. Atomic Energy Commission. The work is part of a continuing program to investigate the uranium possibilities of untested or incompletely tested black shale deposits in the western States. Most of the localities visited are in southwestern and central Montana, central and southeastern Idaho, and northwestern Utah. Approximately 150 gamma ray logs from wells drilled for oil and gas in Montana and adjacent parts of North and South Dakota were scanned for anomalous radioactivity, and samples of drill cores or cuttings from 5 of the wells were submitted for uranium determinations. The index map, figure 1, shows the localities visited and figure 2 the formations examined.

Previous work (Duncan, 1953) indicated that the Heath shale of Late Mississippian age, and a thin black shale sequence called variously the Bakken formation, the Kinderhook shale, or the Exshaw formation of Early Mississipian age, 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 shales of the Phosphoria formation of Permian age in the northern Rocky Mountain region are known to contain uranium, but these rocks were excluded from the study inasmuch as they have been sampled extensively as part of a separate investigation by the Geological Survey.

## FIELD WORK

Outcrops of black shale described in the geologic literature or in unpublished reports available to the writer were examined for radioactivity at




FORMATIONS EXAMINED AT LOCALITIES SHOWN ON MAP

OREGON

Baker County:
1. Triassic? argillite
2. "
3. "

IDAHO

Benewah County:
4. Prichard formation
Kootenai County:
5. Prichard formation
6. " "
Shoshone County:
7. Prichard formation
8. " "
9. " "
Custer County:
10. Garden City phyllite
11. " " "
12. Saturday Mtn. fm.
13. " " "
14. Ramshorn slate
15. Phi Kappa formation
Blaine County:
16. Milligan formation
17. " "
18. " "
Clark County:
19. Unnamed black shale
Butte County:
20. Unnamed black shale
Caribou County:
21. Brazer limestone

IDAHO (cont.)

Bear Lake County:
22. Brazer limestone
23. Spence shale
Oneida County:
24. Spence shale

UTAH

Cache County:
25. Spence shale
26. Swan Peak quartzite
27. " " "
28. Spence shale
29. Madison limestone and Leatham fm.
Rich County:
30. Brazer limestone

MONTANA

Teton County:
31. Colorado shale
Lewis and Clark County:
32. Spokane shale
33. " "
34. Madison limestone
Granite County:
35. Madison? limestone
36. Madison limestone
37. " "
Beaverhead County:
38. Madison limestone

MONTANA (cont.)

Madison County:
39. Wolsey? shale
40. Madison limestone
Jefferson County:
41. Madison limestone
Gallatin County:
42. Madison limestone
43. Madison limestone and Sappington ss.
44. Sappington ss.
Broadwater County:
45. Heath shale
46. Cambrian? shale
47. Heath? shale
48. Greyson shale
49. " "
Meagher County:
50. Heath shale
Judith Basin County:
51. Heath shale
52. " "
53. Colorado shale
54. Heath shale
55. " "
56. " "
57. " "
58. " "
Wheatland County:
59. Otter formation
60. Heath and Otter fms.
Fergus County:
61. Madison limestone
62. Heath shale
63. Heath and Otter fms.

MONTANA (cont.)

Fergus Co. (cont.):
64. Madison ls.
65. " "
66. Amsden and Heath fms.
67. Heath shale
68. " "
69. " "
70. " "
71. Heath and Otter fms.
72. Heath shale
73. Amsden fm.
74. Colo. shale
75. Heath shale
76. " "
Golden Valley Co.:
77. Heath shale
Blaine County:
78. Lodgepole ls.
79. " "
80. " "
Daniels County:
*81. "Bakken fm."
Roosevelt County:
*82. "Bakken fm."
*83. Heath shale
Wibaux County:
*84. Winnipeg fm.

NORTH DAKOTA

Williams County:
*85. "Bakken fm."

* Well samples

FIGURE 1.-INDEX MAP SHOWING BLACK SHALE LOCALITIES EXAMINED FOR URANIUM IN NORTHERN ROCKY MOUNTAIN REGION 1953

Figure 2.--Chart showing the relative stratigraphic relations of formations examined.

| Age | Central and northern Idaho, eastern Oregon | Southeastern Idaho | Northwestern Utah | Central and southwestern Montana | Eastern Montana |
|---|---|---|---|---|---|
| Cretaceous | | | | Colo. sh. | |
| Triassic | Unnamed argillite | | | | |
| Mississippian | Unnamed sh.<br>Milligen fm. | Brazer ls. | Brazer ls.<br>Madison ls.<br>Leatham fm. | Amsden fm. (lower part)<br>Big Snowy group: Heath sh.; Otter fm.; Kibbey ss.*<br>Madison ls.<br>Sappington sandstone | Heath sh.+<br>Lodgepole limestone<br>Bakken fm.+ |
| Ordovician | Saturday Mt. formation<br>Ramshorn slate<br>Phi Kappa formation | | Swan Peak quartzite | | Winnipeg formation+ |
| Cambrian | Garden City phyllite | Spence sh. | Spence sh. | Wolsey sh. | |
| Pre-Cambrian | Prichard formation | | | Spokane sh.<br>Greyson sh. | |

* Not examined
\+ Not exposed, drill cuttings or cores sampled

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 checked on foot with the portable instruments.

## PREVIOUS WORK

The present investigation is a continuation of previous reconnaissance studies conducted at various times since 1951 in the Rocky Mountain region by Duncan, Hail, Gill, Moore, and Vine (Duncan, 1953). Beers and Heroy (1951) have reviewed the geologic literature relating to black shale in the United States, including the states visited in the course of the present work.

## ACKNOWLEDGMENTS

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 by members of the Geological Survey Trace Elements Denver Laboratory.

## USE AND INTERPRETATION OF THE GAMMA RAY LOGS

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

Table 1.--List of wells in northern Great Plains for which gamma ray logs were studied. (See fig. 3.)

| Map no. (fig. 7) | Name of well | Location: Sec. County T., R. State | Gamma ray log available: From (feet) | To (feet) | Deepest formation logged | Source of information on formation boundaries |
|---|---|---|---|---|---|---|
| 1. | Shell Little Beaver no. 21-24 | C NE NW 24-4N-61E Fallon, Mont. | 0 | 8873 | Stoney Mt. shale (Ordovician) | Oil industry scout tops |
| 2. | Farmers Union Bunge no. 1 | C NE NE 31-9N-35E Rosebud, Mont. | 24 | 4353 | Otter fm. (Mississippian) | Do. |
| 3. | Texas Nebraska Feed Co., no. 1 | C SE NE 22-11N-27E Musselshell, Mont. | 3550 | 3800 | Heath shale (Mississippian) | Do. |
| 4. | Farmers Union Thompson no. 1 | SW SW SW 7-11N-31E Musselshell, Mont. | 0 | 5035 | Kibbey ss. (Mississippian) | Do. |
| 5. | Shell Pine Unit no. 1 | SW SW NE 30-12N-51E Wibaux, Mont. | 0 | 9746 | Winnipeg fm. (Ordovician) | Sonnenberg, et al., 1952 |
| 6. | Cities Service K.E.Huffine no. 1 | C SW SE 27-17N-15E Fergus, Mont. | 0 | 6014 | Cambrian undifferentiated | Oil industry scout tops |
| 7. | United Petroleum Good no. 1 | C NE NE 18-23N-4E Chouteau, Mont. | 0 | 3606 | do. | Do. |
| 8. | Marigold Oils, Ltd., Farnham no. 1 | C SW SW 14-25N-48E McCone, Mont. | 5000 | 8953 | Silurian undifferentiated | Do. |
| 9. | Texas Davis no. 1 | C SE SW 4-29N-18E Blaine, Mont. | 0 | 4921 | Cambrian undifferentiated | Do. |

Table 1.--List of wells in northern Great Plains for which gamma ray logs were studied.--Continued.

| Map no. (fig. 7) | Name of well | Location: Sec. T., R. County State | Gamma ray log available: From (feet) | To (feet) | Deepest formation logged | Source of information on formation boundaries |
|---|---|---|---|---|---|---|
| 10. | Deep Rock Picard no. 1 | C NW NE 6-29N-58E Roosevelt, Mont. | 5600 | 9028 | Mission Canyon ls. (Mississippian) | Oil industry scout tops |
| 11. | Gulf R.L.Cornwell no. 1 | C SW NE 14-30N-38E Valley, Mont. | 0 | 7037 | Cambrian undifferentiated | Do. |
| 12. | Continental Fast no. 1 | C NE SE 14-30N-46E Roosevelt, Mont. | 50 | 6312 | Mission Canyon ls. (Mississippian) | Do. |
| 13. | General Petroleum Erickson no. 36-12P | SW NE SW 12-36N-15E Hill, Mont. | 0 | 6312 | Winnipeg fm. (Ordovician) | Do. |
| 14. | Shell H.D.Veal no. 1 | C SE SE 7-17N-15E Perkins, S. Dak. | 0 | 8315 | do. | Do. |
| 15. | Amerada Harry Bakken no. 1 | C SW NE 12-157N-95W Williams, N. Dak. | 6100 | 13715 | do. | Baillie, 1953 Anderson, 1954 |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CRETACEOUS ROCKS | | | | | |
| 1. | Pierre | 200 | 2160 | 1960 | 7 | 2.1 | 2.9 | 1899 | 0.003 |
| | Niobrara | 2160 | 2788 | 628 | 7 | 2.6 | 4.0 | 2210 | .004 |
| | Greenhorn | 2788 | 2915 | 127 | 7 | 2.5 | 3.3 | 2860 | .003 |
| | Belle Fourche | 2915 | 3460 | 545 | 7 | 2.6 | 4.0 | 3335 | .004 |
| | Mowry | 3460 | 3680 | 220 | 7 | 2.2 | 3.4 | 3540 | .003 |
| | Skull Creek | 3710 | 3850 | 140 | 7 | 2.4 | 2.8 | 3811 | .003 |
| | Cloverly | 3850 | 4100 | 250 | 7 | 1.8 | 2.6 | 3908 | .003 |
| 2. | Colorado | 1117 | 2952 | 1835 | 6 | 2.9 | 4.4 | 2161 | .005 |
| | Kootenai | 3032 | 3273 | 241 | 6 | 1.4 | 4.8 | 3151 | .006 |
| 4. | Claggett | 0 | 396 | 396 | 7 | 2.1 | 3.6 | 319 | .004 |
| | Eagle | 396 | 807 | 411 | 7 | 2.9 | 4.0 | 805 | .004 |
| | Colorado | 807 | 2472 | 1665 | 7 | 3.4 | 5.6 | 1629 | .006 |
| | Kootenai | 2577 | 2903 | 326 | 7 | 2.2 | 3.5 | 2738 | .004 |
| 5. | Pierre | 1135 | 2368 | 1233 | 6.7 | 1.5 | 2.3 | 2255 | |
| | Niobrara | 2368 | 2928 | 560 | 6.7 | 2.0 | 3.0 | 2900 | |
| | Greenhorn, Carlile, Belle Fourche, Mowry | 2928 | 3705 | 777 | 6.7 | 2.2 | 3.9 | 3469 | |
| | Muddy, Skull Creek | 3705 | 3945 | 240 | 6.7 | 2.0 | 2.7 | 3935 | .003 |
| | Cloverly | 3945 | 4365 | 420 | 6.7 | 1.6 | 2.9 | 3955 | .003 |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.--Continued.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CRETACEOUS ROCKS (Continued) | | | | | |
| 6. | Colorado | 200 | 1426 | 1226 | 5 | 2.5 | 4.1 | 641 | 0.006 |
| | Kootenai | 1484 | 1990 | 506 | 5 | 1.6 | 3.0 | 1892 | .004 |
| 7. | Colorado | 0 | 1030 | 1030+ | 6 | 1.6 | 2.7 | 200 | .003 |
| | Kootenai | 1030 | 1602 | 572 | 6 | 1.3 | 2.7 | 1330 | .003 |
| 9. | Colorado | 0 | 2449 | 2449+ | 5.5 | 3.3 | 6.0 | 1181 | .008 |
| | Kootenai | 2449 | 2724 | 275 | 5.5 | 2.4 | 3.7 | 2493 | .005 |
| 11. | Clagget and Younger | 0 | 955 | 955+ | 6 | 1.2 | 2.0 | 8 | .002 |
| | Eagle | 955 | 1390 | 435 | 6 | 2.1 | 2.5 | 1319 | .003 |
| | Niobrara | 1390 | 1842 | 452 | 6 | 2.4 | 4.0 | 1405 | .004 |
| | Frontier-Mowry | 1842 | 2585 | 743 | 7 | 2.3 | 4.1 | 2029 | .004 |
| | Skull Creek | 2617 | 2764 | 147 | 6 | 2.1 | 2.5 | 2699 | .003 |
| | Kootenai | 2764 | 3148 | 384 | 6 | 1.8 | 3.4 | 2881 | .004 |
| 12. | Claggett | 1525 | 1950 | 425 | 7 | 1.9 | 3.6 | 1858 | .004 |
| | Eagle | 1950 | 2150 | 200 | 7 | 2.1 | 2.5 | 2019 | .003 |
| | Niobrara | 2150 | 3050 | 900 | 7 | 2.4 | 4.0 | 3038 | .004 |
| | Greenhorn | 3050 | 3250 | 200 | 7 | 2.6 | 4.1 | 3246 | .004 |
| | Belle Fourche | 3250 | 3430 | 180 | 7 | 2.9 | 4.6 | 3348 | .005 |
| | Mowry | 3430 | 3590 | 160 | 7 | 2.6 | 3.8 | 3525 | .004 |
| | Kootenai | 3900 | 4094 | 194 | 7 | 2.4 | 3.1 | 3929 | .003 |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.--Continued.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CRETACEOUS ROCKS (Continued) | | | | | |
| 13. | Claggett | 880 | 1550 | 670 | 6.5 | 2.2 | 3.0 | 1388 | 0.003 |
| | Eagle | 1550 | 2020 | 470 | 6.5 | 3.0 | 4.2 | 2460 | .005 |
| | Niobrara | 2020 | 2503 | 483 | 6.5 | 3.3 | 5.0 | 2760 | .005 |
| | Greenhorn and Belle Fourche | 2503 | 3105 | 602 | 6.5 | 3.3 | 4.8 | 2800 | .005 |
| | Bow Island | 3105 | 3737 | 632 | 6.5 | 2.6 | 3.9 | 3488 | .004 |
| 14. | Pierre | 600 | 2560 | 1960 | 6 | 2.5 | 6.6 | 2212 | .008 |
| | Niobrara | 2560 | 3044 | 484 | 6 | 3.5 | 5.1 | 2560 | .006 |
| | Greenhorn, Belle Fourche, and Mowry | 3044 | 3605 | 561 | 6 | 4.0 | 6.0 | 3480 | .007 |
| | Skull Creek | 3605 | 3853 | 248 | 6 | 0.5 | 5.5 | 3610 | .006 |
| | Kootenai | 3853 | 4037 | 184 | 6 | 2.8 | 4.0 | 3872 and 3895 | .003 |
| | | | | JURASSIC ROCKS | | | | | |
| 1. | Morrison | 4100 | 4180 | 80 | 7 | 2.5 | 4.6 | 4118 | .005 |
| 2. | Do. | 3273 | 3473 | 200 | 6 | 2.0 | 5.1 | 3400 | .006 |
| 4. | Do. | 2903 | 3120 | 217 | 7 | 2.2 | 3.3 | 2922 | .003 |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.--Continued.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | | | | JURASSIC ROCKS (Continued) | | | | | |
| 5. | Morrison | 1990 | 2245 | 255 | 5 | 1.9 | 3.2 | 2239 | 0.004 |
| 6. | Do. | 4365 | 4405 | 40 | 6.7 | 1.2 | 1.6 | 4400 | |
| 10. | Do. | 5600 | 6002 | 402 | 7 | 2.4 | 2.9 | 5661 | .003 |
| 11. | Do. | 3148 | 3162 | 14 | 6 | 2.0 | 2.2 | 3155 | .003 |
| 12. | Do. | 4315 | 4655 | 340 | 7 | 1.9 | 2.7 | 4491 | .003 |
| 13. | Do. | 3737 | 3760 | 23 | 6.5 | 1.8 | 2.0 | 3738 | .002 |
| 14. | Do. | 4037 | 4116 | 79 | 6 | 3.2 | 3.7 | 4088 | .004 |
| | | | | PENNSYLVANIAN AND MISSISSIPPIAN ROCKS | | | | | |
| 1. | Minnelusa | 5700 | 5870 | 170 | 7 | 2.2 | 5.0 | 5870 | .005 |
| | Amsden | 5870 | 6070 | 200 | 7 | 1.9 | 3.7 | 5903 | .004 |
| | Big Snowy Group | 6070 | 6372 | 302 | 7 | 2.0 | 2.8 | 6118 | .003 |
| 2. | Amsden | 4017 | 4233 | 216 | 6 | 0.8 | 2.9 | 4136 | .003 |
| | Heath | 4233 | 4325 | 92 | 6 | 1.6 | 2.8 | 9280 | .003 |
| 3. | Amsden | 3550 | 3747 | 197 | 7.6 | 1.7 | 3.3 | 3558 | .003 |
| | Heath | 3747 | 3800+ | 53+ | 7.6 | 2.4 | 4.5 | 3750 | .004 |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.--Continued.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | PENNSYLVANIAN AND MISSISSIPPIAN ROCKS (Continued) | | | | | | | | |
| 4. | Amsden | 3604 | 3976 | 372 | 7 | 1.7 | 6.0 | 3930 | 0.006 |
| | Heath | 3976 | 4622 | 646 | 7 | 2.1 | 8.9 | 4045 | .009 |
| 5. | Minnelusa | 5820 | 6230 | 410 | 6.7 | 1.2 | 2.4 | 6227 | .003 |
| | Amsden | 6230 | 6374 | 144 | 6.7 | 1.2 | 2.4 | 6356 | .003 |
| | Big Snowy Group | 6374 | 7118 | 744 | 6.7 | 1.8 | 5.0 | 6550 | .005 |
| 6. | Heath | 2817 | 3050 | 233 | 5 | 1.5 | 3.3 | 2940 | .005 |
| | Otter | 3050 | 3395 | 345 | 5 | 1.5 | 4.2 | 3169 | .006 |
| 8. | Amsden | 5650 | 5755 | 105 | 6 | 1.4 | 2.8 | 5745 | .003 |
| | Heath and Otter | 5755 | 5990 | 235 | 6 | 1.5 | 9 + | 5767 to 5775 | .010+ |
| 11. | Amsden | 6996 | 7437 | 441 | 7 | 1.6 | 4.0 | 7304 | .004 |
| | Heath and Otter | 7437 | 7929 | 492 | 7 | 2.0 | 6.7 | 7529 | .007 |
| 13. | "Bakken" | 4940 | 4976 | 36 | 6.5 | 3.8 | 5.8 | 4971 | .006 |
| 14. | Big Snowy Group | 5182 | 5432 | 250 | 6 | 3.5 | 5.4 | 5358 | .006 |
| | Englewood | 6495 | 6570 | 75 | 6 | 3.6 | 5.3 | 6504 | .006 |
| 15. | Heath and Otter | 6900 | 7340 | 440 | 6.7 | 3.1 | 5.2 | 7005 | .006 |
| | "Bakken" | 9613 | 9721 | 108 | 6.7 | 6 | 9 + | 9625 and 9700 | .012+ |

Table 2.--Radioactivity of formations containing black shale in selected oil and gas wells, northern Great Plains.--Continued.

| Map no. (fig. 7) | Formation | Depth From (feet) | Depth To (feet) | Thickness of unit (feet) | Sensitivity index (inches) | Gamma ray deflection (inches) Average | Gamma ray deflection (inches) Maximum | Depth in well of max. deflection (feet) | Estimated eU 1" deflection= 0.0007 eU on 10" sensitivity scale |
|---|---|---|---|---|---|---|---|---|---|
| | | | | DEVONIAN ROCKS | | | | | |
| 7. | Three Forks | 2780 | 3130 | 350 | 6 | 0.9 | 3.8 | 3006 | 0.004 |
| 8. | Do. | 7930 | 8030 | 100 | 6 | 2.9 | 3.7 | 7972 | .004 |
| 13. | Do. | 4976 | 5030 | 54 | 6.5 | 3.3 | 4.5 | 5008 | .005 |
| 14. | Devonian undifferentiated | 6570 | 6822 | 252 | 6 | 2.2 | 4.8 | 6715 | .005 |
| 15. | Qu'appelle Group | 9724 | 9916 | 192 | 6.7 | 2.5 | 4.0 | 9798 | .004 |
| | | | | ORDOVICIAN ROCKS | | | | | |
| 13. | Winnipeg (shale member) | 6285 | 6312 | 25+ | 6.5 | 6.0 | 6.5 | 6309 | .007 |
| 14. | Do. | 9527 | 9666 | 139 | 6.7 | 4.4 | 7.0 | 9635 | .007 |
| 15. | Do. | 13395 | 13562 | 167 | 7 | 4.4 | 5.6 | 13453 and 13466 | .005 |

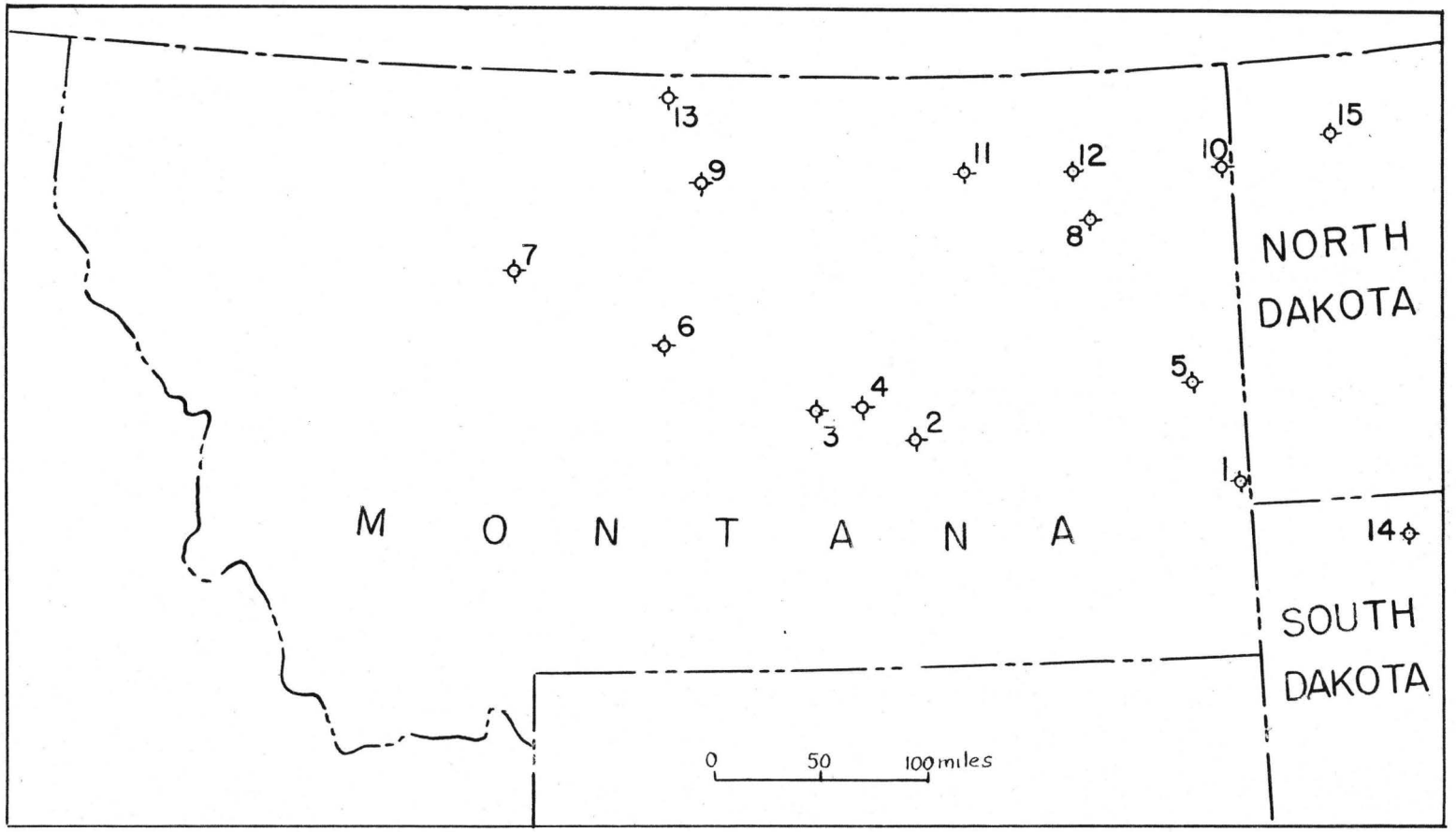



FIGURE 3-MAP SHOWING LOCATIONS OF WELLS LISTED IN TABLE I.

/Text continued from page 10.7

of black shale at the base of the Brazer limestone of Late Mississippian age contains as much as 0.009 percent uranium at one locality in Rich County, Utah (locality 30). The analyses of samples collected at these and other localities are listed on 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 in Musselshell and McCone Counties, Mont., locally contains 0.009 percent equivalent uranium or more, and that the Colorado and Pierre shales of Cretaceous age in Blaine County, Mont. and in Perkins County, S. Dak., respectively, contain as much as 0.008 percent equivalent uranium. No drill cores or cuttings from these wells are available for analyses so that the actual uranium content of the shale is unknown.

## 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 sub-surface in the Williston Basin, where it is described by Nordquist (1953, p. 72) as essentially "...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

/Text of report continued on page 39/

Table 3.--Tabulation of analytical data and outcrops examined.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | | PRE-CAMBRIAN ROCKS | | | |
| | | IDAHO | | | | |
| 4. | Prichard fm. | Benewah County 25-46N-2W | 98503 | 0.001 | --- | Grab sample, 300' exposure of dark gray argillite. |
| 5. | Do. | Kootenai County 27-48N-2W | --- | Not sampled | | 50' exposure dark greenish gray argillite. |
| 6. | Do. | 21-49N-1W | --- | Not sampled | | 100' exposure of dark greenish gray argillite. |
| 7. | Do. | Shoshone County 3and4-48N-3E | --- | Not sampled | | 150' exposure of dark gray argillite. |
| 8. | Do. | 12-49N-4E | 98506 | .002 | --- | Grab sample, dark gray argillite in road cuts. |
| 9. | Do. | 14-49N-5E | --- | Not sampled | | Dark gray thin-bedded argillite examined in road cuts. |
| | | MONTANA | | | | |
| 32. | Spokane shale | Lewis and Clark County 22-14N-4W | 94788 | .002 | --- | Grab sample, dark reddish gray argillite exposed in road cuts. |
| 33. | Do. | 36-13N-6W | 94150 | .001 | --- | Grab sample, dark greenish gray silty shale, exposed in road cuts. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | PRE-CAMBRIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 48. | Greyson shale | Broadwater County 30-7N-4E | 94161 | 0.002 | --- | Grab sample, 200' exposure of dark gray argillite. |
| 49. | Do. | Broadwater County 20-7N-5E | 94162 | .004 | 0.003 | Selected sample, 50' exposure of dark gray argillite. |
| | | CAMBRIAN ROCKS | | | | |
| | | IDAHO | | | | |
| 10. | Garden City phyllite | Custer County SW16-13N-18E | 97044 | .003 | --- | Channel sample, 2' bed of dark gray to black phyllite near middle of 120' exposure. |
| 11. | Do. | NE-3-12N-18E | 97045 | .003 | --- | Grab sample, black phyllite containing disseminated pyrite and chalcopyrite, collected from mine dump. |
| 23. | Spence shale | Bear Lake County 12-13S-42E | 97024<br>97023 | .002<br>.002 | ---<br>--- | Grab samples, upper and lower parts of 60' exposure of dark greenish gray shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | CAMBRIAN ROCKS (Continued) | | | | |
| | | IDAHO(Continued) | | | | |
| 24. | Spence shale | Oneida County<br>35-14S-36E | 97042<br>97043 | 0.003<br>.003 | ---<br>--- | Grab samples, upper and middle parts of 30' exposure dark greenish gray argillite. |
| | | UTAH | | | | |
| 25. | Do. | Cache County<br>10-14N-2E | 97039<br>97040<br>97041 | .003<br>.001<br>.002 | ---<br>---<br>--- | Grab samples, middle and lower parts of 200' exposure of dark greenish gray shale. |
| 28. | Do. | SW4-11N-4E | 97038 | .005 | 0.003 | Channel sample, 5' bed greenish tan micaceous silty shale, lower part of 10' exposure. |
| | | MONTANA | | | | |
| 39. | Wolsey shale? | Madison County<br>NW14-3S-5W | 97012 | .005 | .001 | Grab sample, near middle of 50' exposure of greenish black silty shale. |
| 46. | Unidentified | Broadwater County<br>22-5N-1W | 94790 | .002 | --- | Channel sample, 6' bed of black shale, upper part of 50' exposure. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | | ORDOVICIAN ROCKS | | | |
| | | IDAHO | | | | |
| 12. | Saturday Mt. fm. | Custer County NE28-11N-17E | 97046 | 0.003 | --- | Chip sample, middle 10' of 30' bed dark gray shale. |
| 13. | Do. | 5-11N-17E | --- | Not sampled | | Thin-bedded black dolomite and interbedded black shale exposed in main adit of the Redbird mine for a distance of 1000'. |
| 14. | Ramshorn slate | Custer County SW24-10N-17E | 97047 | .003 | --- | Grab sample, lower part of 200' exposure dark gray to black thin-bedded argillite. |
| 15. | Phi Kappa fm. | Unsurveyed-- 15 miles NE of Ketchum | 97052<br>97053 | .003<br>.003 | ---<br>--- | Chip sample, top 25' of 1,700' exposure black argillite. Chip sample, 10' bed near middle of 1,700' exposure black argillite. |
| | | UTAH | | | | |
| 26. | Swan Peak qtz. | Cache County NW5-14N-4E | 97026<br>97024 | .004<br>.004 | 0.003<br>.003 | Grab samples, upper and lower parts of 45' exposure very dark gray non-calc. shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | | ORDOVICIAN ROCKS (Continued) | | | |
| | | UTAH (Continued) | | | | |
| 27. | Swan Peak qtz. | Cache County NE18-12N-3E | 97031 | 0.004 | 0.003 | Channel sample, 3' bed non-calc. dark gray shale. |
| | | | 97030 | .003 | --- | Channel sample, 6' bed non-calc. dark greenish gray shale. |
| | | | 97029 | .003 | --- | Grab sample, 15' bed dark greenish gray shale. |
| | | | 97028 | .003 | --- | Grab sample, upper part 10' bed dark gray shale. |
| | | MONTANA | | | | |
| 84. | Winnipeg fm. | Wibaux County 30-12N-57E (Shell Pine Unit no. 1) | | .005 | .001 | Drill core, non-calc. black shale, depth 9532'. |
| | | | | .004 | .001 | Same as above, depth 9525-9535'. |
| | | | MISSISSIPPIAN ROCKS | | | |
| | | IDAHO | | | | |
| 16. | Milligen fm. | Blaine County 19,20-7N-15E | --- | Not sampled | | Black fissile shale examined at several outcrops on north side of Pole Creek, no appreciable radioactivity noted. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | IDAHO (Continued) | | | | |
| 17. | Milligen fm. | Blaine County<br>6-4N-18E | 97049<br>97050 | 0.001<br>.001 | ---<br>--- | Grab samples, black graphitic shale on mine dumps, north side Trail Creek. |
| 18. | Do. | 10-4N-18E | 97056 | .002 | --- | Channel sample, 2' bed black graphitic shale at the portal of the Quaker City mine. Black shale of the Milligen fm. examined on several mine dumps in this vicinity, but no appreciable radioactivity noted. |
| 19. | Unnamed black shale | Clark County<br>27-8N-29E | --- | Not sampled | | Flinty black shale examined on talus piles, no appreciable radioactivity noted. |
| 20. | Do. | Butte County<br>34-7N-29E | --- | Not sampled | | Same as above. |
| | | LOWER MISSISSIPPIAN ROCKS | | | | |
| | | UTAH | | | | |
| 29. | Madison ls. | Cache County<br>NW34-11N-2E | | | | Channel samples, 30' bed dark brownish gray shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | LOWER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | UTAH (Continued) | | | | |
| 29. (Continued) | Madison ls. | Cache County NW34-11N-2E | 97032 | 0.002 | --- | Top 6' |
| | | | 97033 | .004 | 0.003 | Next 5' |
| | | | 97034 | .002 | --- | Next 6' |
| | | | 97035 | .003 | --- | Next 6' |
| | | | 97036 | .003 | --- | Bottom 7' |
| | Leatham fm. | NW34-11N-2E | 97037 | .005 | .003 | Channel sample, top 2' of 8' bed, dark brownish black shale. |
| | | MONTANA | | | | |
| 34. | Madison ls. | Lewis and Clark County SW28-13N-1W | 94789 | .006 | .003 | Channel sample, 2½' bed non-calc. black shale. |
| 35. | Do. | Granite County NE31-8N-12W | | | | Channel samples, 20' bed non-calc. black shale. |
| | | | 94153 | .002 | --- | Top 4½' |
| | | | 94154 | .003 | --- | Bottom 6' |
| 36. | Do. | NE5-7N-12W | 94151 | .001 | --- | Grab sample, 6' bed black shale, #4 adit Brooklyn mine. |
| 37. | Do. | SW4-7N-12W | 94152 | .002 | --- | Channel, 2' bed black graphitic shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | LOWER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 38. | Madison ls. | Beaverhead County NE34-9S-8W | 97015 | 0.005 | 0.003 | Grab samples, upper and lower parts of 15' bed non-calc. black shale. |
| | | | 97016 | .004 | .003 | |
| 40. | Do. | Madison County NE13-3S-5W | 97013 | .004 | .001 | Chip sample, 5' bed dark gray to black shale. |
| 41. | Do. | Jefferson County NW16-1N-2W | 94148 | .002 | --- | Grab sample, partings of black shale interbedded with gray limestone, 5' exposure. |
| | | | 94147 | .003 | --- | Channel sample, top 1½' of 20' bed dark gray shale and brown shaly siltstone. |
| 42. | Do. | Gallatin County 11-11S-3E | 97011 | .002 | --- | Grab sample, black shale partings interbedded with gray limestone, 3' exposure. |
| 43. | Do. | SW25-2N-2E | 94139 | .004 | .002 | Channel samples, 2½' bed non-calc. black shale. Top 1'. |
| | | | 94140 | .004 | .005 | Bottom 1½' |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | LOWER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 43. | Sappington ss. | Gallatin County SW25-2N-2E | | | | Channel samples, 7½' bed black silty shale. |
| | | | 94141 | 0.003 | --- | Top 2' |
| | | | 94142 | .002 | --- | Next 2' |
| | | | 94143 | .003 | --- | Next 2' |
| | | | 94144 | .002 | --- | Bottom 1½' |
| | | | 94145 | .006 | 0.002 | Channel sample, 1' bed dark brownish black shale, base of the Sappington ss. |
| 44. | Do. | SE2-2N-2E | 94155 | .006 | .002 | Channel samples; top 3' of 10' bed brownish black shale. |
| | | | 94156 | .007 | .001 | Next 2' |
| | | | 94157 | .008 | .003 | Next 2' |
| | | | 94158 | .006 | .001 | Next 2' |
| | | | 94159 | .004 | .005 | Bottom 1' |
| 61. | Madison ls. | Fergus County 9-13N-17E | 201460 | .004 | .002 | Grab sample, non-calc. black shale. |
| 64. | Do. | SW8-12N-18E | 94176 | .004 | .002 | Channel sample, 1' bed black shale. |
| 65. | Do. | 32-12N-19E | 94764 | .004 | .002 | Channel sample, 3' bed non-calc. black shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | LOWER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 78. | Lodgepole ls. | Blaine County 5-25N-24E | 201457 | 0.003 | --- | Grab sample, non-calc. black shale. |
| 79. | Do. | 2-26N-24E | 201458 | .004 | 0.002 | Grab sample, 1' bed non-calc. black shale. |
| 80. | Do. | 22-26N-25E | 201459 | .003 | --- | Grab sample, non-calc. gray shale. |
| 81. | "Bakken fm." | Daniels County | | | | |
| | | SW12-36N-47E | 204065 | .006 | .002 | Depth 6964' |
| | | (Carter #1 | 204066 | .005 | .002 | Depth 6966' |
| | | Danielson) | 204067 | .010 | .003 | Depth 6968' |
| | | | 204068 | .007 | .004 | Depth 6970', pyritic |
| | | | 204069 | .008 | .004 | Depth 6971', pyritic |
| | | | 204070 | .003 | .002 | Depth 6974', some light gray calc. laminae. |
| 82. | Do. | Roosevelt County NE2-28N-51E | | | | Drill cores, non-calc. black shale. |
| | | (Murphy et al. | 98518 | .006 | .006 | Depth 7165-7175' |
| | | E. Popular unit #1) | 98519 | .004 | .002 | Depth 7190-7200' |
| | | NORTH DAKOTA | | | | |
| 85. | Do. | Williams County NW12-157N-95W | | | | Drill cuttings, non-calc. black shale. |
| | | (Amerada, Harry | 98520 | .004 | .005 | Depth 9620-9630' |
| | | Bakken #1) | 98521 | .008 | .007 | Depth 9700-9710' |
| | | | 98522 | .009 | .006 | Depth 9710-9720' |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | | UPPER MISSISSIPPIAN ROCKS | | | |
| | | IDAHO | | | | |
| 21. | Brazer ls. | Caribou County SE33-7S-40E | 94767 | 0.003 | --- | Grab sample, black cherty shale. |
| 22. | Do. | Bear Lake County NE23-12S-44E | 97017 | .001 | --- | Grab sample, 3' bed of calc. black shale. |
| | | UTAH | | | | |
| 30. | Do. | Rich County 32-13N-6E | 97018 | .001 | --- | Chip sample, 10½' bed calc. black shale containing thin lenses of black chert. |
| | | | 97019 | .004 | 0.006 | Channel sample, middle 2' of 14' bed of dark brown shale and shaly black limestone. |
| | | | 97020 | .004 | .003 | Channel sample 2½' bed of non-calc. dark brown shale. |
| | | | 97021 | .004 | .001 | Channel sample, 2' bed of non-calc. dark brown shale. |
| | | | 97022 | .004 | .009 | Chip sample, upper half of 8' bed of dark brownish black shale. |
| | | MONTANA | | | | |
| 45. | Heath shale | Broadwater County SE29-3N-2E | 94791 | .002 | --- | Grab sample, 1' bed calc. black shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | UPPER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 47. | Heath shale | Broadwater County 5,7-4N-3E | 94160 | 0.003 | --- | Grab sample, 10' bed calc. black shale. |
| 50. | Do. | Meagher County 14-9N-10E | 94163 | .002 | --- | Channel sample, 3' bed of fossiliferous black shale. |
| 51. | Do. | Judith Basin County SW3-16N-10E | 94778 | .002 | --- | Channel sample, 2½' bed gypsiferous black shale. |
| | | | 94779 | .002 | --- | Chip sample, 12' bed calc. black shale. |
| 52. | Do. | NE2-16N-10E | 94780 | .004 | 0.002 | Chip sample, 20' bed non-calc. black shale. |
| 54. | Do. | 6-15N-12E | 94781 | .001 | --- | Grab sample, 30' bed black shale. |
| 55. | Do. | NE11-14N-11E | 94773 | .003 | .002 | Chip sample, calc. black shale interbedded with gray limestone, 30' exposure. |
| 56. | Do. | NW19-14N-12E | 94771 | .002 | --- | Chip samples, top 6' of 60' exposure black shale. |
| | | | 94772 | .001 | --- | Bottom 6' of unit above. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | UPPER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 57. | Heath shale | Judith Basin County 29-12N-14E | 94766 | 0.001 | --- | Channel sample, 2' bed calc. black shale. |
| 58. | Do. | 21-11N-15E | 94765 | .003 | 0.002 | Grab sample, middle of 40' bed black shale. |
| 59. | Otter fm. | Wheatland County 5-10N-13E | 94783 | .001 | --- | Grab sample, 6' bed black shale. |
| 60. | Heath shale | 7-10N-13E | 94785 | .002 | --- | Grab sample, 5' bed non-calc. black shale. |
| 60. | Otter fm. | do. | 94784 | .003 | .002 | Grab sample, 4' bed non-calc. black shale. |
| 62. | Heath shale | Fergus County 7-13N-18E | 94177 | .002 | --- | Grab sample, 5' bed calc. black shale. |
| 63. | Do. | NW23-13N-17E | 94173 | .003 | --- | Channel sample, 5½' bed calc. black shale. |
| | | | 94174 | .004 | .003 | Channel sample, 4' bed calc. black shale. |
| 63. | Otter fm. | do. | 94175 | .004 | .003 | Grab sample, 2' bed non-calc. black shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | UPPER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 66. | Amsden fm. | Fergus County 6-12N-20E | 94755 | 0.001 | --- | Grab sample, 20' bed maroon shale. |
| 66. | Heath shale | do. | 94756 | .001 | --- | Channel sample, top 4' of 5' bed non-calc. black shale. |
| | | | 94757 | .001 | --- | Channel sample, top 4' of 30' bed non-calc. black shale. |
| | | | 94758 | .002 | --- | Channel sample, middle 4' same unit as above. |
| | | | 94759 | .001 | --- | Channel sample, bottom 4' same unit as above. |
| | | | 94760 | .003 | 0.002 | Channel sample, top 3' of 25' bed of calc. silty black shale. |
| | | | 94761 | .003 | .003 | Grab sample, middle part of unit above. |
| | | | 94762 | .006 | .003 | Channel sample, top 6' of 70' bed calc. silty black shale. |
| 67. | Do. | SW30-16N-19E | 94786 | .001 | --- | Grab sample, dark gray non-calc. shale from mine dump. |
| 68. | Do. | SW14-15N-19E | 94169 | .004 | .003 | Grab sample, 3' bed black shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | UPPER MISSISSIPPIAN ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 69. | Heath shale | Fergus County 17-14N-21E | 94178 | 0.003 | --- | Channel samples, top 1½' of 15' bed non-calc. black shale. |
| | | | 94179 | .002 | --- | Same unit as above, next 1'. |
| 70. | Do. | SE30-14N-21E | 94182 | .002 | --- | Channel sample, top 2½' of 15' bed of calc. black shale. |
| | | | 94183 | .002 | --- | Channel sample, next 2½' same unit as above. |
| | | | 94184 | .003 | --- | Channel sample, bottom 6' same unit as above. |
| 71. | Do. | NE-13N-21E | 94185 | .001 | --- | Grab sample, 10' bed of black non-calc. shale. |
| 72. | Do. | SW17-14N-21E | 94180 | .003 | --- | Channel sample, bottom 2' of 3' bed calc. black shale. |
| 73. | Amsden fm. | SW16-14N-22E | 94192 | .002 | --- | Grab sample, 4' bed non-calc. black shale. |
| 75. | Heath shale | SE13-12N-22E | 94187 | .002 | --- | Grab sample, upper part 15' bed of non-calc. black shale. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | UPPER MISSISSIPPIAN ROCKS (Continued) | | | | |
| 75. | Heath shale (Continued) | Montana (Continued) Fergus County SE13-12N-22E | 94188 | 0.002 | --- | Grab sample, lower part 15' bed of non-calc. black shale. |
| 76. | Do. | NW20-14N-24E | 94190 | .002 | --- | Grab sample, black shale parts in 40' bed light gray sandstone. |
| 77. | Do. | Golden Valley County 30-11N-21E | --- | Not sampled | | Scattered outcrops of black shale examined, no appreciable radioactivity noted. |
| 83. | Do. | Roosevelt County SE13-28N-50E (Carter Lowe #1) | 207572 | .002 | --- | Drill core, dark gray to black shale. Depth 4925' |
| | | | 207573 | .003 | --- | Depth 4930' |
| | | | 207574 | .003 | --- | Depth 4933' |
| | | TRIASSIC ? ROCKS | | | | |
| | | OREGON | | | | |
| 1. | Unnamed fm. | Baker County 31-12S-46E | --- | Not sampled | | Dark gray and dark greenish gray argillite examined in road cuts and at natural exposures; no appreciable radioactivity noted. |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | | TRIASSIC ? ROCKS (Continued) | | | |
| | | OREGON (Continued) | | | | |
| 2. | Unnamed fm. | Baker County 32-11S-45E | --- | Not sampled | | Same as above. |
| 3. | Do. | 33-9S-46E | --- | Not sampled | | Same as above. |
| | | | CRETACEOUS ROCKS | | | |
| | | MONTANA | | | | |
| 31. | Colorado sh. | Teton County 9-24N-8W | 98508 | 0.002 | --- | Grab sample, near middle of 60' bed of dark gray bituminous shale. (Top of the sequence). |
| | | | 98509 | .002 | --- | Channel sample, bottom 1½' same unit as above. |
| | | | 98510 | .001 | --- | Grab sample, ½' bed of dark gray bituminous limestone. |
| | | | 98511 | .004 | 0.002 | Channel sample, 1' bed of light yellow bentonite. |
| | | | 98512 | .003 | .001 | Chip sample, 4' bed of black bituminous shale. |
| | | | 98513 | .001 | --- | Channel sample, top 3' of 25' bed of dark gray bituminous shale. (Base of the sequence). |

*--Dash indicates that uranium not determined chemically.

Table 3.--Tabulation of analytical data and outcrops examined.--Continued.

| Map no. (fig. 1) | Formation | Location (Sec., T., R.) | Laboratory no. | Equivalent uranium (percent) | Uranium* (percent) | Description |
|---|---|---|---|---|---|---|
| | | CRETACEOUS ROCKS (Continued) | | | | |
| | | MONTANA (Continued) | | | | |
| 53. | Colorado sh. | Judith Basin County 1-16N-11E | 94777 | 0.005 | 0.003 | Grab sample, silicified limestone concretions in the upper part of 25' bed yellowish gray bentonite. |
| | | | 94776 | .002 | --- | Channel sample, bottom 1½' of 25' bed of yellowish gray bentonite. |
| | | | 94775 | .002 | --- | Grab sample, ½' bed of gray silicified shale underlying bed of bentonite described above. |
| | | | 94774 | .002 | --- | Channel sample, 4' bed of dark gray shale underlying unit above. |
| 74. | Do. | Fergus County NW20-14N-24E | 94189 | .002 | --- | Channel sample, 4' bed of silty black shale near middle of a 30' exposure of interbedded shale and yellowish gray silty sandstone, base of the Colorado shale. |

*--Dash indicates that uranium not determined chemically.

/Text of report continued from page 20./

Utah. The lower shale and medial sandstone-dolomite units may correlate with the Sappington sandstone, 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 are regarded by Nordquist to correlate respectively with the Exshaw shale and the basal sandstone of the overlying Baniff formation. In most parts of the northern Rocky Mountain region, the Bakken formation and its equivalents unconformably overlie the Three Forks or Jefferson formations of Late Devonian age, and are conformably overlain by limestone of the Madison, Lodgepole, or Baniff formations of Early Mississippian age.

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. Graphic sections at 10 of these localities are shown by figure 4. 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. (locality 43), and 0.005 percent in the basal part of a 10-foot bed of brownish-black shale nearby (locality 44).

The Bakken formation 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 Harry Bakken no. 1, Williams County, N. Dak., contain 0.005 to 0.007 percent uranium. A sample of drill core from a 10-foot thick bed of black shale in the Murphy, et al., East Popular no. 1 well, Roosevelt County, Mont., contains 0.006 percent uranium. One of six samples of drill core from a 10-foot thick bed of black shale in the Carter no. 1 Danielson well, Daniels County, Mont.,

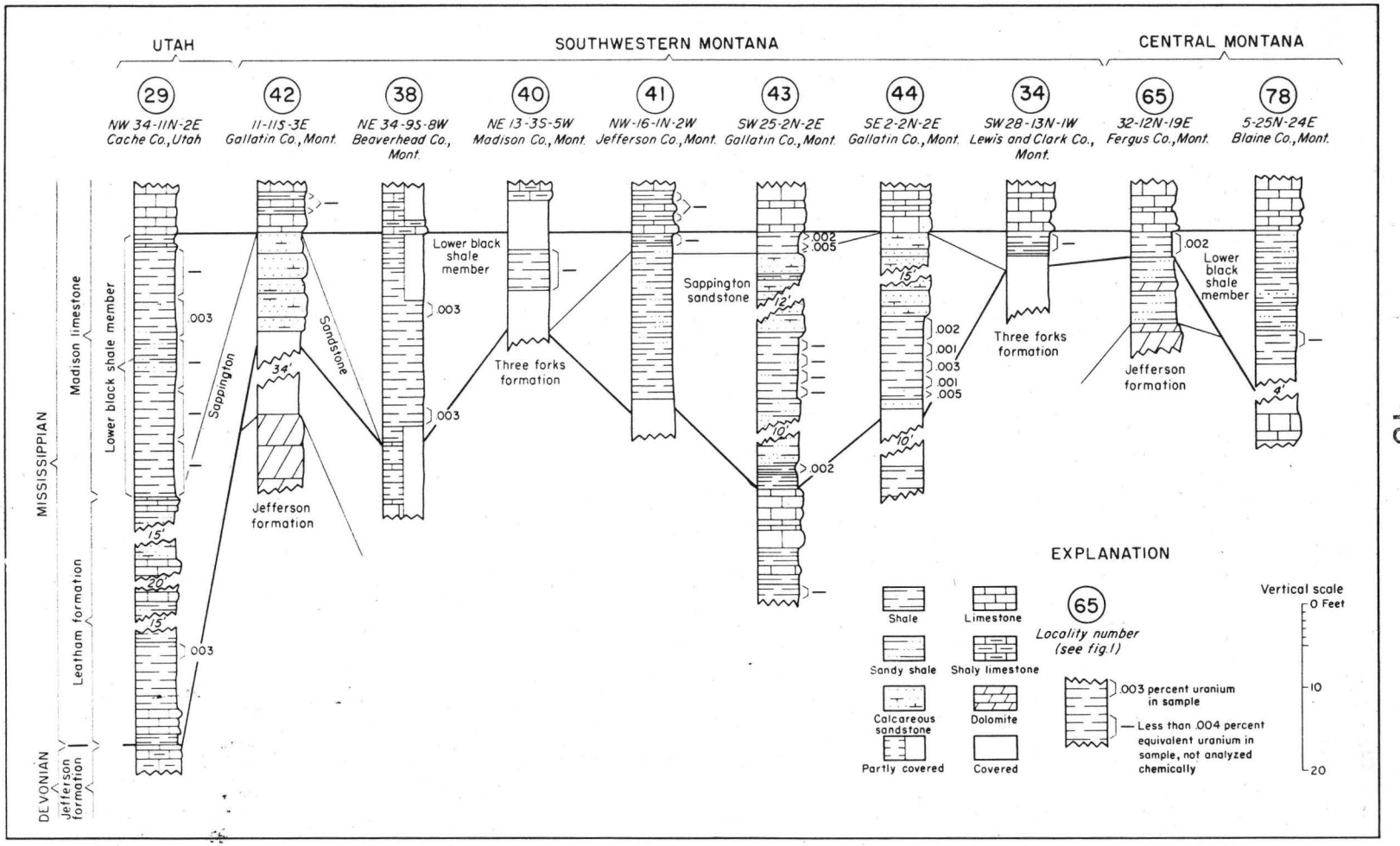



FIGURE 4.-GRAPHIC SECTIONS SHOWING URANIUM CONTENT OF BASAL MISSISSIPPIAN BLACK SHALE AT OUTCROPS IN THE NORTHERN ROCKY MOUNTAIN REGION.

contains 0.004 percent uranium. The samples from the Carter no. 1 Danielson well are anomalous in that they are decidedly out of balance in favor of equivalent uranium as indicated by the table below:

Descriptions of samples from the Carter no. 1 Danielson well, Daniels County, Montana

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

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

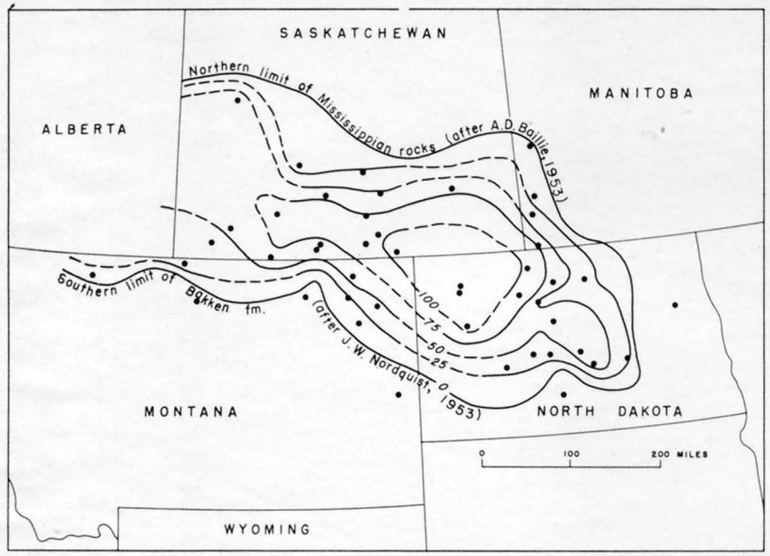
| Sample no. | Equivalent uranium (percent) | Uranium (percent) | $Th^{232}$ percent (radio-chemical) | $Th^{230}$ (ionium) (percent equivalent) | Radium (percent equivalent) |
|---|---|---|---|---|---|
| 204067 | .010 | .003 | .003 | .009 | .006 |

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.

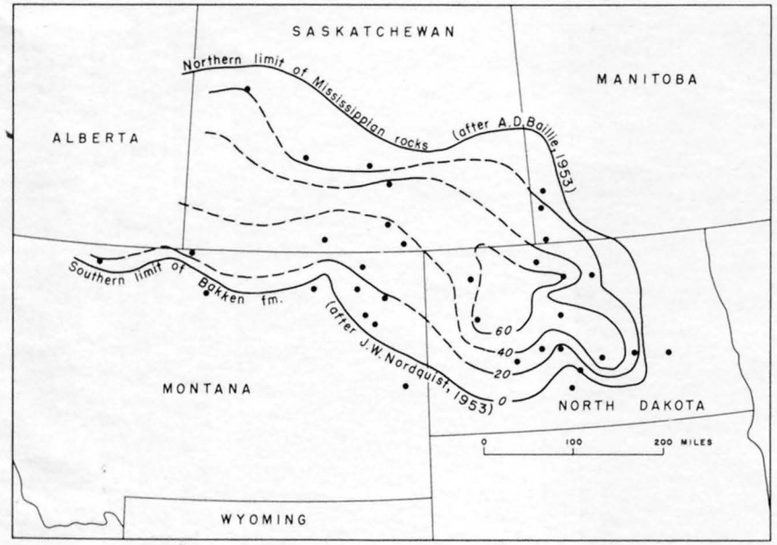
The thickness and the areal distribution of radioactivity in the Bakken formation as determined from published sample descriptions and gamma ray logs is shown by figure 5. These maps suggest that black shale in the Bakken formation is thickest in northwestern North Dakota and that the formation is most radioactive slightly east of this area near the northeastern corner of Montana. No convincing conclusions can be drawn from the data presented, but it seems evident that radioactivity in the Bakken formation varies appreciably from place to place with a definite pattern. Recognition of the pattern doubtless will help in outlining areas in which maximum concentrations of uranium in the formation might be expected.

Black shale at the base of the Brazer limestone

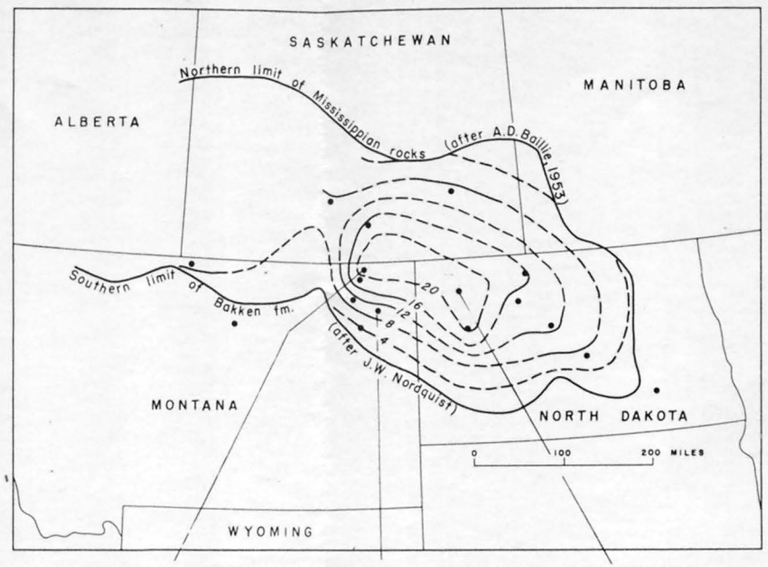
The basal part of the Brazer limestone of Upper Mississippian age in parts of Utah and Idaho consists of a black phosphatic shale sequence ranging in thickness from a few inches to about 75 feet. Exposures of this zone were tested at two places in southeastern Idaho (localities 21 and 22), and at one place in northwestern Utah (locality 30). Beds of black shale in the sequence at the two Idaho localities are essentially non-uraniferous, 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 uranium, and a bed of shale 8 feet thick in the lower part contains as much as 0.009 percent uranium. The measured sections and



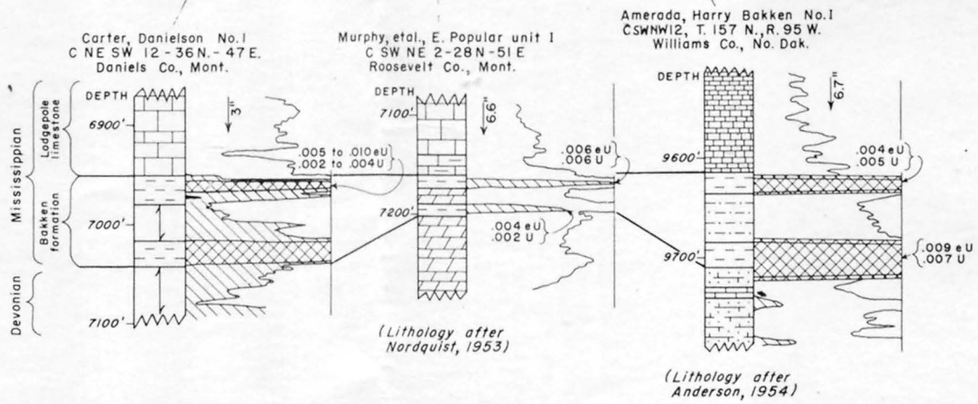

THICKNESS MAP OF THE BAKKEN FORMATION




THICKNESS MAP OF BLACK SHALE IN THE BAKKEN FORMATION




ISORADIOACTIVITY MAP OF THE BAKKEN FORMATION




GRAPHIC SECTIONS SHOWING RADIOACTIVITY AND URANIUM CONTENT OF THE BAKKEN FORMATION, SELECTED WELLS

## EXPLANATION

Locations of oil or gas wells from which thickness or radioactivity measurements were taken.

25

Thickness in feet, line is dashed where thickness control is poor.

8

Maximum deflection on gamma-ray log in inches, calculated to Lane Wells sensitivity index of 10 inches; line is dashed where control is poor. *(Eight inches deflection represents approximately .005 percent equivalent uranium.)*

Limestone

Dolomite

Shale

Sandy shale

Calcareous sandstone

Shaly limestone

Lithology unknown

Radioactivity increases

0 1 2 3 inches deflection

.005 eU
.003 U

Gamma ray log curve
Showing abnormal deflection
*(Curve telescoped to fit column)*
.005 eU is percent equivalent uranium, and .003 U is percent uranium in sample

6.9"

Lane Wells sensitivity index

FIGURE 5. - MAPS AND SECTIONS SHOWING THICKNESS AND RADIOACTIVITY OF THE BAKKEN FORMATION, NORTHERN GREAT PLAINS

uranium content of the black shale at the three localities are shown graphically by figure 6.

Black shale at the base of the Brazer limestone was examined by D. C. Duncan (1953, p. 68) in Ogden Canyon, Weber County, Utah, about 45 miles southwest of the Rich County locality described above. Duncan reported that at Ogden Canyon beds of phosphatic shale about 1 foot thick contained as much as 0.005 percent uranium, 0.18 percent vanadium oxide, and 17.3 percent 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 has been penetrated in drill holes throughout a large area in eastern Montana and western North Dakota. The formation consists largely of marine 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 as much as 400 feet thick where exposed on the flanks of the Little Belt and Big Snowy Mountains to the west. (See fig. 7.) The Heath is underlain by the Otter formation of Late Mississippian age which consists of green and black shale and gray limestone, and it is overlain by the Amsden formation of Late Mississippian and Pennsylvanian age which consists mostly of red shale and sandstone and gray limestone and dolomite.

Outcrops of the Heath shale were examined for radioactivity at 8 places by Hail and Gill during 1951 (Duncan, 1953, p. 42-43) and outcrops of the Heath shale were examined at 24 places by the writer during 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 NW$\frac{1}{4}$ sec. 24, T. 14 N., R. 20 E., Fergus County. At this locality, the upper 4 feet of a

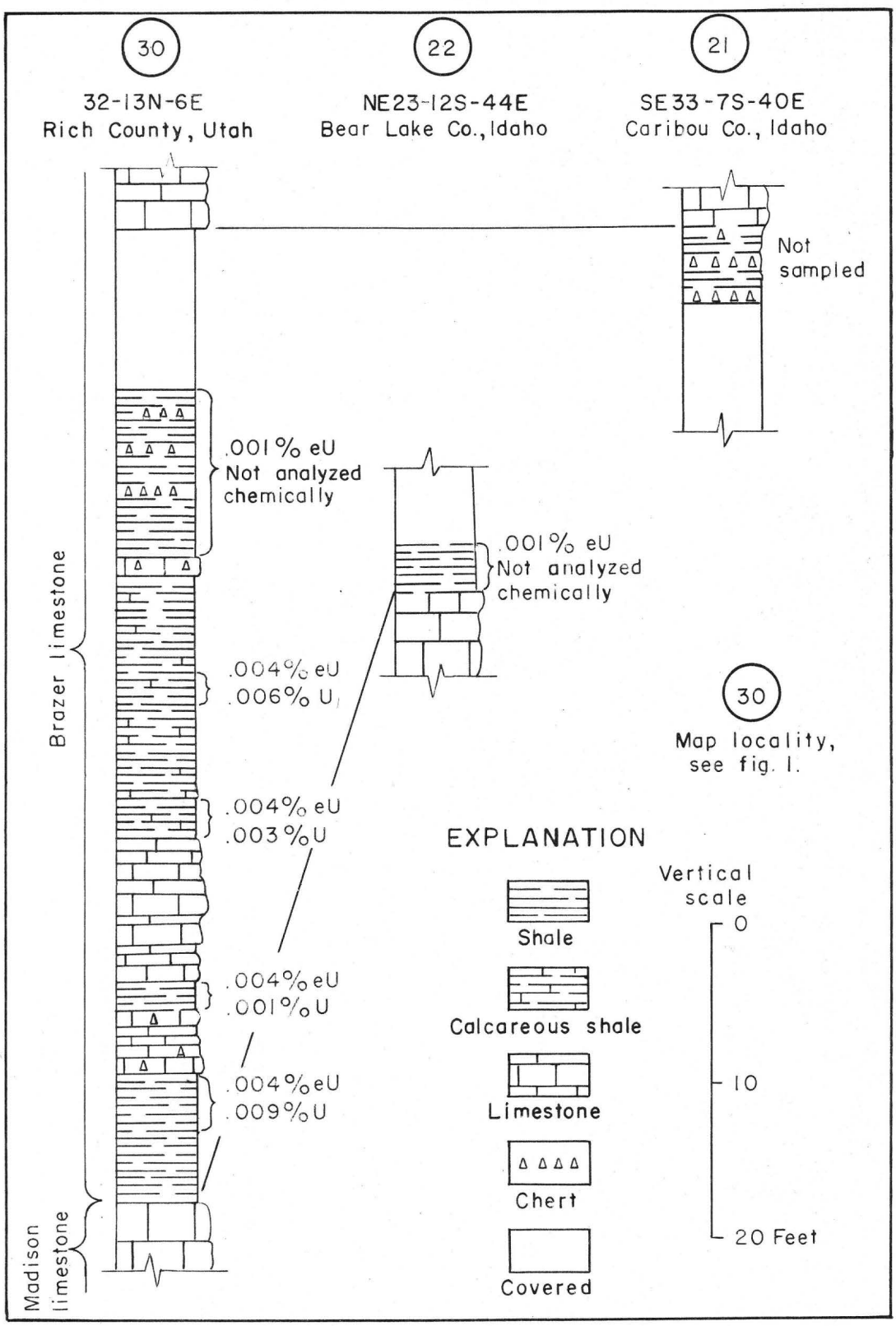



FIGURE 6.-GRAPHIC SECTIONS SHOWING THE URANIUM CONTENT OF BLACK SHALE AT THE BASE OF THE BRAZER LIMESTONE, UTAH AND IDAHO

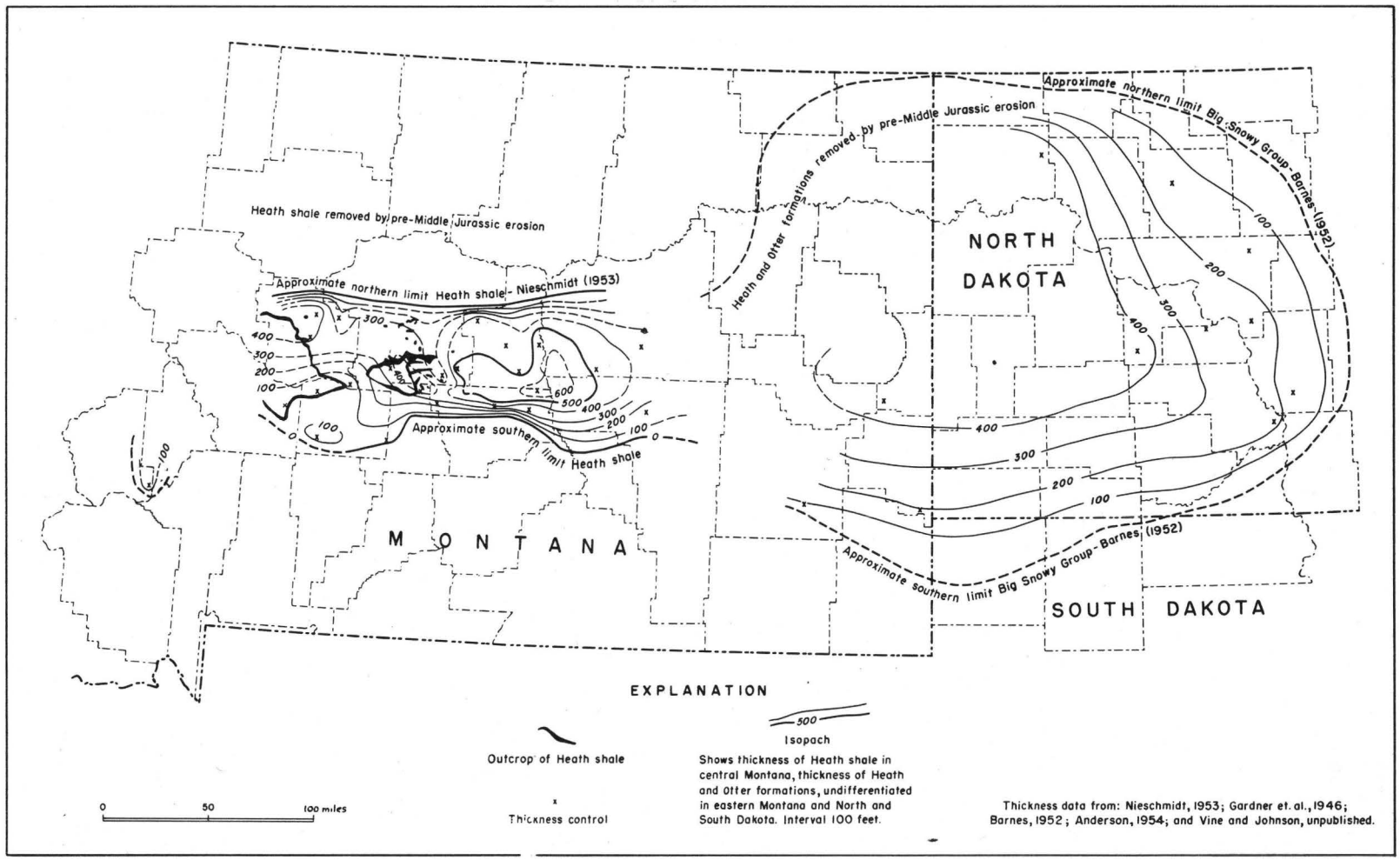



FIGURE 7.--MAP SHOWING THICKNESS AND DISTRIBUTION OF THE HEATH SHALE IN CENTRAL MONTANA AND THE HEATH AND OTTER FORMATIONS IN EASTERN MONTANA AND ADJACENT PARTS OF NORTH AND SOUTH DAKOTA

6-foot thick bed of black shale near the top of the formation contains 0.006 percent uranium. Samples of black shale from the Heath formation elsewhere in central Montana contain a maximum of 0.003 percent 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 (locality 66) contains 7 parts per billion 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 Oils Ltd. Farnham no. 1 well, McCone County, Mont. (well 6, table 1), may contain more than 0.01 percent equivalent uranium, and gamma ray logs show some parts of the formation to be nearly as radioactive in Musselshell County, Mont. Not enough information is available so far to attempt to analyse the distribution of radioactivity in relation to the variations in thickness and lithology of the Heath.

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PART II

PLANS

Gamma ray logs and surface sampling indicate that at some places deposits of black shale at the base of the Mississippian system, black shale at the base of the Brazer limestone, and the Heath shale, all of Mississippian age, and some deposits of black shale of Cretaceous age, contain more than ordinary amounts of uranium. Accumulation of gamma ray logs and of well cuttings and cores of these shale deposits is continuing in order to make more complete interpretations of the areal and stratigraphic distribution of radioactivity and the relation of radioactivity to such geologic features as thickness and lithology.

Field examination of Cretaceous shales is underway in South Dakota, Nebraska, Kansas, and Colorado.