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LOW-GRADE URANIUM IN THE FORT UNION FORMATION, CROOKED WASH AREA, NORTHWESTERN COLORADO

By
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CONTENTS

ILLUSTRATIONS

TABLE

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INTRODUCTION

Carbonaceous shale beds in the upper member of the Fort Union Formation of Paleocene age contain several low-grade uranium occurrences in the Crooked Wash area about 40 km (25 mi) northwest of Meeker, Colo. (fig. 1). This area was investigated for the Department of Energy National Uranium Resources Evaluation (NURE) program and initially described in the open-file folio report on the Vernal 1° x 2° Quadrangle (Craig and others, 1981[1]). The present report provides additional and more detailed information based on recent field work also supported in part by the Department of Energy NURE program. Nine outcrop occurrences containing a minimum of 100 ppm (0.01 percent) uranium were examined and are described below. These occurrences had not been reported previous to the these investigations, and this report contains the results of reconnaissance observations that permit a preliminary appraisal of the uranium potential of the Fort Union Formation in this area. Maximum uranium values thus far known do not exceed 340 ppm (0.034 percent), and the deposits cannot presently be regarded as economically valuable. Table 1 shows the uranium content of samples from the known occurrences.

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1 Work performed under U.S. Department of Energy, Contract No. DE-A113-78GJ01686.

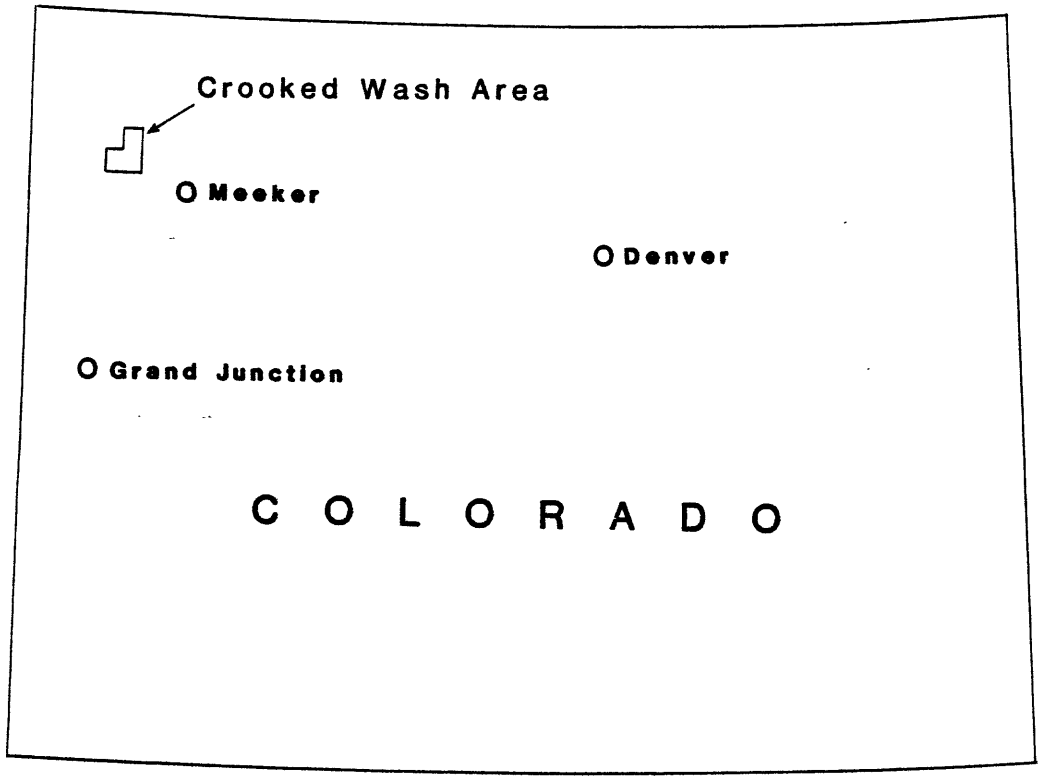


FIGURE 1. -- Index map showing location of the Crooked Wash area

Table 1.--Uranium content and lithology of samples from known occurrences

Occurrence number	Sample number	Radiometric count times background[1]	Uranium (ppm)	Lithology
1	MDW 216	2	154	Coal
	MDW 217	3	216	Carbonaceous shale
	MDW 218	3	251	Carbonaceous shale
	MDW 219	4	340	Carbonaceous shale
2	MDW 202	2	48	Coaly carbonaceous shale
	MDW 203	3	76	Coal
	MDW 204	2	25	Coaly carbonaceous shale
	MDW 205	3	169	Coaly carbonaceous shale
	MDW 206	3	23	Coaly carbonaceous shale
	MDW 278	3_{1-2}	109	Shaly coal
3	MDW 207	2	66	Carbonaceous claystone
	MDW 208	3	73	Carbonaceous claystone
	MDW 209	2	19	Carbonaceous claystone
	MDW 210	3	110	Carbonaceous shale
	MDW 211	3	152	Carbonaceous shale
4	MDW 270	5	215	Carbonaceous shale
	MDW 271	5	248	Carbonaceous shale
	MDW 272	5	110	Carbonaceous shale
	MDW 273	3	78	Carbonaceous shale
	MDW 279	2_{1-2}	125	Carbonaceous shale
	MDW 280	3_{1-2}	168	Carbonaceous shale
5	MDW 274	2_{1-2}	114	Shaly coal
	MDW 275	2_{1-2}	89	Coaly carbonaceous shale
6	MDW 214	3	84	Carbonaceous shale
	MDW 215	3	153	Carbonaceous shale
7	MDW 281	3	84	Carbonaceous claystone
	MDW 282	3	257	Coaly carbonaceous shale
	MDW 283	2	100	Coaly carbonaceous shale
8	MDW 295	3_{1-2}	145	Coaly carbonaceous shale
9	MDW 294	3_{1-2}	116	Carbonaceous shale

[1] Instrument used: LaRoe Model FV6S.

Geologic Setting

The Crooked Wash area lies at the northwestern margin of the Piceance Creek Basin (fig. 2). The rocks of the southern part of this area are described by Hail (1973, 1974). The Fort Union Formation, consisting of alluvial basin deposits, is divided in this area into a lower member of early or middle to late Paleocene age, and an upper member of late Paleocene age. The outcrop of the upper member in the southern part of the Crooked Wash area is shown on plate 1. The outcrop of the upper member in the northern part of the area is shown on plate 2. Known uranium occurrences are limited to the upper member. The Fort Union unconformably overlies the Late Cretaceous Mesaverde Group, and conformably underlies the Paleocene and Eocene Wasatch Formation.

The Fort Union Formation and equivalent units of Paleocene age crop out around the entire margin of the northwestern part of the Piceance Creek Basin (fig. 2). West of longitude 108°30', Barnum and Garrigues (1980) included the Fort Union equivalent with the overlying Wasatch Formation. North of latitude 40°15', in the Elk Springs 15-minute quadrangle, Dyni (1968) included rocks equivalent to the Fort Union in a unit designated "Wasatch Formation and associated rocks." On the eastern margin of the Gray Hills Syncline (fig. 2), along Strawberry Creek, Pipiringos and Rosenlund (1977), and G. A. Izett (written commun., 1978) mapped basal Paleocene rocks as Fort Union Formation, and included higher Paleocene rocks in the lower part of the Wasatch Formation. In the Crooked Wash area, the upper and lower members of the Fort Union are readily differentiated (Hail, 1973, 1974). West of longitude 108° 30', the two members begin to lose their distinct lithologic identities and are not separated in mapping. On the east side of the Gray Hills Syncline, the Fort Union is mostly sandstone.

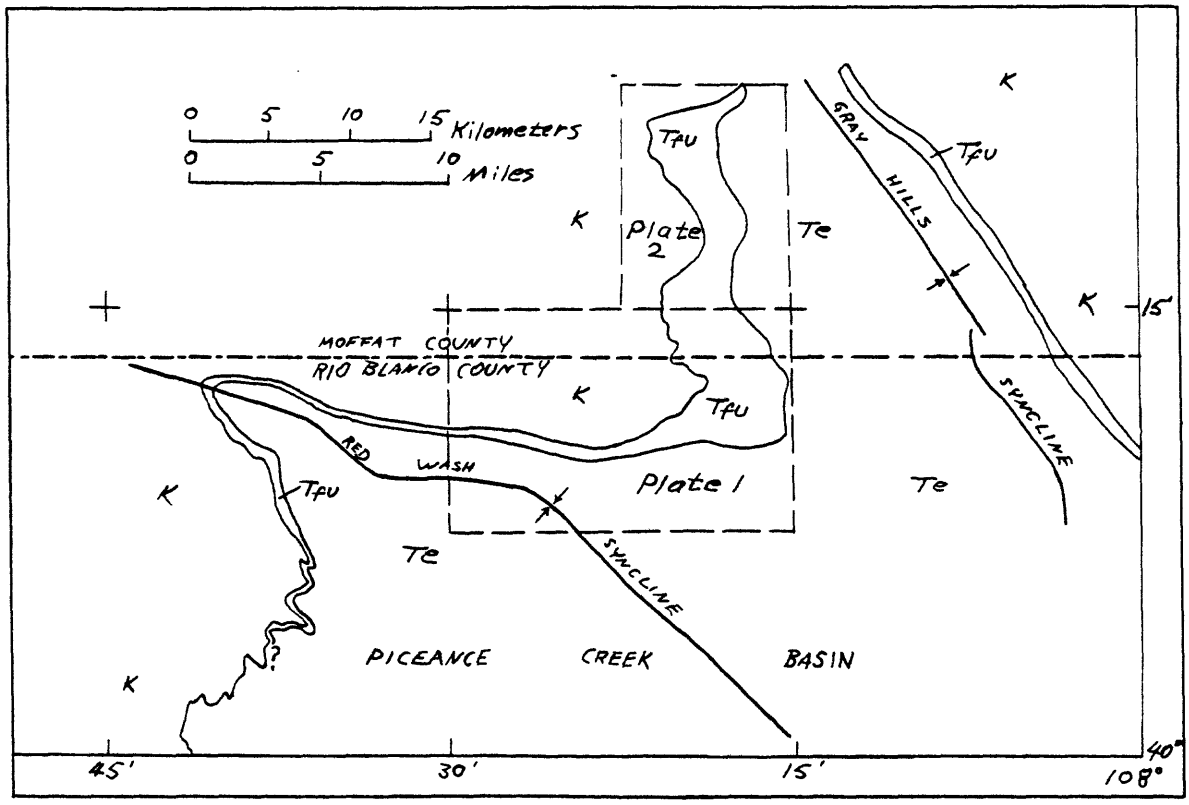


FIGURE 2. -- Northwestern part of the Piceance Creek Basin. Dashed line encloses areas of Plates 1 and 2. K, Cretaceous and older rocks; Tfu, Fort Union Formation and other Paleocene rocks; Te, Eocene rocks. Geology modified from published USGS maps and geologic reconnaissance

The lower member of the Fort Union Formation lies unconformably on the Williams Fork Formation of the Late Cretaceous Mesaverde Group, and conformably underlies the upper member of the Fort Union. The lower member is dominantly light-greenish-gray, variably calcareous claystone, mudstone, and lenticular channel-type sandstone. In the outcrop area north of Deep Channel Creek, a few claystone or mudstone beds are locally red or purple. Sandstone beds rich in organic material are sparse, and the channel-sandstone beds are generally free of carbonaceous trash or other organic material. The thickness of the lower member ranges from about 45 m (150 ft) to about 520 m (1,700 ft).

The upper member of the Fort Union Formation lies conformably on the lower member and conformably underlies the Paleocene and Eocene Wasatch Formation. Rocks of the upper member were deposited in a low-lying, swampy alluvial flood basin. Gray shale is the dominant lithology but considerable carbonaceous material is present, with numerous beds of brown carbonaceous shale and claystone. Some of the carbonaceous shale beds grade laterally into argillaceous or silty coal beds. The coal beds, even where best developed, are thin, lenticular, and probably of poor grade, although no coal analyses are available. The carbonaceous clay and coal beds were deposited in poorly drained swamps, shallow ponds, or lakes. Also present are thin but relatively persistent beds of paludal siltstone and sandstone. Lenticular channel-type sandstone beds are present locally. The thickness of the upper member ranges from about 100 m (300 ft) to about 170 m (550 ft). Three sections (occurrences 1, 2, and 3) were measured through essentially the entire thickness of the upper member. The overlying Wasatch Formation is dominantly varicolored claystone and shale, and thick lenticular crossbedded channel-fill sandstone.

Uranium

The nine presently known uranium occurrences are shown on plates 1 and 2. They span a distance along the outcrop of about 25 km (15 mi). A brief examination of outcrops between the known occurrences showed some indication of anomalous radioactivity locally; generally about two to three times background levels. Reconnaissance along the Fort Union outcrop west and southwest of occurrence 1 (pl. 1 and fig. 2) showed no evident anomalous

radioactivity. In this area, the upper member of the Fort Union begins to lose its identity as a distinctive mappable unit, probably as it approaches its western depositional edge, which lies a short distance west of the present outcrop.

As a part of this study, the outcrop of the upper member of the Fort Union was mapped north of latitude 40°15' N., in the southeastern part of the Elk Springs 15-minute quadrangle. This outcrop is shown on plate 2 and is a continuation of the outcrop to the south shown on plate 1. The outcrop extends northward for about 13 km (8 mi) where it disappears under the Miocene Browns Park Formation at Wapiti Peak. The upper member of the Fort Union in this area is for the most part poorly exposed but retains essentially the same lithology and thickness as in the southern part of the area. It is dominantly a dark-gray to brown shale unit. A radiometric reconnaissance examination of the upper member was made in this area, and two occurrences (No's. 8 and 9) were found in the southern part. The apparent lack of other such anomalous occurrences to the north is not regarded as definitive, owing to the poorly exposed character of the upper member throughout most of this area. The unit is regarded as favorable for uranium occurrences throughout its extent.

All the uranium occurrences are clearly stratiform, although they are present at various stratigraphic positions within the upper member (fig. 3). Most of the uranium-bearing or radioactive beds are very thin. Those beds containing at least 100 ppm uranium range from a few centimeters to about 1.5 m (5 ft) in thickness; most are less than 0.5 m (2 ft). Anomalous concentrations of uranium and anomalous radioactivity are limited to the more carbonaceous beds: coal, carbonaceous shale, and carbonaceous claystone. These are black or brown in color, in contrast to the dominantly gray color of the shale or claystone which is not mineralized. Siltstone and mudstone beds also are not mineralized. It is evident that carbonaceous material, occurring largely as plant remains, is the reducing medium for concentrating uranium, although not all carbonaceous beds are mineralized. Commonly, anomalous radioactivity persists within a single relatively thin bed along its strike for a considerable distance. Known distances range from a few meters to 335 m (1,100 ft), and these distances are limited to the dimension of the surface exposures. Uranium minerals are unknown, and it is assumed that the uranium present is in organic compounds.

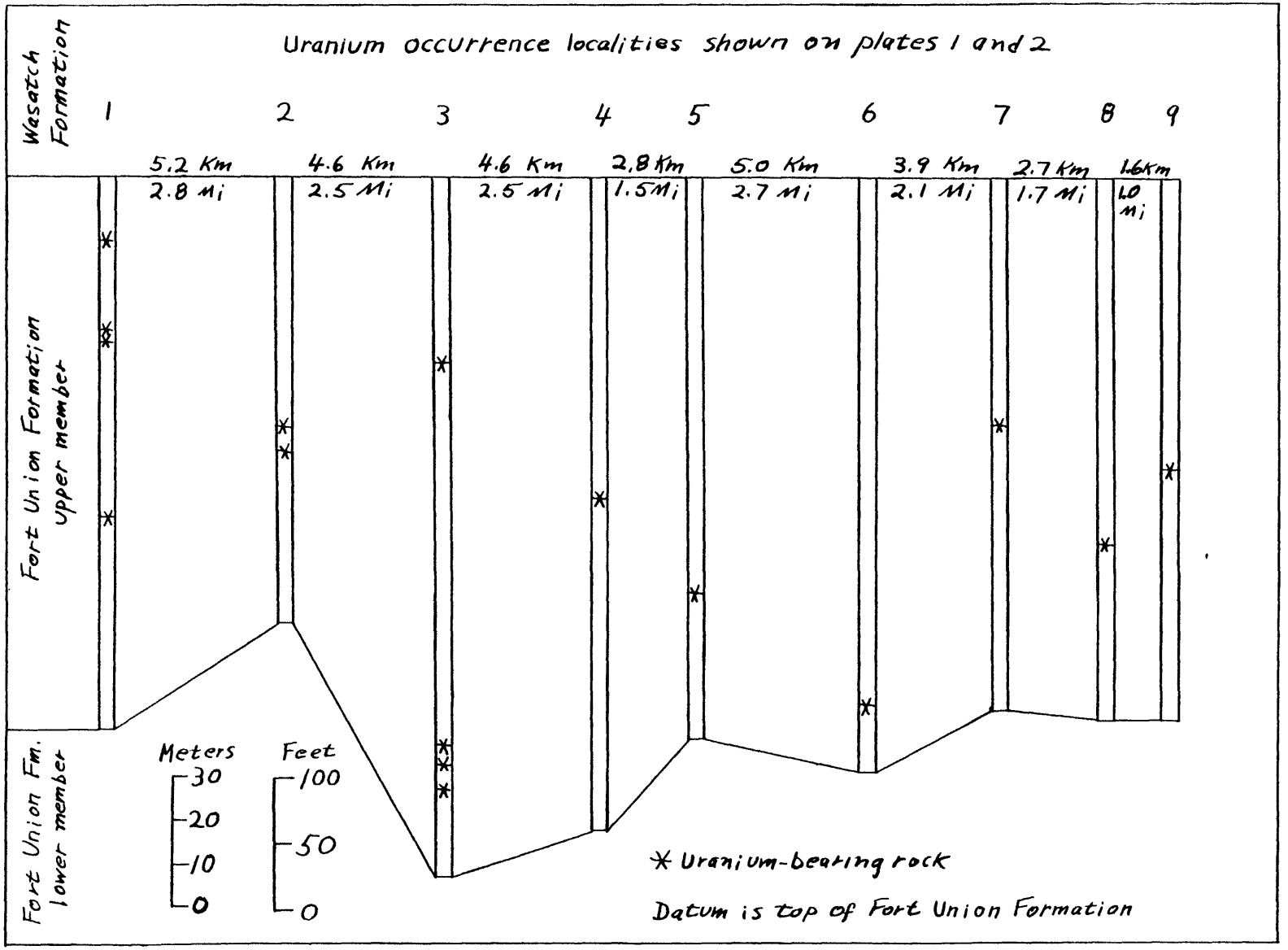


FIGURE 3. -- Stratigraphic position of uranium-bearing rock at known occurrences in the upper member of the Fort Union Formation

Numbered Occurrences

Uranium occurrences 1, 2, and 3 (pl. 1 and fig. 3) are located in fairly well exposed ground, and the measured sections at these localities show much or all of the upper member of the Fort Union Formation. Radiometric examination of the exposures is, therefore, believed to have revealed most, if not all of the anomalously radioactive beds. Occurrences 4 through 9, however, are in poorly exposed ground, and radiometric examination may have missed radioactive beds within these sections. Thus, the columns for these sections shown on figure 3 do not necessarily show all the occurrences that may be present. Figures 4 through 11 graphically depict the sample localities at all the known occurrences except occurrence 9 where rocks are too poorly exposed to be measured.

Occurrence 1 (pl. 1 and fig. 4) is the farthest west of the known occurrences, and the one yielding the sample with the highest known uranium content (340 ppm). Occurrence 1 is located in the NW1/4 sec. 6, T. 2 N., R. 98 W., at latitude 40°10'42" N., longitude 8°26'24" W., Rough Gulch 7 1/2-minute topographic quadrangle. The rocks strike N. 85° W., and dip 45° S. Here the upper member of the Fort Union Formation is 128 m (419 ft) thick. Four samples were collected. Sample MDW 216, containing 154 ppm uranium, came from a bed of coal and coaly carbonaceous shale lying 49 m (160 ft) above the base of the upper member. This bed ranges from 0.15 m (0.5 ft) to 0.75 m (2.5 ft) in thickness, and is anomalously radioactive throughout the length of the exposure, a distance of at least 60 m (200 ft). Sample MDW 217, containing 216 ppm uranium, came from a bed of coaly carbonaceous shale 90 m (294 ft) above the base of the upper member. This bed is 0.1 m (0.3 ft) thick and lies in a carbonaceous shale unit 1.5 m (5 ft) thick. The bed is intermittently exposed but is anomalously radioactive throughout the length of the exposure, a distance of at least 30 m (100 ft). Sample MDW 218, containing 251 ppm uranium came from a shale bed 0.37 m (1.2 ft) thick, lying 92 m (303 ft) above the base of the upper member. This bed is poorly exposed, and its lateral extent is not known. Sample MDW 219, containing 340 ppm uranium came from a carbonaceous shale bed 0.33 m (1.1 ft) thick, lying 113 m (370 ft) above the base of the upper member. Although poorly exposed, this bed can be traced laterally for at least 6 m (20 ft), and it is anomalously radioactive throughout this distance.

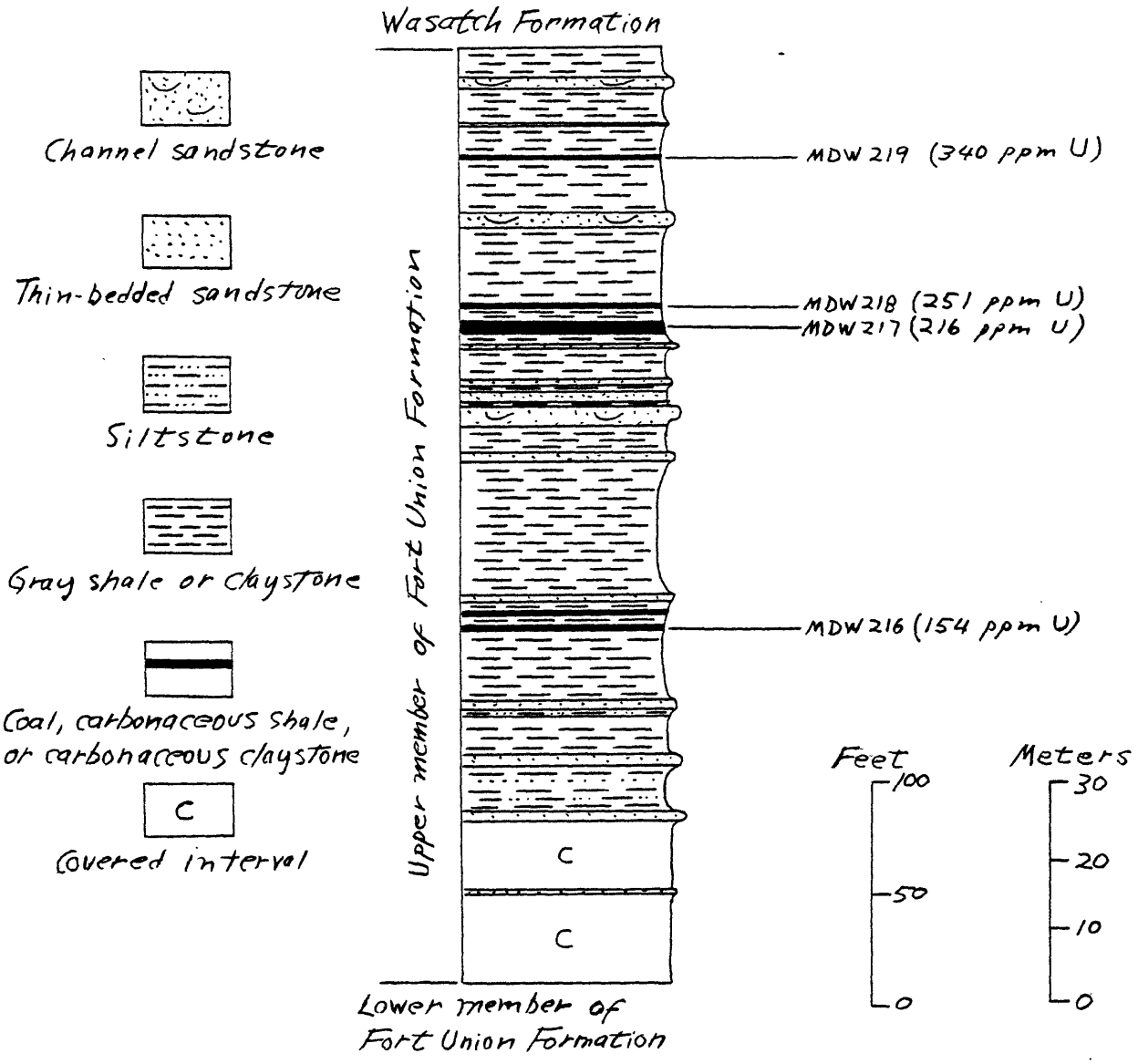


FIGURE 4. -- Measured section at occurrence 1

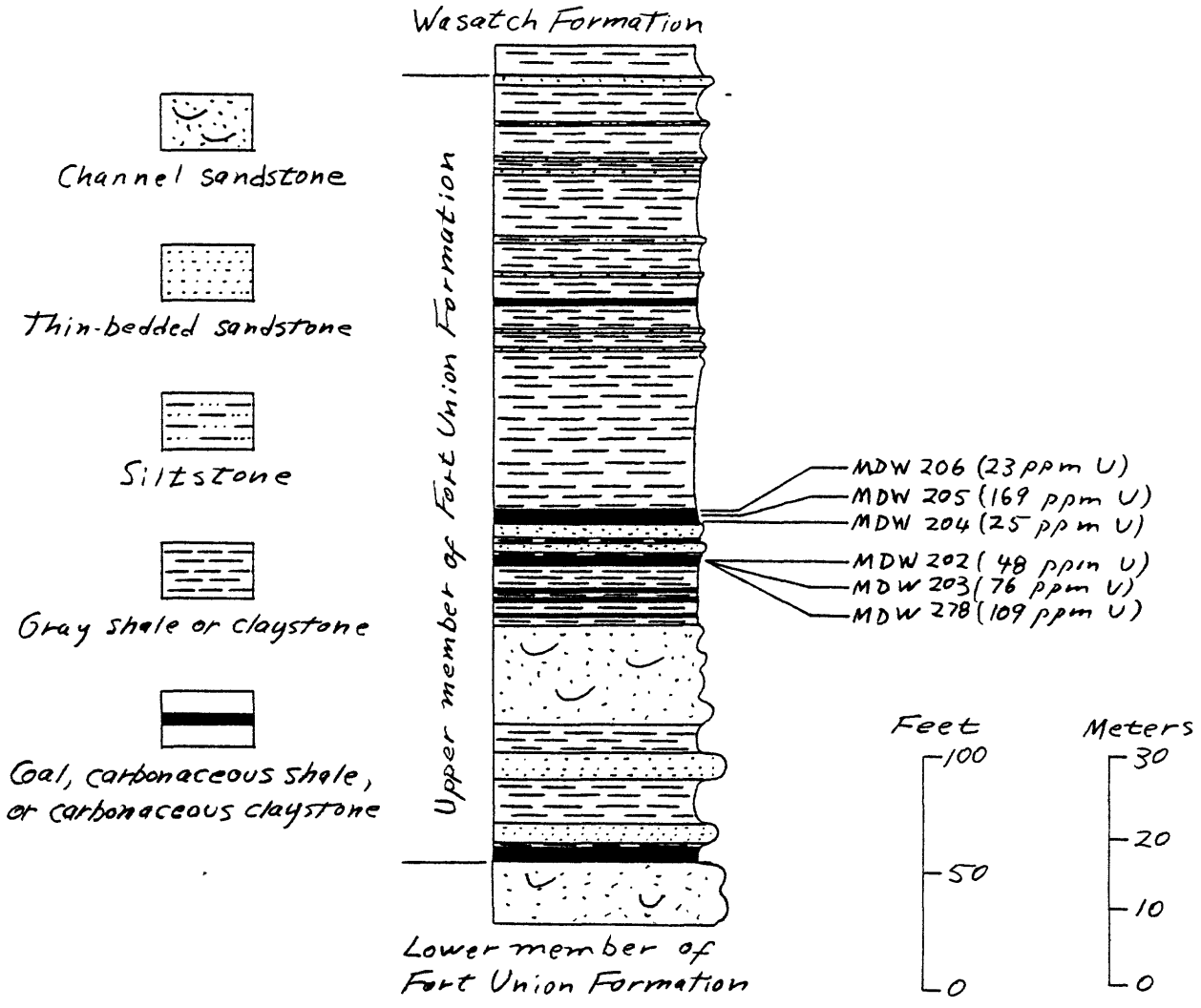


FIGURE 5. -- Measured section at occurrence 2

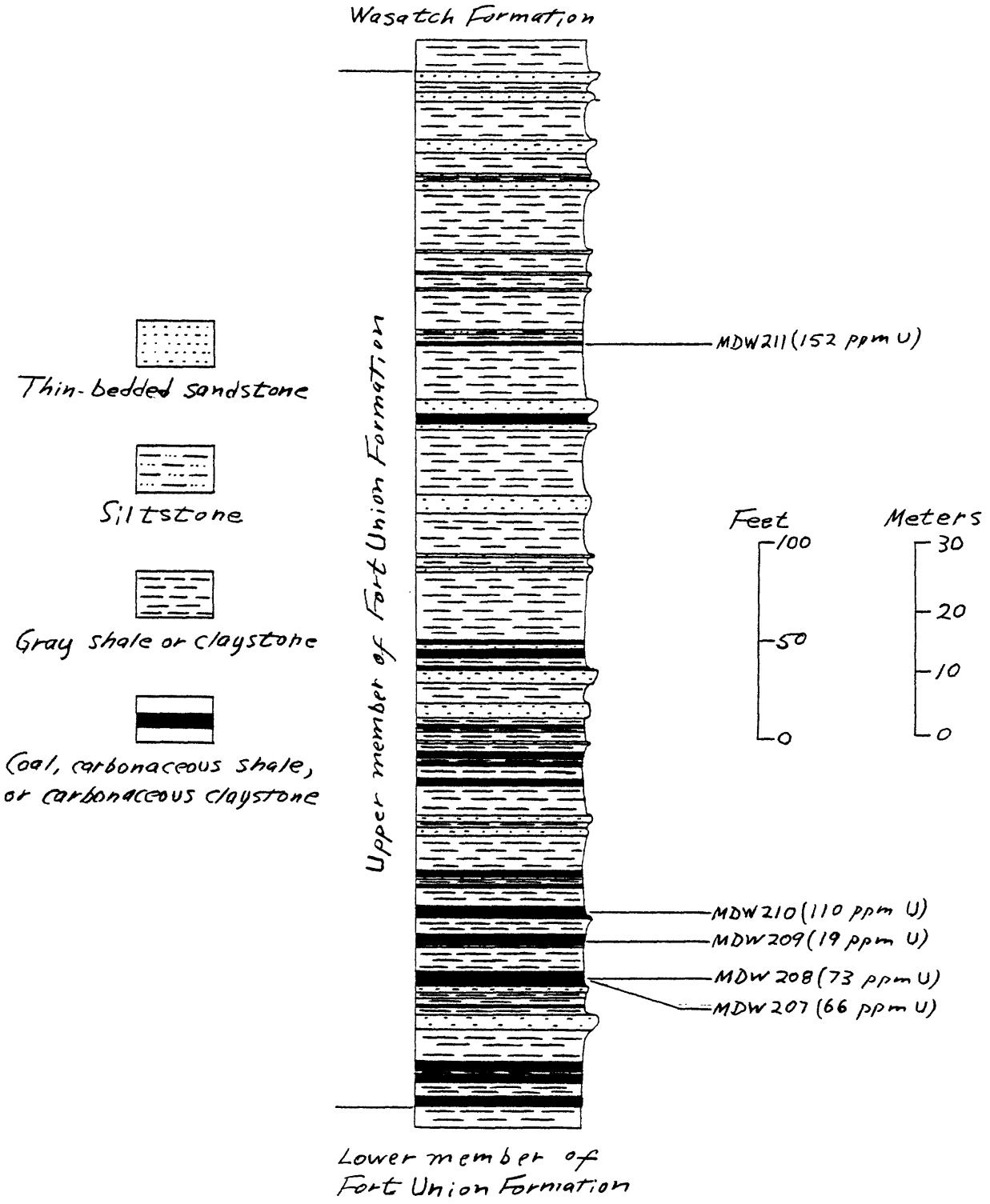
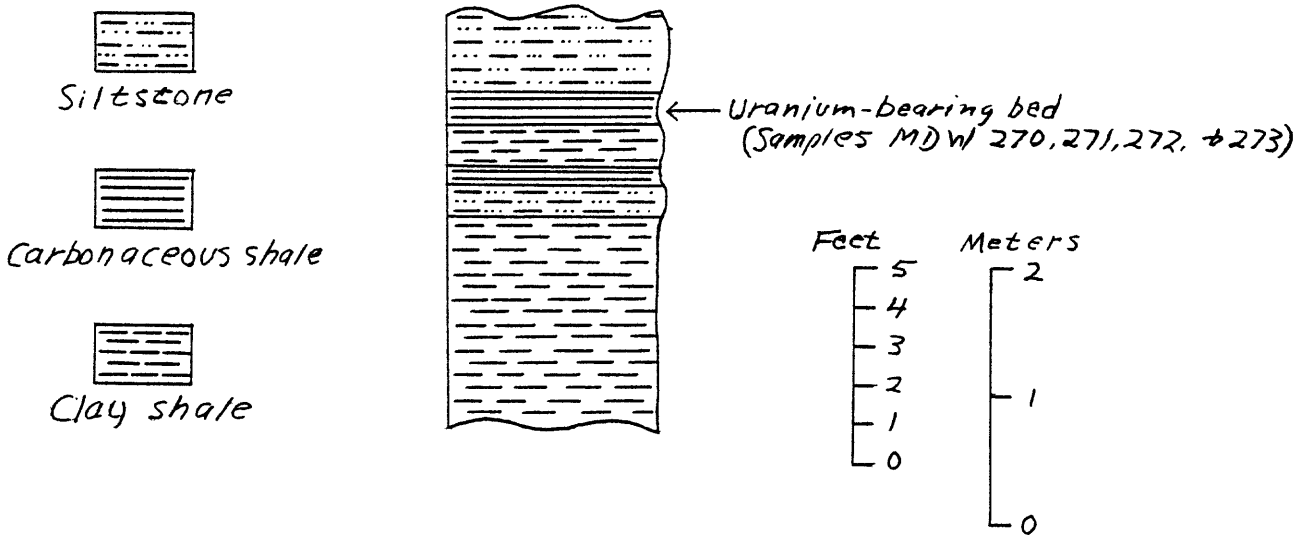
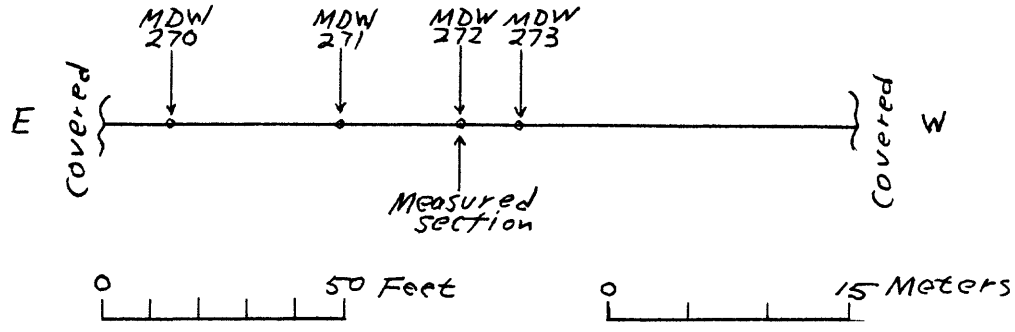


FIGURE 6. -- Measured section at occurrence 3



Note: samples MDW279 and MDW280 were collected 200 m (650 ft) and 330 m (1000 ft) respectively southeast of this locality



MDW 270 - 215 ppm U
MDW 271 - 248 ppm U
MDW 272 - 110 ppm U
MDW 273 - 78 ppm U
MDW 279 - 125 ppm U
MDW 280 - 168 ppm U

FIGURE 7. -- Measured section at occurrence 4

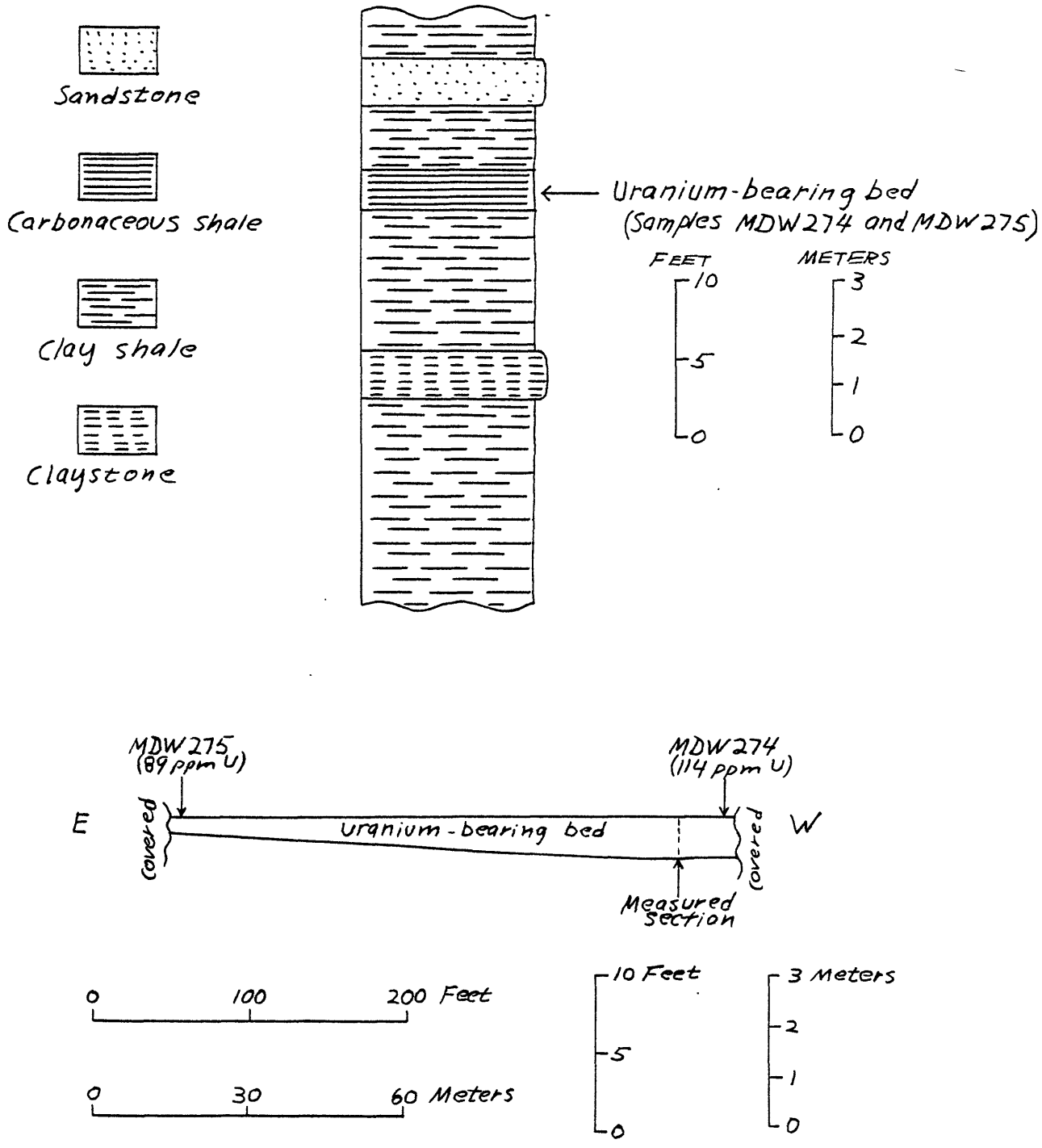


FIGURE 8. -- Measured section at occurrence 5

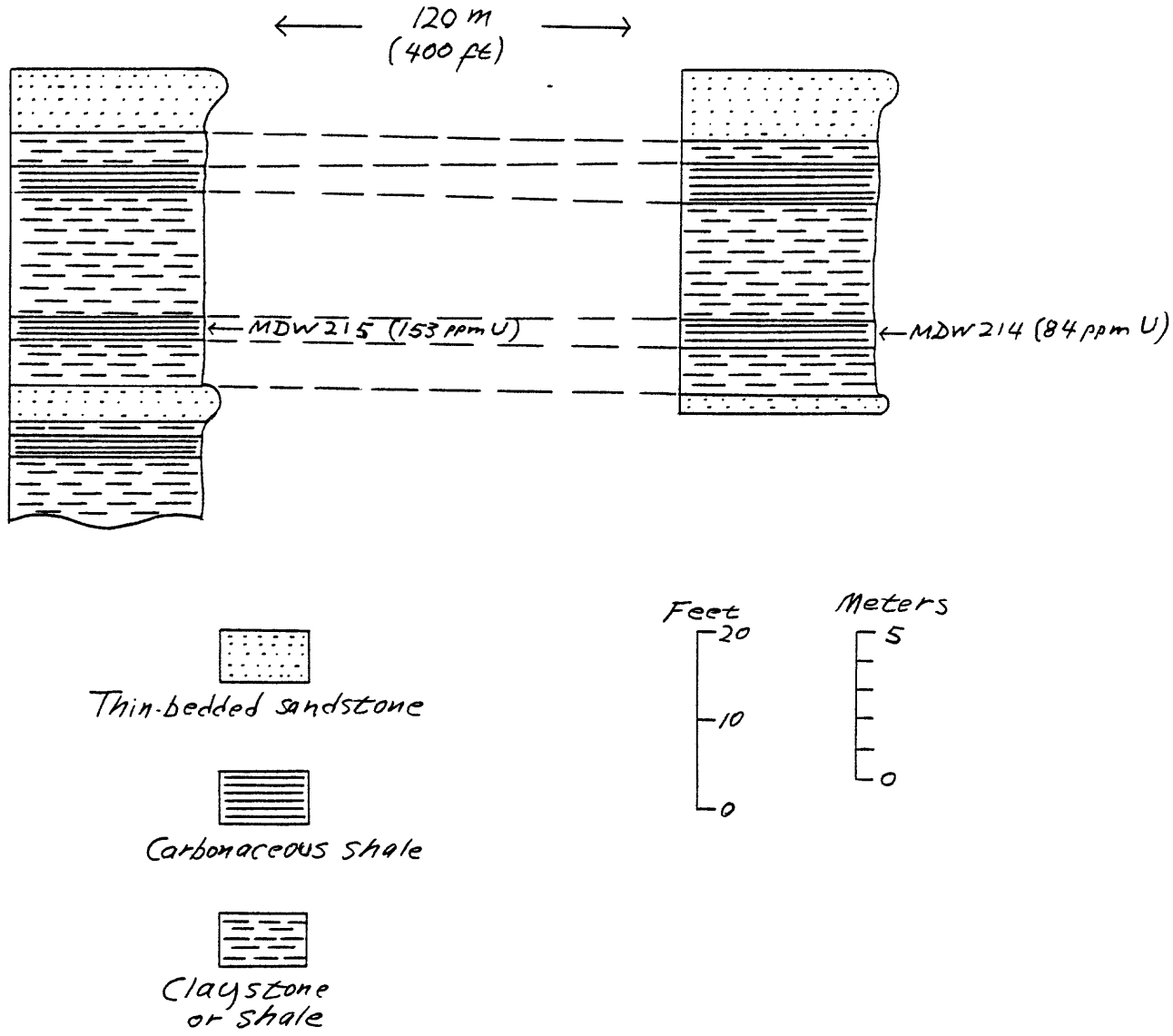


FIGURE 9. -- Measured section at occurrence 6

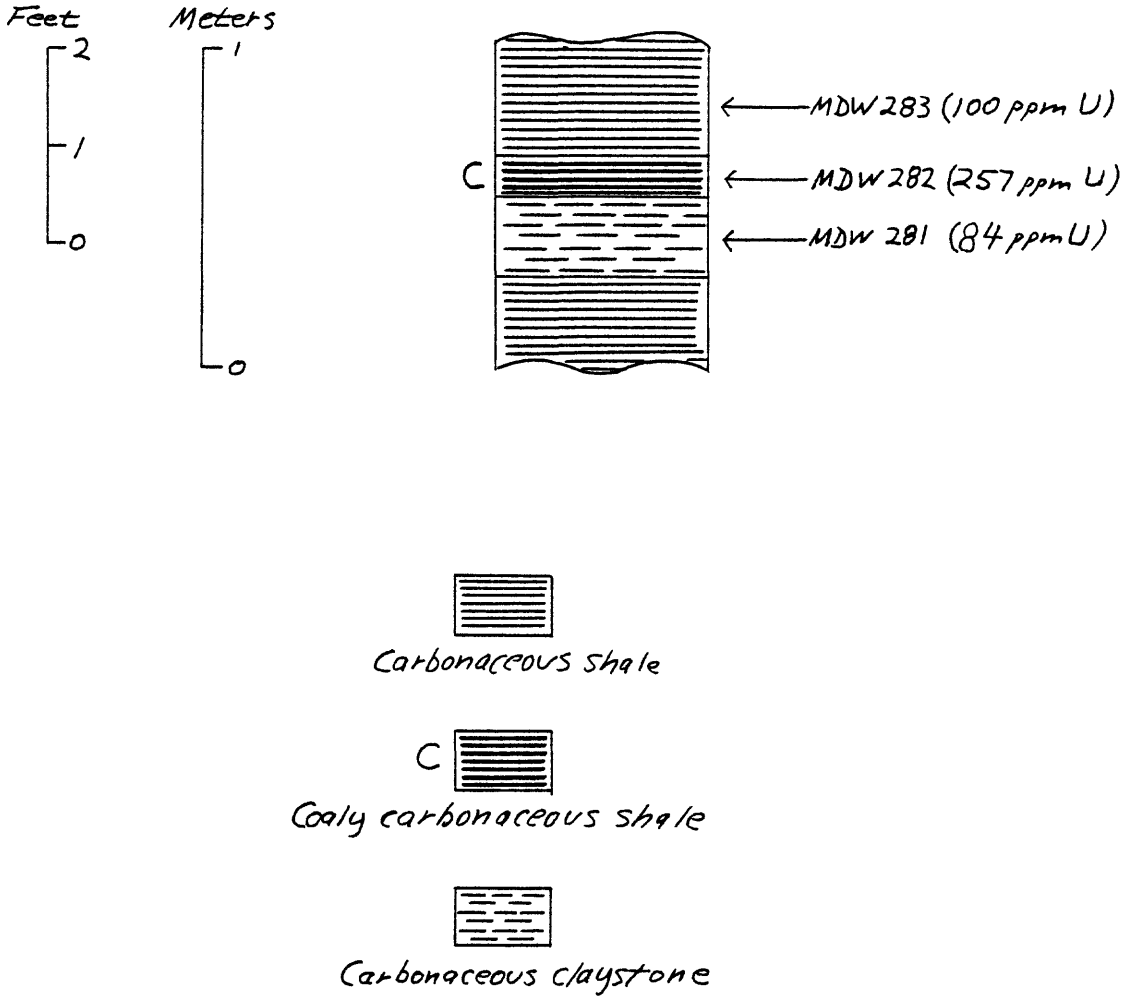


FIGURE 10. -- Measured section at occurrence 7

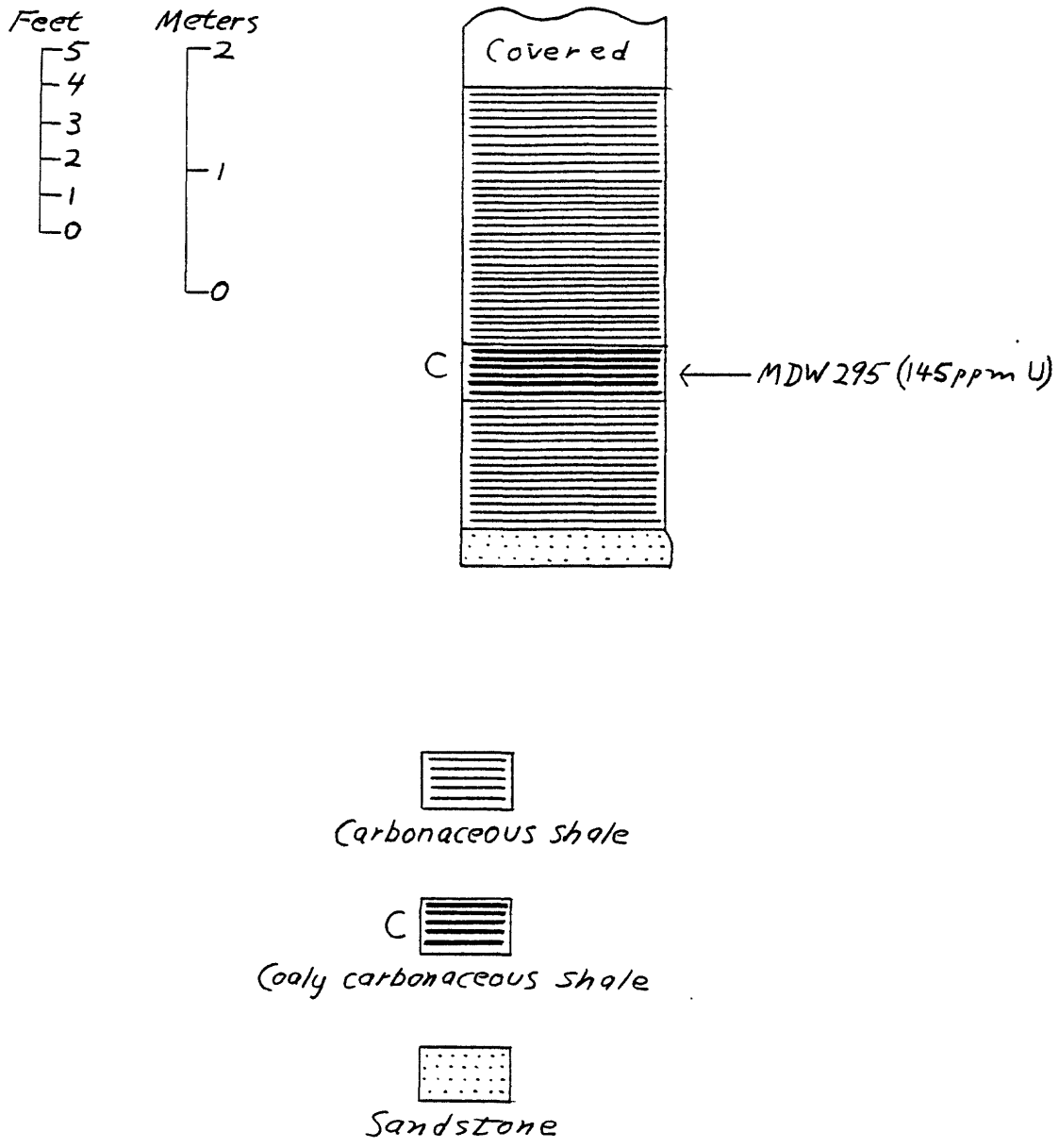


FIGURE 11. -- Measured section at occurrence 8

Occurrence 2 (pl. 1 and fig. 5) is located in the SE1/4 sec. 4, T. 2 N., R. 98 W., at latitude 40°10'4" N., longitude 108°23'26" W., Rough Gulch 7 1/2-minute topographic quadrangle. The rocks strike N. 87° W., and dip 29° S. The upper member at this locality is 103 m (338 ft) thick. Six samples were collected from two beds. Samples MDW 202, MDW 203, and MDW 278, containing 48 ppm, 76 ppm, and 109 ppm uranium respectively, came from a coal or coaly carbonaceous shale bed lying 39 m (129 ft) above the base of the upper member. The coal bed ranges from 0.15 m (0.5 ft) to 0.3 m (1 ft) in thickness, and it lies within a carbonaceous shale unit 1.2 m (4 ft) thick. The bed is exposed continuously for a distance of at least 80 m (250 ft) and is anomalously radioactive throughout this distance. Samples MDW 204, MDW 205, and MDW 206, containing 25 ppm, 169 ppm, and 23 ppm uranium respectively, came from a bed of coaly carbonaceous shale lying 45 m (148 ft) above the base of the upper member. The bed is 1.8 m (6 ft) thick and consists of coaly carbonaceous shale with some shaly coal. Sample MDW 205 represents a lens of coaly carbonaceous shale 0.3 m (1 ft) thick, from the middle of the bed. The bed is well exposed eastward from the sample locality for a distance of 41 m (135 ft), and it is anomalously radioactive throughout this distance.

Occurrence 3 (pl. 1 and fig. 6) is located in the NW1/4 sec. 1, T. 2 N., R. 98 W., at latitude 40°10'21" N., longitude 108°20'41" W., Smizer Gulch 7 1/2-minute topographic quadrangle. The rocks strike N. 75° W., and dip 23° SW. The upper member of the Fort Union here is 161 m (528 ft) thick, and the entire member is fairly well exposed. Five samples were collected from four anomalously radioactive beds. Three of these beds are in the lower part of the upper member, and one is in the upper part (figs. 3 and 6). Samples MDW 207 and MDW 208, yielding 66 ppm and 73 ppm uranium respectively, came from a bed of black carbonaceous claystone 19.5 m (64 ft) above the base of the upper member. The claystone bed ranges from 0.15 m (0.5 ft) to 0.3 m (1 ft) in thickness and lies in a carbonaceous shale zone 2 m (6 ft) thick. The two samples were collected about 60 m (200 ft) apart. Sample MDW 209 yielded only 19 ppm uranium. It came from the upper part of a slightly radioactive bed of coaly carbonaceous claystone 1.8 m (6 ft) thick, lying 25 m (83 ft) above the base of the upper member. Sample MDW 210, yielding 110 ppm uranium, came from a bed of coaly carbonaceous shale 0.4 m (1.2 ft) thick, within a carbonaceous shale unit 1.8 m (6 ft) thick. This unit lies 30 m (99 ft) above the base of the upper member. The sampled unit is well exposed for at least 7.6 m (25 ft)

south of the sample locality and is anomalously radioactive throughout this distance. Sample MDW 211, yielding 152 ppm uranium, was taken from a carbonaceous shale bed in the upper part of the upper member of the Fort Union Formation 119 m (391 ft) above the base of the member. The uranium-bearing bed is mostly brown carbonaceous shale, becoming black carbonaceous clay near its base, and it ranges in thickness from 0.6 m (2 ft) to 0.75 m (2.5 ft). The bed is fairly well exposed for about 28 m (92 ft) and is anomalously radioactive throughout this distance.

Occurrence 4 (pl. 1 and fig. 7) is located in the NE1/4 sec. 5, T. 2 N., R. 97 W., at latitude 40°10'33" N., longitude 108°17'55" W., Smizer Gulch 7 1/2-minute topographic quadrangle. Rocks of the upper member of the Fort Union Formation are poorly exposed here. The upper member is estimated to be about 151 m (495 ft) thick, and the sample locality lies about 77 m (252 ft) above the base of the member (fig. 3). Rocks here strike N. 80° W., and dip 10° S. The uranium-bearing bed is coaly carbonaceous shale, which ranges from 0.25 m (0.8 ft) to 0.37 m (1.2 ft) in thickness. It is overlain by a bed of tuffaceous siltstone at least 0.6 m (2 ft) thick and is underlain by a unit consisting of varying proportions of gray clay shale and brown carbonaceous shale. The uranium-bearing bed is well exposed for a distance of 47 m (155 ft), and it is anomalously radioactive throughout this distance. Four samples were collected at this locality: MDW 270 (215 ppm uranium), MDW 271 (248 ppm uranium), MDW 272 (110 ppm uranium), and MDW 273 (78 ppm uranium). The same bed, although not continuously exposed, was examined and sampled at localities about 200 m (650 ft) and 300 m (1,000 ft) southeast of this exposure. Samples MDW 279 and MDW 280 yielded 125 ppm and 168 ppm uranium respectively.

Occurrence 5 (pl. 1 and fig. 8) is located in the NW1/4 sec. 3, T. 2 N., R. 97 W., latitude 40°10'40" N., longitude 108°16'18" W., Smizer Gulch 7 1/2-minute topographic quadrangle. Rocks of the upper member of the Fort Union are poorly exposed here. The member is estimated to be about 130 m (425 ft) thick, and the sample locality lies about 34 m (110 ft) above the base of the member (fig. 3). The beds here strike N. 80° E., and dip 12° S. The uranium-bearing bed is coaly carbonaceous shale, which ranges from 0.3 m (1 ft) to 0.9 m (2.5 ft) in thickness. It is underlain and overlain by beds of gray clay shale. It is intermittently exposed for a distance of 110 m (360 ft) and is anomalously radioactive throughout this distance. Two samples were collected from the west end and east end of the exposed bed, about 105 m (350 ft)

apart. These were samples MDW 274 and MDW 275, which yielded 114 ppm uranium and 89 ppm uranium respectively.

Between occurrences 4 and 5, in sec. 4, T. 2 N., R. 97 W., two localities were examined that yielded samples containing anomalous amounts of uranium. The first of these localities is about 1,160 m (3,800 ft) east of occurrence 4 and is believed to be in the same carbonaceous shale bed as the uranium-bearing bed at occurrence 4. Sample MDW 293 from the middle of a bed of radioactive carbonaceous shale 0.6 m (2.6 ft) thick contained 106 ppm uranium. The second locality is about 760 m (2,500 ft) west-southwest of occurrence 5. The radioactive bed apparently lies stratigraphically lower than the uranium-bearing bed at occurrence 4, and stratigraphically higher than the uranium-bearing bed at occurrence 5. Here, two samples were taken from a bed of radioactive coaly carbonaceous shale 0.8 m (2.6 ft) thick. Sample MDW 290, representing the upper part of the bed, contained 90.3 ppm uranium. Sample MDW 291, representing the lower part of the bed, contained 111 ppm uranium.

Occurrence 6 (pl. 1 and fig. 9) is located in the NW1/4 sec. 22, T. 3 N., R. 97 W., at latitude 40°12'51" N., longitude 108°16'5" W., Smizer Gulch 7 1/2-minute quadrangle . Much of the upper member of the Fort Union Formation is poorly exposed in this area. The rocks strike N. 62° W., and dip 8° NE. The upper member here is estimated to be about 137 m (450 ft) thick, and the uranium-bearing bed lies about 15 m (50 ft) above the base of the upper member (fig. 3). The rocks at the sampled locality are well exposed along a low ridge, and the uranium-bearing bed was traced for about 300 m (1,000 ft) along the outcrop. It is anomalously radioactive throughout this distance. Two samples, MDW 214 (84 ppm uranium) and MDW 215 (153 ppm uranium) were collected from sections 120 m (400 ft) apart. The uranium-bearing bed is carbonaceous shale, which ranges from 0.37 m (1.2 ft) to 0.76 m (2.5 ft) in thickness and is overlain and underlain by noncarbonaceous shale or claystone. Other carbonaceous shale beds in the measured section (fig. 9) are nonradioactive.

Occurrence 7 (pl. 13 and fig. 10) is located in the SE1/4 sec. 9, T. 3 N., R. 97 W., at latitude 40°14'26" N., longitude 108°17'27" W., Smizer Gulch 7 1/2-minute topographic quadrangle. The rocks strike N. 44° W., and dip 5° NE. The upper member of the Fort Union is estimated to be 123 m (404 ft) thick here, and the uranium-bearing bed lies about 66 m (217 ft) above the base of the member (fig. 3). Exposures are generally poor, and the uranium-bearing bed is mostly covered. It lies in a carbonaceous shale or claystone unit, which may be as much as 6 m (20 ft) thick. Anomalous radioactivity is confined to a thickness of only about 1 m (3.5 ft). Three samples were collected at this locality: MDW 281 (84 ppm uranium), MDW 282 (257 ppm uranium), and MDW 283 (100 ppm uranium). Sample MDW 282 represents a bed of coaly carbonaceous shale 0.12 m (0.4 ft) thick. The enclosing carbonaceous unit is apparently present just below the crest of a persistent sandstone hogback for a distance of at least 2.4 km (1.5 mi). It was not further examined in this area. The same bed was examined about 1.6 km (1 mi) northwest of occurrence 7, in sec. 5, T. 3 N., R. 97 W., and no anomalous radioactivity was detected.

Occurrence 8 (pl. 2 and fig. 11) is located in the NW1/4 sec. 5, T. 3 N., R. 97 W., at latitude 40°15'39" N., longitude 108°18'23" W., Elk Springs 15-minute topographic quadrangle. The rocks here strike N. 20° W., and dip 6° NNE. in an area of generally poor exposures. The upper member of the Fort Union is estimated to be about 125 m (410 ft) thick here, and the uranium-bearing bed lies about 41 m (135 ft) above the base of the member (fig. 3). At this locality, as much as 3.6 m (12 ft) of dark-brown carbonaceous shale is exposed. This unit is underlain by a thin bed of fine-grained brown sandstone, and overlain by a covered interval 3 m (10 ft) thick, which appears to be carbonaceous shale grading upward to gray clay shale. All of the exposed carbonaceous shale unit is slightly anomalously radioactive, with scintillometer readings of 1 1/2 to 2 1/2 times the background count. This unit is exposed for a distance of about 64 m (210 ft) and is anomalously radioactive throughout this distance. The most radioactive bed is a bed of coaly carbonaceous shale 0.5 m (1.5 ft) thick, lying between 1 m (3.5 ft) and 1.5 m (5 ft) above the base of the carbonaceous shale unit. Scintillometer readings on this bed were about 3 1/2 times the background count. Sample MDW 295 (145 ppm uranium) was taken from the middle of this bed.

Occurrence 9 (pl. 2) is located in the NW1/4 sec. 32, T. 4 N., R. 97 W., at latitude 40°16'33" N., longitude 108°18'20" W., Elk Springs 15-minute topographic quadrangle. The rocks here strike N. 34° E., and dip 8° SE., in an area of generally poor exposures. The upper member of the Fort Union is estimated to be about 125 m (410 ft) thick here, and the uranium-bearing bed lies about 58 m (190 ft) above the base of the member (fig. 3). Here in very poorly exposed ground, is a carbonaceous shale unit possibly as much as 2.5 m (8 ft) thick that contains a thin radioactive carbonaceous shale bed. Scintillometer readings for this bed were about 3 1/2 times the background count, and sample MDW 294 from this bed contained 116 ppm uranium. No section was measured, and the lateral extent of the radioactive bed is unknown.

Source of the Uranium

Low-grade uranium deposits in coal and carbonaceous shale beds are present at scattered localities in the Western United States. Denson (1959, p. 1-10) briefly summarizes the uranium mineralization at seven such localities in North Dakota, South Dakota, Montana, Wyoming, and Idaho. The source of uranium at all these localities is ascribed to a blanket of tuffaceous sandstone overlying or adjacent to the mineralized carbonaceous beds. Uranium was leached from the tuffaceous rocks and moved in solution through permeable beds to depositional sites in the carbonaceous beds.

The origin of the uranium in the Fort Union of the Crooked Wash area is not known but is presumed to be epigenetic. Syngenetic mineralization is believed to be unlikely because of the irregular distribution of the occurrences within the upper member of the Fort Union. This is in sharp contrast to the remarkably uniform distribution of syngenetic uranium concentration in marine black shales (Jones, 1978, p. 24). Possible sources of the uranium include the Browns Park Formation of Miocene age, and the Wasatch Formation mostly of Eocene age.

The Browns Park Formation is a highly tuffaceous unit. East of Maybell, Colorado, the Browns Park contains commercial uranium deposits whose source was probably the tuffaceous beds within the Browns Park itself. The Browns Park crops out extensively to the north of the Fort Union outcrop where it unconformably overlies older rocks. It is quite likely that the Browns Park once extended much farther south than the present exposures on Wapiti Peak, and unconformably overlay truncated beds of the Fort Union and other rocks. However, it appears unlikely that the Browns Park could ever have been present

as far south as occurrences 1 through 5. Furthermore, a previously existing blanket of Browns Park south of its present outcrop area would be as likely to have caused mineralization of coaly and carbonaceous shale beds of the Mesaverde Group just west of the Fort Union outcrop. Such mineralization of the Mesaverde remains a possibility, but thus far no uranium occurrences have been reported from the Mesaverde in this area.

The Wasatch Formation conformably overlies the Fort Union Formation in this area and may possibly have been a source for the uranium in the upper member of the Fort Union. Although detailed petrologic studies of the Wasatch are lacking, the Wasatch contains abundant arkosic material at least in the southern part of the Piceance Creek Basin, and eastern part of the Sand Wash Basin (Tweto, 1975, p. 16-17); arkosic or feldspathic material is present in sandstones of the formation in the central to western Sand Wash Basin, and northern Piceance Creek Basin. The upper member of the Fort Union is directly overlain by the Wasatch which contains fairly abundant fluvial channel-sandstone beds in its lower part. The Wasatch overlies the Fort Union or its equivalents everywhere in the Piceance Creek Basin. West of the Piceance Creek Basin, the Wasatch overlaps the Fort Union and lies directly on the Mesaverde Group of Cretaceous age. In that area, uranium occurrences are locally present in the Mesaverde. The presence of the Wasatch or other Eocene rocks overlying mineralized rock in both areas suggests a possible association.

Presumably the dominantly clay shale lithology of the upper member of the Fort Union would have poor permeability for the movement of mineralizing solutions. However, the few thin but persistent siltstone and sandstone beds, and bedding planes in the shale could provide adequate permeability, and as noted by Denson and Gill (1965, p. 29, fig. 17), lignites in the Williston Basin are themselves moderately permeable, and presumably capable of transmitting mineralizing solutions.

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