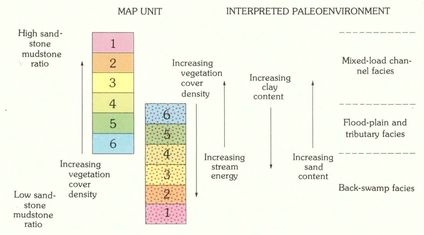
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1501

EXPLANATION

The numbers 1 through 6 represent vegetation cover density from high to low density, respectively, that are interpreted from the Landsat color-coded 5/6 ratio images. The dot pattern indicates areas of clinker or areas where clinker detritus has significantly contributed to the soils, that are interpreted from the Landsat color-ratio-composite images. The correlation between vegetation cover density, lithofacies, and paleoenvironments is indicated.



Twr Oligocene White River Formation
Tw Eocene Wasatch Formation } TERTIARY
Tf Paleocene Fort Union Formation

BASIN-AXIS LINEAMENT—Approximately located, dashed where questionable

FORMATION CONTACTS—After Colton and others (1978); Love, Christiansen, Earle, and Jones, 1978; Love, Christiansen, and Sever, 1978; and Keefer, 1974

VEGETATION COVER DENSITY LITHOFACIES BOUNDARY—Generally gradational

INTRODUCTION

The purpose of this report is to present an interpretation of the lithofacies distribution of the Eocene Wasatch Formation and Paleocene Fort Union Formation for the Powder River basin, to present a paleoenvironmental interpretation of the Wasatch Formation, and to define areas of the Wasatch Formation that appear favorable for uranium deposits on the basis of the model proposed by Raines and others (1978).

The Eocene Wasatch Formation crops out over a large part of the Powder River basin. The unit is lithologically variable, both vertically and horizontally, and its contact with the underlying Paleocene Fort Union Formation is commonly gradational and very difficult to define (Connor and others, 1976). The economic significance of coal and uranium in the Wasatch Formation has prompted much detailed work on local facies changes and patterns of deposition, but little is known about the regional facies patterns.

Work by Raines and others (1978) showed that vegetation density patterns which can be identified on Landsat color-coded 5/6 ratio images relate to the contrast between lithofacies in the Powder River basin. Thus, the vegetation can be used as a tool to map lithofacies within the Wasatch and Fort Union Formations. The rationale for producing the Landsat color-coded 5/6 ratio image is that generally, as the amount of vegetation cover in an area decreases, the reflectance increases in Landsat band 5 and decreases in band 6. Thus, a 5/6 ratio is inversely proportional to vegetation-cover density, and the vegetation-cover density is directly proportional to the sandstone-mudstone ratio of the bedrock. The exact relationship, however, depends upon the spectral properties of the rocks, soils, and plants present. Color coding of this ratio was done to further enhance subtle differences. The color-coded 5/6 images were interpreted by visually mapping areas of uniform colors or groups of colors.

LITHOFACIES

The lithofacies map was made for the Powder River basin using this color-coded 5/6 ratio image technique; however, modification for areas of clinker is necessary. The dot pattern on the map shows areas of clinker or areas where clinker detritus has made a significant contribution to the soils. This information was interpreted from a Landsat color-ratio composite image, discussed in Raines and others (1978). The conversion from vegetation density to lithofacies must be modified from that used by Raines and others (1978) because clinker provides an environment more favorable for vegetation, often including extensive stands of pine trees. The weathered clinker probably allows more moisture to accumulate in the soils, so more plants can grow in these areas. However, because clinker is the result of natural burning of coal beds, the areas of clinker are where coal swamps once existed. Therefore, the relationship between vegetation density and lithofacies has to be inverted and offset to change from the environment without clinker to the environment with clinker. This modification is indicated diagrammatically in the explanation of the map. Simply stated, in areas without the dot pattern, increasing numbers indicate a decreasing amount of vegetation and a decreasing sandstone-mudstone ratio in the bedrock. In areas covered by the dot pattern, increasing numbers indicate a decreasing amount of vegetation and an increasing sandstone-mudstone ratio in the bedrock. The correlation between these two numbering schemes is: unit 6 with dots has an approximately equal sandstone-mudstone ratio to the lower range of unit 4 without dots as indicated in the explanation on the map. This correlation was derived from consideration of the spatial distribution of the various lithofacies, the spatial distribution of coal areas, and the transition between environments of deposition.

Comparison of the lithofacies map with available geologic maps (Colton and others, 1978; Love, Christiansen, and McGrew, 1977, 1978; Love, Christiansen, and Earle, 1978; Love, Christiansen, Earle, and Jones, 1978; Love, Christiansen, and Sever, 1978; Denson and Horn, 1975; Keefer, 1974) shows a fair correlation with the Wasatch-Fort Union contact in the southern Powder River basin. This boundary in the southern Powder River basin is generally on the boundary of units 4 without dots and 6 without dots. Farther north, this relationship does not hold, and the previously mapped contact is within unit 4, indicating that the Wasatch Formation is generally clay rich and similar to the Fort Union Formation. This is not altogether unexpected because there is much controversy about the validity of this formation boundary in the Powder River basin (Connor and others, 1976; Levinson and others, 1979).

The lithofacies map shows only surface distribution of sediments, and the validity of extending these differences to depth may be questioned. However, Raines and others (1978) used well-log data to show that lithofacies boundaries in the southern Powder River basin separate more or less vertically bounded packages of sediments within the Wasatch Formation. This suggests that the regional environments of deposition were in a steady state through Wasatch time; that is, rates of subsidence stayed in equilibrium with rates of sedimentation so that the environments of deposition remained fixed in space. We suspect this steady-state condition was controlled by steadily developing geologic structures and was prevalent over the entire Powder River basin region. This is further supported by the stacking of the coal beds in the Wasatch and Fort Union Formations, which requires the coal swamps to have stayed spatially fixed.

The manner in which these units are exposed on a surface with topographic relief as shown in the diagrammatic cross section further supports this interpretation. This east-west cross section from the Buffalo area to east of Gillette shows that facies boundaries are nearly vertical or at least horizontally restricted. The local topographic relief is about one-third of the total formation thickness, and structural dip is significant on the western side of the basin, yet the mapped facies boundaries show relatively little influence of these factors. On the west, the entire Wasatch stratigraphic section is mapped as unit 3, a coarse-grained, moderately sand rich facies; on the east is unit 4, a fine-grained, moderately clay rich facies which includes at least half the Wasatch section; and in the center between Crazy Woman Creek and the Powder River is unit 6, a very fine grained, very clay rich unit, flanked on both the east and west side by unit 4. It is not possible to explain units 4 and 6 as a flat-lying sequence without proposing some rather complex and unsubstantiated folding. Even if folding were present, there is the problem of a contact between unit 3 (including all the Wasatch in the west) and units 4 and 6 (including all the Wasatch in the east). A nonhorizontal contact is required between these lithofacies.

Assuming the lithofacies map is a valid representation of the horizontal changes in vertically bounded packages of sediments in the Wasatch Formation, we interpret these lithofacies to be the products of the paleo-environments indicated in figure 1. The lithofacies of the exposed parts of the upper Fort Union Formation show a good spatial correlation with those of the Wasatch Formation. This suggests that the distribution of paleo-environments of the upper Fort Union was similar to that of the Wasatch Formation; therefore, the following discussion is probably equally applicable to the upper Fort Union Formation.

In the east and southeast, the Wasatch is composed of fine-grained, clay-rich sediments generally associated with coal. This indicates that for these areas with sources of sediments in the Black Hills and (or) the Hartville uplift, the only preserved parts are the fine-grained basin-interior sediments. The coarse-grained basin-margin sediments have been removed by erosion. These fine-grained facies are not suitable hosts for uranium deposits, and if uranium deposits existed in the Wasatch Formation from the Black Hills or Hartville sources such deposits have most likely been destroyed by erosion. Continuing west in the southern part of the basin are units 2 and 3. Unit 2 is associated with the main channels that crossed the Laramie Range and entered the basin from the south, probably from a Granite Mountains source. Here unit 3 is composed of the lateral, finer grained, overbank deposits of lesser channels associated with the major channels from the Laramie Range. This is in agreement with the findings of Seeland (1976; oral commun., 1979) concerning channel patterns in the southern part of the basin.

In the area extending from Sussex, along the Powder River, to Crazy Woman Creek is a large triangular area of the finest grained, most clay-rich part of the Wasatch Formation, unit 6. This is in the area where Seeland (1976) proposed that the paleo-Wind River entered the basin. The areas interpreted as unit 4 enclosed within unit 6, clay-rich but more sandy than unit 6, are interpreted as the deposits of the youngest channel of the paleo-Wind River where it crossed the associated clay wedge at the edge of the basin. The area north or downstream from this clay wedge is then modified by addition of sand mostly from the Black Hills source areas, but also possibly some sand from Bighorn Mountains streams that passed through the coal swamps.

Farther north along the eastern front of the Bighorn Mountains, the pattern shows exactly what should be expected. The Bighorn Mountains were high enough to be a barrier during Wasatch time (Rocky Mountains Association of Geologists, 1972, p. 236) and were a source of sediment. Very coarse, conglomeratic material deposited by high-energy streams is found near the mountain front (Sharp, 1948), but over a very short distance the facies change to coal swamps, now often indicated by the presence of clinker. Therefore, the eastern front of the Bighorn Mountains was, undoubtedly, very abrupt during Wasatch time.

BASIN-AXIS LINEAMENT

The basin-axis lineament, an important factor in the uranium deposition model, was defined as a tectonically active boundary between northwest-trending and east-northeast-trending linear features for the southern Powder River basin (Raines and others, 1978). The lineament extended into the northern part of the basin is shown on the map. The lineament is dashed because it is not well defined in the northern part of the basin, where no evidence for recent tectonic activity could be found. Therefore, there is some doubt as to whether this lineament extends northward beyond the Pumpkin Butte area. The interpretation from this previous work was that the basin-axis lineament was associated with post-Pliocene folding in the southern Powder River basin and is a boundary between an east-northeast-trending fracture domain on the west side of the basin and a northwest-trending fracture domain on the east side of the basin. These factors are believed to be influencing the ground-water system to make the area just east of this lineament more favorable for formation of uranium deposits.

URANIUM POTENTIAL

In Raines and others (1978) a regional model for the localization of roll-front uranium deposits in the Wasatch Formation in the southern Powder River basin was proposed. There are two basic factors in this model. First, uranium deposits occur at the boundary between domains containing northwest-trending and east-northeast-trending linear features, and this boundary is approximately defined by the basin-axis lineament. Second, and probably most important, the uranium deposits are associated with an areally restricted facies having an intermediate sandstone-mudstone ratio. The lithofacies associated with the uranium deposits (unit 3) terminates near Pine Tree except for a small branch continuing north to North Pumpkin Butte. This lithofacies in the southern part of the basin contains all of the known uranium deposits in the southern Powder River basin.

The facies sequence along the front of the Bighorn Mountains is similar to that in the southern Powder River basin which hosts uranium deposits. Also, the basin-axis lineament which divides unit 2 from unit 3 in the southern basin may divide these same units along the front of the Bighorn Mountains, and the surface waters, which are possibly associated with the ground-water flow, cross the lineament. Therefore, there may be a ground-water influence making the east side of the basin-axis lineament along the Bighorn Mountains favorable for uranium. Unit 3 along the Bighorn Mountains is similar to unit 3 in the southern basin, both in lithologic characteristics and structural setting, and is therefore proposed to have potential for uranium deposits similar to those in the southern Powder River basin. The major differences are: (1) the source areas are different, and (2) during Wasatch time the stream gradients probably changed more abruptly as the stream flowed out from the Bighorn Mountains, whereas in the southern part of the basin, the stream gradients were probably very gentle and parralleled the long axis of unit 3. These differences are difficult to evaluate, and no uranium deposits are known to us in the Wasatch Formation along the eastern side of the Bighorn Mountains. Possibly this lack of known deposits is because the rapid rates of sedimentation caused the uranium deposits to be buried, poorly formed, or associated with coal beds. Another possibility is that the Precambrian rocks of the Bighorn Mountains are not a good source of uranium, if a granite source is needed. However, we feel that there are sufficient similarities between unit 3 along the eastern side of the Bighorn Mountains and unit 3 in the southern part of the basin as described in the regional uranium deposition model presented by Raines and others (1978) that the area of unit 3 along the Bighorn Mountains should be carefully evaluated for uranium potential.

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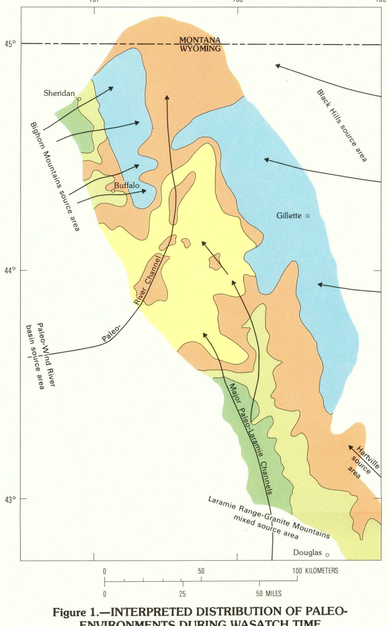
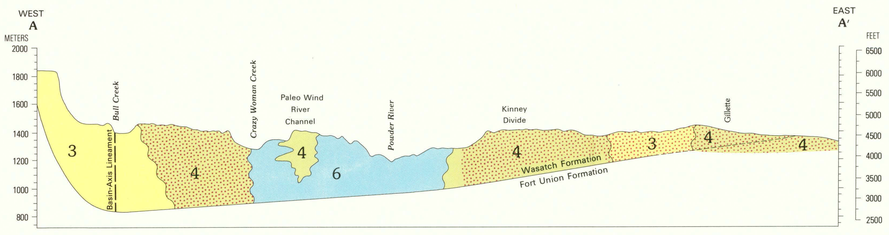


Figure 1.—INTERPRETED DISTRIBUTION OF PALEO-ENVIRONMENTS DURING WASATCH TIME



DIAGRAMATIC CROSS SECTION OF THE WASATCH FORMATION

SCALE 1:500 000

10 0 10 20 30 40 50 MILES

10 0 10 20 30 40 50 KILOMETERS

CONTOUR INTERVAL 500 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Base from U.S. Geological Survey
Montana, 1965, and Wyoming, 1964
State base maps

LITHOFACIES MAP, CROSS SECTION, AND FAVORABLE AREAS FOR URANIUM DEPOSITS, POWDER RIVER BASIN, WYOMING AND MONTANA

By
Gary L. Raines and Ronald W. Marrs

1983

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