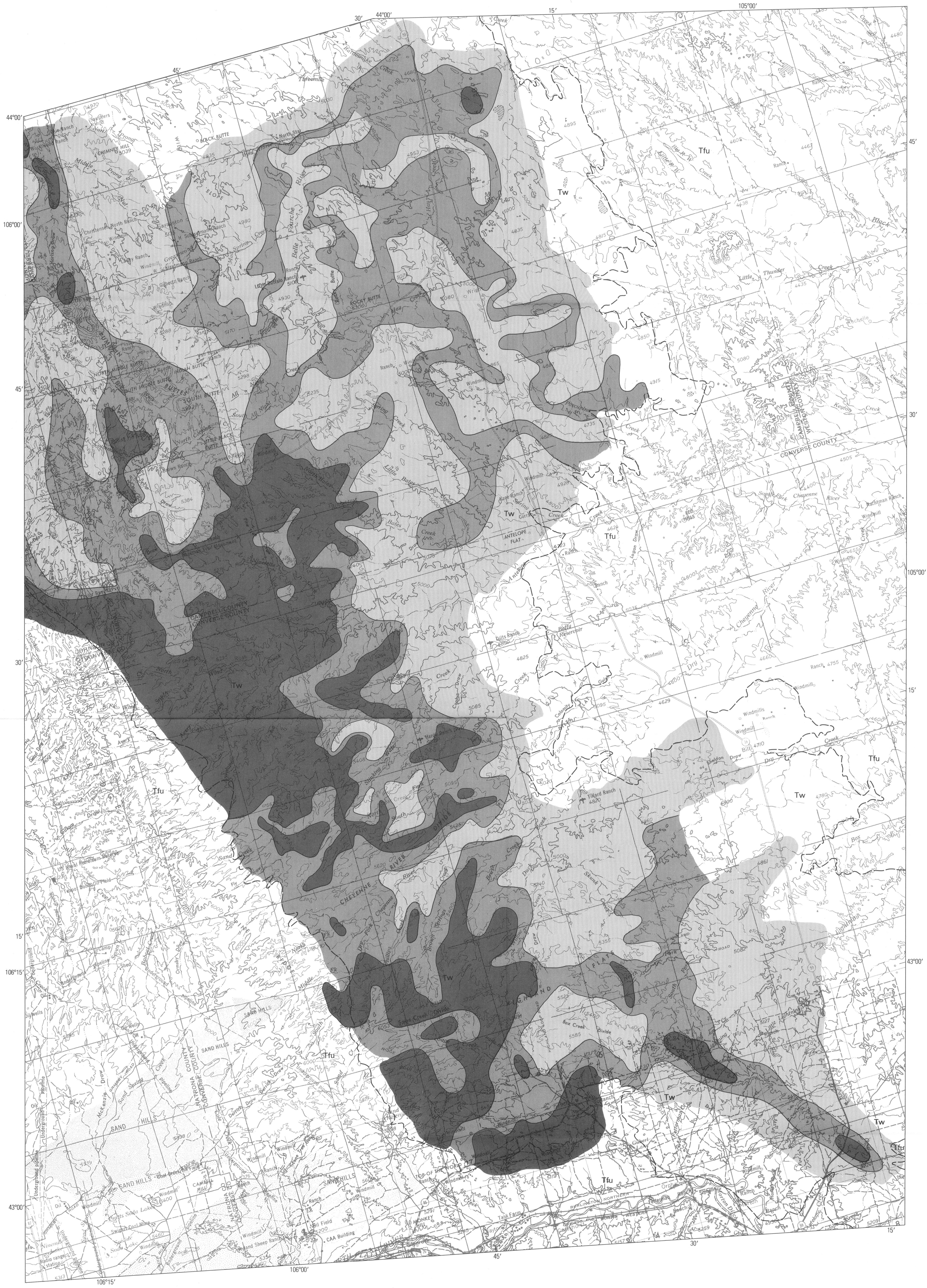


EXPLANATION

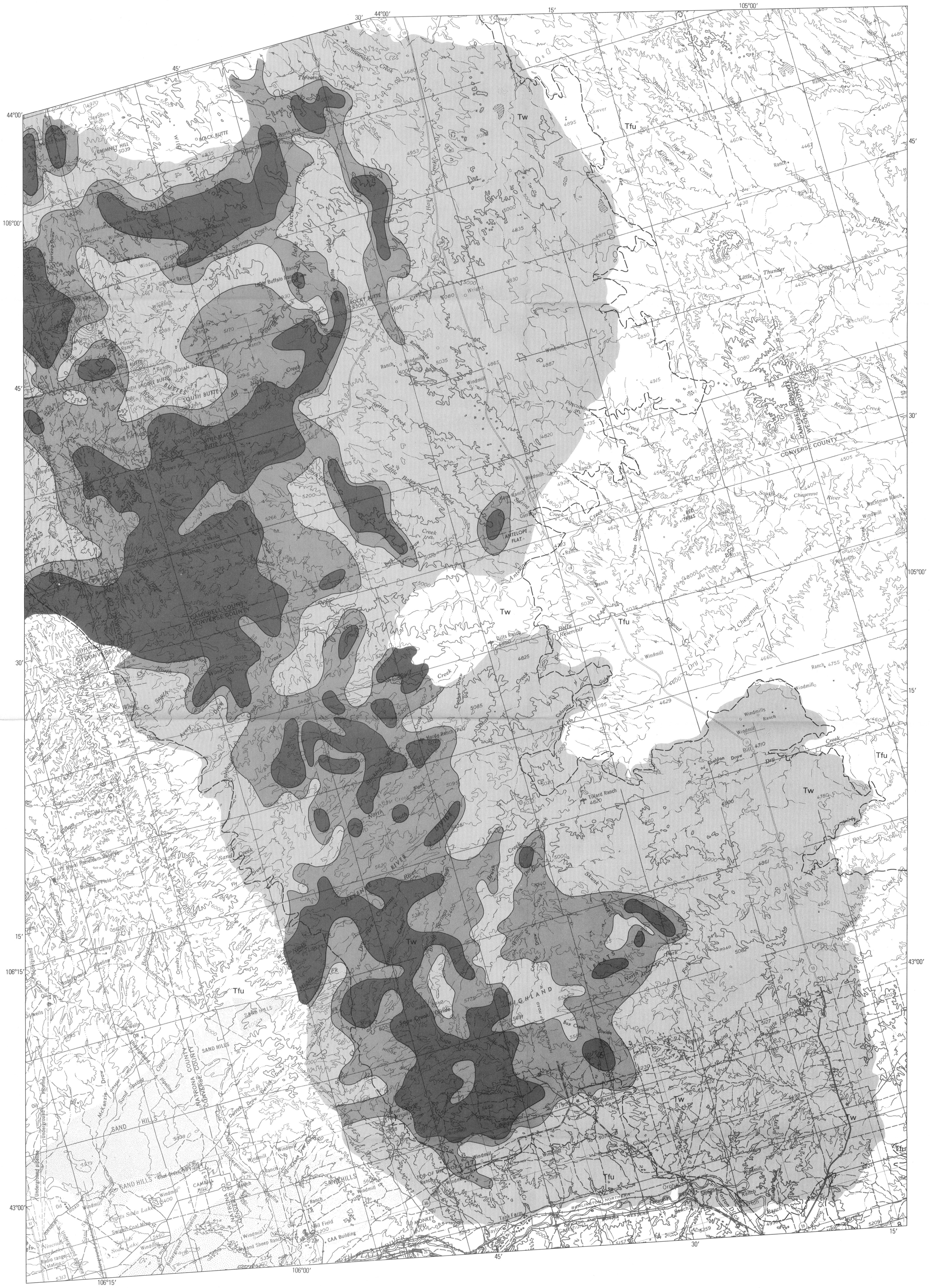
Tw	WASATCH FORMATION	TERTIARY
Tfu	FORT UNION FORMATION	TERTIARY

WASATCH-FORT UNION CONTACT—From Denson and Horn (1975) and Denson (written commun., 1977)

SANDSTONE/MUDSTONE THICKNESS RATIOS

- >1.0—Primarily coarse grained
- 0.5–1.0—Primarily intermediate grained
- <0.5—Primarily fine grained

MAP 4.—LITHOFACIES MAP OF SANDSTONE/MUDSTONE RATIOS FROM THE SURFACE TO 92 M



MAP 5.—LITHOFACIES MAP OF SANDSTONE/MUDSTONE RATIOS FROM 92 M TO 183 M

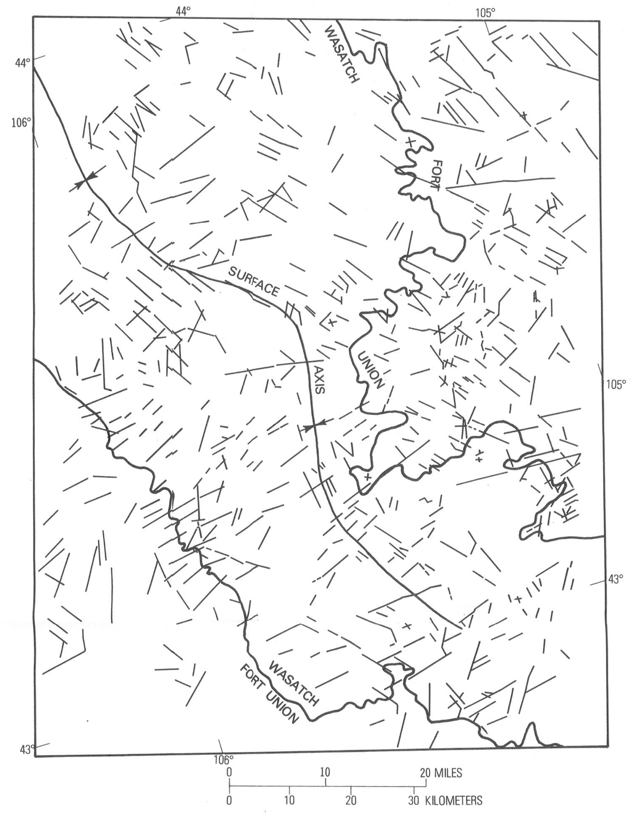


Figure 1.—*Digitized lineament map of the study area. The lineaments were digitized as straight lines that approximately follow the observed lineaments. The Fort Union-Wasatch contact is shown to aid in location.*

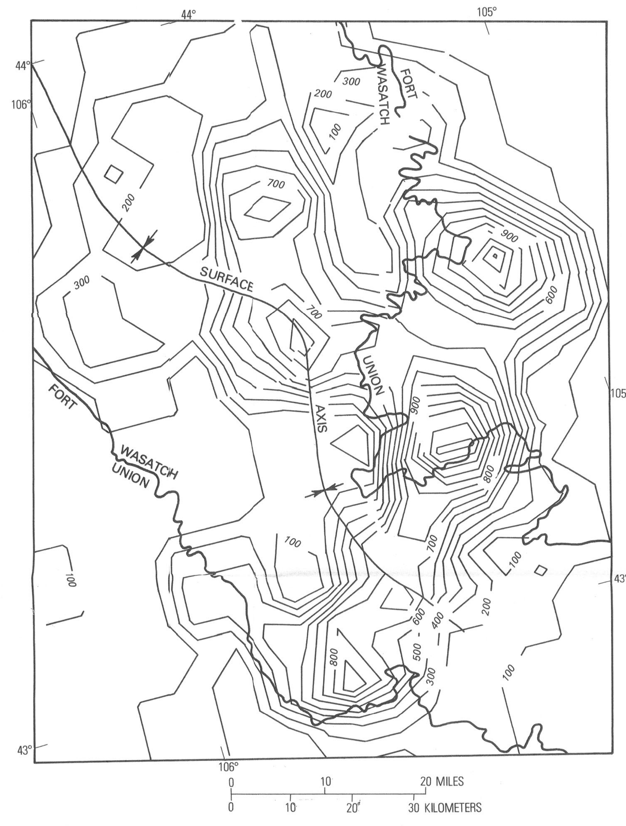


Figure 2.—*Contour map showing relative concentration of lineaments with a northwest trend (N. 55° W. to N. 32° W.), per 6-km grid cell. The contour interval, 100, is relative concentration and, therefore, is unitless. The Fort Union-Wasatch contact is shown to aid in location.*

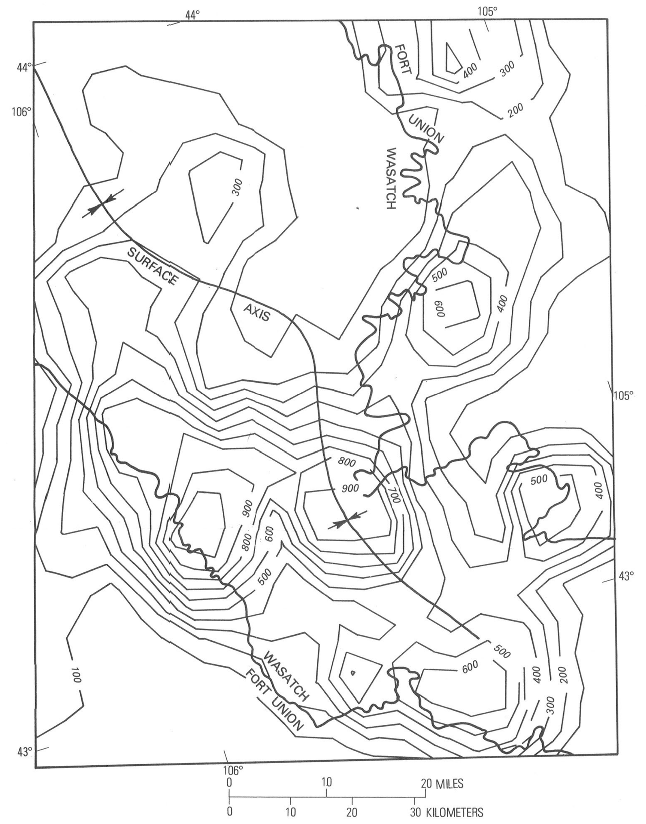


Figure 3.—*Contour map showing relative concentration of lineaments with a east-northeast trend (N. 82° E. to N. 55° E.), 6-km grid cell. The contour interval, 100, is relative concentration and, therefore, is unitless. The Fort Union-Wasatch contact is shown to aid in location.*

INTRODUCTION

Computer-enhanced Landsat images of the southern Powder River Basin have been used to define lithofacies within the Wasatch Formation and the regional distribution of limonite. From analysis of these data, regional controls of uranium deposition have been defined. In this analysis the limonite distribution was of marginal utility because both Landsat resolution restrictions and dense vegetation cover make detection of the limonitic altered areas difficult. Three of the five maps in this report are generated from Landsat imagery and include a computer-enhanced color-coded Landsat 5/6 ratio image (map 1), an interpreted vegetation map derived from the ratio image that subdivides the Wasatch Formation into three lithofacies on the basis of vegetation differences (map 2), and a limonite distribution map (map 3). The two other maps are supporting sandstone/mudstone ratio maps prepared from well logs (maps 4 and 5). This report briefly summarizes how maps 1, 2, and 3 were produced from the Landsat data and how they were interpreted. Full discussion of the work is presented in Raines and others (1978).

The rationale for producing the color-coded Landsat 5/6 ratio image is that generally, as the amount of vegetation cover in an area decreases, the reflectance generally increases in Landsat band 5 and decreases in band 6. Thus, a 5/6 ratio is inversely proportional to vegetation cover density. The exact relationship, however, depends upon the spectral properties of the rocks, soils, and plants involved. In a study of the sedimentary rock terrains along the Front Range of Colorado (Raines, 1974), vegetation cover was found to be adjusted in a very sensitive way to bedrock lithology. Therefore, the Landsat 5/6 ratio was anticipated to be a sensitive indicator of subtle lithologic changes. Color coding of this ratio was done to further enhance subtle differences. The color-coded 5/6 image (map 1) was interpreted by visually mapping areas of uniform colors or groups of colors. The results of this interpretation are shown in map 2.

As discussed in Raines and others (1978), from a statistical analysis of field measurements of vegetation density, the correlation coefficient between average values of the 5/6 ratio and measured vegetation density is 0.83. Squaring the correlation coefficient, 69 percent of the variation seen in the color-coded 5/6 image is due to vegetation density alone. Conclusions drawn from field observations were that (1) the differences in vegetation observed on the ratio image are real but very subtle, and (2) the hypothesis that bedrock sand content increased with vegetation cover is valid, but could be better evaluated from subsurface data.

Therefore, data from electric, gamma-ray, and lithologic logs of 1,180 holes drilled in as many sections in the southern part of the basin were used to generate two sandstone/mudstone ratio maps, one from the surface to a depth of 91 m (map 4), and one for the range 91 m to 183 m below the surface (map 5). These intervals were selected because (1) the large uranium-ore bodies now being produced occur very deep, well below the depths effecting vegetation, and (2) there was the question of what the relationship is between the surface and the subsurface. Both maps show that a high-energy fluvial facies, characterized by many thick sandstone units and relatively thin intercalated mudstone, siltstone, and coal beds, makes up the Wasatch Formation near its southern and western extent in the basin. To the north and east there is a progressive change to a relatively low energy facies characterized by a few thin sandstone units separated by thick units of mudstone, siltstone, and coal. Even though the intervals on each of the two maps (maps 4 and 5) cut across time-equivalent stratigraphic horizons, the similarity of the two facies maps indicates the high-energy facies in the near-surface rock persists to considerable depth. The sandstone/mudstone ratio maps, therefore, generally reflect a true picture of lateral facies changes in the Wasatch Formation. These facies are generally coincident with those defined at the surface in the vegetation density map (map 2). The lack of exact coincidence is left to be due to the differences in the intervals involved in the maps.

A lineament map from enhanced Landsat images (fig. 1) was constructed (Raines and others, 1978) on the premise that present-day linear topographic elements are, at least in part, fracture controlled and may reveal patterns related both to basin development and to specific local structures, paleotopography, and paleo-channel development. This lineament map was statistically analyzed and the patterns shown in figures 2 and 3 resulted. This analysis indicates that the west and east flanks of the basin are dominated by east-northeast and northwest fracture domains, respectively. The boundary between these domains is approximately the boundary of the high-energy, high sandstone/mudstone ratio and intermediate energy, sandstone/mudstone facies of map 2.

Perhaps the single most significant structural feature, the basin-axis lineament, was first observed on map 1. The color-coded image shows clearly that drainage systems flowing northeast are either deeply incised or sharply deflected where they cross this lineament. The most marked change in stream patterns across this lineament is characterized by alluviated channels west of the lineament, a few kilometers of narrow, incised channels with bunched meanders where they cross the lineament, and finally, broad channels again east of the lineament. Cross sections constructed from well logs suggest the presence of a low-amplitude synclinal downwarp extending the length of the lineament, with its axis directly under the lineament. It appears that the streams predate the latest tectonic activity of this structure, and that probably as the streams flowed across a newly forming sag, they were forced to cut their channels more sharply across the downstream or east flank of the sag. East of this lineament and within the intermediate sandstone/mudstone ratio area (the Y-G area of map 2) are the areas of the uranium-bearing Box Creek, Highland Flats, and Monument Hill districts. Also included are the large production areas and most of the small prospects of the Turnercrest and Pumpkin Buttes districts.

Based on these maps and considering the known uranium occurrences in the study area, three primary findings are made that have a bearing on localization of uranium. First, analysis of lineaments shows the west flank of the basin to be dominated by east-northeast-trending lineaments, and the east flank to be dominated by northwest-trending lineaments. Secondly, the basin-axis lineament marks a recently active tectonic feature and is the approximate boundary between the two lineament domains; most of the uranium is just east of this lineament. Finally, the study of vegetation distribution, which can be related to lithofacies within the Wasatch Formation, suggests that the uranium deposits are associated with an areal-restricted facies, having an intermediate sandstone/mudstone ratio.

The limonite distribution map (map 3) can be integrated, in a limited fashion, with these findings. This map is a computer-generated interpretation of a Landsat color-ratio composite. The objective in producing this map was to test the applicability of mapping limonite with Landsat data as an exploration guide to altered areas related to uranium deposits. As the map clearly shows, most of the limonitic areas are not within the Wasatch Formation. Furthermore, field checking indicated that these areas are generally related to types of limonitic materials unassociated with uranium deposits, especially clinkers from burned coal beds. Therefore, by combining the facies defined in map 2 with this limonite distribution map, most of the inappropriate limonitic areas can be eliminated and only those limonitic areas within the intermediate facies favorable for uranium need to be considered. The limonitic Y-G areas, located within the Wasatch formation on the northeast part of the map, can be eliminated as areas of high uranium association. By knowing that the major limonitic areas are associated with clinkers and that a denser growth of vegetation develops on clinker soils than the clay-rich Wasatch-derived soils, these Y-G areas are excluded from those of uranium favorability. Thus, the conclusion regarding the utility of the limonite map is that (1) some of the known uranium districts have associated limonitic areas, most of which are not well defined, and (2) the limonite map is useful in sorting out clinker-related vegetation changes that are unrelated to general bedrock lithology.

REFERENCES CITED

Denson, N. M., and Horn, G. H., 1975, Geologic and structure map of the southern part of the Powder River Basin, Converse, Niobrara, and Natrona Counties, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-877, scale 1:125,000.

Raines, G. L., 1974, Evaluation of multiband photography for rock discrimination: Golden, Colorado, Colorado School of Mines, unpublished Ph.D. thesis, p. 6–19.

Raines, G. L., Offield, T. W., and Santos, E. S., 1978, Remote-sensing and subsurface definition of facies and structure related to uranium deposits, Powder River Basin, Wyoming: Economic Geology, v. 73, no. 8, p. 1706–1723.

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1980—G80062

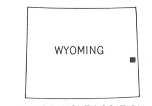
Compiled by Elmer S. Santos, 1979

Base from U.S. Geological Survey
Arminto, 1955–74, Casper, 1955–61,
Newcastle, 1955–62 and Torrington, 1954–62

APPROXIMATE MEAN DECLINATION 1980

SCALE 1:250 000

CONTOUR INTERVAL 200 FOOT
NATIONAL GEODETIC VERTICAL DATUM OF 1929



QUADRANGLE LOCATION

MAPS SHOWING LITHOFACIES AND LIMONITE DISTRIBUTION OF THE WASATCH FORMATION IN SOUTHERN POWDER RIVER BASIN, WYOMING

By

Gary L. Raines and Elmer S. Santos

1980