GEOLOGICAL SURVEY CIRCULAR 176

PRELIMINARY REPORT ON URANIUM DEPOSITS IN THE PUMPKIN BUTTES AREA POWDER RIVER BASIN WYOMING

By J. D. Love

UNITED STATES DEPARTMENT OF THE INTERIOR
Oscar L. Chapman, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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ABSTRACT

On October 15, 1951, the writer discovered in the Wasatch formation (lower Eocene) of the Pumpkin Buttes area, in the Powder River Basin, a roll in sandstone which was outlined by yellow and black highly radioactive minerals. An average of six grab samples taken from various parts of the roll was found to contain 15.14 percent uranium. During November, 1951, 10 similar rolls, each exhibiting the yellow and black radioactive minerals, were found within a radius of 10 miles of the discovery roll. Ore samples from some of these rolls contain the following percentages of uranium: 3.92, 0.54, 7.27, 1.38, 4.57, 5.42, and 1.77. Vanadium oxide content of these samples ranges from 0.35 to 2.44 percent.

In addition to the rolls showing the yellow and black minerals, seven other rolls or masses of dark-gray sandstone containing 0.1 percent equivalent uranium and 0.05 percent or less uranium, and one siltstone containing 0.1 percent uranium, were found.

The writer proposes a theory of origin based on that advanced by Denson, Bachman, and Zeller for the South Dakota uranium-bearing lignites; namely that the source of uranium was tuff in the White River formation (Oligocene) that once overlay this portion of the Powder River Basin. The available evidence suggests that the uranium was carried downward along aquifers in the Wasatch formation and concentrated in favorable host rocks.

If this theory is correct, it is possible that other parts of the more than 12,000 square miles of the Powder River Basin surrounding Pumpkin Buttes, which have not yet been examined, might yield just as rich uranium deposits as those described in this report.

The commercial grade of some of the ore, the easy accessibility throughout the area, the soft character of the host rocks and associated strata, and the fact that strip-mining methods can be applied to all the deposits known at the present time, make the area attractive for exploitation.

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INTRODUCTION

Events leading to the discovery

Uranium ore was discovered by the writer on October 15, 1951, in the Wasatch formation of early Eocene age on the south side of North Pumpkin Butte, in the west-central part of the Powder River Basin, Wyo. The deposit is in one of eight areas comprising about 1,250 square miles recommended in April 1950, for investigation in the search for uranium-bearing lignites and tuffs. In response to this recommendation, an airborne radiometric reconnaissance of most of these areas was undertaken by the U. S. Geological Survey in October 1950. The uranium deposit is in the vicinity of one of the radioactivity anomalies located by this survey. A snowstorm forced termination of work in the area on the day of the discovery and another month passed before it was possible to resume field investigations.

Ten similar deposits, some of which are also in the vicinity of airborne radioactivity anomalies, were found during a five-day investigation in mid-November, 1951. Bad weather hampered, and finally forced, termination of the investigation.

ACKNOWLEDGMENTS

With the writer at the time of the original discovery of uranium ore in the Pumpkin Buttes area were R. K. Hose and F. B. Van Houten. Hose and M. L. Troyer provided able assistance in the subsequent field investigations and were responsible for discovery of many of the ore bodies. Van Houten provided a petrographic analysis of volcanic pebbles from the White River formation and made comparisons with volcanic rocks in central and northwestern Wyoming. M. J. Hough identified the vertebrate fossils from the area. The collaboration and assistance of N. M. Denson was most helpful both in the field and in all subsequent stages of the investigation. Lewis F. Rader, Jr., chief chemist Denver Laboratory, Trace Elements Section, Geochemistry and Petrology Branch, and his staff furnished analytical data promptly and efficiently at a time when speed was essential. Ralph L. Miller and W. G. Pierce, through their continual support of this project from its initial stages, have helped make the study far more productive than would otherwise have been possible.

This work is part of a program of exploration for radioactive raw materials undertaken by the U. S. Geological Survey on behalf of the U. S. Atomic Energy Commission.

Geographic Setting

The Powder River Basin is in part a topographic, as well as a structural, basin covering a large part of northeastern Wyoming and extending into southeastern Montana (fig. 1). The basin is flanked by the Bighorn Mountains on the west side, the Laramie Mountains on the south side, and the Black Hills on the northeast side. The northwestern half of the basin is drained by the Powder River and its tributaries, and the southeastern half by the Cheyenne and Belle Fourche Rivers and their tributaries. The entire basin has low to moderate relief; elevations range from somewhat less than 4,000 feet along the Montana-Wyoming State line to a maximum of about 6,000 feet on the Pumpkin Buttes. The greater part of the basin is sparsely populated. No towns are present between Gillette and Douglas, a north-south distance of 114 miles. No towns are present between Midwest and Newcastle, an east-west distance of about 100 miles across the basin. One U. S. highway, 14 and 16 combined, crosses the northern part of the basin, and two state highways, 387 and 59, join in the middle of the basin (fig. 2) and extend north to the U. S. highway at Gillette. These are the only oiled roads in the area but the entire basin is covered with a network of both unimproved and graded roads.

The chief industries are stock raising and dry farming on the upland areas and irrigated farming along the major stream valleys. Extensive coal-mining operations have been conducted in the northern and northwestern parts of the basin.

GEOLOGIC SETTING OF POWDER RIVER BASIN

The Powder River structural basin is bounded on the west by the Bighorn Mountains, on the south by the Laramie Mountains, on the southeast by the Hartville uplift, and on the east by the Black Hills and associated folds. A geologic map (Love and Weitz, 1951) and a structure contour map (Pierce and Girard, 1945) which cover the entire basin area show the regional geology and structure. The highest point on the pre-Cambrian rocks on the west side of the basin is about 13,165 feet above sea level at Cloud Peak in the Bighorn Mountains, 90 miles northwest of Pumpkin Buttes; in the deepest part of the structural basin, pre-Cambrian rocks lie at an estimated depth of 11,000 feet below sea level, 15 miles west of Pumpkin Buttes.

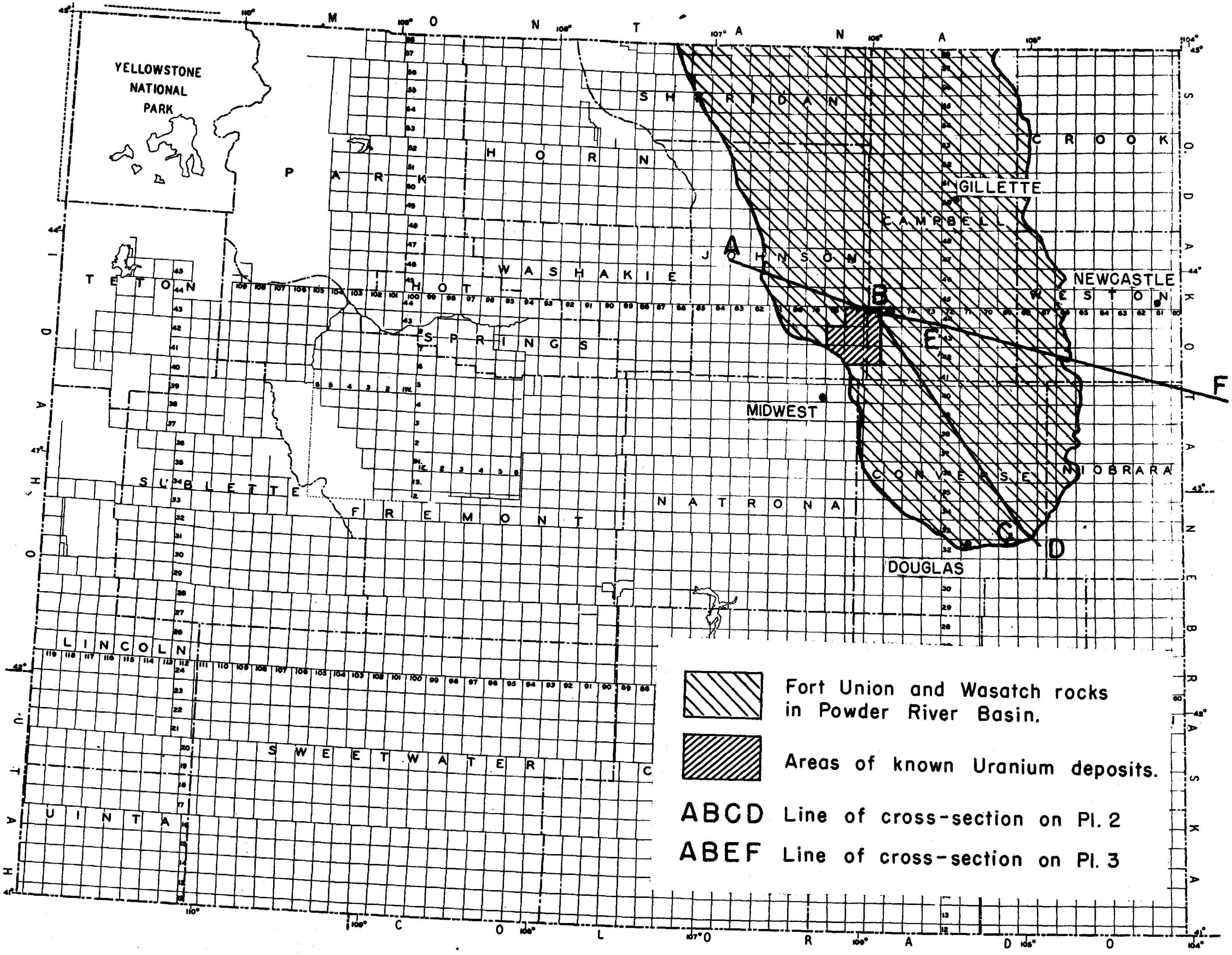

Figure 1.--Index map of Wyoming, showing location of Powder River Basin, areas of known uranium deposits, and positions of lines of cross-sections.

Exposed at the surface overlying the deeper part of the structural basin are rocks of Paleocene and early Eocene age. These rocks cover an area of 12,000 square miles within the Wyoming part of the Powder River Basin (fig. 1), and records from wells drilled for oil indicate that they have a combined thickness of at least 6,000 feet in places a few miles west of Pumpkin Buttes. The Cretaceous rocks there are 7,000 feet thick, the Jurassic rocks 500 feet thick, the Triassic rocks 600 feet thick, and the Paleozoic rocks 2,000 feet thick. Therefore, it is estimated that in the vicinity of Pumpkin Buttes the pre-Cambrian rocks lie at a depth of about 16,000 feet.

STRATIGRAPHY OF THE PUMPKIN BUTTES AREA

Wegemann (1917) and Wesemann, Howell, and Dobbin (1928) mapped and described the geology of the Pumpkin Buttes area. Wesemann classified all the rocks in this vicinity as Wasatch, including the cap-rock sandstone on all the buttes.

Fort Union formation

The Fort Union formation of Paleocene age is not exposed in the Pumpkin Buttes area, but forms extensive outcrops along the Great Pine Ridge escarpment, 15 miles to the southwest (fig. 2). The formation, as described by Wegemann (1917), consists of about 2,000 feet of fine-grained sandstone, bluish-white shale, and coal beds. The presence of coarse-grained, cross-bedded ferruginous sandstone in the upper part of the formation is responsible for the topographic feature known as the Great Pine Ridge. Above this sandstone is coal bed H which Wesemann (in Wesemann, Howell, and Dobbin, 1928, p. 5) regards as the top bed of the Fort Union formation.

Wasatch formation

The Wasatch formation (early Eocene age) in the Pumpkin Buttes area has been described in some detail by Wegemann (1917), but he also included in this formation younger rocks now known to be of Oligocene age that cap the buttes. The Wasatch formation covers many thousands of square miles in the Powder River Basin. Along the western margin of the basin are places where the Wasatch formation unconformably overlies the Fort Union formation, but in most areas the contact is arbitrarily placed at the top of the Roland coal bed or equivalent, for want of evidence of a structural or stratigraphic break.

The lithology of the upper part of the Wasatch formation is shown graphically in figure 15, and detailed descriptions are given in appendices A and B to this report. Figures 5, 8, and 9 show typical exposures of the Wasatch formation. It is characterized by variegated claystones, both lenticular and continuous sandstones, and thin coal and carbonaceous shale beds (fig. 23). Many thin units have remarkable persistence, and a detailed stratigraphic study probably would show that many such units can be correlated over a wide area. The thickness of the formation in this area is not known, but it is probably in excess of 2,000 feet.

Of particular interest in the present study are the soft porous, pink or tan concretionary sandstone rolls in which uranium was discovered. These sandstones occur at several horizons and appear to be persistent over a considerable area. The characters that make these sandstones favorable host rocks for uranium are not known.

In the vicinity of the Pumpkin Buttes there are no thick coal beds, but it is believed that the Felix coal mapping by Wegemann, Howell, and Dobbin (1928) in areas to the north and east is probably represented in the measured sections on the buttes (fig. 15). Detailed stratigraphic work will be necessary in order to confirm this. The matter is of some significance, for all the coal and carbonaceous strata examined in the Pumpkin Buttes area contain some uranium, and in several places sandstones overlying the coals contain uranium. A sandstone overlies the Felix coal, but it has not been examined for uranium. Clinker from either the Felix coal bed or another coal at a slightly higher stratigraphic position, about 15 miles east of South Pumpkin Butte, shows 21 counts per second above background on the Halross Gamma Scintillometer.

Wegemann (1917) reports vertebrate fossils of early Eocene age from the upper beds in the Wasatch formation on Dome Butte (fig. 5) just north of North Pumpkin Butte. He also reports vertebrate fossils of similar age from a lower horizon between North and North-middle Pumpkin Buttes. The writer found numerous pelecypods, gastropods, and fossil leaves in the sandstones and shales in this part of the section. All evidence indicates that the Wasatch formation here is of early Eocene age.

White River formation

The White River formation has not previously been recognized in this area, but has been included in the Wasatch formation (Wegemann, 1917 and Wegemann, Howell, and Dobbin, 1928). This formation caps all the Pumpkin Buttes (pl. 1). The areal extent of the formation in the vicinity of the Buttes was once much greater, for several high hills to the north and northeast of the buttes are capped by slumped masses of quartzitic ferruginous sandstone with the White River type of lithology, apparently let down several hundred feet by erosion of the less-resistant underlying Wasatch formation. Black Butte, 13 miles northeast of North Pumpkin Butte is capped by blocks of such sandstone. Five miles south of North Pumpkin Butte, a block of similar sandstone, exposed parts of which measure 20 feet by 18 feet by 8 feet, is 500 feet below its normal position on the tops of the buttes (fig. 7). The relationship of this block to the surrounding drainage pattern makes it unlikely that it was transported to its present position by streams or landslides from the buttes. This block contains radioactive interstitial chalcedony identical to that in the caprock sandstone part of the White River formation (fig. 25).

The lithologic character and thickness of the White River formation are shown graphically in fig. 15,

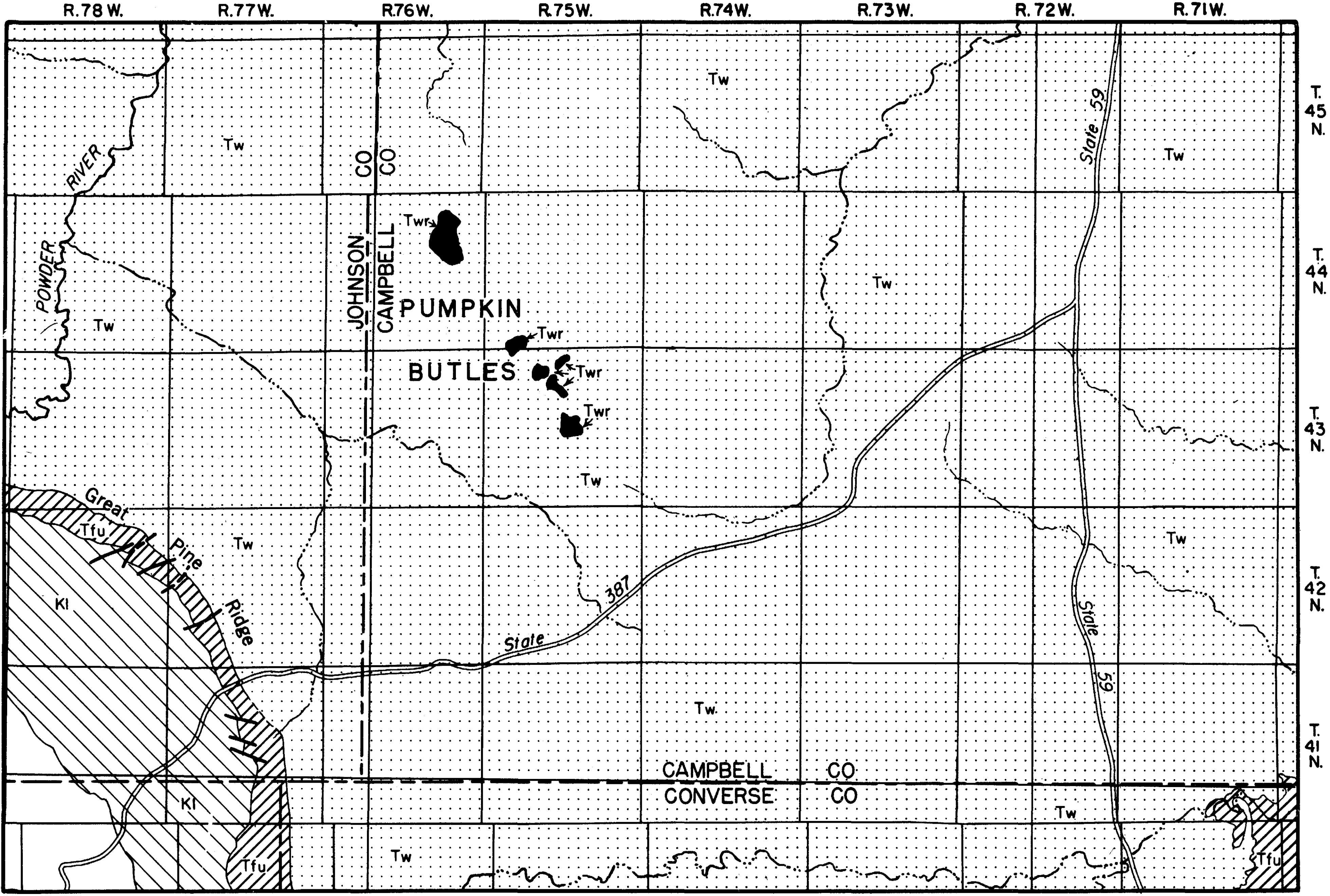

Figure 2.--Geologic map of south-central part of Powder River Basin.

and detailed descriptions are given in the two stratigraphic sections appended to this report. Characteristic exposures are illustrated in figures 3, 10, 11, 12, and 13. Three facies are present. The basal facies consists of soft coarse-grained sandstone, about 200 feet thick in the northern part of the area and less than 100 feet thick in the southern part. Some sandstones near the top of the underlying Wasatch formation superficially resemble this facies. Where it is locally indurated (fig. 12), however, this lower facies of the White River formation cannot be distinguished lithologically from the overlying caprock. The sandstone also has a different suite of minerals from that in the sandstones of the Wasatch.

The caprock facies, which overlies the soft sandstone facies is, because of its resistant nature, responsible for the preservation of the buttes. It is quite uniform in lithology throughout the area, and has a thickness of 30 to 50 feet. Silicification appears to be secondary. Grain size is characteristically very coarse, but only in the Middle Pumpkin Buttes are there conglomerates throughout the caprock facies. Conglomerates are present, however, at the top of the caprock on North Pumpkin Butte, but none extends far down into the caprock there. Most of the conglomerate pebbles in this facies are of Paleozoic and pre-Cambrian rocks derived from the Bighorn Mountains to the west, but about 15 percent are of Tertiary volcanic rocks rich in green-brown hornblende, hypersthene, and augite. Petrographically, they are similar to the basal conglomerate in the White River formation on the Beaver Divide in central Wyoming (Van Houten, 1950) and to pyroclastic rocks in the basal part of the Wiggins formation in the Absaroka Mountain area 150 miles to the west. They are not at all like the Tertiary volcanic rocks in the Black Hills 85 miles to the northeast or the Rattlesnake Hills volcanic rocks of middle Eocene age 95 miles to the southwest. Some of the Paleozoic and pre-Cambrian rock fragments are subrounded and as much as 1 foot in diameter, although the average is commonly 1 to 2 inches. In contrast, the pebbles of volcanic rocks, which presumably have come a much greater distance, are more highly rounded and rarely exceed 3 inches in diameter.

A white and pink tuff and bentonitic claystone facies overlies the caprock, but it is so soft that it has been eroded from most of the area underlain by the caprock. This tuffaceous claystone facies resembles typical fine-grained tuffaceous pink and white claystones in the White River formation that have been identified in areas to the northwest, east, and south.

The White River formation overlies the Wasatch formation with an erosional unconformity marked by some channeling. At the position of this unconformity 90 miles to the west, lie from 500 to 1,000 feet of middle and late Eocene strata (Tourtelot, 1946) on the high divide between the Bighorn and Wind River Basins.

The White River formation on the Pumpkin Buttes is correlated with previously-recognized deposits of the White River formation on the basis of both lithology and vertebrate fossils. The distal end of a metapodial bone of a medium-sized titanothere of Chadrou age and an astragalus of Leptomeryx, both indicative of White River age, were found embedded in tuffaceous claystone directly overlying the caprock sandstone on the North-middle Pumpkin Butte. More bone fragments in this locality were too fragile to be removed from the rock in the time available. At a slightly higher horizon are abundant water-worn fragments ments of tooth enamel resembling that from titanotheres in the lower part of the White River formation in adjacent areas. Jaw and tooth fragments of other mammals were collected but were so water-worn that they could not be identified.

Oligocene rocks of similar lithology have been recognized on the crest of the Bighorn Mountains (Osterwald, 1949, p. 37), where the age is based on the identification of a medial phalanx of Mesohippus, a horse characteristic of the White River formation. The writer has observed bentonitic tuffs, sandstones, and conglomerates similar to rocks of known Oligocene age in adjacent areas, underlying sandstones indistinguishable from positively identified Miocene rocks, on the crest of the Bighorn Mountains 55 miles to the northwest, at an elevation of roughly 9,000 feet (photographed by Darton, 1906, pl. 22). Flat Top Mountain, also known as Shawnee Butte, (pl. 2, locality C), 65 miles to the southeast of Pumpkin Buttes, is capped by titanothere-bearing strata of White River age similar in lithology to the finer-grained facies developed on Pumpkin Buttes. These correlations are strengthened by the fact that the Halross Gamma Scintillometer shows moderately uniform radioactivity in these strata in each area. The same type of brilliant yellow fluorescence was noted in both the Shawnee Butte caprock and the Pumpkin Buttes caprock (fig. 25). In the Black Hills, the White River formation, with similar lithology, caps many of the higher hills, and in some places is overlain by slightly radioactive, sandstone of Miocene age.

The writer concludes that all evidence available supports the the theory that the White River formation originally covered much, if not all, of the Powder River Basin, and that the formation subsequently has been removed by erosion from most parts of the basin except in the vicinity of the Pumpkin Buttes. Because of the widespread occurrence of small amounts of uranium in the White River formation wherever it has been identified in this part of Wyoming, it is reasonable to presume that a similar uranium content likewise was present in the White River formation throughout its original extent in the Powder River Basin.

URANIUM DEPOSITS

General characteristics of deposits

Uranium ores containing more than 1 percent uranium are found in several types of sandstone and at several stratigraphic horizons in the Wasatch formation in the Pumpkin Buttes area. None of these ore bodies has been extensively sampled or prospected because the deposits were discovered just as winter snows set in and covered the outcrops. Table 2 lists all uranium and vanadium analyses made from samples taken in this area.

The richest uranium deposits are those that occur in soft porous concretionary tan or pink sandstones. The uranium-bearing minerals have not been specifically identified, although identification is being made. Although many minerals may be present, there are two general types. One is lemon-yellow and the other is black and very heavy. The two types occur

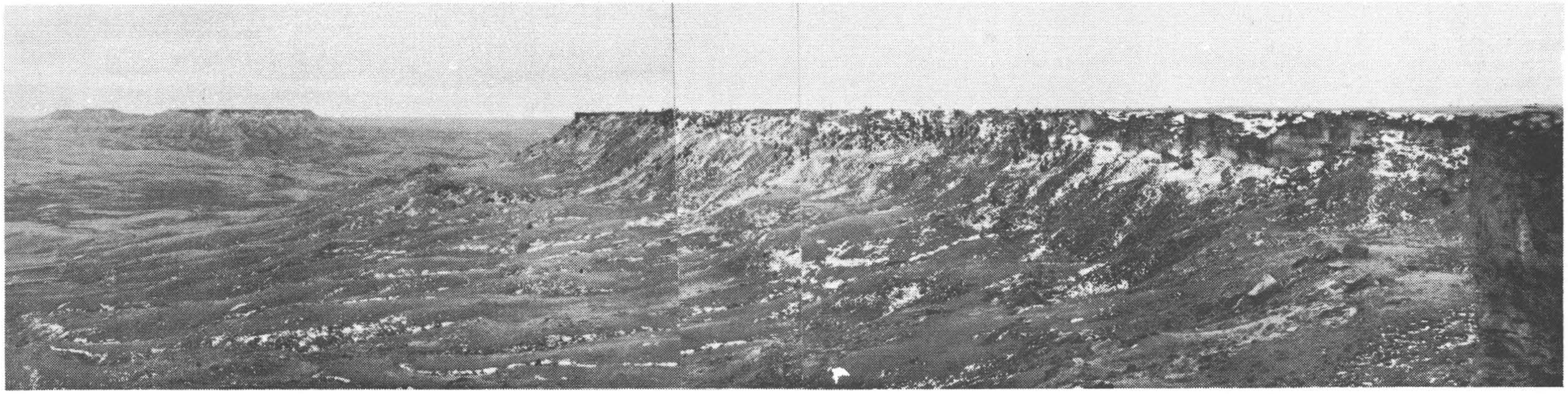

Figure 3.--View of Pumpkin Buttes, looking south from northeast corner of north butte. Farthest south butte is 10 miles from camera. Caprock on all accordant summits is sandstone of the White River formation of Oligocene age.

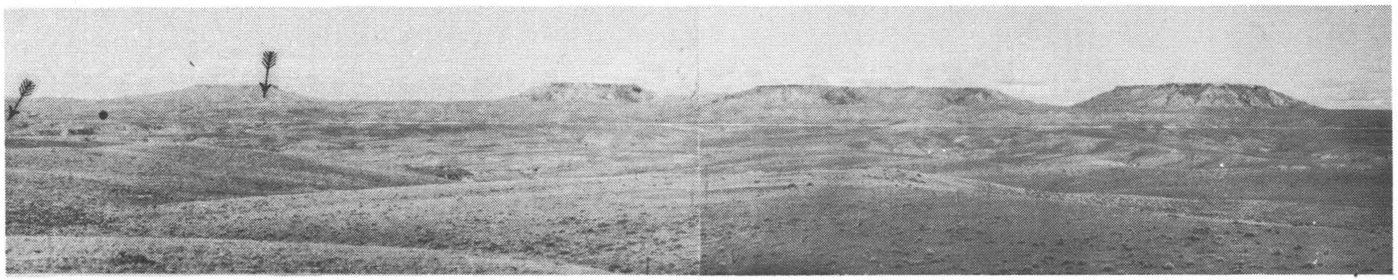

Figure 4.--View of all 4 Pumpkin Buttes, looking northeast. Sandstone of the White River formation of Oligocene age caps all buttes. Arrow at extreme left indicates uranium deposit L1-78, one sample of which contained 1.78 percent uranium. Arrow on North Pumpkin Butte indicates uranium deposit LW-19, one sample of which contained 15.14 percent uranium.

together, commonly in rolls (figs. 14, 16, 17, 18) similar to some described by Fischer (1942, p. 380) in the Colorado Plateau area. The rolls are roughly tabular and very irregular masses that in general are parallel to bedding. The size of the known deposits, as judged from surface exposures, varies considerably.

Eleven rolls were discovered 10 of which are shown in figure 19, and one on plate 1. The uranium content of these samples ranges from 0.34 percent to 15.14 percent, and the vanadium oxide content ranges from a maximum of 0.35 percent in the leanest deposit to a maximum of 2.44 percent in the richest deposit.

The richest sandstone roll (a representative ore sample contains 15.14 percent uranium found in the Pumpkin Buttes area occurs on the south face of North Pumpkin Butte at station LW-19 (pl. 1). The stratigraphic position of the roll is shown in figure 15, and the host rock is described in Appendix A, unit 2. This is the only roll found in tan or brown sandstone. It occurs about 10 feet above the base of a brown medium-grained sandstone about 25 feet thick and 500 feet below the top of the Wasatch formation. The sandstone has a considerable lateral extent but has not been examined in other areas for uranium deposits. The ore body is described in detail later in this report. Figure 14 shows the physical appearance of the outcrop of the roll.

The ore bodies shown in figure 19 are all from approximately one stratigraphic level in a pink sandstone, which has been identified for a distance of 10 miles in a north-south direction, and which forms one of the most conspicuous units in the area. A detailed section, summarized graphically on figure 19, was measured at locality L1-66 (fig. 23), as follows:

<u>Stratigraphic section at locality L1-66, figure 23</u>

Unit no.		Thickness (in feet)
8	Claystone, greenish-gray, soft, interbedded with gray siltstone and fine-grained gray sandstone	10+
7	Sandstone, brown, fine-grained, hard	2
6	Sandstone, deep pink, soft, non-calcareous, coarse-grained, with angular grains; ferruginous cement; local clay-pellet conglomerate lenses; in lower 1 to 3 feet are greenish-yellow elliptical uranium-bearing rolls with black rims; some yellow ferruginous nodules; many lemon-yellow splotches of uranium mineral and some irregular yellow masses without rims, commonly less than 1 foot in diameter; some thin lenses of gray blocky claystone in lower 5 feet of sandstone. In adjacent localities, within one half mile to the north and south (fig. 19), there are numerous rolls of yellow and black uranium ore about 15 feet above the base of the sandstone, but there is no conspicuous difference in lithology between this zone and the sandstone above and below. A channel sample of the basal 6 inches contains 0.008 percent uranium, 0.037 percent equivalent uranium, and 0.10 percent vanadium oxide (LW-64, table 2). . .	33-38
5	Coal, interbedded with carbonaceous shale, in approximately equal amounts. This unit contains 0.10 percent uranium, 0.079 percent equivalent uranium, and 0.06 percent vanadium oxide (LW-63, table 2).	0.4
4	Shale, brown, carbonaceous, laminated.	0.3
3	Coal, black, soft, slightly shaly.	0.25
2	Shale, brown, carbonaceous, laminated.	0.6
1	Claystone, green, blocky, silty, forming slope; upper 2 feet gray and carbonaceous. This unit is part of a widespread green claystone bed. Underlying rocks are not exposed here.	7.0

All of the coals and carbonaceous rocks examined in the Wasatch formation in the Pumpkin Buttes area are abnormally radioactive. Most of the coals are about 1 foot thick, but some of the combined coal and carbonaceous shale beds, such as units 3, 11, 17, 21, and 25 of the stratigraphic section measured on South-middle Pumpkin Butte, and unit 4 and parts of unit 3 of the stratigraphic section measured on North Pumpkin Butte, range from 2 to 4 feet in thickness. Chemical analyses are available for only two of the coal beds. Unit 6 of the North Pumpkin Butte section contains 0.004 percent uranium and 0.005 percent equivalent

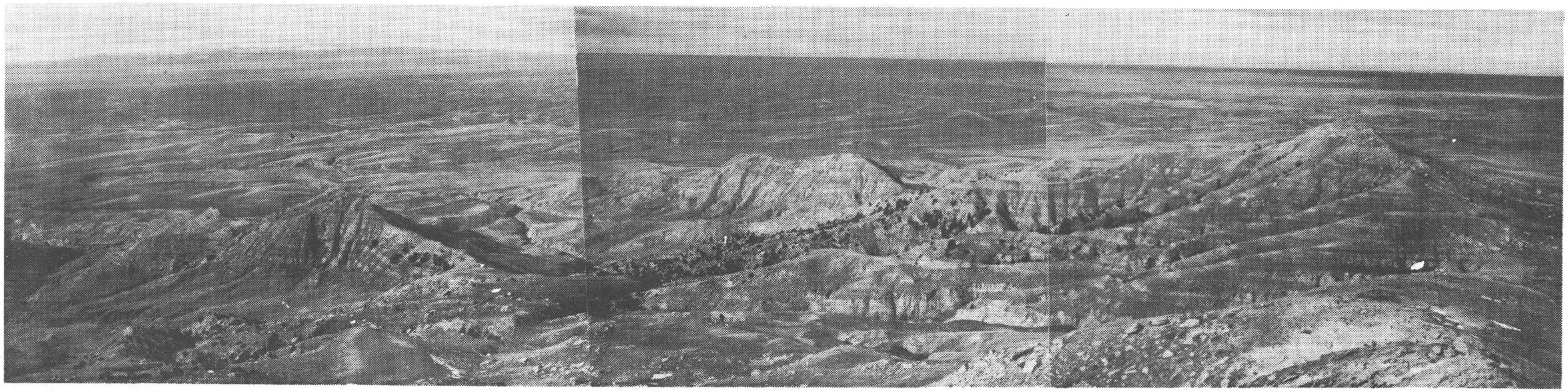

Figure 5.--View of badlands cut in the Wasatch formation extending north and west into Powder River Basin from North Pumpkin Butte. Camera pointing north at right margin of panorama and northwest at left margin, toward snow-capped Bighorn Mountains 90 miles away. None of the area has been examined for uranium deposits or flown with airborne Geiger counter.

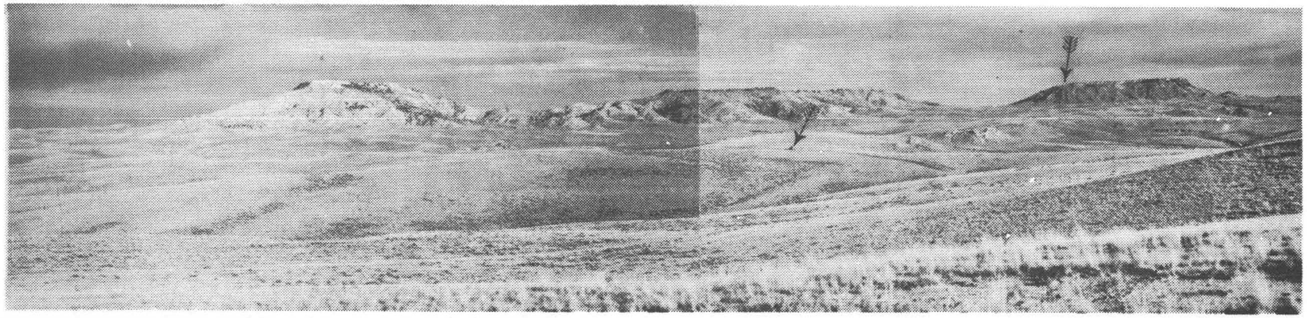

Figure 6.--View looking east toward Middle and South Pumpkin Buttes, 4 miles away. Arrow near center of picture indicates jeep for scale. Arrow at upper right shows point on caprock where sample containing 0.004 percent uranium, shown in figure 25, was taken.

uranium 1/. Analysis of a sample of the other coal bed, unit 5, 0.4 feet thick in the section measured at locality L1-66 shown 0.10 percent uranium, 0.079 percent equivalent uranium, and 0.06 percent vanadium oxide. This coal bed (fig. 23) can be identified for more than a mile in the vicinity of the area shown in figure 19, and probably will be found to extend over a much wider area. If it should thicken in any direction and still maintain its uranium content, it could be an important source of uranium. Other thin coal beds in the Pumpkin Buttes area show from 30 to 600 counts per second above background on the Halross Gamma Scintillometer.

In addition to the 11 rolls containing yellow and black uranium ore, 7 other rolls and masses of sandstone were found (figs. 20, 21 and 22) that contain much lower-grade uranium deposits. The low-grade rolls consist of dark-gray sandstone containing as much as 0.1 percent equivalent uranium but only as much as 0.053 percent uranium. Radium and its disintegration products may be responsible for the excess radioactivity. Figure 22 shows two of these low-grade rolls mapped in detail. The easternmost of these two is shown in figures 20 and 21. Both consist of medium-grained cross-bedded sandstone. Part of the sandstone is dark gray and highly radioactive and part is pale pink and much less radioactive. The rolls are commonly tabular and about 1 foot wide and 3 feet in vertical extent. They are roughly oval in cross-section, and bedding appears to extend outward into poorly-indurated gray sandstone which contains only 0.006 percent uranium. The longest roll found measures about 240 feet. The rolls occur at various levels in the Wasatch formation. The two shown in figure 22 trend north, but others apparently have random orientations. These leaner rolls are not considered to be of economic significance at the present time.

In the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 11, T. 42 N., R. 78 W., 16 miles southwest of the Pumpkin Buttes, there is a conspicuous clinker and baked red siltstone zone resulting from burning of coal bed H (Wegemann, Howell, and Dobbin 1928, p. 5), at the top of the Fort Union formation. At the top of the clinker is a 2'foot bed of red soft porous siltstone (fig. 24) grading laterally into tan hard siltstone. One sample of the red siltstone contains 0.062 percent uranium. An analysis of the tan siltstone shows 0.10 percent uranium. The light-colored layers in the red siltstone fluoresce a brilliant dusty yellow under ultraviolet light (fig. 26). A sample of the coal that extends laterally into clinker contains 0.003 percent uranium.

1/ Equivalent uranium is based on the assumptions that all of the radioactivity of a sample arises from uranium and its disintegration products and that none of the radioactivity arises from the thorium series or from potassium; and that the uranium is in radioactive equilibrium with all of its disintegration products wherein each radioactive product in the series is disintegrating at exactly the same rate at which it is being formed.

The caprock sandstone of the White River formation contains interstitial, radioactive, yellow-fluorescing chalcedony (fig. 25). A chemical analysis of a sample taken where the Halross Gamma Scintillometer indicated the greatest radioactivity showed 0.004 percent uranium and 0.004 percent equivalent uranium. (LW-27 in table 2).

Description of deposits

The deposits are described individually in order to provide specific data on locations of samples listed in Table 2, and to show local characteristics of each deposit. Each deposit is identified by a field number which is shown on plate I, figure 19 or figure 22.

Deposits LW-19 (L1-35)

The ore in the discovery roll LW-19 (L1-35) in the Pumpkin Buttes area (fig. 14) has the highest content of uranium (15.14 percent) thus so far reported from Wyoming. The roll occurs about 10 feet above the base of a brown medium-grained cross-bedded sandstone about 25 feet thick and 500 feet below the contact between the Wasatch and White River formations on the south face of North Pumpkin Butte. Both black and yellow uranium minerals are present. The black mineral fills the interstitial spaces between sand grains and outlines the rolls, and in many places shows a botryoidal structure. The yellow mineral is sprinkled throughout the black but has no large concentrations. On weathered surfaces the rock exfoliates in concentric shells independent of bedding. Although the ore body is roughly tabular, parallel to bedding, some thin stringers of black ore cut across bedding planes in the sandstone for several feet.

The writer was unable to see any conspicuous differences between the sandstone where the ore is concentrated and the sandstone where there is no ore. The pods of ore are extremely irregular and many of them have weathered out and slumped down the slope so it is difficult to give an accurate figure of dimensions of the deposit. Halross Gamma Scintillometer readings are more than 6,000 counts per second on the ore body and readings on a Victoreen beta-gamma survey meter exceed 20 on the 20 scale. Random half-pound samples from six parts of the ore body were lumped, and from this composite sample the chemical analysis of 15.14 percent uranium was obtained. There is no way of estimating how much, if any, of the deposit extends into the hill, but the entire spur could be stripped very easily with a power shovel and the extent of the deposit determined.

Deposit L1-66

Deposit L1-66 is shown on figures 19 and 23; a description of the stratigraphic section has been given previously. The stratigraphic level of this deposit and all others shown on figure 19 is approximately 700 feet below that at locality LW-19, and 1,200 feet below the contact between the Wasatch and White River formation. A sample of the uppermost 0.4-foot coal bed of this

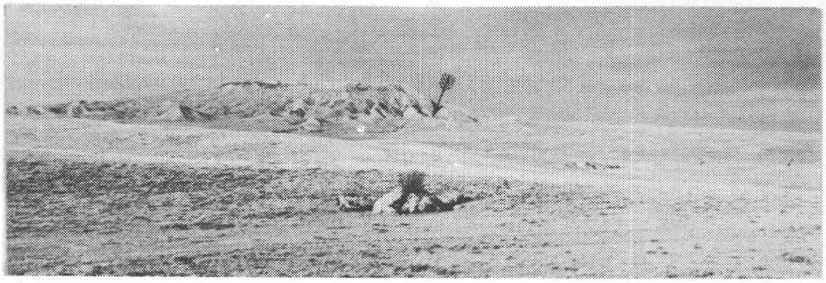

Figure 7.--View looking north toward North Pumpkin Butte 5 miles away. Arrow shows position of uranium deposit LW-19. Boulder in foreground is remnant of radioactive caprock sandstone of White River formation.

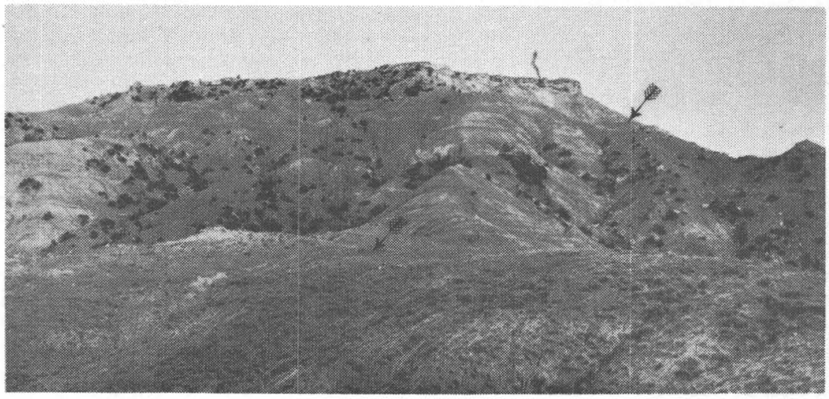

Figure 8.--View looking north at south face of North Pumpkin Butte. Arrow in center shows position of LW-19. Arrow at upper right marks contact between Wasatch formation below and White River formation.

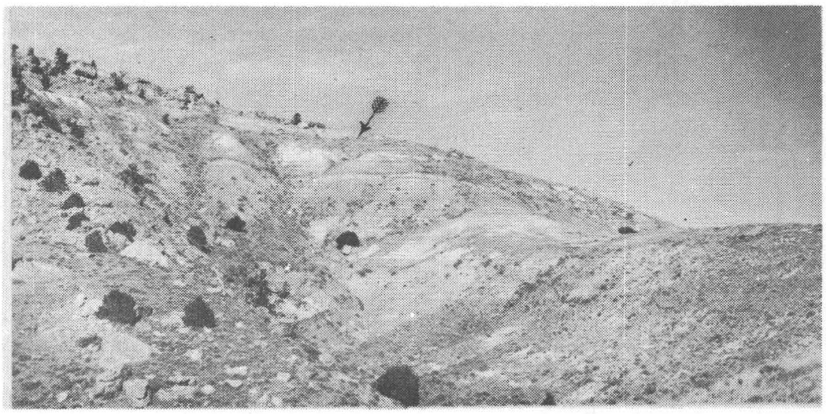

Figure 9.--View of Wasatch and White River formations on south face of South-middle Pumpkin Butte. Arrow marks base of White River formation.

deposit contains 0.10 percent uranium, 0.079 percent equivalent uranium, and 0.06 percent vanadium oxide (LW-63 in table 2). Other coal partings in this section have not been analyzed. A trench sample of the basal 6 inches of pink sandstone directly overlying the coal contains 0.008 percent uranium, 0.037 percent equivalent uranium, and 0.10 percent vanadium oxide (LW-64 in table 2). In the lower 3 feet of the pink sandstone, and extending along the outcrop for a distance of 100 feet or more are many cross-sections of bun-shaped and lens-shaped yellow rolls of uranium ore with black rims. They are commonly less than 1 foot long and 6 inches high. Many small splotches and irregular rimless masses of yellow uranium ore are likewise present in the pink sandstone. The sandstone containing the rolls appears identical to the barren sandstone. These small rolls have not been analyzed, but none of the yellow and black ore from adjacent rolls has contained less than 1 percent uranium. The distance this deposit extends into the hill is not known, but there is no excessive amount of overburden and exploratory stripping could be done cheaply with a power shovel.

Deposit Ll-67

Deposit Ll-67 is shown on figure 19, and is the largest and one of the richest found in the area. It occurs in the pink sandstone about 10 feet stratigraphically above the coal bed at Ll-66, shown graphically in the section on figure 19. The entire deposit is a mass of black ore lenses and nodules embedded in coarse-grained pink sandstone. Numerous yellow "eyes" with concentric layers of yellow and black uranium minerals are present. A sample (LW-44) representative of the ore and composed of quarter-pound specimens of black and yellow ore from various parts of the deposit and lumped together shows on chemical analysis 3.92 percent uranium, 4.2 percent equivalent uranium, and 1.97 percent vanadium oxide. A representative sample of the coarse-grained pink sandstone host rock obtained in the same manner contains 0.007 percent uranium, 0.009 percent equivalent uranium, and 0.10 percent vanadium oxide (LW-47) in table 2). A power shovel could strip off the overburden and thus determine the eastern extent of this deposit.

Deposit Ll-67 A and B

The most extensive bedded deposit containing uranium ore in the area is Ll-67 A and B. The ore occurs in the basal 3 feet of the pink sandstone overlying the coal shown in the graphic section (fig. 19). Throughout an outcrop distance of 213 feet, this basal zone consists of coarse-grained angular pink sandstone containing white limy clay-pellet conglomerate lenses. There are many cross-sections of yellow "eyes" and sparse black nodules of uranium ore scattered throughout this sandstone ledge. The ledge shows 4,000 counts per second on the Halross Gamma Scintillometer at the eastern end of the exposure, where a channel sample of the basal 1 foot of sandstone contains 0.54 percent uranium, 0.54 percent equivalent uranium, 0.35 percent vanadium oxide (LW-45 in table 2).

At the western end of the exposure, the ledge shows from 2,000 to 3,500 counts per second on the Halross Gamma Scintillometer and a channel sample of the lower 3 feet of the ledge contains 0.15 percent uranium, 0.20 percent equivalent uranium, and 0.14 percent vanadium oxide (LW-46 in table 2). The coal directly underlying this ledge shows 275 counts per second on the Gamma Scintillometer. Exploratory stripping to determine the extent of this deposit could be done easily with a power shovel.

Deposit Ll-68

The uranium content of a sample from deposit Ll-68 is the second highest (7.27 percent) in the area. The ore occurs in the basal part of the pink sandstone zone directly overlying the coal that is shown in the graphic section (fig. 19). Black botryoidal masses of ore, sprinkled with a yellow bloom, are abundant. A sample of this ore contains 7.27 percent uranium, 7.4 percent equivalent uranium, and 1.63 percent vanadium oxide (LW-50 in table 2). A representative sample of the pink sandstone host rock contains 0.001 percent uranium, 0.004 percent equivalent uranium, and 0.06 percent vanadium oxide (LW-49 in table 2). Directly underlying the ore body is the coal sequence. The top 6 inches of coal shows 300 counts per second on the Halross Gamma Scintillometer, and on analysis was found to contain 0.024 percent uranium, 0.027 percent equivalent uranium, and 0.06 percent vanadium oxide (LW-48 in table 2).

Exposures of this ore body are limited to the face of a moderately steep hillside, and the lateral extent is unknown. The locality is near the top of a spur, and exploratory stripping with a power shovel could easily determine how far the deposit extends into the hill.

Deposit Ll-70

Ore body Ll-70 is in the pink sandstone about 15 feet above the coal bed shown graphically in figure 19. The ore consists of abundant masses of both yellow and black mineralized sandstone embedded in coarse-grained angular pink sandstone host rock. A representative sample of the ore was obtained by lumping quarter-pound samples from various parts of the deposit. This sample contains 1.38 percent uranium, 1.2 percent equivalent uranium, and 0.96 percent vanadium oxide (LW-52 in table 2). A representative sample of the pink sandstone host rock, obtained in the same manner, contains 0.004 percent uranium, 0.006 percent equivalent uranium, and 0.07 percent vanadium oxide (LW-53 in table 2).

This deposit is shown at the far right in figure 16. As the photograph indicates, there is very little overburden and exploratory stripping could easily determine how far back in the hill the deposit extends and whether it merges with the one shown in the middle of figure 16.

Deposit Ll-71

Deposit Ll-71 is the thickest of all the deposits known in this area and the one with the most yellow uranium mineral. The ore body is shown in the middle of figure 16, and details of mineralization are illustrated in figures 17 and 18. Lenses and nodules of the black uranium mineral appear about

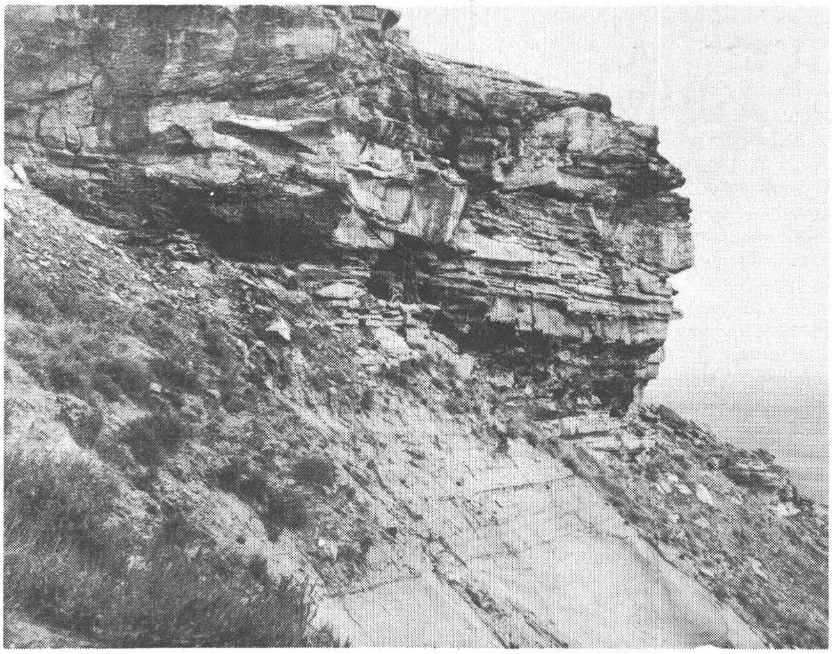

Figure 10.--White River formation on south face of North Pumpkin Butte. Caprock is silicified uranium-bearing sandstone underlain by soft tuffaceous sandstone. Arrow indicates man at base of cliff.

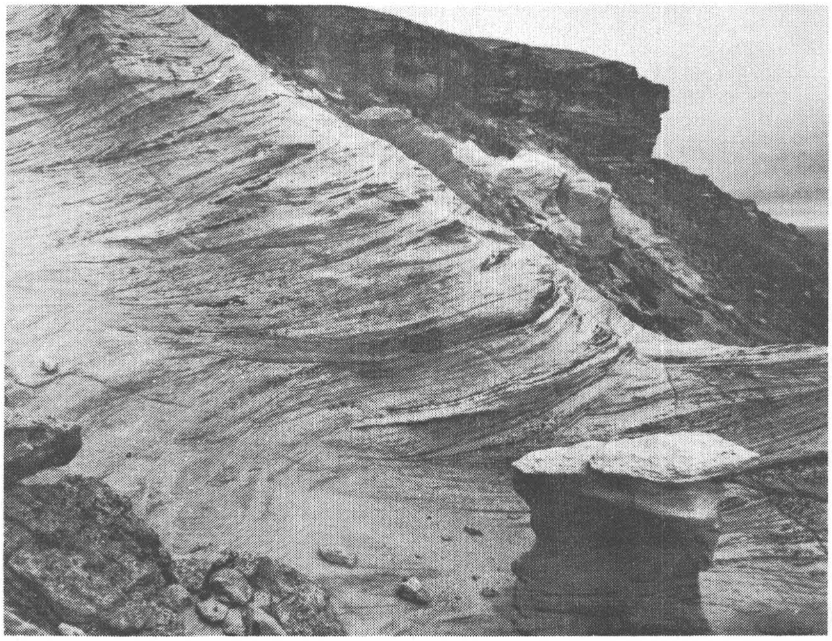

Figure 11.--Coarse-grained cross-bedded tuffaceous sandstone in White River formation, south face of North Pumpkin Butte. Caprock shown in figure 10 is in background.

5 feet above the coal bed shown in figure 19, and both black and yellow masses become more abundant upward, reaching a maximum concentration about 15 feet above the coal, at the horizons of figures 17 and 18. A channel sample representing 1 foot of the pink host sandstone taken 2 feet above the coal, in the same stratigraphic position as the upper part of the ore body at locality Ll-67 A and B, and 2 feet below the lowest black uranium-bearing nodules, contains 0.002 percent uranium, 0.003 percent, equivalent uranium, and 0.06 percent vanadium oxide (LW-59 in table 2). A similar 6-inch channel sample of the pink sandstone beginning 1 foot above the preceding sample, and 3 feet above the coal contains 0.010 percent uranium, 0.009 percent equivalent uranium, and 0.04 percent vanadium oxide (LW-60 in table 2). Because this sample is only 6 inches below the lowest black uranium-bearing nodules, it appears that at this locality the uranium content of the sandstone decreases downward from the black nodules toward the coal. A representative sample composed of many small black nodules such as are shown in figure 17 contains 0.19 percent uranium, 0.26 percent equivalent uranium, and 0.86 percent vanadium oxide (LW-61 in table 2). A representative sample consisting of many fragments of yellow ore from different parts of the deposit contains 4.57 percent uranium, 4.6 percent equivalent uranium, and 1.72 percent vanadium oxide (LW-62 in table 2). As shown in figure 16, exploratory stripping by a power shovel could easily indicate how far back into the hill this deposit extends. Because of its thickness, it is one of the more attractive ore bodies.

<u>Deposit Ll-72</u>

Ore body Ll-72 is shown at the left margin of figure 16, and once may have been continuous with the other two ore bodies, Ll-71 and Ll-70, likewise shown in this picture. This deposit occurs about 10 feet above the coal bed, in the pink coarse-grained cross-bedded sandstone. A representative sample of the black and yellow uranium ore combined from pieces taken from various parts of the ore body contains 5.42 percent uranium, 5.5 percent equivalent uranium, and 2.44 percent vanadium oxide (LW-54 in table 2). This sample contains the highest vanadium content of any sample, taken thus far in the Pumpkin Buttes area.

A 4-foot channel sample of the host sandstone contains 0.013 percent uranium, 0.018 percent equivalent uranium, and 0.04 percent vanadium oxide (LW-55 in table 2). Although the overburden is somewhat greater at this locality than that above the two ore bodies directly to the south, it is believed that exploratory stripping is feasible.

<u>Deposit Ll-73</u>

Deposit Ll-73, like the others shown in figure 19, is in the pink sandstone and 10 to 15 feet above the coal bed. There is not as much yellow and black ore in this deposit as in those directly to the south. A cut of representative ore samples from the body contains 1.77 percent uranium, 1.7 percent equivalent uranium, and 1.31 percent vanadium oxide (LW-56 in table 2). A 3-foot channel sample of the host sandstone across the ore body contains 0.004 percent uranium, 0.006 percent equivalent uranium, and 0.05 percent vanadium oxide (LW-57 in table 2). It would be difficult to strip back the overburden to determine the extent of this deposit.

The bottom of the valley occupied by the intermittent stream that flows southward between localities Ll-73 and Ll-72 (fig. 19) supports a moderately thick stand of one of the seleniferous species of the vetch <u>Astragalus</u>. An analysis of several of these plants, collected dry on November 16, 1951, when most of the sap was gone, shows 14 parts per million of uranium in ash [the analyst notes that "contamination from soil probably largely accounts for this uranium value"]. More investigation and more analyses are necessary in order to determine whether this is true. The sample of dried plant contains 500 parts per million of selenium.

On the east side of the valley opposite LW-73 and north of LW-72, the cliff facing west, contains many small elongate pods and lenses of yellow and black uranium ore about 15 feet above the coal bed, in the pink sandstone. These pods are commonly less than 3 inches thick and less than 2 feet long. The total tonnage of exposed ore is insignificant, but the presence of the uranium minerals suggests that more ore bodies similar to those just described may be present under the hill to the east of the outcrops.

<u>Deposits Ll-78 and Ll-78A</u>

The small ore bodies Ll-78 and Ll-78A lie approximately 3 miles southeast of the cluster of deposits shown in figure 19. The ore is in the form of several small rolls the largest of which is about 2 feet long and 0.8 feet thick, projecting from the face of a cliff of pink coarse-grained sandstone which may represent the same pink sandstone that is the host rock for the uranium deposits to the northwest. Not only is the sandstone similar in lithology, but the thickness is about the same and the pods of ore are in the basal part. Underlying the pink sandstone in the western part of the locality is a coaly shale similar to the coal bed shown in figure 19. A sample of the pink sandstone ledge contains 0.53 percent uranium 0.31 percent equivalent uranium, and 0.53 percent vanadium oxide (LW-69 in table 2). In the eastern part of the locality the pink sandstone rests on a greenish-gray silty claystone which overlies the coaly shale. The ore rolls are at approximately the same level in the pink sandstone and are about 100 feet apart. A representative sample of the ore contains 1.78 percent uranium, 0.98 percent equivalent uranium, and 0.67 percent vanadium oxide (LW-66 in table 2). The pink host sandstone contains 0.020 percent uranium, 0.021 percent equivalent uranium, and 0.04 percent vanadium oxide (LW-67 in table 2). The upper 3 inches of the greenish-gray siltstone between the coaly shale and the pink sandstone contains 0.007 percent uranium, 0.008 percent equivalent uranium, and 0.08 percent vanadium oxide (LW-68 in table 2). Exploratory stripping to determine the lateral extent of the ore rolls would be comparatively inexpensive.

<u>Deposit Ll-34</u>

Deposit Ll-34 is the only uraniferous deposit found to date in the Fort Union formation in this area.

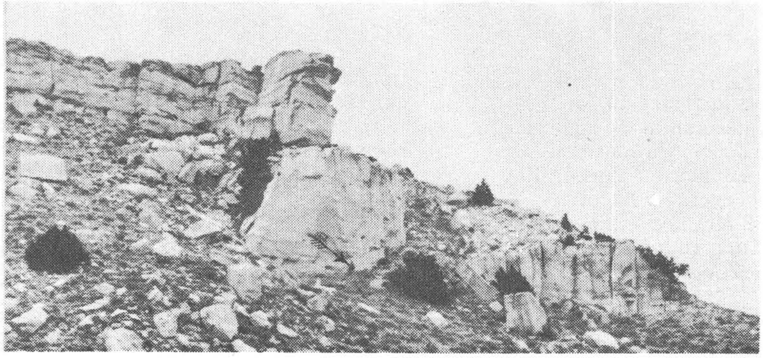

Figure 12.--West face of North-middle Pumpkin Butte. Upper cliff is caprock sandstone. Lower cliff is locally-hardened lower sandstone in White River formation.

Figure 13.--Soft tuffaceous sandstone facies in White River formation, south face of North Pumpkin Butte.

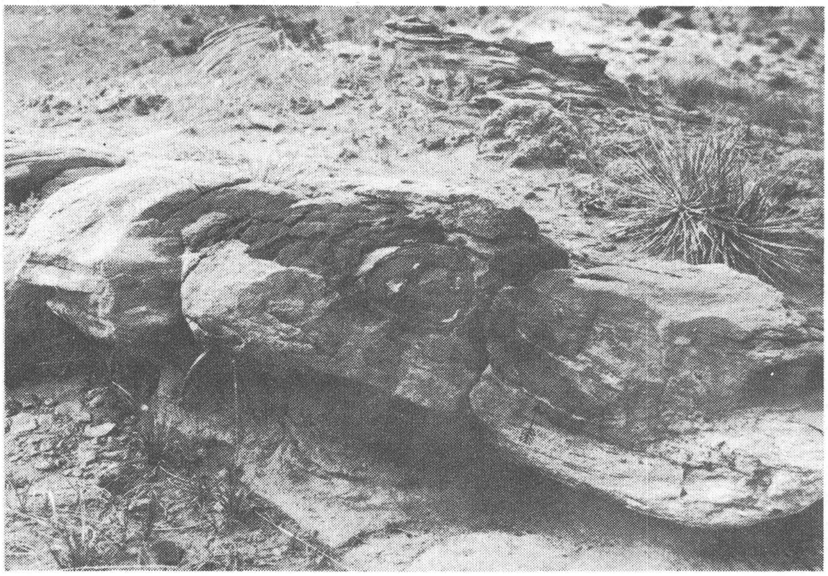

Figure 14.--Sandstone roll in Wasatch formation at LW-19. A single sample contains 15.14 percent uranium. Arrows indicate yellow uranium ore. Black rock is also uranium ore.

It lies about 16 miles southwest of the Pumpkin Buttes in the NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 11, T. 42 N., R. 78 W., in and adjacent to a clinker and baked siltstone zone at the top of the Fort Union formation. The clinker can be followed along strike into coal bed H (Wegemann, Howell, and Dobbin, 1928, p. 5). The deposit is on Great Pine Ridge about 150 feet west of the county road leading from the town of Sussex to the Sussex oil field, just north of the road cut through the Pine Ridge escarpment in the Fort Union formation, and about 200 yards north of a big open pit where clinker is stripped for road metal.

The upper part of the clinker zone consists of 6 feet of somewhat massive bright red baked siltstone (fig. 24). Geiger counter readings with beta-shield closed, spaced 0. 8 feet apart from bottom to top of the face shown in this photograph are as follows: (bottom) 3, 5, 4, 8, 8, 15, 60, 7, 6 (top). The zone where the 60 reading was obtained showed 2, 500 counts per second on the Halross Gamma Scintillometer and was the zone sampled for chemical analysis. Figure 26 shows a specimen from this zone, photographed under ultraviolet light, and illustrates the type of bedding present. This sample contains 0. 062 percent uranium and 0. 10 percent equivalent uranium (LW-17 in table 2).

Lack of time and a mantle of snow prevented tracing this deposit, but it appears to have a linear pattern, trending northeast for at least 35 feet from the face shown in figure 24. In that direction the color changes from red to tan but the scintillometer reading remains 2, 500 counts per second, and a sample of the tan siltstone 35 feet northeast of the face contains 0. 1 percent uranium, 0. 12 percent equivalent uranium, and 0. 08 percent vanadium oxide (LW-71 in table 2). The tan siltstone likewise shows abundant dusty eyellow fluorescence under ultraviolet light.

The clinker passes laterally into several coal beds separated by shales and siltstones. All of the coals show higher counts per second on the gamma scintillometer at the top than at the bottom, and the coal with the highest reading (40 counts per second) contains 0. 003 percent uranium and 0. 001 percent equivalent uranium (LW-16 in table 2).

No estimate of tonnage was made for the siltstone deposit which could be excavated inexpensively with a power shovel, for there is comparatively little overburden.

Deposit L1-79

Deposit L1-79 is about 600 feet downstream, (southwest) from locality L1-78. A 6-inch brown ferruginous sandstone at the base of the pink sandstone shows 250 counts per second on the gamma scintillometer. Where this sandstone ledge changes to green, the count goes up to 350. A sample of this greenish sandstone shows 0. 012 percent uranium, 0. 033 percent equivalent uranium, and 0. 53 percent vanadium oxide (LW-70 in table 2). No ore was observed, but as the zone is the same as that in which other ore bodies occur, the area is worth considerable prospecting.

Deposit L1-69

Deposit L1-69 is too low-grade to be classed as an ore body but it shows certain features of interest. About 5 feet below the coal horizon shown graphically in figure 19 is a bulbous mass of red siltstone, 5 feet in diameter, which grades laterally into green siltstone in a distance of 4 feet. The red cuts sharply across bedding planes and apparently is secondary. The red siltstone shows 250 counts per second on the Halross Gamma Scintillometer, but the green siltstone 5 feet away at the same stratigraphic horizon shows only 175 counts per second. It is apparent that the higher radioactivity is related in some way to the presence of the red substance. The top of the overlying coal bed shows 175 counts per second on the scintillometer and the pink coarse-grained sandstone just above the coal likewise shows 175 counts per second. A channel sample of the lower 3 feet of the sandstone, in the same stratigraphic position as the ore deposit at locality L1-67 A and B, contains 0. 025 percent uranium, 0. 036 percent equivalent uranium, and 0. 07 percent vanadium oxide (LW-51 in table 2).

Deposit L1-57

Deposit L1-57, shown on figure 22, is a roll in sandstone approximately 140 feet long, trending due north. The stratigraphic position of the roll in the Wasatch formation is about midway between the horizon of the richest uranium-bearing deposit at LW-19 and the pink sandstone where the cluster of uranium deposits shown in figure 19 occurs. The roll is roughly tabular, is in a vertical position in horizontal sandstone, is elliptical in cross-section, and consists of gray, hard, medium-grained, angular sandstone with abundant dark mineral grains embedded in a very soft tan sandstone of the same type and coarseness. The sandstone bed in which the roll occurs is about 5 feet thick and rests on a greenish-gray, fine-grained, blocky claystone. Some parts of the roll are apale pink, and these parts show a lower reading on the gamma scintillometer than do the gray parts. Analyses and scintillometer readings are shown on figure 22. The highest scintillometer reading is 2, 200 counts per second, the highest analysis of uranium is 0. 010 percent (LW-35 in table 2), the highest equivalent uranium analysis is 0. 092 percent (LW-33 in table 2), and the highest vanadium oxide analysis is 0. 20 percent (LW-33 in table 2). There is a notable discrepancy between the uranium and equivalent uranium content (see analyses LW-30 to LW-35, inclusive) in this deposit. Thorium was looked for but not detected.

The southern part of the roll was dug out. A sample at the top of the roll here contains 0. 003 percent uranium, 0. 027 percent equivalent uranium, 0. 20 percent vanadium oxide (LW-34 in table 2), and read 1, 500 counts per second on the Halross Gamma Scintillometer. A sample from the bottom part of the roll at this same point contains 0. 010 percent uranium, 0. 032 percent equivalent uranium, and 0. 06 percent vanadium oxide (LW-35 in table 2). A sample of the soft sandstone in which the roll is embedded, taken 1 foot east of the roll, contains 0. 006 percent uranium, 0. 007 percent equivalent uranium, and 0. 07 percent vanadium oxide (LW-36 in table 2).

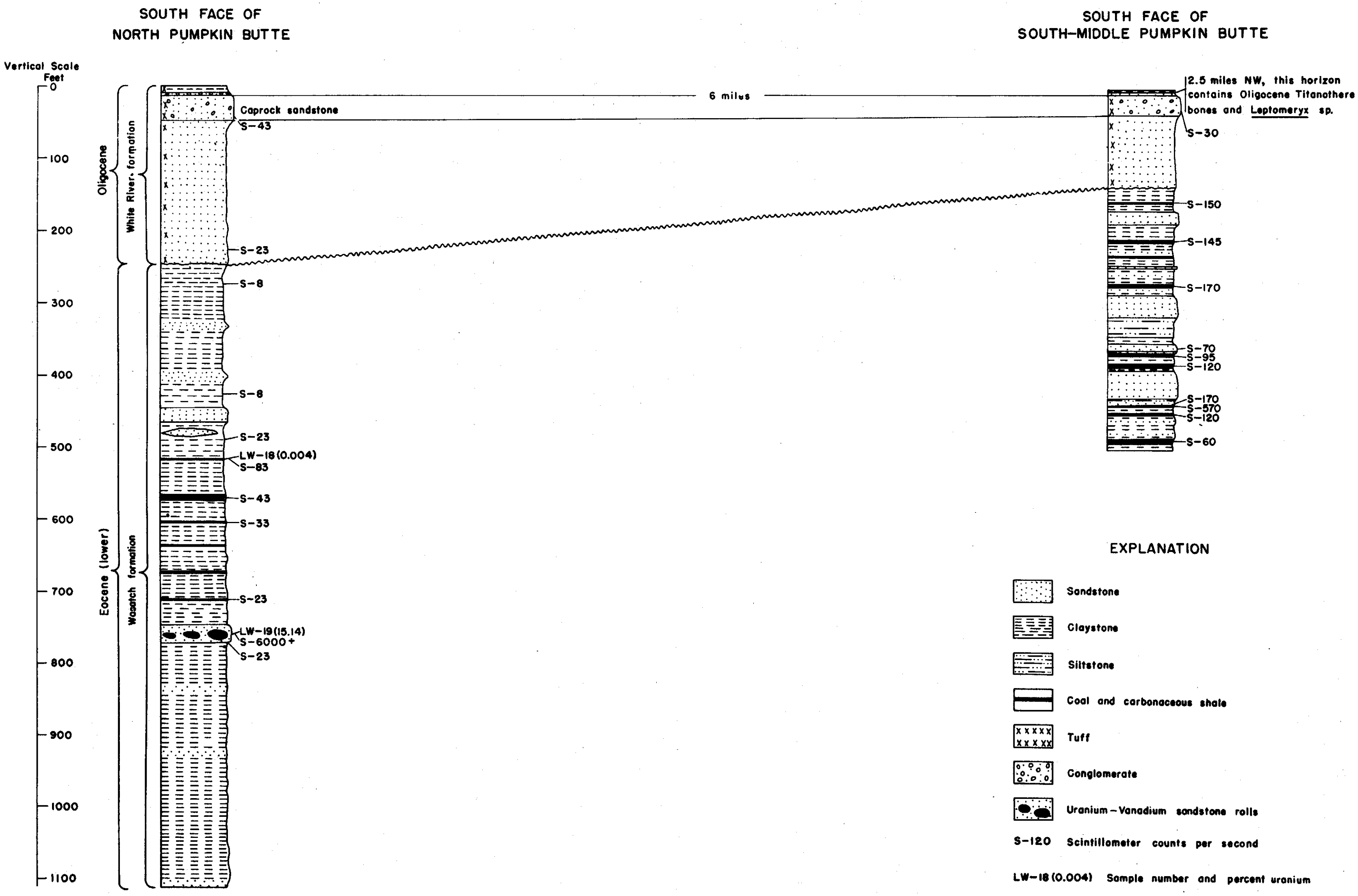

Figure 15.--Columnar sections of rocks at Pumpkin Buttes.

It is interesting to note that the highest chemical analysis of uranium comes from the bottom of the roll and that at that point there is a greater proportion of uranium to equivalent uranium. It would be easy to excavate the entire roll with a power shovel, for there is no overburden. Perhaps commercial-grade uranium ore may be found in some places at the bottom of the roll. This possibility should be investigated.

Deposit L1-58

Deposit L1-58 (fig. 22) is a roll about 125 feet east of L1-57, trends due north and is about 220 feet long. It is oval in cross-section, with the long axis vertical. It consists of pboth pink and gray sandstone, hard, fine-grained, and with many dark grains. The color, as well as the shape of the roll, is independent of the horizontal bedding.

About 9 feet of the roll was dug out (figs. 20 and 21). The pink part measured 350 counts per second on the scintillometer and contains 0.026 percent uranium, 0.031 percent equivalent uranium, and 0.12 percent vanadium oxide (LW-39 in table 2), whereas the adjacent gray part of the roll shows 1,500 counts per second on the scintillometer, and contains 0.053 percent uranium, 0.10 percent equivalent uranium, and 0.24 percent vanadium oxide (LW-38 in table 2). Here again there is a notable discrepancy between the uranium content and the equivalent uranium content. Thorium was looked for but not detected. Because it would be easy to excavate the entire roll with a power shovel, the possibility of finding higher grade ore along the base of the roll would be worth investigating.

Deposit L1-50

Deposit L1-50 is roughly circular, about 100 feet in diameter, on a pediment surface sloping north from Middle Pumpkin Butte. There are no outcrops of bedrock but gamma scintillometer readings show counts ranging from 200 along the margin of the area to 3,000 at the center. A pit was dug where the readings of 3,000 were obtained, and bedrock was found to be a gray, soft, silty, porous sandstone with multicolored grains. This sandstone is in the Wasatch formation, about 500 feet below the base of the White River formation. A sample which showed 3,000 counts per second on the Halross Gamma Scintillometer contains only 0.004 percent uranium, 0.051 percent equivalent uranium, and 0.04 percent vanadium oxide (LW-25 in table 2). Thorium was looked for but not detected. The thickness of the deposit is not known. This soft sandstone could readily be excavated with a power shovel and it is possible that higher grade ore could be obtained from the lower part of the sandstone.

Deposit L1-61

Deposit L1-61 is about 300 feet east of airborne radioactivity anomaly 18-B (pl. 1) in an alluvial flat underlain by the Wasatch formation, more than 500 feet below the contact with the White River formation. Within a 15-foot area scintillometer readings are 700 counts per second. A pit dug to bedrock shows a gray fine-grained silty sandstone with abundant dark grains. Analyses show only 0.002 percent uranium, 0.007 percent equivalent uranium, and 0.12 percent vanadium oxide (LW-43 in table 2). The thickness of the sandstone is not known. Excavation with a power shovel might show a higher uranium concentration in the lower part of this sandstone.

Deposit L1-65

Deposit L1-65 is in the vicinity of airborne radioactivity anomaly 18-F (pl. 1), in the Wasatch formation about 500 feet below the top of North-middle Pumpkin Butte, in a soft gray roll of sandstone largely concealed by a gentle grassy slope. A roll in this soft sandstone shows 900 counts per second on a gamma scintillometer, and a sample at this point contains 0.006 percent uranium, 0.013 percent equivalent uranium, and 0.06 percent vanadium oxide (LW-65 in table 2). The thickness of the sandstone is not known. This roll could be excavated with a power shovel to determine the distribution of uranium and its grade.

Theory of origin of Powder River Basin uranium deposits

Denson, Bachman, and Zeller (1950) originated the theory that the uranium now present in the South Dakota uranium-bearing lignites migrated downward from radioactive tuffs in the overlying White River formation of Oligocene age and the Arikaree formation of Miocene age. The writer believes that the Powder River Basin uranium deposits were formed in a similar manner; that is, the uranium was originally in tuffs within the White River formation that once overlay this portion of the Powder River Basin, that the uranium was leached out and carried downward by ground water travelling along sandstone aquifers in the Wasatch formation, and that the uranium concentrated wherever favorable host rocks were found. The following data support this theory of origin:

1. Cross-section A-D (pl. 2) shows the relative positions of known deposits of the White River formation along a line running southeastward from the Bighorn Mountains through Pumpkin Buttes to Shawnee. At the locality shown in the Bighorn Mountains the White River strata are slightly radioactive, showing 20 to 30 counts per second above background on the Halross Gamma Scintillometer. The basal strata consist of soft pink tuffaceous claystone containing abundant manganese nodules. These nodules and manganese stains extend downward into the underlying Flathead sandstone (Cambrian) and disappear within a few feet below the contact. Just below the base of the White River formation, the Flathead sandstone has about the same count on the scintillometer as the White River formation, but the count decreases rapidly downward, even along the same stratigraphic horizon. To the writer, this suggests downward movement of the radioactive materials in the White River formation. In addition, the topographic relief at the beginning of White River time was high and the White River strata observed were deposited on the crest of a narrow ridge of Flathead sandstone. This ridge seems an unlikely place for ore-bearing juices to have stopped if they came from below along the Flathead sandstone.

Along the southeastern margin of the Powder River Basin, in the vicinity of Flat Top Mountain

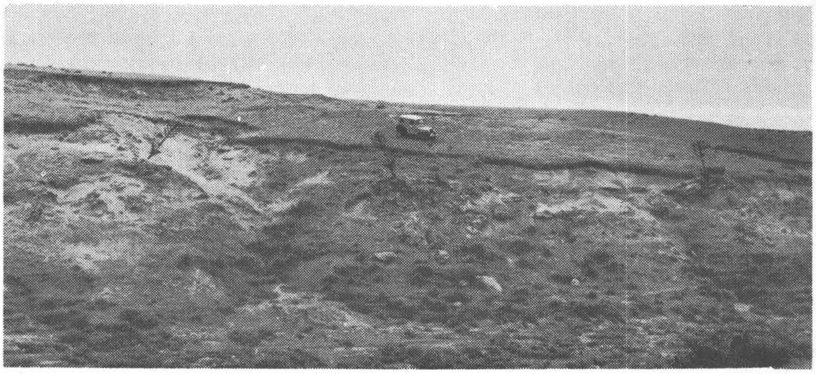

Figure 16.--View looking east at 3 rolls of uranium-bearing sandstone. Rolls are indicated by arrows. High-grade sample from left roll contains 5.42 percent uranium, center 4.57 percent uranium, and right 1.38 percent uranium.

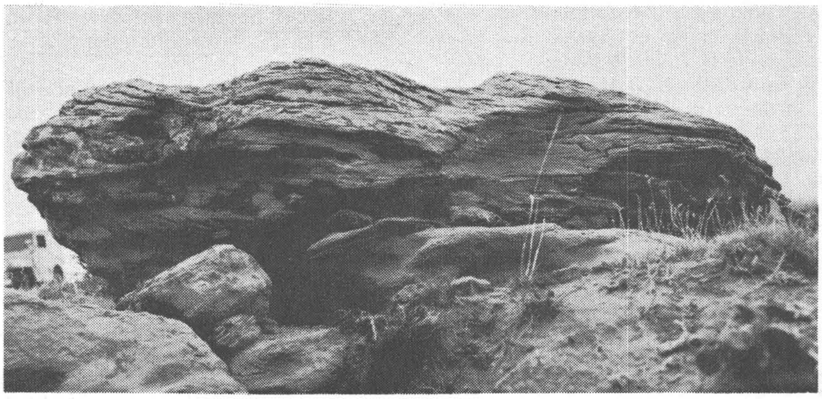

Figure 17.--Detail of ore distribution in roll shown in center of figure 16. Note at and below arrow rounded masses of black ore, possibly vanadiferous.

Figure 18.--Detail or ore distribution on bedding surfaces in sandstone roll shown in center of figure 16. Arrow indicates mass of yellow uranium mineral.

(Shawnee Butte) and the Onion coal mine, well identified White River strata are uniformly radioactive and show some of the brilliant yellow type of fluorescence present in the caprock sandstone on the Pumpkin Buttes. In addition, the coal beds in the Fort Union formation directly underlying the White River formation in this locality contains significant amounts of uranium (Denson, 1950). It is believed that the uranium in the coal was derived by downward leaching from uranium-bearing tuff in the White River formation, as gamma-ray logs of the underlying Fort Union formation and Cretaceous rocks in the Powder River Basin show no conspicuously radioactive zones.

2. Cross-section A-F (pl. 3) shows the relative positions of known deposits of the White River formation along a line extending eastward from the Bighorn Mountains, through Pumpkin Buttes to Craven Canyon, about 10 miles north of Edgemnot, S. Dak. The purpose of extending this section to Craven Canyon is to show the striking similarity of relationships between the White River formation and the underlying uranium deposits there and the White River formation and underlying uranium deposits in the Pumpkin Buttes area. Darton and Smith (1904) mapped a remnant of the White River formation on the west edge of Craven Canyon and described the rock as a brown conglomeratic grit. Adjacent outcrops of this formation to the northeast contain white tuffaceous beds in addition to the conglomerate. The uranium occurs as carnotite in fractures and porous beds in the nearly horizontal Lakota sandstone of Early Cretaceous age. The carnotite deposits are being studied by L. R. Page and others of the U. S. Geological Survey and a circular describing them is in preparation. The strata mapped as part of the White River formation lie horizontally and about 300 feet in altitude above the carnotite deposits. It seems to be more than coincidence that in every place in Wyoming and in the Edgemont area as well, where uranium deposits are found on the surface in pre-White River sedimentary rocks, the White River formation is present in the area, or evidence indicates that it once was present.

3. The thickness of the sedimentary section underlying the uranium deposits in the Pumpkin Buttes area and overlying the pre-Cambrian rocks is estimated to be about 16,000 feet; so, it seems unlikely that ore-bearing juices migrated upward for such a great distance and through such a variety of sandstones, shales, limestones, dolomites, and coal beds before finding a favorable host rock in which to concentrate.

4. Reflection seismograph surveys, airborne magnetometer surveys, and gravity meter surveys have all been made of this general region and none of them indicated any concealed Tertiary intrusive igneous mass that could have furnished the uranium. The nearest Tertiary igneous rocks are in the Black Hills, 85 miles away. It is doubtful, that ore-bearing juices migrated laterally for such a distance before they were concentrated in a favorable host rock.

5. The absence of dips exceeding 5 degrees and lack of evidence of faulting within 15 miles of the area reduce the possibility of upward migration of ore-bearing juices that may have derived their uranium content from older sedimentary rocks. Gamma-ray logs from wells drilled for oil in the region to the west do not show any such sedimentary rocks with significant radioactivity.

6. The structure of the ore-bearing rolls in sandstones in the Wasatch formation precludes the possibility that the ore in the sandstone is syngenetic. The coal beds are too thin to have contributed significant amounts of uranium.

7. The White River formation has been identified throughout much of Wyoming. The formation contains fine-grained tuffaceous clays that show remarkably little variation in appearance, mineralogy, or grain size in outcrops extending from Nebraska to western Wyoming and from Montana to Colorado. The only conspicuous change in grain size occurs in the Absaroka Mountains and the southeast corner of Yellowstone National Park, where volcanic conglomerates and agglomerates occur (Love, 1939, p. 79-85 and pl. 14, fig. 2). There is little question that the source of much of the volcanic material in the White River formation was in the Absaroka region. The Oligocene age of a significant amount of the pyroclastic rock appears to have been established by the writer's discovery in 1949 of the following assemblage of vertebrate fossils near the head of Fox Creek, about 3 miles south of Yellowstone National Park, in section 33, T. 48 N., R. 112 W., unsurveyed: Poebotherium sp., Teleodus uintensis, Ischyromys aff. I. pliacus, and Cylindrodon aff. C. fontis (Hough, 1950). These fossils occur in white tuffaceous clays typical of those in the White River formation in areas to the east. The volcanic conglomerate associated with these claystones contains rock fragments petrographically similar to the volcanic pebbles found on Pumpkin Buttes. The tuffaceous claystones are radioactive in the Fox Creek locality and similar ones are likewise radioactive in every area to the east and southeast where they have been identified and examined for radioactivity.

8. Springs emanating from the White River formation along the Beaver Divide in central Wyoming, 100 miles southwest of Pumpkin Buttes, and from the same formation where it overlies uranium-bearing lignites in South Dakota, 175 miles to the northeast, contain uranium in amounts of 10 parts per billion or more. Many springs, are present in the White River formation on several of the Pumpkin Buttes but they have not yet been sampled for uranium analysis.

In summary, the White River formation has a widespread uranium content wherever it has been checked in Wyoming, regardless of what rocks it was deposited on; therefore, it is assumed that at least some of the uranium was a primary constituent of the ash which forms a major part of the formation; the ash originated in part, at least, in the Absaroka region; springs now emanating from the White River formation, both in Wyoming and South Dakota, contain uranium; so, it is known that at present the uranium can be leached out by ordinary groundwater processes; it is assumed that similar processes could have operated in the past to leach the uranium out of the White River formation, carry it along aquifers in underlying rocks, and deposit it in favorable host rocks.

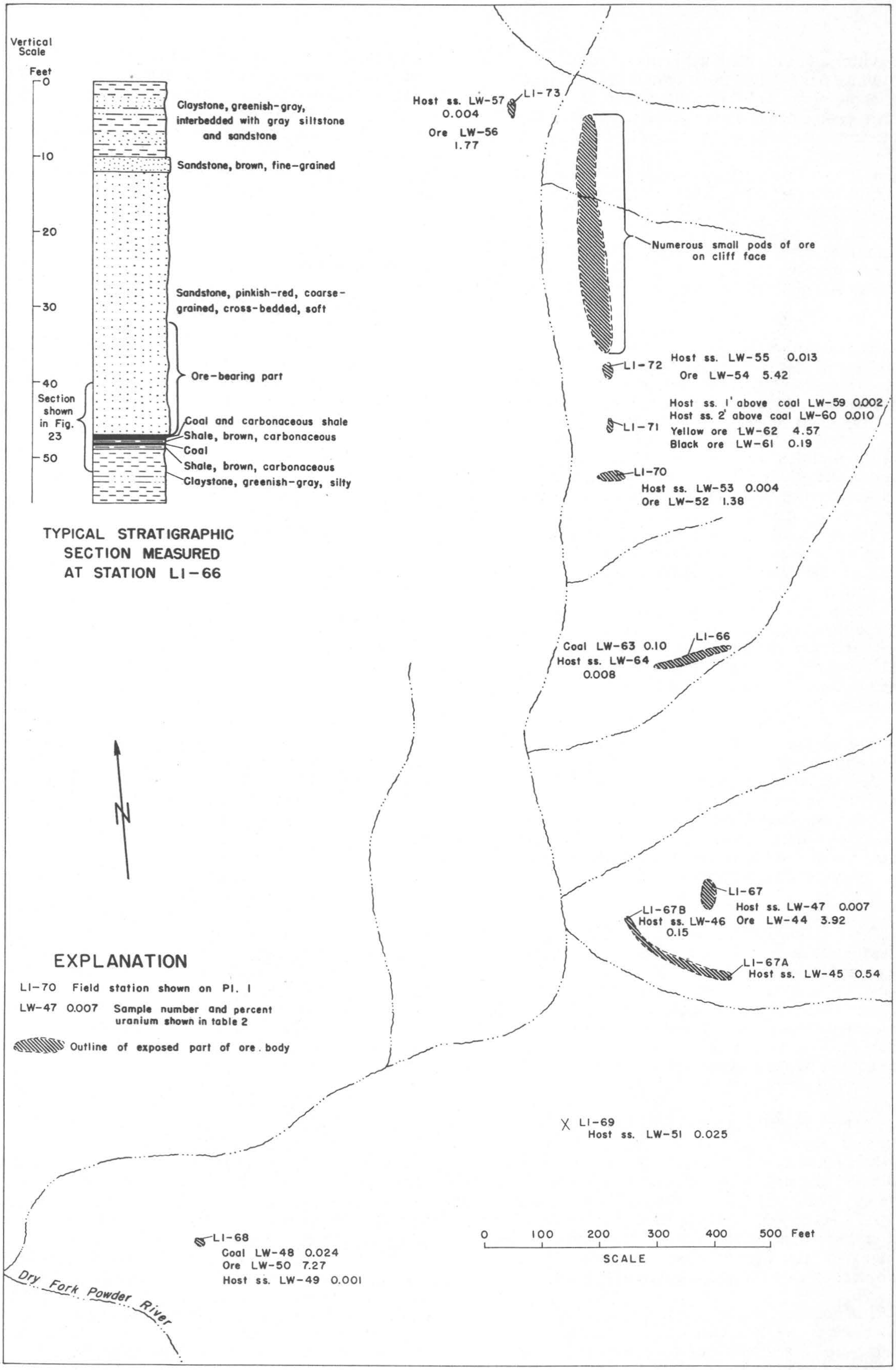

Figure 19.--Sketch map showing ore-bearing sandstone rolls 5 miles southwest of North-middle Pumpkin Butte.

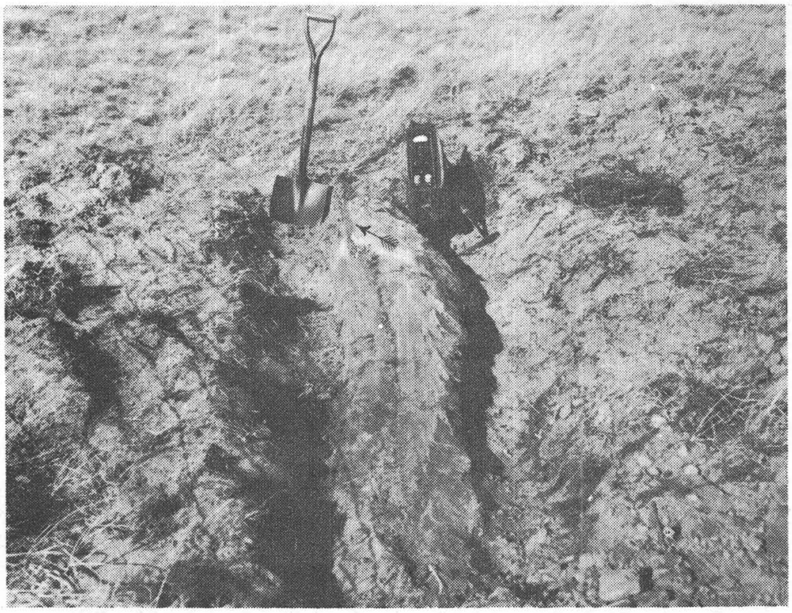

Figure 20.--Central part of sandstone roll in Wasatch formation shown in fig. 22. Arrow points to contact between light-colored lean rock containing 0.026 percent uranium, and darker rock containing 0.053 percent uranium.

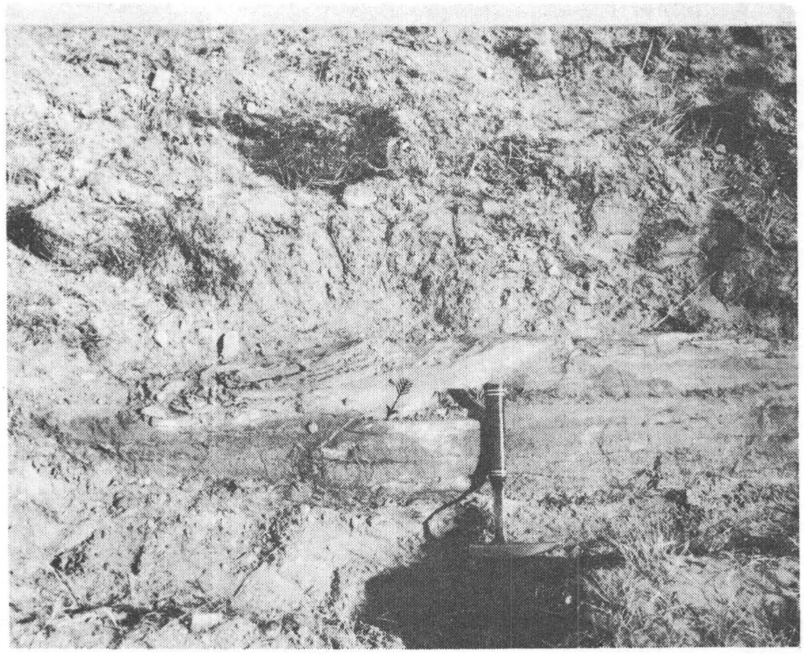

Figure 21.--Side view of sandstone roll shown in figures 20 and 22. Arrow indicates contact between light-colored low-grade rock and dark-colored richer rock.

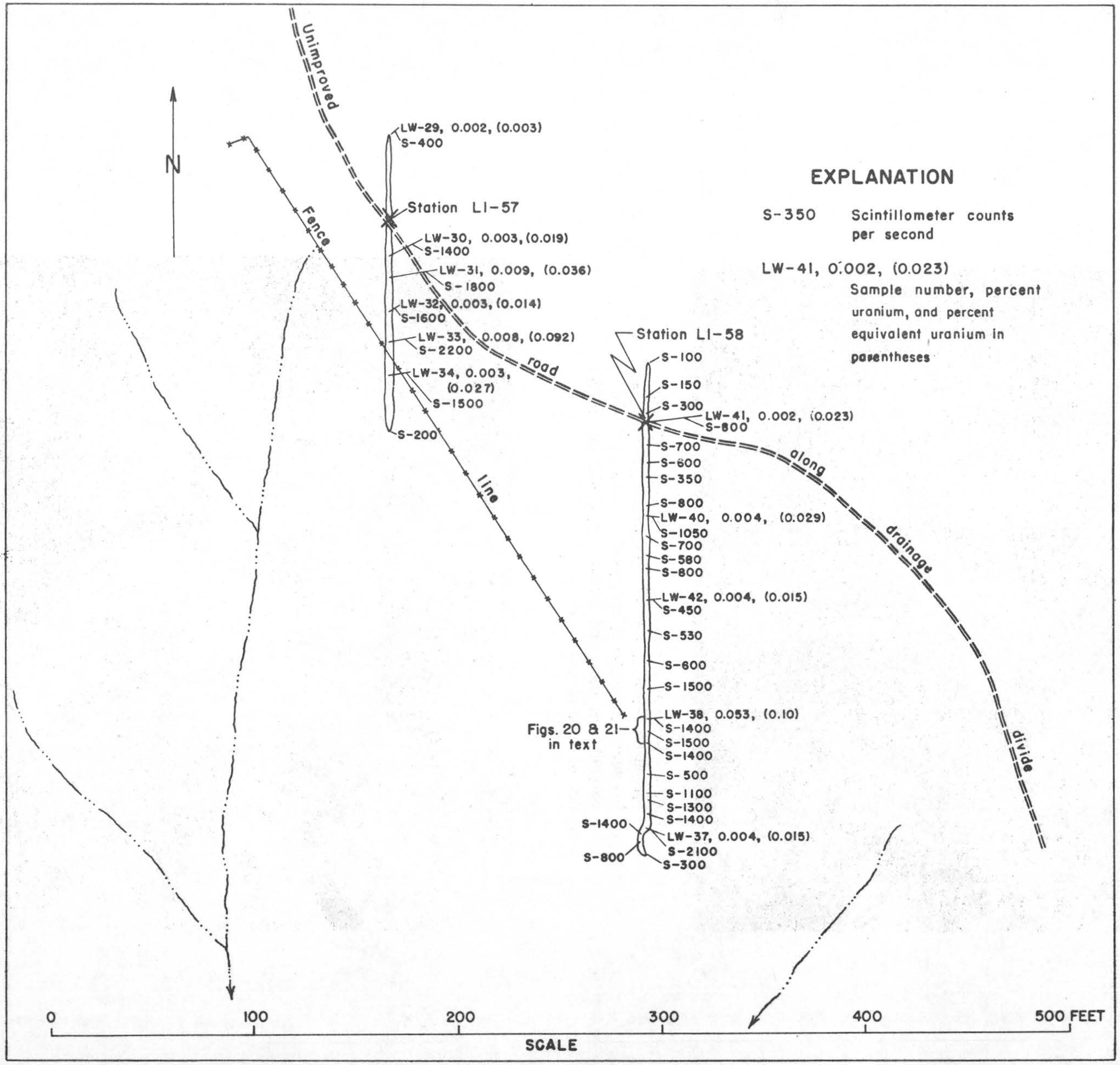

Figure 22.--Sketch map of two low-grade uranium-bearing sandstone rolls near stations L1-57 and L1-58.

Aerial radioactivity anomalies

In April 1950, the writer proposed an airborne radioactivity survey of the area between the Sussex oil field and Pumpkin Buttes to search for uranium-bearing lignites and tuffs. In October 1950, flight lines 1 through 18 and 32 through 37 (pl. 1) were flown. Because time did not permit complete flying of all projects in the State of Wyoming, lines 19 to 32 of the Pumpkin Buttes area were omitted. Of 3,700 traverse miles flown in Wyoming, 500 were in the Pumpkin Buttes district. Ground checks indicate that the best uranium deposits were found on the edges of this flight gap, adjacent to anomalies recorded on flights 18 and 32 (table 1). It is difficult to evaluate the number of deposits that may be present within this gap, but it will be covered as part of the extensive detailed airborne radioactivity survey to be flown in this region as the result of the preliminary airborne work and field investigations.

Table 1 summarizes the results of field checks on the airborne radioactivity anomalies. Thirty-nine of 60 the anomalies, including almost all of the peak anomalies, were checked in the field. Of the 39 checked, 6 were found to overlie uranium deposits of interest. Two additional anomalies are in the general area of uranium deposits. However, the circle drawn around each of these two anomalies missed the deposit by one-fourth to one-half mile (see anomalies 10- A and 10-B in relation to Ll-78 and Ll-79 on pl. 1). Four of the 39 anomalies were over such low-grade deposits that it is astonishing that the airborne counter recorded them. Field checks of 27 of the 39 anomalies yielded negative results. Only one "very good peak" anomaly was recorded by the airborne Geiger counter in the area, but a thorough field check did not reveal any radioactive deposit in this vicinity.

The lack of precise coincidence between the position of the anomalies as plotted on the map and as found on the ground is caused by several factors: (1) radiation from concealed deposits or from widespread low-grade deposits possibly may be recorded by airborne equipment even though this radiation is not sufficient to be noticed on the ground. This is especially possible when the ground check is made with a Geiger counter rather than a scintillometer; (2) the instruments used for this survey required a relatively long counting interval, and the peak count occurred a few seconds after the deposit had been crossed. Although new instruments now in use have shorter counting intervals, comparison such as this of the positions of airborne anomalies and ground discoveries are needed and will continue to be needed to determine the lag correction to be applied to the airborne information.

Although the airborne equipment used for this survey is considerably inferior to that developed since, this investigation has demonstrated the value of airborne reconnaissance surveys as a means of prospecting for areas containing radioactive deposits. Further ground checking of airborne radioactivity anomalies will materially improve their usefulness.

Possibilities of there being other uranium deposits in the Powder River Basin

If the theory of origin is correct that the uranium originated in the Pumpkin Buttes area migrated downward from the White River formation, traveled along aquifers and was concentrated in favorable host rocks, the writer knows no reason similar deposits could not have been formed elsewhere within the 12,000 square miles or more of that part of the Powder River Basin underlain by Tertiary rocks. This is strengthened by the fact that one deposit occurs in the Fort Union formation (figs. 24 and 26) on the west margin of the Powder River Basin, and coals in the Fort Union formation in the vicinity of the Onion mine along the southeastern margin of the basin contain uranium (pl. 2). The presence of carnotite in the Lakota sandstone of Early Cretaceous age below the White River formation in the Craven Canyon area, S. Dak. (pl. 3) and radioactivity observed in the Flathead sandstone of Cambrian age and Gros Ventre formation in the Bighorn Mountains, suggest that the possibilities of concentration of uranium ores can be extended to include pre-Tertiary rocks.

It seems likely that some areas in the Powder River Basin have been eroded so far below the original base of the White River formation that any significant uranium deposits would have been removed by erosion. For example, the more deeply dissected areas shown on plate 2 between the Bighorn Mountains and Powder River probably have fewer possibilities than the upland area between Pumpkin Buttes and the Dry Fork of the Cheyenne River.

Upland area attractive for uranium explorations, where the present land surface is within 500 to 700 feet of the postulated original position of the base of the White River formation, are: (1) the area extending from South Pumpkin Butte southward to the Converse County line; (2) the area extending eastward from the Pumpkin Buttes to the Rochelle escarpment (see pl. 3); (3) the area extending north-northeast from North Pumpkin Butte toward Gillette; (4) the narrow strip between the Pumpkin Buttes and Powder River.

There is some justification for the assumption that these areas are worth prospecting for uranium ore deposits. For example, there is a clinker bed in sec. 33, T. 44 N., R. 72 W., about 20 miles east of the Pumpkin Buttes, that shows 21 counts per second above background on the Halross Gamma Scintillometer. This clinker bed is about 25 feet thick and was derived by burning of either the Felix coal bed or the coal 100 feet stratigraphically above the Felix, in the upper part of the Wasatch formation. The topographic position of this bed is on the upland part of the Powder River Basin.

Along the high drainage divide between North Pumpkin Butte and Gillette all the coal and carbonaceous shale beds are radioactive. Black Butte, 13 miles northeast of North Pumpkin Butte, is capped by large blocks of the caprock sandstone from the White River formation, which have apparently been let down several hundred feet. The sandstone shows 80 counts per second and the carbonaceous shale and coal beds in the

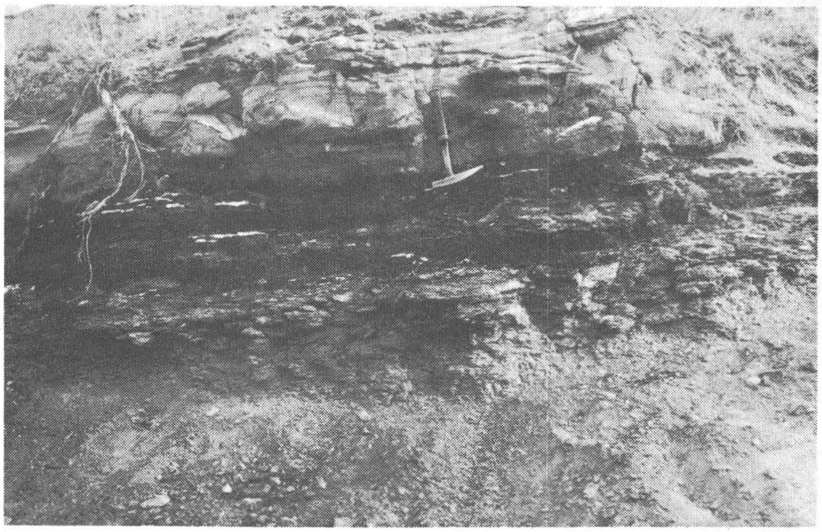

Figure 23.--Uranium-bearing coal, carbonaceous shale, and sandstone in the Wasatch formation. Coal contains 0.10 percent uranium, overlain by pink sandstone containing 0.008 percent uranium. Arrow indicates pods of yellow uranium mineral. White patches on coal and sandstone are snow.

Figure 24.--Uranium-bearing red sandy siltstone in the Fort Union formation on Great Pine Ridge. Arrow indicates bed containing 0.062 percent uranium, shown in figure 26.

Wasatch formation, underlying these sandstone blocks, show 225 counts per second on the Halross Gamma Scintillometer.

The presence of uranium ore deposits on the upland area west and southwest of the Pumpkin Buttes has already been demonstrated. Other areas that have not been examined but that should be favorable lie along the drainage divide between the Dry Fork of Powder River and Powder River, and the area south and southeast of Pumpkin Buttes. Another area lies about 25 miles northeast of the Pumpkin Buttes, in the vicinity of the old Four Horse store. Dobbin and Barnett (1927, p. 11) describe the occurrence of gravel beds containing boulders of Paleozoic and pre-Cambrian rocks on one of the highest points in the region, in sec. 33, T. 46 N., R. 69 W. It is possible that this deposit is a remnant of the conglomeratic facies of the White River formation, similar to that on Pumpkin Buttes. The conglomerate is underlain by the Roland coal bed, 7 feet thick, at the top of the Fort Union formation, and a coal bed 6 feet thick in the lower part of the Wasatch formation. Many carbonaceous sandstones are present. These factors suggest that the area would be worth investigating for uranium deposits.

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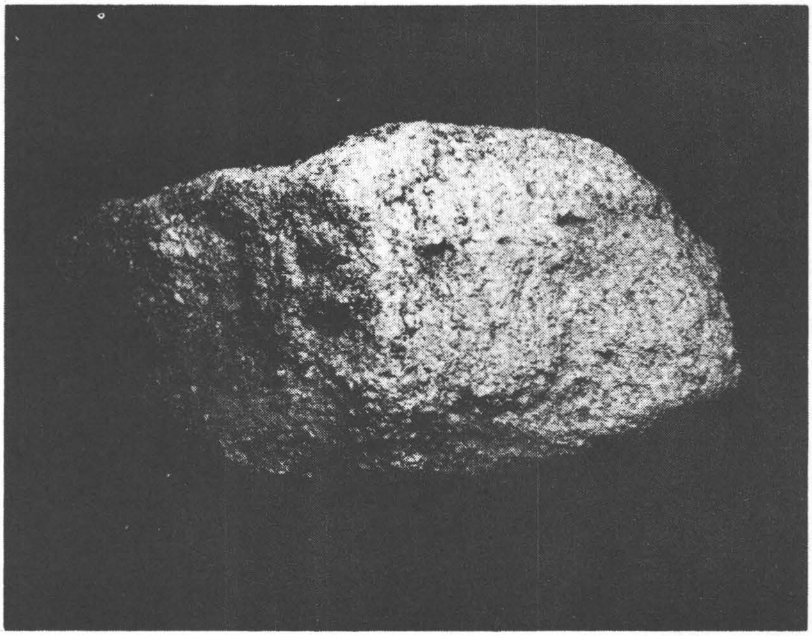

Figure 25.--Uranium-bearing caprock sandstone in the White River formation, South Pumpkin Butte, containing 0.004 percent uranium, photographed under ultraviolet light. Light-colored areas fluoresce bright yellow.

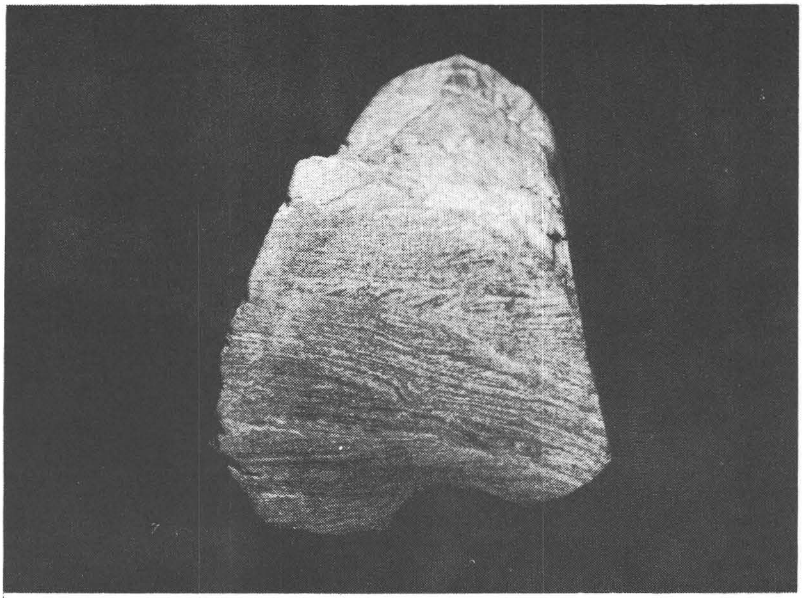

Figure 26.--Uranium-bearing red sandy siltstone from horizon in the Fort Union formation shown in figure 24, photographed under ultraviolet light. Light-colored layers fluoresce bright dusty yellow.

APPENDIX A

Stratigraphic section on south face of North Pumpkin Butte

[This generalized section was measured by J. D. Love on October 15, 1951, with an aneroid barometer for major intervals and steel tape for thin beds. Units are numbered consecutively from oldest to youngest.]

Unit no.		Thickness (feet)
14	Loess soil, yellowish tan, soft, with ashy material in lower 2 feet, which gives a reading of 6 counts per second above background on scintillometer	8
	(Contact between Pleistocene (?) deposits and White River formation).	
	White River formation:	
13	Claystone and conglomerate, flesh pink to gray, interbedded; claystone is soft, blocky, tuffaceous; conglomeratic beds are gray to pink, poorly sorted, with rounded fragments of granite, chert, quartzite, and andesite as much as 2 inches in diameter. This unit is exposed only at the northwest corner of the butte. It contains many waterworn fragments of titanothere(?) tooth enamel and small fragments of bone.	10
12	Conglomerate, light gray, soft; contains a great variety of boulders and pebbles, as much as 1 foot in diameter, but averaging about 2 inches, of chert, ocher-colored jasper, bluish-gray to brown agate that fluoresces brilliant yellow under ultra-violet light, granite, black gneiss, quartzite (from the Flathead and Tensleep formations), limestone (from the Madison and Phosphoria formations), and chert (from the Amsden and Madison formations); all fragments moderately to highly rounded; embedded in light gray tuffaceous limy matrix.	3
11	Caprock sandstone, tannish-gray, coarse-grained, angular-grained, hard, cross-bedded, noncalcareous, with much fluorescent chalcedonic cement; forms vertical cliff on this and all other Pumpkin Buttes; some fine-grained sandstone beds near top. Lower part reads 43 counts per second above background on scintillometer. Thickness is variable, and may be more than 50 feet. Where unit 12 is absent and the claystones of unit 13 rest on this sandstone, there are abundant manganese stains and some manganese has impregnated the upper 6 inches of the sandstone.	35
10	Sandstone, light yellow to tan, highly cross-bedded, with laminae marked by limonite concentrations, coarse-grained, hardly indurated; forms smooth slopes where not covered with talus; clean, with little clay matrix; near top are pale green, very sandy tuffaceous claystones; near base are white sandy tuff beds containing lenses of flesh pink to tan bentonitic claystone. Throughout the unit the scintillometer shows 23 counts per second above background.	200
		248
	(Contact between White River formation and Wasatch formation. Actual point of contact is covered. There appears to be some channeling, but little angular discordance).	
	Wasatch formation:	
9	Claystone, variegated, chiefly red, purple, green, yellow, white, with soft dull colors; rock is soft, waxy, possibly bentonitic, fine-grained, plastic; forms badlands; contains some soft, poorly consolidated, yellowish sandstone beds as much as 10 feet thick. Scintillometer shows 3 to 13 counts per second above background.	200
8	Sandstone, tan to brown, hard to soft, medium-grained to coarse-grained; forms conspicuous light-tan zone on face of hill	20
7	Claystone, drab bluish-gray, interbedded with some sandstone. Scintillometer shows 23 counts per second above background	50

Unit no.		Thickness (feet)
6	Coal, black, very soft, interbedded with gray carbonaceous shale. Astragalus bisulcatus growing on coal, indicating presence of selenium. Scintillometer shows 83 counts per second above background. Sample LW-18 taken here contains 0.004 percent uranium, 0.005 percent equivalent uranium	1
5	Shale and claystone, gray, green, brown, pale pink, with yellowish lenticular sandstone near top.	50
4	Coal and carbonaceous shale, dark gray to black. Scintillometer shows 43 counts per second above background.	4
3	Claystone and shale, variegated, chiefly dull green, with some dull pink and gray; 4 zones of carbonaceous shale and coal, each about 2 feet thick. Upper coal shows 33 counts per second and lower coal 23 counts per second above background on scintillometer.	175
2	Sandstone, light tan, medium-grained to coarse-grained, soft, porous, concretionary; about 10 feet above base are secondary rolls of sandstone outlined by yellow and black uranium minerals that cut across cross-bedding, like those in the Morrison formation in the Colorado Plateau area. Sample LW-19 contains 15.14 percent uranium and 14.0 percent equivalent uranium.	25
1	Claystone, dully variegated, interbedded with soft gray and tan sandstone; some carbonaceous beds; one 3 inches thick at very top, in contact with unit 2, showing 40 counts per second above background on scintillometer; another about 15 feet above base of section in vertical face at the bottom of the Willow Creek Valley. This unit was not measured in detail because of a snowstorm.	340 ±
		865

APPENDIX B

Stratigraphic section on south face of South-middle Pumpkin Butte

[This section was measured by aneroid barometer and steel tape on the south face of South-middle Pumpkin Butte, on November 9, 1951, by J. D. Love. Units are numbered consecutively from oldest to youngest.]

Unit no.		Thickness (feet)
White River formation:		
30	Tuffaceous claystone, white, semitranslucent on thin edges, bentonitic, plastic, finely blocky; overlain by lag gravels of chert, quartzite, silicified wood, and opalized wood, with rock fragments as much as 8 inches in diameter. Scintillometer shows 30 counts per second above background on claystone.	3
29	Sandstone, white, tuffaceous, medium-grained, soft; has white tubelike objects, perhaps silicified root fillings. Scintillometer shows 30 counts per second above background. This horizon on the North-middle Pumpkin Butte, 2 miles to the northwest, contains leg bones and tooth fragments of titanotheres characteristic of the Chadron formation and an astragalus of Leptomeryx. These fossils establish the age of this unit as early Oligocene.	3
28	Caprock sandstone, white to light gray, weathering reddish-brown, highly cross-bedded; abundant angular grit beds and numerous sporadic chert pebbles 1 to 2 inches in diameter.	30
27	Sandstone, light yellowish-brown, very soft, highly cross-bedded, with laminae marked by concentrations of limonite; some green and pale pink claystones near top; exposures poor and slumped in part.	100
		136

(Contact between White River formation and Wasatch formation. The actual contact is exposed but not for enough lateral distance to be sure how much channeling there is, or whether there is any angular discordance).

Unit no.		Thickness (feet)
26	Claystone, yellow, green, and pink, soft, blocky	20
25	Shale, black, carbonaceous, fissile, full of plant remains and fairly well-preserved leaves. Scintillometer shows 150 counts per second above background.	2
24	Claystone, yellow, pale pink, and green, waxy, soft, finely blocky.	10
23	Sandstone, chalky white, massive, very soft, coarse-grained, with angular quartz grains and a few dark grains but some pink; forms conspicuous white stripe along surface outcrop (fig. 9).	20
22	Claystone, greenish to tan, slightly pink near base, soft, blocky	20
21	Coaly shale, black, fissile; a mass of plant fragments. Scintillometer shows 145 counts per second above background.	4
20	Claystone, green near top, gray and silty near base, with 4 feet of gray soft silty sandstone 2 feet above base.	12
19	Claystone, pale green, with pink layers near top and in middle, with middle one overlain by 1 foot of silty limestone or limy siltstone; 2 feet of carbonaceous shale, with leaves, at top of unit	20
18	Sandstone, ocher-colored, fine-grained, hard, nodular; forms conspicuous ledge.	3
17	Claystone, green, interbedded with 1- to 5-foot beds of ocher-colored, fine-grained sandstone. A 4-foot carbonaceous shale is 10 feet above base; between this and base is some pink claystone. The carbonaceous shale registers 170 counts per second above background on scintillometer.	40
16	Sandstone, white, and limonite-tan, soft, medium- to coarse-grained, with laminae of cross-bedding marked by limonite concentrations; looks like sandstone in unit 27.	30
15	Siltstone and silty sandstone, white to pale-greenish in upper 5 feet, grading down to white cross-bedded fine-grained sandstone; in lower 10 feet are some coarse-grained granitic grits and some greenish claystone blebs. A 3-inch marker layer of black and pink carbonaceous shale lies at base.	25
14	Claystone, green, interbedded with 1-foot beds of pink and ocher-colored sandstone in lower part.	10
13	Sandstone, tan, pinkish-stained, forming ragged knobby ledge	10
12	Sandstone, siltstone, and claystone, gray to greenish, soft, with a 2-foot sandstone layer at base.	5
11	Coal and carbonaceous shale; about 1.5 feet of dusty coal. The coal shows 95 counts per second above background on scintillometer, and overlying sandstone 70 counts above background at a apoint about 200 feet south of gully where section was measured.	3
10	Claystone, greenish-gray, soft, finely blocky	10
9	Shale, black, carbonaceous, 1 foot thick, at top; 2 feet of green blocky claystone in middle, and 1.5 feet of carbonaceous shale at base. The carbonaceous shale reads 120 counts per second above background on scintillometer. . , ...	4.5

Unit no.		Thickness (feet)
8	Claystone, green and pink, soft, finely blocky	4.5
7	Sandstone, light yellow, massive to cross-bedded, soft, medium-grained, with vertical limonite laminae cutting across bedding; near base are ferruginous concretions and petrified wood, neither of which gives a positive reaction on scintillometer.	40 ±
6	Sandstone, gray, poorly exposed; some tubular gray sandstone rolls and concretions, and near base some pink and green claystone; at base is a 2-foot yellow, medium-grained sandstone of 170 counts per second above background on scintillometer.	10
5	Coaly shale, black, soft. This unit shows 570 counts per second above background on scintillometer.	1
4	Claystone and shale, gray, soft, with abundant small limy nodules	10
3	Coaly shale, brown to black, soft. This unit runs 120 counts per second above background on scintillometer	2
2	Claystone, siltstone, and fine-grained sandstone, gray, soft, with some limy concretions, and some large and small ferruginous and gypsiferous concretions, all of which give no positive reaction on the scintillometer.	35
1	Coaly shale, brown to black, soft, conspicuous as the lowest carbonaceous shale on this spur. The end of the measured section here is 30 feet vertically above, and 200 feet east of iron fence post and pile of rocks. This unit registers 60 counts per second above background on scintillometer.	4
		353

Table 1.--Results of ground checks on airborne radiometric anomalies, Pumpkin Buttes area

Station	Type Anomaly	Checked Complete Circle	Checked Only Center of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
1B	? Not checked								
1C			x			Poor	Geiger counter	Negative	
2A	Very broad		x			Heavy cover	Geiger counter	Negative	
2B	Peak		x			Heavy cover	Geiger counter	Negative	
2C	Peak		x	x		Center located in alluvium	Geiger counter	Negative	
2D	Peak	x	--	x		Fair	Scintillometer	200 cps1/ in carbonaceous shales	
2E	Broad double anomaly			x		Fair	Geiger counter and scintillometer	Negative	
2G	Very broad		x			Heavy cover	Geiger counter	Negative	
2H	Very broad			x		Good	Geiger counter	Negative	
2I	Broad; not checked					Poor			
4A	Broad	x		x		Fair to poor	Geiger counter	Negative	
4B	Broad			x		Fair	Geiger counter	Negative	
4C	Broad		x			Poor	Geiger counter	Negative	
4D	Broad		x		x	Poor	Geiger counter	Negative	

Table 1.--Results of ground checks on airborne radiometric anomalies, Pumpkin Buttes area (Continued)

Station	Type Anomaly	Checked Complete Circle	Checked Only Center of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
4E	Very broad; not checked								
4F	Very broad	x				Poor	Geiger counter Scintillometer	Negative	
4G	Very broad; not checked								
4H	Broad; not checked								
6A	Broad; not checked								
6B	Very broad			x		Fair	Geiger counter	Negative	Red sandstone present
6C	Broad			x		Fair	Geiger counter	Negative	
6D	Broad		x			Poor	Geiger counter Scintillometer	Negative	
8A	Very broad				x	Poor	Geiger counter	Weak	Carbonaceous shale
8B	Not checked								
8C	Very broad			x		Fair	Geiger counter	Negative	
8D	Broad; not checked								

Table 1.--Results of ground checks on airborne radiometric anomalies, Pumpkin Buttes area (Continued)

Station	Type Anomaly	Checked Complete Circle	Checked Only Center of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
8E						Fair	Geiger counter	Negative	
8F	Peak and broad		x			Poor	Scintillometer	150 cps	
8G	Very good peak	x				Very poor	Geiger counter Scintillometer	Negative	
8H	? Not checked								
10A	Broad			x		Poor	Geiger counter	Weak	Carbonaceous shale
10B	Broad			x		Fair	Scintillometer	350 ± cps	See analyses LW-66-70 incl. in Table 2
10C	Peak	x				Poor	Scintillometer	Negative 100 ± cps	
10D	Broad				x	Fair	Geiger counter		
12A	? Not checked								
12B	?	x				Poor	Scintillometer	3000 cps	See analysis LW-25, Table 2
14A	Broad				x	Poor	Geiger counter	-	

Table 1.--Results of ground checks on airborne radiometric anomalies, Pumpkin Buttes area (Continued)

Station	Type Anomaly	Checked Complete Circle	Checked Only Center Of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
14B	Broad; not checked								
14C	Broad; not checked								
15A	Very broad; not checked								
16A	? Not checked								
17A	Peak			x		Fair to poor	Scintillometer Geiger counter	Negative	
18A	Peak	x				Good	Scintillometer	6000 cps	See analyses LW-44-64, incl., Table 2
18B	?	x				Poor	Scintillometer	700 cps	See analysis LW-43, Table 2
18C	?	x				Poor	Scintillometer	Negative	
18D	Very broad; not checked								
18E	Very broad; not checked								

Table 1.--Results of ground checks on airborne radiometric anomalies, Pumpkin Buttes area (Continued)

Station	Type Anomaly	Checked Complete Circle	Checked Only Center of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
18F	Peak			x		Poor-Fair	Scintillometer	900 cps	See analysis LW-65, Table 2
32E	Peak	x				Good	Scintillometer	6000 cps	See analysis LW-19
32F	Peak			x		Fair	Scintillometer	118 cps	Carbonaceous shale See analysis LW-20, Table 2
32G	Peak; not checked								
33A	Peak			x		Fair-good	Scintillometer	Negative	
33B	Peak; not checked								
34A	Peak; not checked								
35A	?		x			Poor	Scintillometer	Negative	
35B	? Not checked								
35C	Peak	x				Poor	Scintillometer	200 cps	Carbonaceous shale

Table 1.--Results of ground checks on airborne radiometric anomllies, Pumpkin Buttes area (Continued)

Station	Type Anomaly	Checked Complete Circle	Checked Only Center of Circle	Checked Complete Exposed Section	Checked Only Carbonaceous Shales And Coals	Exposures	Instrument Used In Field Check	Results	Remarks
37A	Peak; very broad			x		Fair	Scintillometer	Negative	
37B	Peak very broad			x		Fair	Scintillometer	Negative	
37C	Peak very broad; not checked								

1/ cps means counts per second

Table 2.--Analyses of samples taken in Pumpkin Buttes area, Wyoming

Serial No.	Field station	Field sample No.	Equivalent uranium (percent)	Uranium (percent)	Vanadium oxide (percent)	Remarks
54128	L1-34	LW-16	0.001	0.003		Coal (Fort Union)
54129	L1-34	LW-17	0.10	0.062		Red siltstone (Fort Union)
54130	L1-35	LW-18	0.005	0.004		Coal (Wasatch)
54131	L1-35	LW-19	14.0	15.14		Yellow and black ore
54132	L1-35	LW-20	0.022	0.026		Green siltstone
54986	L1-50	LW-25	0.051	0.004	0.04	Gray sandstone
54987	L1-51	LW-26	0.021	0.015	0.05	Coal (Wasatch)
54988	L1-53	LW-27	0.004	0.004	0.05	Sandstone (caprock) in White River formation
54989	L1-56	LW-28	0.020	0.022	0.13	Pink sandstone
54990	L1-57	LW-29	0.003	0.002	0.06	Fig. 22
54991	L1-57	LW-30	0.019	0.003	0.17	Fig. 22
54992	L1-57	LW-31	0.036	0.009	0.18	Fig. 22
54993	L1-57	LW-32	0.014	0.003	0.05	Fig. 22
54994	L1-57	LW-33	0.092	0.008	0.07	Fig. 22
54995	L1-57	LW-34	0.027	0.003	0.20	Fig. 22, top of sandstone roll
54996	L1-57	LW-35	0.032	0.010	0.06	Fig. 22, bottom of sandstone roll
54997	L1-57	LW-36	0.007	0.006	0.07	Fig. 22, 1 foot east of sandstone roll
54998	L1-58	LW-37	0.015	0.004	0.08	Fig. 22
54999	L1-58	LW-38	0.10	0.053	0.24	Fig. 22
55000	L1-58	LW-39	0.031	0.026	0.12	Fig. 22, soft sandstone
55001	L1-58	LW-40	0.029	0.004	0.12	Fig. 22
55002	L1-58	LW-41	0.023	0.002	0.07	Fig. 22
55003	L1-58	LW-42	0.015	0.004	0.19	Fig. 22
55004	L1-61	LW-43	0.007	0.002	0.12	Gray sandstone
55005	L1-67	LW-44	4.2	3.92	1.97	Fig. 19, yellow and black ore
55006	L1-67A	LW-45	0.54	0.54	0.35	Fig. 19, pink sandstone
55007	L1-67B	LW-46	0.20	0.15	0.14	Fig. 19, pink sandstone
55008	L1-67	LW-47	0.009	0.007	0.10	Fig. 19
55009	L1-68	LW-48	0.027	0.024	0.06	Fig. 19, coal
55010	L1-68	LW-49	0.004	0.001	0.06	Fig. 19, pink sandstone
55011	L1-68	LW-50	7.4	7.27	1.63	Fig. 19, yellow and black ore
55012	L1-69	LW-51	0.036	0.025	0.07	Fig. 19, pink sandstone
55013	L1-70	LW-52	1.2	1.38	0.96	Fig. 19, yellow and black ore
54014	L1-70	LW-53	0.006	0.004	0.07	Fig. 19, pink sandstone
55015	L1-72	LW-54	5.5	5.42	2.44	Fig. 19, yellow and black ore
55016	L1-72	LW-55	0.018	0.013	0.04	Fig. 19, pink sandstone
55017	L1-73	LW-56	1.7	1.77	1.31	Fig. 19, yellow and black ore
55018	L1-73	LW-57	0.006	0.004	0.05	Fig. 19, pink sandstone
55019	L1-73	LW-58				Plant sample. See text, p. 23
55020	L1-71	LW-59	0.003	0.002	0.06	Fig. 19, pink sandstone
55021	L1-71	LW-60	0.009	0.010	0.04	Fig. 19, pink sandstone
55022	L1-71	LW-61	0.26	0.19	0.86	Fig. 19, black ore
55023	L1-71	LW-62	4.6	4.57	1.72	Fig. 19, yellow ore
55024	L1-66	LW-63	0.079	0.10	0.06	Fig. 19, coal bed ·
55025	L1-66	LW-64	0.037	0.008	0.10	Fig. 19, basal pink sandstone
55026	L1-65	LW-65	0.013	0.006	0.06	Gray sandstone
55027	L1-78	LW-66	0.98	1.78	0.67	Yellow and black ore
55028	L1-78	LW-67	0.021	0.020	0.04	Pink sandstone
55029	L1-78	LW-68	0.008	0.007	0.08	Gray claystone
55030	L1-78A	LW-69	0.31	0.53	0.53	Pink sandstone
55031	L1-79	LW-70	0.033	0.012	0.53	Brownish red sandstone
55032	L1-34	LW-71	0.12	0.10	0.08	Brown siltstone in Fort Union formation