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GEOLOGICAL SURVEY

Gold And Uranium Potential Of The Wind River Formation On The Wind River Reservation, Northwestern Wyoming

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Contents

ILLUSTRATIONS

TABLES

ABSTRACT

On the southwest side of the Wind River Basin Eocene paleostream flow was generally to the northeast off the northwest-southeast trending Wind River Range. An important deviation from this pattern is apparent in an area north of Fort Washakie where the streams were deflected northward by an anticlinal ridge that rose synchronously with the Wind River Range. Anticlinal stream deflections should result in decreased stream gradients, thicker sandstone bodies, and concentrations of organic debris. Areas of lowered stream gradients would thus create favorable environment for the formation of an uranium deposits, and, once formed, a deposit in this position would be more likely to be preserved. Similar deflections of Eocene streams by structural ridges occurred at both the Gas Hills and Shirley Basin districts. Other anticlinal ridges, now deeply buried, that are perpendicular to Eocene stream flow such as the Riverton, Beaver Creek, Sheldon and Steamboat Butte anticlines may also have created Eocene paleo-environments favorable to the formation and preservation of uranium deposits.

Analyses of samples of unmineralized Eocene sandstone and siltstones from the western part of the Wind River Basin on the Wind River Reservation show that samples from the area south of the Eocene Wind River, as located by a paleocurrent study, have significantly more uranium than equivalent samples north of the river. Analyses of granitic rock samples from the Wind River Range on the south side of the basin and from the Owl Creek Mountains on the north side of the basin shows a corresponding difference: granitic rocks on the south side of the basin contain substantially more uranium than those on the north side. This relationship suggests that the provenance of the sandstones may be an important factor that favors the formation of uranium deposits.

Study of sand-grain size and shape data suggests that three major tributaries to the Wind River of Eocene time entered the Wind River Basin from the south. Sediments deposited in these tributaries provided host sandstones that are favorable uranium exploration targets. The streams drain areas of favorable granitic source rocks. Oligocene streams with similar alignments may have provided access of uranium-rich water to the favorable sandstones thus supplementing the uranium derived from granitic sources. Oligocene sedimentary rocks of Wyoming are rich in volcanic ash and devitrification of the ash has been postulated to be an important source of uraniferous ground water.

The distribution of roundstone conglomerates in the uppermost Wind River Formation in the western Wind River Basin marks the course of the Wind River of Eocene time as determined by crossbedding direction studies. The course of the Wind River of Eocene time is significant because gold analyses of panned concentrates of the roundstone conglomerates may indicate economic potential. At 1986 prices (335 dollars per ounce), the mean gold value per cubic meter is about one and one-half dollars. About 300 million cubic meters of roundstone conglomerate are indicated by surface exposures. Conglomerate volumes decrease eastward but gold content does not. If sandstones of this stratigraphic horizon exist to the east, and have an similar gold content, then the course of the Wind River of Eocene time should define the location of a substantial additional volume of auriferous rocks.

INTRODUCTION

This report, which is focused on the gold and uranium potential of the early Eocene Wind River Formation of the western Wind River Basin, supplements an earlier report that reviewed all the known economic mineral and energy resources of the Wind River Reservation and proposed additional geologic investigations (Seeland and Brauch, 1975). The results of those additional investigations, in part funded by the Bureau of Indian Affairs, are detailed in this report. Permission to perform geologic investigations on the reservation was granted by the Tribal Council representing the Arapahoe and Shoshone tribes.

URANIUM POTENTIAL OF THE WIND RIVER FORMATION

Although uranium has been found in Wyoming rocks ranging in age from Precambrian to Pleistocene (Finnell and Parrish, 1958), the major deposit of the Wind River Basin--The Gas Hills district--and the other major deposits of Wyoming, the Crooks Gap, Shirley Basin, and Powder River Basin districts, are in rocks of Early Eocene age. Early Eocene rocks cover nearly one-half of the area of the reservation. It is highly probable that if economic concentrations of uranium are found on the reservation they will be found in the early Eocene Wind River Formation. This report will, therefore, assess the favorability of and develop guides to areas of the early Eocene Wind River Formation which might be explored for uranium by additional geologic or geophysical work, or by drilling.

Most of the major uranium districts of Wyoming are in areas of arkosic sandstones derived from specific granitic terranes. A paleocurrent study defining provenance areas is thus of fundamental importance in assessing the uranium potential of the Wind River Formation on the reservation.

A geochemical study was also made that identified the most likely uranium source terrane. Sand-grain size and shape studies were used with the paleocurrent information to infer an Eocene stream pattern that, with the geochemical data, suggests which areas of the reservation are most likely to contain uranium deposits.

Samples and data were collected for the paleocurrent, geochemical, and petrographic studies throughout the Reservation at the locations shown on figure 1.

Paleocurrent Study

Methods

Crossbedding is ubiquitous in the fluvial sandstones of the Wind River Formation and provides the basic information for a paleocurrent study. Trough crossbedding is the dominant type, but other types of crossbedding are present. A total of 1206 crossbed measurements were made at 93 localities in the Wind River Formation on or near the Reservation (fig. 2).

Crossbed dips and dip directions (azimuths) were determined with a compass and level crossbed measuring device. Trough axis orientation of cross-bed sets was preferentially chosen but was not often available. The mean number of crossbed measurements made at each outcrop was 13 and ranged from 5 to 20.

The mean transport direction at a locality was determined by a vector summation of the individual crossbed orientations (Potter and Pettijohn, 1963). The vector summation method used here involves "tail to head" addition of unit-length vectors. The resultant is the vector mean and the mean river current direction. The length of the resultant divided by the number of measurements times 100 is the vector strength, a measurement of variability of the current direction at the locality. If all crossbeds at a locality have the same orientation the vector strength is 100 percent; if the crossbeds are randomly oriented then the vector strength is zero.

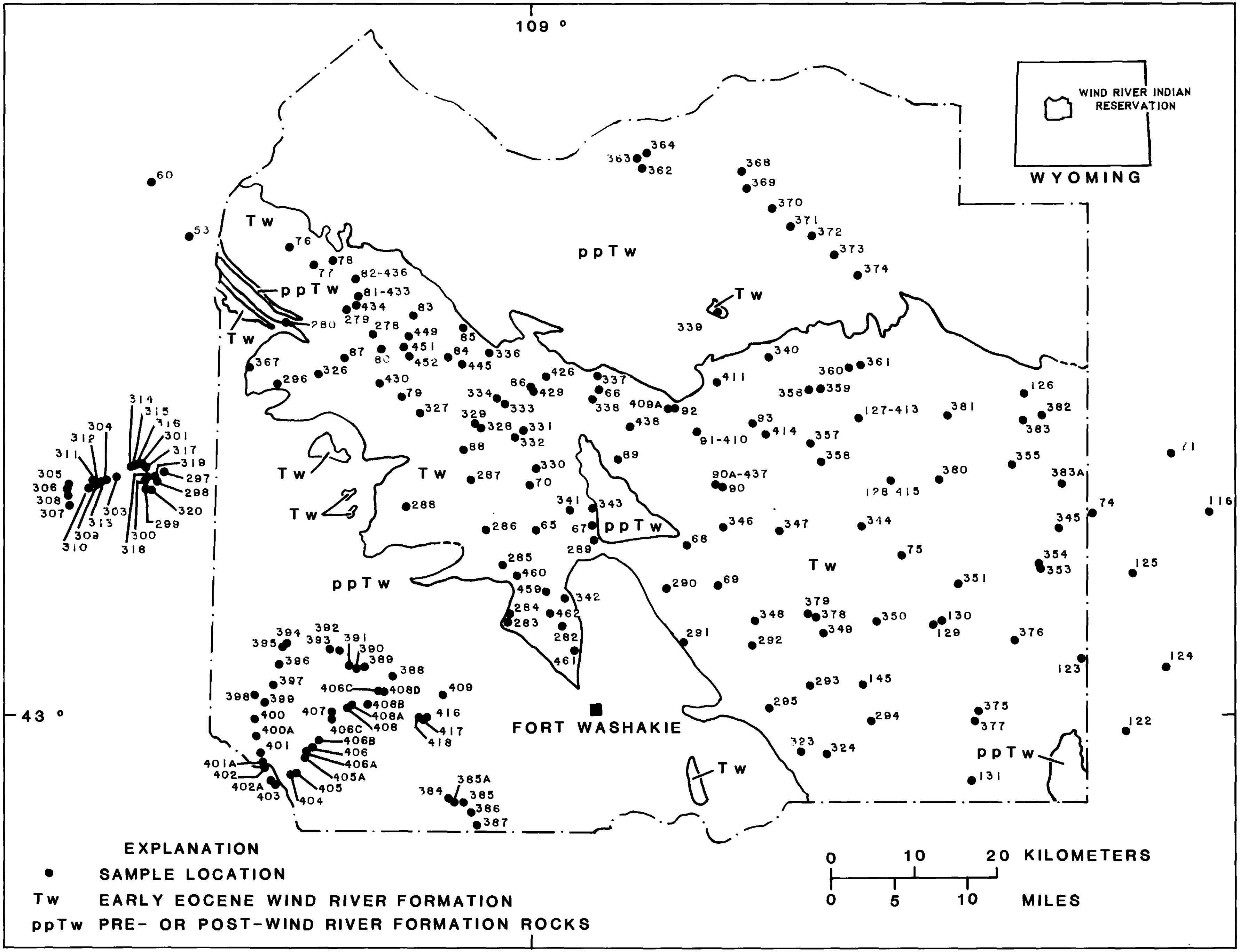

Figure 1.--Field station location map.

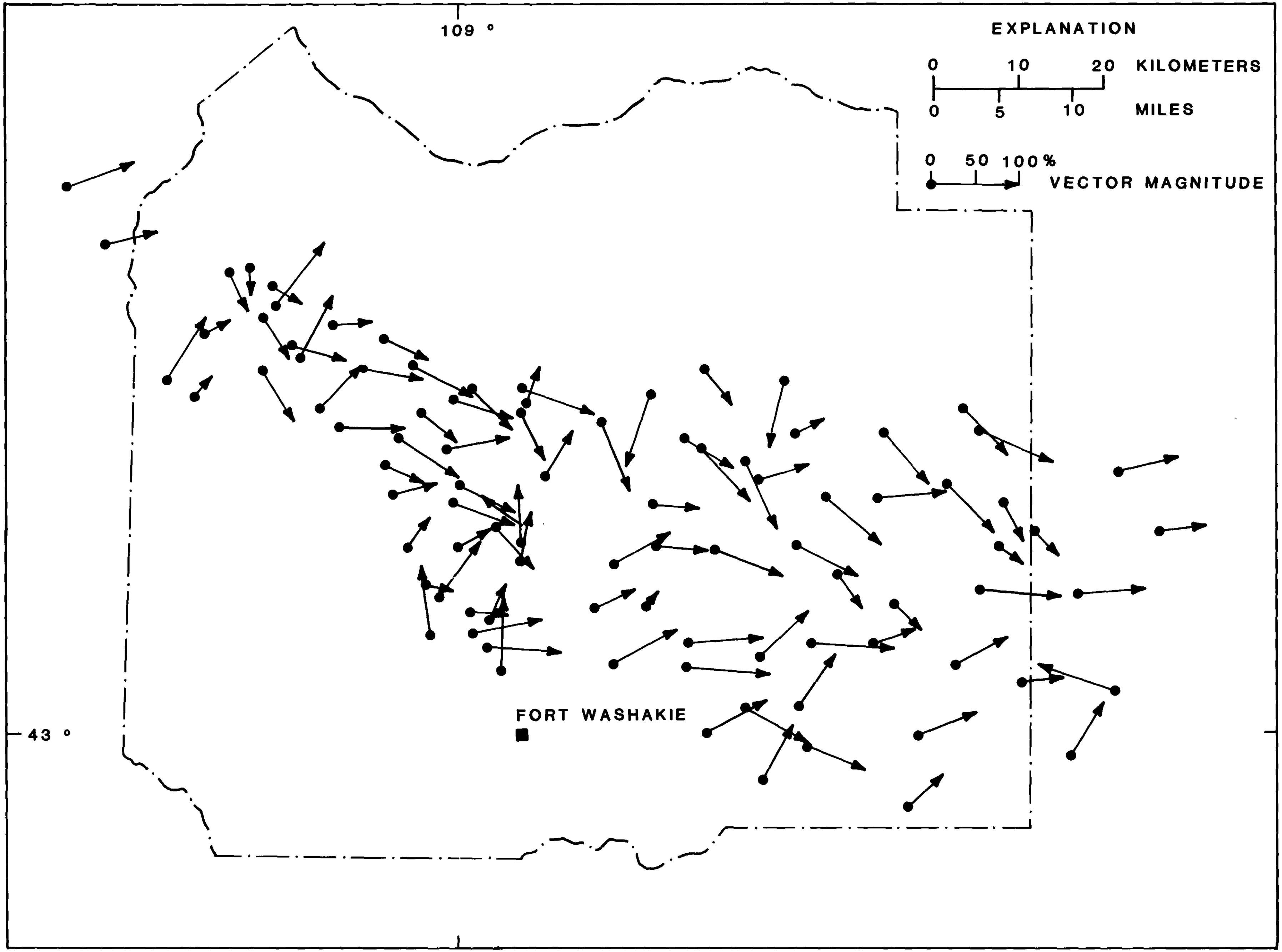

Figure 2.--Crossbedding vector mean map of the early Eocene Wind River Formation.

A vector mean map (fig. 2) shows the locality vector means. The length of the arrow is proportional to the vector strength. The vector mean map was smoothed using a moving average technique (Potter and Pettijohn, 1963), to produce the moving average map (fig. 3). The technique consists of placing an appropriately sized grid over the vector mean paleocurrent map and graphically obtaining a vector mean direction for the field stations included in each two by two group of four squares; the arrow representing the mean direction was plotted at the center of the group of four squares.

In the marginal areas of the map single divergent current directions can result in as many as four moving averages that repeat the one direction. This is particularly misleading because of their visually prominent positions. In order to minimize this effect, the two vector mean crossbed directions outside of but closest to the center of the block of four squares were used to perform a three-component vector summation. If a four-square block contained two crossbed localities then one locality outside of but closest to the center of the group was used to perform a three component vector summation. Again, the length of the arrow is proportional to the vector strength.

Eocene stream pattern

In many places the fluvial channel sandstones cap linear ridges as at station 128. Where topographic conditions are optimum, linear ridges in the topography can be seen on the topographic maps; these parallel the current directions obtained by crossbed measurements. A sinuous channel trend, only partially reflected in the topography, was seen but most channel trends are linear and are generally parallel or subparallel to current directions as interpreted from the moving average map. A vector summation of all 1206 crossbed measurements indicates the average current direction and the average channel orientation were 89.7^{0} and that the overall vector strength was 44 percent. A visual estimate of the mean transport direction and the degree of dispersion can be made from the crossbedding dip direction rose diagram (fig. 4).

Grid spacing was determined by a trial and error process and should vary depending on the field station density and the desired degree of smoothing. If the grid spacing is much too large the data is reduced to a single vector mean. If the grid spacing is very small trends are obscured and in most cases a group of four squares will have less than the required three crossbed localities. The moving average map (fig. 3) has a grid line spacing of 5 km and the center of each arrow is centered on the grid point so as not to displace the perceived location of the current direction toward the point of the arrow. The course of the Wind River of Eocene time trends eastward across the reservation and is plotted on figure 5. It was located by drawing a line of convergence between southeasterly trending and northeasterly trending moving average current directions. The Wind River of Eocene time flowed eastward through the northern part of the Wind River Basin and left the Basin near the town of Waltman (fig. 6), then flowed across the Casper Arch and entered the Powder River Basin near the town of Sussex, and flowed northward along the west side of the basin (Seeland, 1976, 1978).

On the Wind River Reservation, as in the rest of the western Wind River Basin, the Wind River of Eocene time separates an area of Wind River Formation to the south that had a dominantly Wind River Range source, from an area to the north that had a dominantly Owl Creek Mountains-Washakie Range source (fig. 6). This source area contrast will be used later in the geochemical assessment of the relative favorability of different parts of the reservation for uranium deposits.

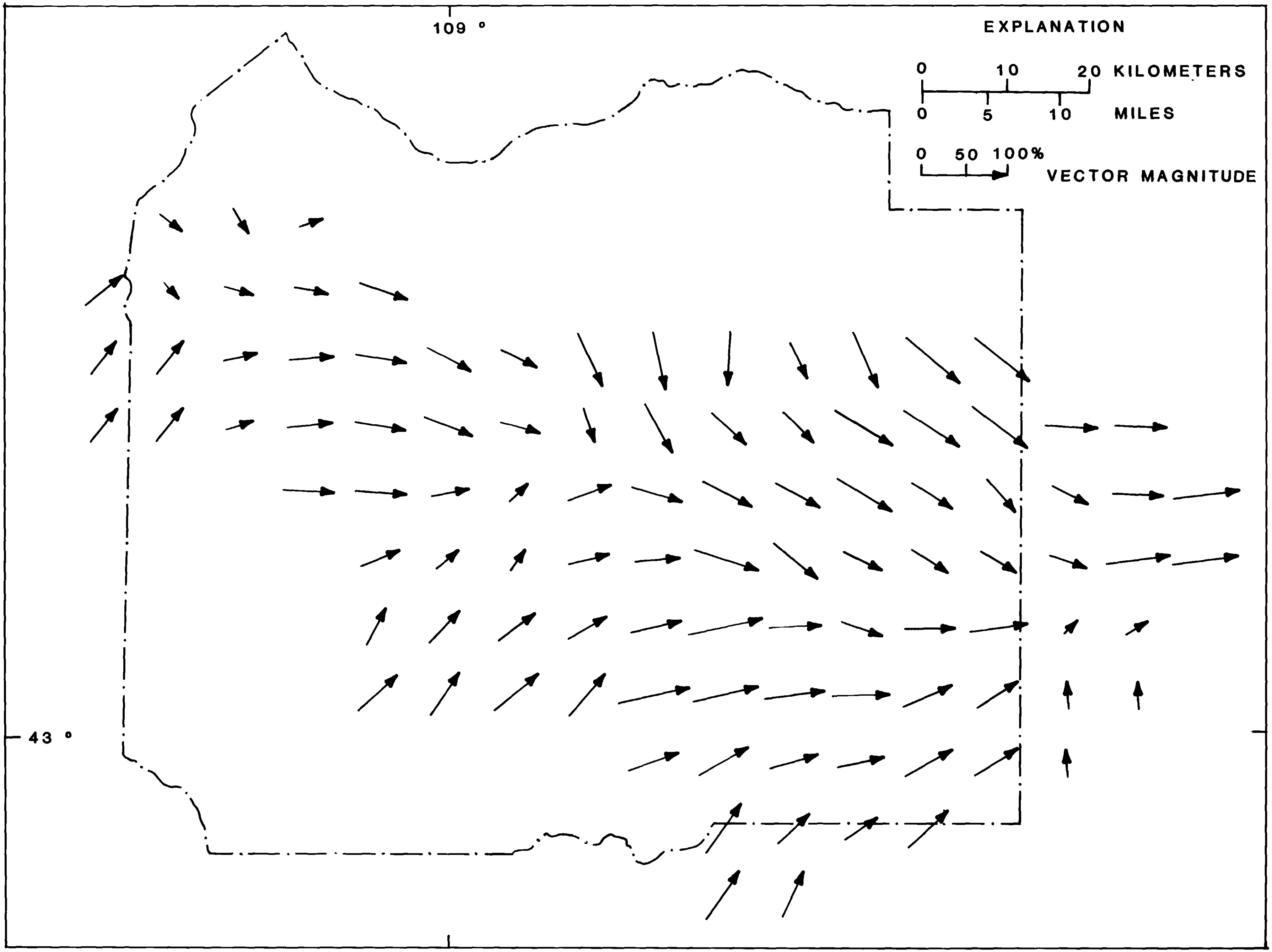

Figure 3.--Crossbedding moving average map of the early Eocene Wind River Formation.

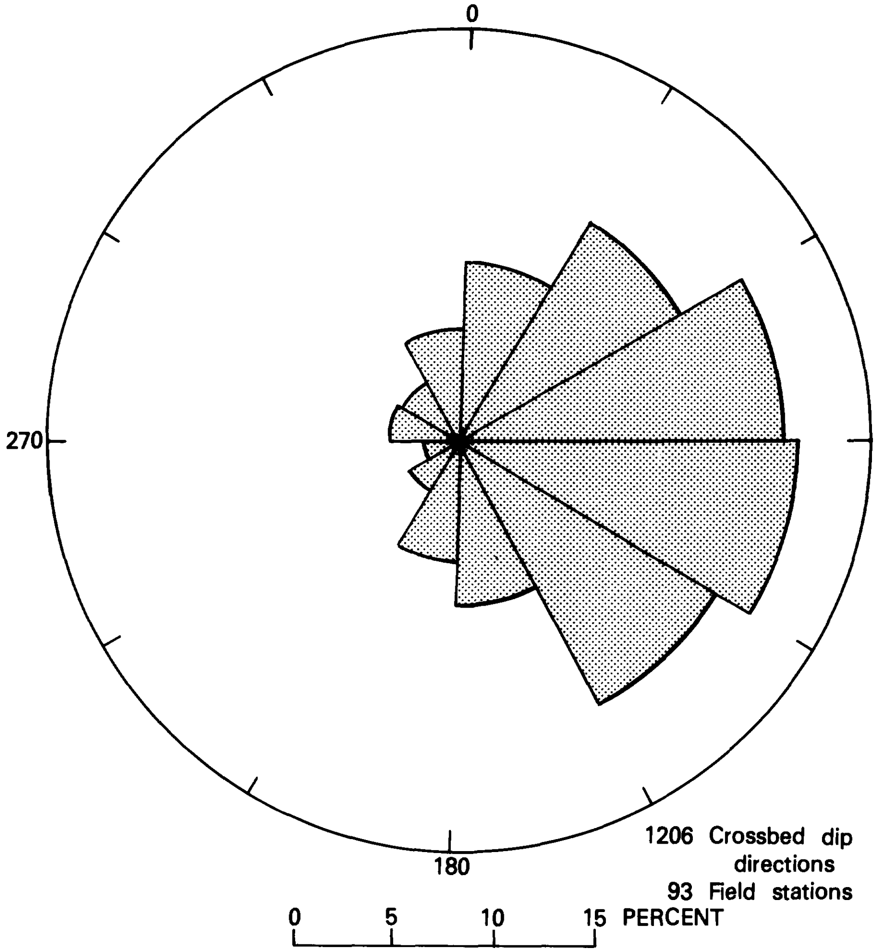

Figure 4.--Crossbedding dip direction rose diagram of the early Eocene Wind River Formation.

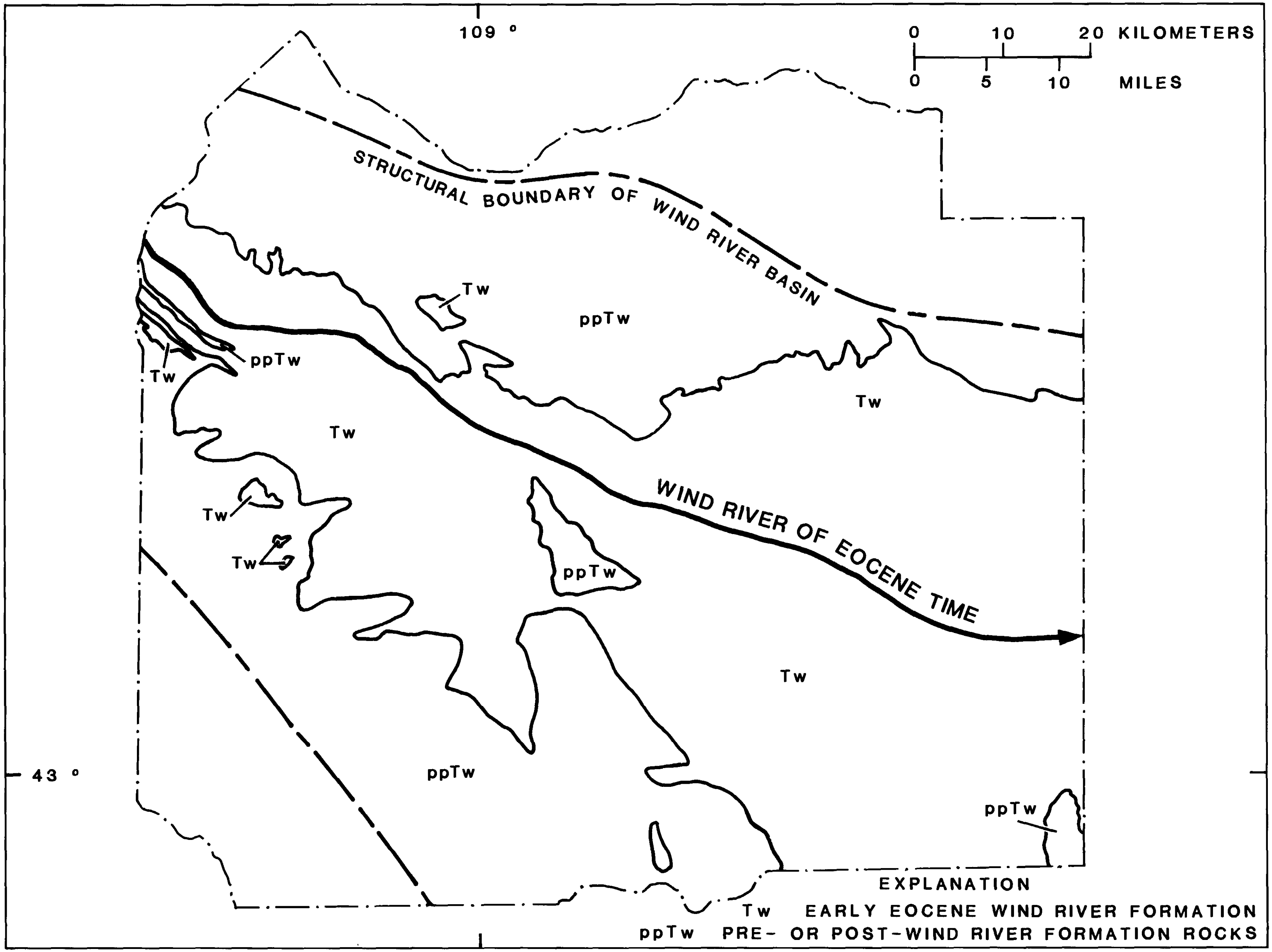

Figure 5.--Course of the Wind River of Eocene time.

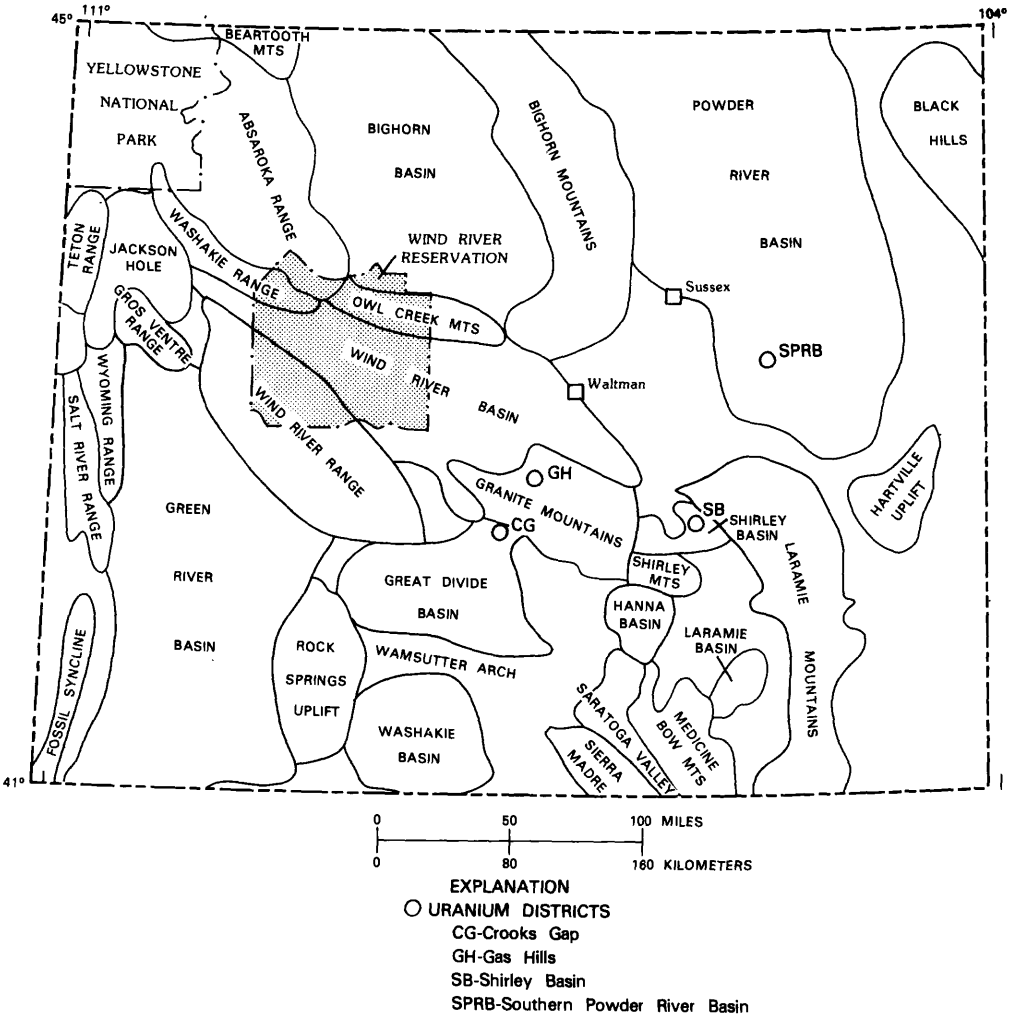

Figure 6.--Uplifts, basins, and uranium districts of Wyoming.

Anticlinal stream deflections on the Wind River Reservation

The vector mean crossbedding map (fig. 2) shows that a fairly obvious perturbation of early Eocene stream directions occurred in an area northwest of Fort Washakie. In this area a nearly continuous series of oil-producing structures, the Sage Creek, Winkleman, Pilot Butte, and Steamboat Butte anticlines bring Mesozoic rocks to the surface (fig. 7). These anticlines seem to have risen synchronously with the Wind River Range (Keefer, 1970) and to have formed a series of anticlinal hills that were approximately perpendicular to the eastward to northeastward flowing streams of the northeast flank of the Wind River Range. This series of anticlines continues to the north side of the basin. The Sheldon and Northwest Sheldon anticlines lie north of the Wind River of Eocene time. The deflection of streams by the anticlines can be seen on figure 8. The Sage Creek-Winkleman-Pilot Butte anticlinal trend south of the Eocene Wind River has a mean trend of 165 degrees. The stream directions west of and closer than 10 km to this part of the anticline have a vector mean azimuth of 35^{0}. The streams east of and closer than 20 km to this part of the anticline have a vector mean azimuth of 71^{0}. The vector mean data indicate that the topographic expression of the anticlinal structures north of Fort Washakie caused a northward deflection of the streams flowing off the northeast flank of the Wind River Range during the Eocene. A consequence of this deflection would be lowered stream gradients, which would decrease the energy available for sediment transport. Much coarse-grained arkosic sand carried in by relatively high gradient streams would be deposited. The coarse-grained sand would be interbedded with organic debris and fine-grained overbank silts and muds which would seem to be an ideal sedimentary environment for the formation of a uranium deposit. The anticlinal ridge might be expected to have the same effect on ground water flow that it would have on stream flow, that is, a decrease in the flow velocity which would tend to decrease the rate at which a uranium deposit, once formed, would move basinward. Thus, deflection of early Eocene streams by anticlinal hills is a factor, when taken together with other favorable conditions, that increases the probability of the formation and preservation of a uranium deposit in certain areas.

Figure 9 is a map showing anticlinal crest lines on the Wind River Reservation combined with a generalized interpretative paleostream map based on paleocurrent directions and the grain size and shape analysis. The areas thought to be most favorable for the discovery of uranium deposits lie on the upstream sides of the anticlines. The anticlines are located on both the north and south sides of the basin, and north and south of the Eocene Wind River. Stream deflection behind the Sage Creek-Winkelman-Pilot Butte anticlinal trend near Fort Washakie is documented by field observations. Deflections shown on the upstream side of other anticlines such as the Little Dome and Riverton anticlines are hypothetical because of the anticlines deeply-buried positions in the interior of the basin. The streams were deflected early in the development of the anticlinal ridges. Basin subsidence and deposition resulted in the eventual overtopping of the ridges by the accumulating sediments allowing the streams to flow unimpeded toward the Wind

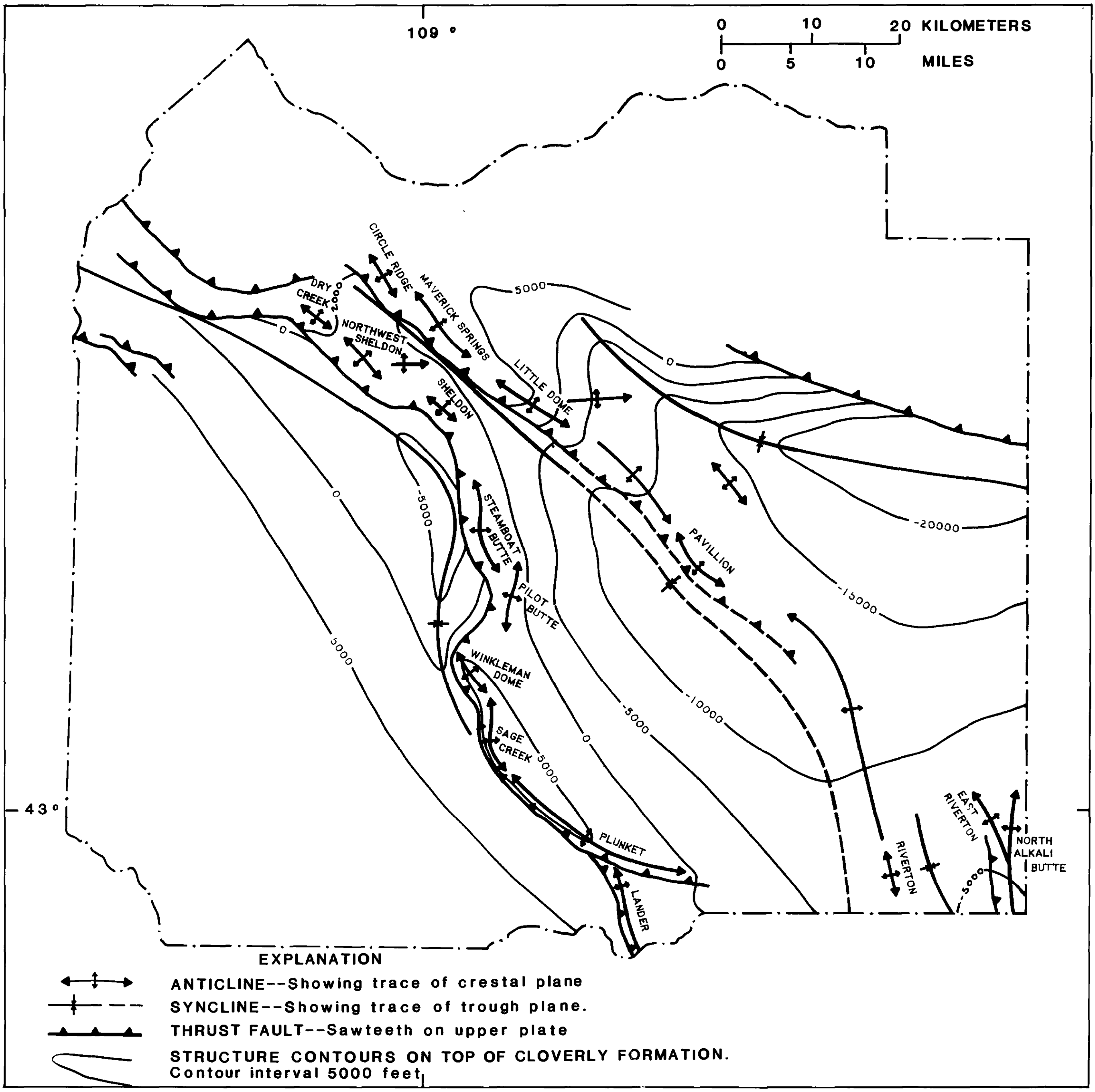

Figure 7.--Laramide structures of Wind River Basin, Wind River Reservation.

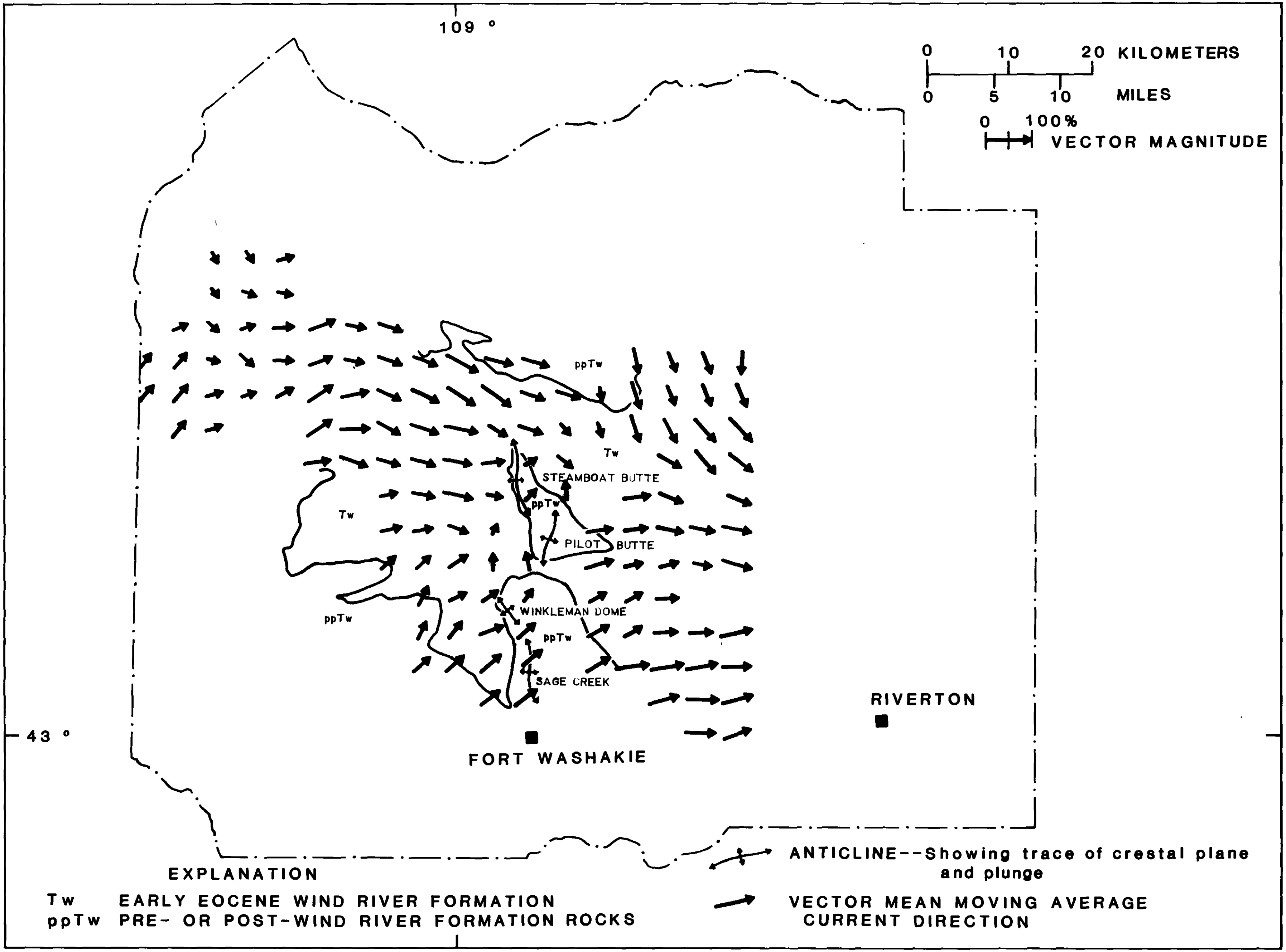

Figure 8.--Deflection of early Eocene streams by anticlinal hills.

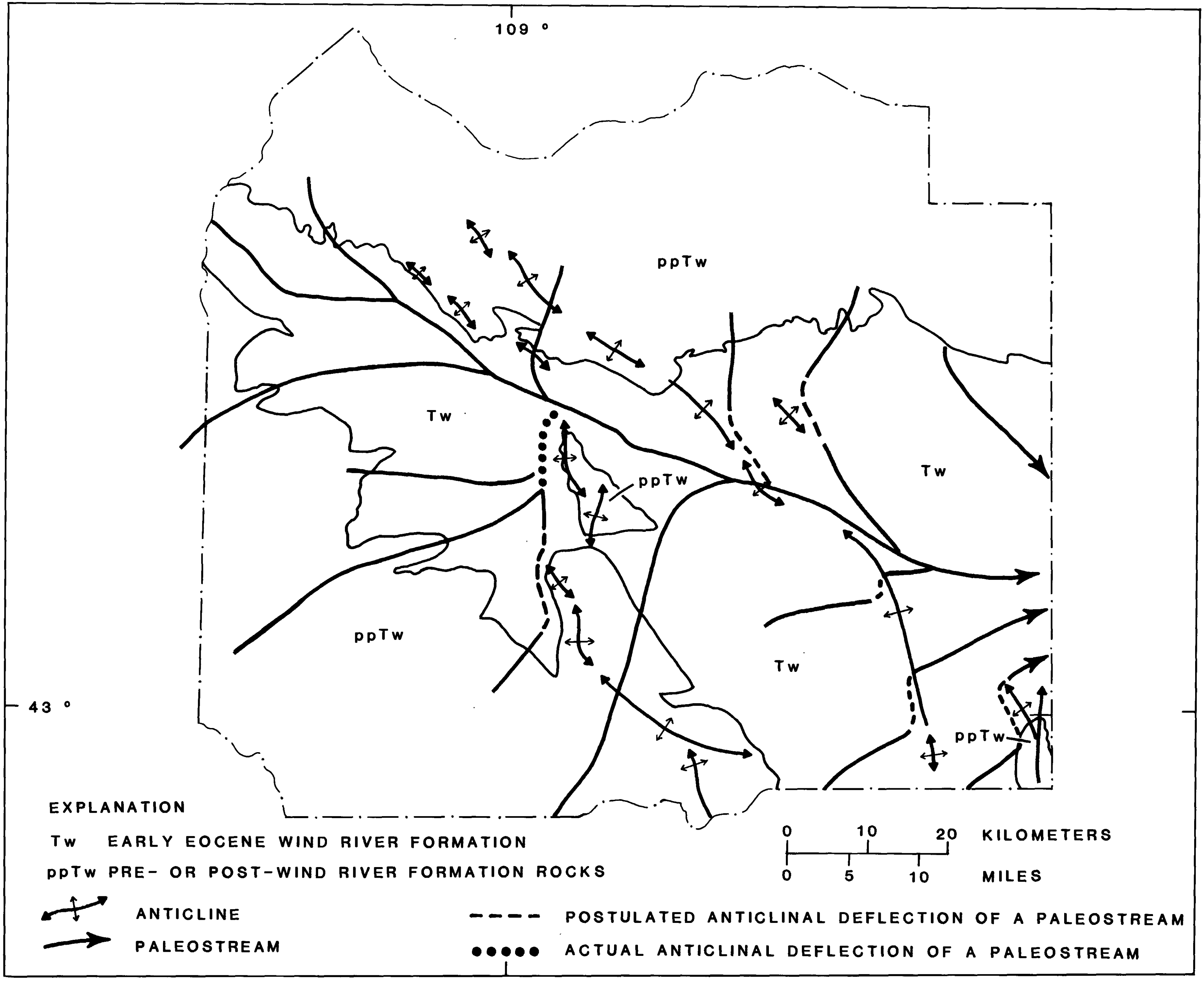

Figure 9.--Interpretative early Eocene paleostream map.

River of Eocene time at the depositional center of the basin, unless subsequent tectonism caused the re-establishment of the anticlinal ridge. This is not likely because structural deformation was most intense at the beginning of Wind River time and decreased until near-quiescence was reached at the end of Wind River time.

Many uranium deposits have been found by the examination of gamma-ray logs from oil tests but most exploratory drilling for oil on the Reservation has been concentrated on the axes of the anticlines and thus the most favorable areas for the occurrence of uranium deposits along the upstream sides of the buried anticlines may not have been adequately tested.

Anticlinal stream deflection and the localization of Wyoming uranium deposits

The areas thought to be most favorable for the discovery of uranium deposits lie on the upstream sides of the anticlines. The suggestion that anticlinal stream deflection might localize uranium deposits on the Wind River Reservation could be dismissed as entirely speculative, but three of the four largest uranium districts of Wyoming lie up-basin from structurally formed buried or partially buried topographic ridges as noted in the Shirley basin by Harshman (1961, 1972). Most of the Shirley Basin deposits are in Eocene sandstones west of a buried ridge of Cretaceous sandstone but some of the deposits are east of lows or gaps in the ridge. The ridge, formed by the resistant Wall Creek Sandstone Member of the Frontier Formation of Late Cretaceous age ranges in height from 30 to 120 m. The major stream of the basin flowed northwestward along the west side of the ridge (Harshman, 1972) but because the stream originated in the Granite Mountains to the west (Seeland, 1978) it had to turn sharply northward. Thick lignitic coal beds interbedded with siltstone and cut by channel sandstones (Harshman, 1972) found west of the Wall Creek Sandstone ridge attest to the low stream gradient and the resulting low-energy depositional environment.

Another major uranium mining district, the Gas Hills, lies on the north side of the Granite Mountains on the south flank of the Wind River Basin (fig. 6). The Gas Hills uranium district lies southwest of the Rattlesnake anticline which is also known as the Rattlesnake Range and which has about 300 m of topographic relief. The Dutton Basin anticline, which presently has about 100 m of topographic relief, and the Coyote anticline, which has no topographic expression, pass through the district. Paleocurrent measurements by Seeland (1978) and Grant (1954) and sedimentary facies mapping by Soister (1968) indicate sediment transport to the northwest parallel to the pre-Wind River structural grain during part of Wind River time. Thus, the Eocene stream courses in the Gas Hills area were determined by a complex interaction of sedimentation and tectonism, and for at least part of Wind River time, anticlinal structures on the north flank of the ancestral Granite Mountains deflected streams and influenced both the volume and type of sedimentation.

Soister (1968) lists the following sedimentary factors that contributed to the localization of the Gas Hills uranium deposits: (1) the coarse-grained permeable Puddle Springs Arkose Member (probably deposited at this location because of decreased stream gradients, which could be at least in part influenced by anticlinal deflection), (2) subsidiary basins formed by post-Miocene faulting (but the presence of anticlinal ridges would also have a similar effect), (3) aquifuges of pre-Tertiary rocks in fault or erosional contact (the erosional contacts are of anticlinal origin), (4) aquicludes, fine grained beds of the Wind River (a likely development resulting from ponding or decreased stream gradient behind anticlines), and (5) precipitating agents including carbonaceous material (the central carbonaceous zone is "behind" the Dutton Basin anticline).

In summary, most of the lithologic factors to which Soister relates the occurrence of uranium in the district can be related to the presence of pre-Wind River anticlines perpendicular to the regional paleoslope. A final factor unrelated to lithology that Soister (1968) feels is important in the localization of the uranium deposits is southward tilting, caused by subsidence of the Sweetwater (Granite Mountains) uplift.

The trend of the south margin of the Granite Mountains just north of the Crooks Gap district is about east-west (fig. 6). In the Crooks Gap district the uranium deposits are in the early Eocene Battle Springs Formation which consists of conglomerate, arkosic sandstone and siltstone. Southeast trending anticlines cut through the district. The Battle Springs is folded, but the overlying Crooks Gap Conglomerate of Love (1970) is not. The topographic ridges produced by the folding were buried completely in Crooks Gap Conglomerate time. Stephens (1964) suggests that major uranium deposits are concentrated in synclinal troughs in the Battle Springs. The structural setting could be important in the localization of these deposits but they were probably at least in part localized by sedimentary factors related to their original and present position between anticlinal ridges. Minimal paleocurrent data of this study from crossbedded sandstones of the Battle Springs Formation suggests deflection of southward flowing streams both to the northwest and southeast by anticlinal ridges that were formed synchronously with sedimentation.

Granite as a Potential Uranium Source

The source of the uranium in the known sandstone uranium deposits of Wyoming has been the subject of much discussion. The two ultimate sources most often proposed are Precambrian granitic rocks and post-Eocene volcaniclastic rocks (Love, 1970). The known uranium deposits of Wyoming are not adjacent to the probable source of post-Eocene ash in northwestern Wyoming. Instead there is a close spatial association of the Eocene host sandstones of the major uranium districts of Wyoming with the uranium-enriched Precambrian granitic core of the Granite Mountains (Stuckless, 1979) which emphasizes the importance of the uranium content of granitic source terranes in the search for new uranium deposits in Wyoming. Although the Granite Mountains were not a source for any of the Wind River Formation on the reservation (Seeland, 1978), the granitic cores of the Wind River Range and the Owl Creek Mountains, which acted both as sediment source terranes and as water sources for the early Eocene rocks of the Wind River Reservation could have been uranium source rocks.

In order to ascertain which area of granitic rock was more favorable as a uranium source, scintillometer traverses were made in each of the ranges and granitic rock samples from each of the ranges were analyzed for uranium. Siltstone, sandstone, and conglomerate of the Wind River Formation were also analyzed for uranium. The potential of the uranium source rock was greater in the Wind River Range on the south side of the basin for the following reasons. First, the area of exposed granitic rocks is many times greater. Second, the proportion of granitic rocks to sedimentary rocks is larger. Third, it is probable that the Wind River Range was an elevated range with much precipitation and large streams in the early Eocene.

Granitic rock samples were collected from 4 different areas in the Wind River Range: the northwest area (17 samples), the middle area (19 samples), the Washakie Park area (4 samples) (fig. 1), 10 km west of Reservation boundary and the South Pass area (5 samples, 60 km due south of Ft. Washakie). Twelve granitic rock samples were collected from the Owl Creek Mountains. Delayed neutron determinations of uranium and thorium were made by U.S. Geological Survey analysts H. T. Millard, Jr., C. M. Ellis, and V. C. Smith. The results are summarized in table 1.

Average granites have about 15 ppm thorium and about 4 ppm uranium and a thorium to uranium ratio of 3 to 5 (Rogers and Adams, 1967). Leaching does not remove thorium from granitic rocks, but it may remove uranium, so the thorium to uranium ratios exhibited by the Wind River and Owl Creek granitic rocks, 8 and 10.5 respectively, indicate substantial loss of uranium by chemical leaching. If the thorium to uranium ratio was originally 5 in the Wind River Range, then the original uranium content was 5.66 ppm. Compared to the present average of 3.53 ppm this means there has been about a 38 percent loss of uranium on weathering. Some of this 38 percent may have been available for the formation of uranium deposits. In the Owl Creek Mountains, if the original thorium to uranium ratio was also 5, then both the present and original uranium content of the Owl Creek Range was about one-third the uranium content of the Wind River Range and less was made available by leaching for the formation of deposits in the sedimentary rocks of the basin.

The analytical differences in uranium content were corroborated by hand held scintillometer traverses in the granitic core rocks of the Owl Creek Mountains and the Wind River Range which indicated substantial differences in the content of radioactive elements. The mean value of 71 scintillometer readings in the Wind River Range is about 10 counts per second and the mean value of 12 scintillometer readings in the Owl Creek Mountains is about 4 counts per second.

The radioactivity in the Wind River Range is about 2.5 times that in the Owl Creek Mountains, a factor which considering the uncertainties involved is remarkably similar to the factor of 2.7 obtained by comparing mean neutron activation values for uranium in the two mountain ranges.

Another way of looking at the relative favorability of the two mountain ranges as sources of uranium is to examine the mean uranium content of the siltstones having a Wind River Range source south of the Wind River of Eocene time and those having an Owl Creek source north of the Wind River of Eocene time; these values were respectively 5.41 ppm and 4.69 ppm uranium, table 2. The siltstones with an Owl Creek source are about twice as high in uranium as would be expected if they were derived from an exclusively Owl Creek granite source. Marine phosphorites are high in uranium and the Permian Phosphoria Formation crops out on both sides of the Wind River Basin in the Owl Creek Mountains and in the Wind River Range. However, comparison of the present areal extent of exposed sedimentary rocks in the Owl Creek Mountains and the Wind River Range suggests that during the early Eocene a larger proportion of the sediment incorporated in the Wind River Formation came from Paleozoic and Mesozoic sedimentary rocks on the Owl Creek side of the basin than on the Wind River side of the basin. It is therefore possible that the Phosphoria is the source of the "excess" uranium in the siltstones north of the Wind River of Eocene time.

The average uranium content of shale (DeVoto, 1978) is 3.2 ppm. The siltstone of the western Wind River Basin, with about 5 ppm uranium, contains more uranium than the average shale which may reflect its greater than average component of first cycle detritus.

The average uranium content of sandstone is also higher on the south side of the basin but the uranium content of the conglomerate samples from the north side of the basin is higher than those from the south side (table 2). However, the differences are small and may not be significant.

Table 1.--Uranium and thorium content of granites in the Wind River Range and Owl Creek Mountains

Location	Number of samples	Mean value		
		U (ppm)	Th (pm)	Th/U
Owl Creek Mountains	12	0.99	10.43	10.53
Northwest Wind River Range	17	4.54	33.60	7.40
Middle Wind River Range	19	1.52	20.55	13.54
Washakie Park area, Wind River Range	4	7.79	41.10	5.28
South Pass area, Wind River Range	5	1.94	21.55	11.11
Composite Wind River Range	45	3.53	27.42	8.01

Table 2.--Comparison of uranium content and thorium to uranium ratios of early Eocene sedimentary rock and their granite source rocks north and south of the Wind River of Eocene time

	Conglomerate		Sandstone		Siltstone		Granite	
	N	S	N	S	N	S	N	S
U (ppm)	2.83	2.46	2.36	2.53	4.69	5.41	0.99	3.53
Th/U	8.26	9.54	2.75	3.40	2.81	3.21	10.53	8.01

Grain Size and Shape Analysis

Sand-grain size and shape determinations were made on 250 grains per sandstone sample. This data was used to determine major source areas for the sandstones of the Wind River Formation and supplemented the paleocurrent study.

Sand grains nearer their source area are larger, more elongate, and less regular in outline. This data combined with maximum conglomerate clast size data was used to define major tributaries to the Wind River of Eocene time (Seeland, 1978). Three major streams affected sedimentation patterns in the Wind River Formation. They are aligned with major present-day drainages: Dinwoody Creek, Bull Lake Creek and the North Popo Agie River (fig. 9). This alignment suggests that these drainages were also well-developed in Eocene time.

Basin-margin alluvial fan-channel sandstone facies, formed where the major tributary streams left the mountains, are the host rocks for major uranium deposits in other areas of Wyoming, for example: the Gas Hills, Shirley Basin, and Southern Powder River Basin Districts. The mountain valleys also probably contained major streams during Oligocene time. They thus provide ideal places for uraniferous ground water from devitrifying Oligocene ashes to enter lithogically favorable Eocene sandstones and to supplement the uranium derived from granitic sources.

Of the 3 major Eocene streams draining the Wind River Range, only the Bull Lake Creek of Eocene time seems to be involved in anticlinal deflection (by the Sage Creek, Winkleman Dome, Pilot Butte, and Steamboat Butte anticlinal trend). The Riverton and East Riverton anticlines are oriented perpendicular to other streams, probably minor, draining the Wind River Range and should be expected to have deflected Eocene streams. North of the Wind River of Eocene time paleocurrent directions are mostly subparallel to the anticlinal trends and little deflection of stream directions is expected to have occurred.

GOLD POTENTIAL OF THE WIND RIVER FORMATION

A short-lived "gold boom" took place along the Wind River in the vicinity of Riverton in 1910 (Schrader, 1915). This boom which included the operation of two dredges, was the culmination of possibly as much as 50 years of sporadic and small-scale mining of the alluvial gold placers of the western Wind River Basin. The Neble dredge of the Shoshoni Gold Dredging Company treated gravel said to average 28 cents per cubic yard (at 20 dollars per ounce of gold) and the dredge of the Riverton Mining and Dredging Company located about 7 miles west of Riverton treated gravel reported by the company to average 76 to 80 cents per cubic yard. Schrader reported in 1915 that neither dredge was able to save gold in paying quantities because it was difficult to separate the gold from the associated heavy sand.

Schrader said:

> "It seems certain, however, that here, as in most other placer fields, the gold, like the gravel deposits in which it occurs, was derived by erosion and disintegration from the rocks in the mountains about the basin, especially from those on the west or Rocky Mountain side. Furthermore, the occurrence of gold-bearing lode deposits in nearly all the deep-mine developments both within and surrounding the area points strongly to the quartz lodes, veins, and stringers in the pre-Cambrian granites and schists and in the complex of these and associated rocks as the chief source of the gold."

Source of the Gold in the Wind River and its Tributaries

Schrader (1915) postulated that disintegration of gold-bearing quartz veins in the mountains adjacent to the Wind River basin provided the gold now found in placer deposits in the Wind River and its tributaries. The diminution of gold values between Lenore and Circle (fig. 10) on the Wind River (now abandoned) suggested to Schrader that Crow Creek and Sand Coulee on the north and Dry and Meadow Creeks on the south may be important contributors of gold to the modern placer deposits. No outcrops of roundstone conglomerate were found west of Sand Coulee and it and Crow Creek drain large areas in which the gold-bearing roundstone conglomerate is found (fig. 10). Thus, gold distribution along the course of the Wind River (Schrader, 1915) suggests that much of the gold in the recent gravels was derived from the roundstone conglomerates of the Eocene Wind River Formation rather than lode deposits in the Wind River, Owl Creek and Absaroka Mountains as Schrader (1915) suggested.

Source of the Roundstone Conglomerate of the Wind River Formation and its Gold

The distribution of the roundstone conglomerate in the upper Wind River Formation coincides almost exactly with the course of the Eocene Wind River as defined by a study of crossbedding (fig. 11). This coincidence could have been predicted because, based on clast lithology and shape, the source of the conglomerates had to be the late Cretaceous and Paleocene auriferous quartzite roundstone conglomerates of the Jackson Hole area that were described by Lindsey (1972), Antweiler and Love (1967) and Love (1973). The source of the conglomerates, for the most part, lay west of and outside the present Wind River Basin and thus they could be expected to be distributed along the basin axis. It is not clear why the roundstone conglomerates of the Eocene Wind River were carried so far eastward along the basin axis. Perhaps the Eocene Wind River drained a large area west of the present structural basin and was a much larger and more competent stream than the marginal streams of the basin. There can be little doubt that the upper reaches of the marginal streams were able to move large quantities of exceedingly coarse debris. The boulder conglomerate of the Eocene alluvial fan near Bull Lake attests to this.

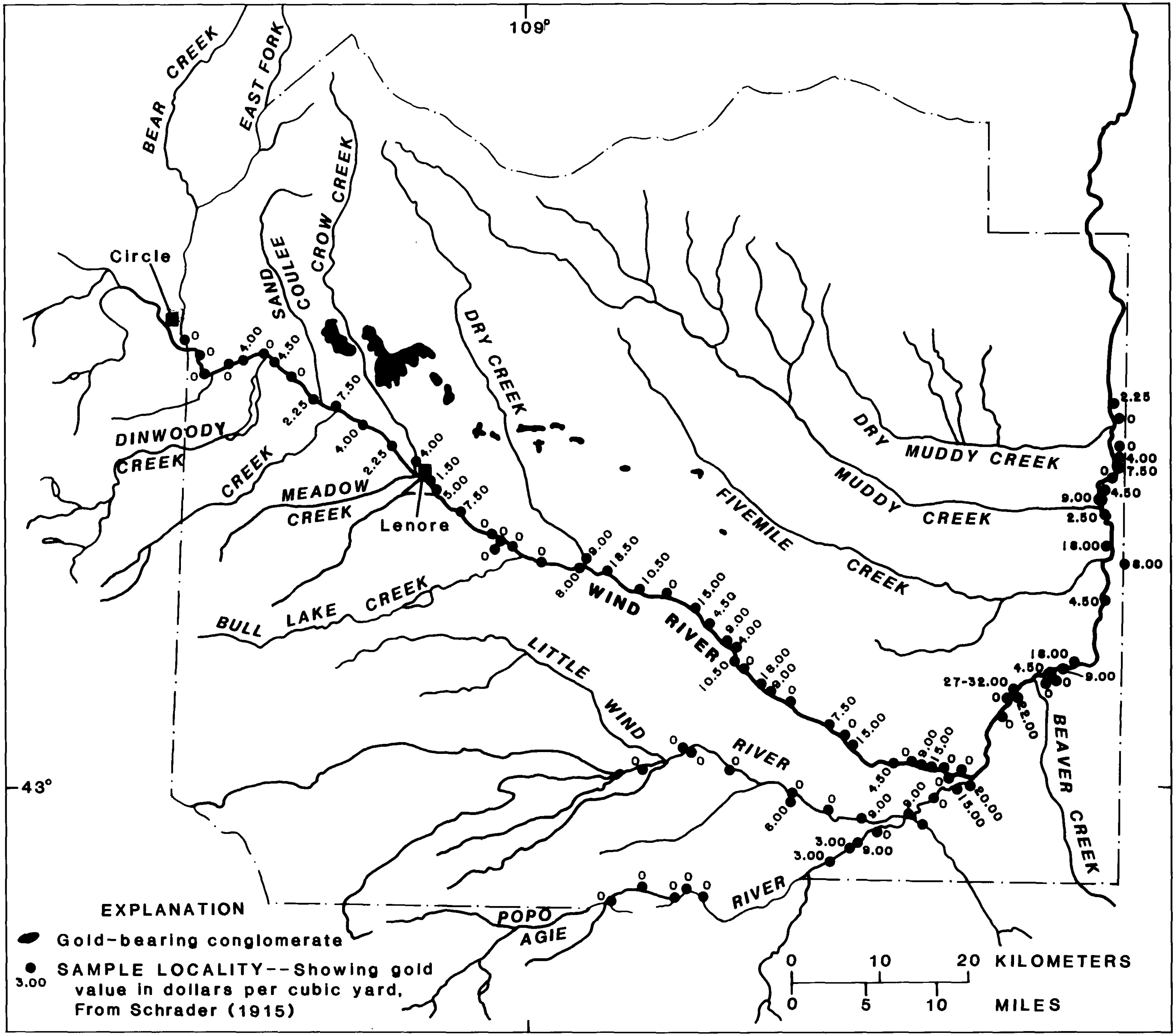

Figure 10.--Gold-placer values in modern stream gravels and location of gold-bearing roundstone conglomerate outcrops.

Additional evidence bearing on the source of the gold is provided by analytical work on gold flakes from the Wind River by John C. Antweiler (personal commun.) of the U.S. Geological Survey. He has shown that they are characterized by Au-Ag ratios that are the same as gold from the Harebell and Pinyon Formations of the Jackson Hole region.

The source of the auriferous Harebell and Pinyon roundstone conglomerates was a previously existing uplift northwest of the Teton range in eastern Idaho called the Targhee uplift (Antweiler and Love, 1967; Lindsey, 1972). The Targhee uplift was perhaps only the penultimate source of the gold. The gold of the Targhee uplift is contained in quartzites of Late Precambrian and Cambrian age and it may thus have been derived from either vein deposits in crystalline rocks or even from pre-existing sedimentary rocks. Transport directions in the Cambrian were from east to west (Seeland, 1968) and it is likely that the eastward migration of the gold from the Late Cretaceous to the present is returning the gold closer to its original source rocks, the Precambrian rocks of the Black Hills and vicinity. Because the transgressive basal Cambrian marine clastics become younger from west to east, westward transport in the marine environment would only be effective for relatively short distances in the nearshore zone of coarse clastics. Paleontologically determined Cambrian shorelines (Lochman-Balk, 1956) were north-south which means that both the subaerial and submarine paleoslopes were due west. The subaerial and submarine surface was smooth with few irregularities; the result of a long period of subaerial weathering termed the Lipalian interval by Walcott (1908). This long period of weathering and planation provided an opportunity for the liberation of gold particles from weathered rocks and their concentration in Cambrian stream and marine sediments. A combination of west-flowing streams and westerly marine transport could have carried the gold due west from the Black Hills to eastern Idaho.

On Bald Mountain 5 km south-southwest of Dubois (fig. 11), a very well indurated quartzite roundstone comglomerate lying on Cambrian limestone has a mean maximum clast size and a transport direction determined from pebble imbrication that are as would be predicted from extrapolation from maps of similar data from the Pinyon conglomerate west of the Wind River Range (Lindsey, 1972). The degree of induration is puzzling because no other such well indurated Laramide roundstone comglomerates were seen in the region or are described in the literature. The induration may be a local phenomenon unrelated to the age of the conglomerate. The conglomerate is not on the basin axis but the basin is very narrow in this area. However, it is possible that the conglomerate is part of the Pinyon or Harebell that once extended into the western Wind River Basin.

Analytical Methods and Results

Samples were collected from both roundstone conglomerate of the Wind River Formation, and Quaternary stream deposits derived entirely or mostly from the conglomerate. The stream sediment samples contained more than 90 percent sand size material, and the conglomerate samples, which were from short channels or pits, contained more than 50 percent quartzite clasts. No attempt was made to favor matrix material or sandstone beds in the conglomerate samples. The bulk samples, which weighed from 7 to 10 kg, were

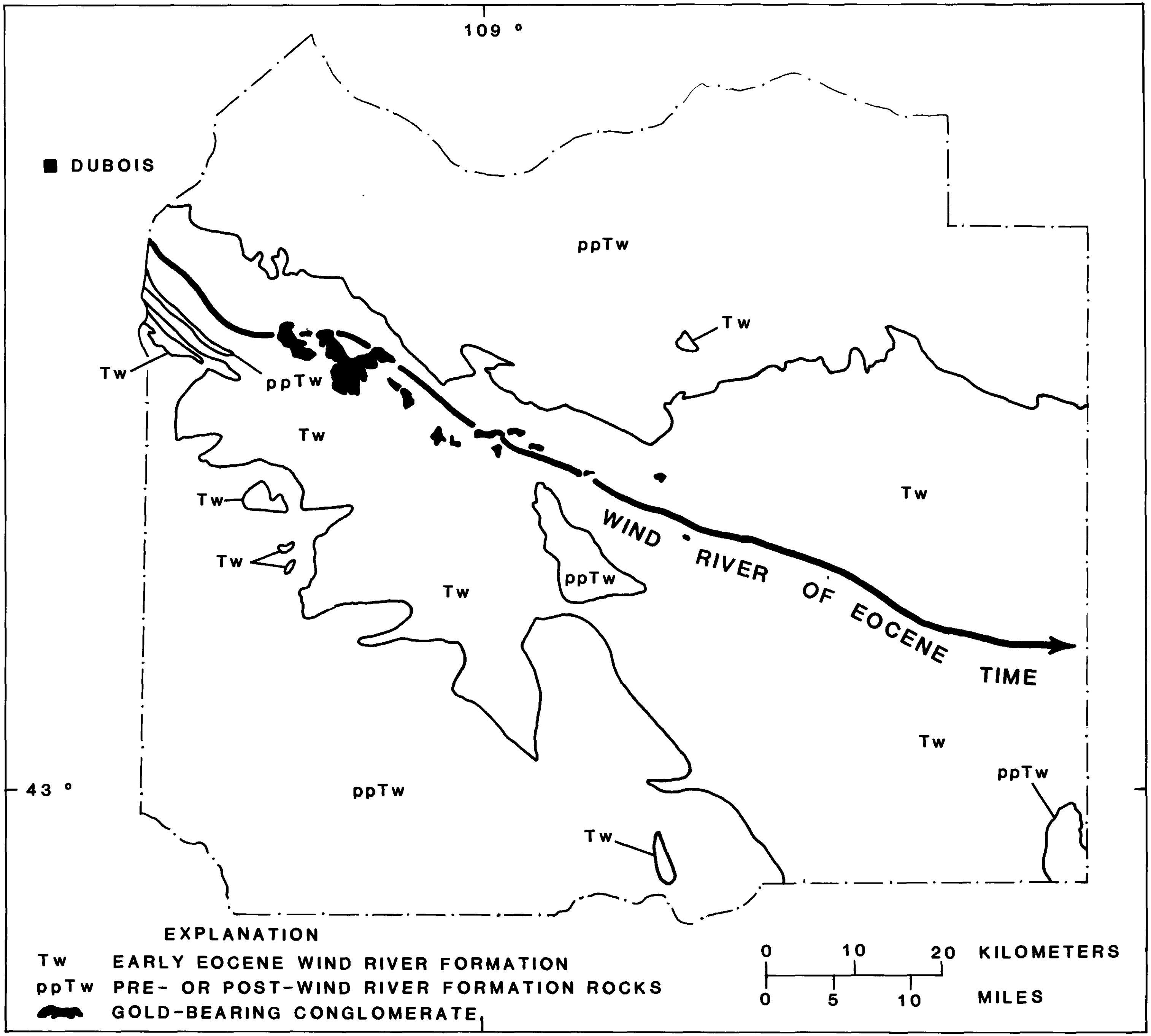

Figure 11.--Location of gold-bearing roundstone conglomerates.

panned until a heavy mineral concentrate weighing between 5 and 60 grams was obtained. The concentrates were analysed for gold using fire assay - atomic absorption procedures by J. G. Crock, A. W. Haubert, and J. Haffty of the Geological Survey's Branch of Analytical Laboratories.

The conglomerate may not have contained detectable gold as postulated by Seeland and Brauch (1975) so panned concentrates were analyzed in order to increase the likelihood of gold values in excess of the lower limit of detection (25 ppb) in at least some of the samples. Unless many 10 g sample splits of a single sample are analyzed, the particle sparsity effect (Clifton, Hubert, and Phillips, 1967) suggests that at low concentrations of gold many of the 10 g splits of a sample would contain no gold. It is difficult to make direct comparisons of gold analyses of panned roundstone conglomerate samples from the Wind River Basin with the gold values reported by Antweiler and Love (1967) in the Pinyon and Harebell Formations in the Jackson Hole area for the following two reasons. First, the true gold content of the Pinyon and Harebell Formations is likely to be less than the reported values because preference was given to sampling conglomerate matrix and sandstone (Antweiler and Love, 1967). Second, the gold recovered by panning is less than the true gold content.

Many of the conglomerate beds contain 50 percent or more by weight of roundstones. The gold is largely confined to conglomerate matrix and sandstone so the removal of the roundstones from a sample will increase the apparent gold content of the sampled rock unit. In the case of removal of 50 percent of the sample before analysis the actual gold content of the rock would be one-half the reported value. Gold recovered by panning of these units is usually less than the true gold content for two reasons: one, some gold particles are so small that they float on the surface of the water and, two, some gold particles may be included in, or adhere to, larger light particles that are washed out during the panning process. The source of the gold found in the Wind River Formation is certainly the Pinyon and Harebell Formations so after yet another cycle of erosion, transport, and deposition, the gold is likely to be even finer and more susceptible to loss by panning.

Antweiler and Love (1967) determined gold content of quartzite conglomerates by a cold extraction atomic absorption technique. They analyzed both panned and bulk samples and calculated the gold content of the bulk sample and analyzed 15 gram splits of the bulk sample. Using figures for percent recovery by panning listed in table 9 of Antweiler and Love (1967) it is calculated that the actual gold content of these samples is about 8 times the content obtained by panning. This is then a minimum factor by which the gold values obtained for the Wind River Formation can be multiplied. The mean gold content of bulk samples thus seems to be a better measure of the actual gold content but this technique was avoided for this study because of the "particle sparsity effect" (Clifton, Hubert, and Phillips, 1967). The particle sparsity effect refers to the problem of determing low concentrations of particulate gold of small analytical samples where the analytical results depend on the presence or absence of a single gold particle. Since only 15 samples (11 roundstone conglomerate samples and 4 samples from stream gravel in streams adjacent to conglomerate outcrops) were collected it would not be unreasonable to obtain entirely negative results on all 15 samples if 15 gram splits of each were analyzed. Although panning losses were inevitable, the relative values would be valid, and a convenient correction factor was available to correct the results from the work of Antweiler and Love (1967). Using the correction factor (8.44) the corrected mean gold content of the 11 roundstone conglomerate samples collected becomes 8.44 times the observed gold concentration of 5.44 ppb or 44.28 ppb. The mean concentration of gold from 15 gram splits of bulk samples of Pinyon and Harebell collected by Antweiler and Love (1967) is about 82 ppb. However, they point out that preference was given to sampling conglomerate matrix and sandstone lenses. If one-half the weight of a representative sample consisted of roundstones then the 82 ppb mean could be halved and both roundstone conglomerates would contain about the same gold concentration.

At the current (October, 1982) price of gold of about 435 dollars per ounce a cubic meter of conglomerate would contain about 2 dollars worth of gold. Approximately 300 million cubic meters of roundstone conglomerate occur on the reservation in near-surface deposits. This represents a sizable dollar value, however, much larger volumes of auriferous conglomerates exist elsewhere in northwest Wyoming. Antweiler, Love and Campbell (1977) estimate that the middle Eocene Pass Peak Formation, also derived from the Harebell and Pinyon conglomerates, contains more than 46 million ounces of gold.

Antweiler and Love (1967) point out that their study is not a resource appraisal but rather the preliminary results of a geological investigation. This is even more emphatically true of this study of the Wind River Formation. More geologic work followed by larger scale attempts at gold recovery should precede any conclusion as to whether the quartzite roundstone conglomerates of the Wind River Formation constitute an economic gold resource.

Possible Gold Concentrations in Non-conglomeratic Sandstone

In addition to the gold present on the reservation in the roundstone conglomerate, additional gold may be present in the channel sandstone of the Wind River of Eocene time east of the easternmost outcrops of conglomerate. This suggestion is made because the distribution of the roundstone conglomerate coincides almost exactly with the course of the Eocene Wind River as was seen in figure 12. Although conglomerate clast size and volume does decrease downstream, average gold grade shows no diminution from west to east (fig. 12). These relationships suggest that the channel sandstones deposited by the Eocene Wind River in downstream areas may contain substantial additional quantities of gold. However, it is not known if sandstones that are the downstream equivalents of the roundstone conglomerates are present or if they have been removed by erosion.

Gold Recovery from the Roundstone Conglomerate

Heap leaching has been used for hundreds of years to remove copper from ore. Recently the method has been used with success on gold and silver ores. Cyanide heap leaching provides an economical and environmentally sound method of processing low-grade gold ore (Eveleth, 1968, and Kappes, 1978).

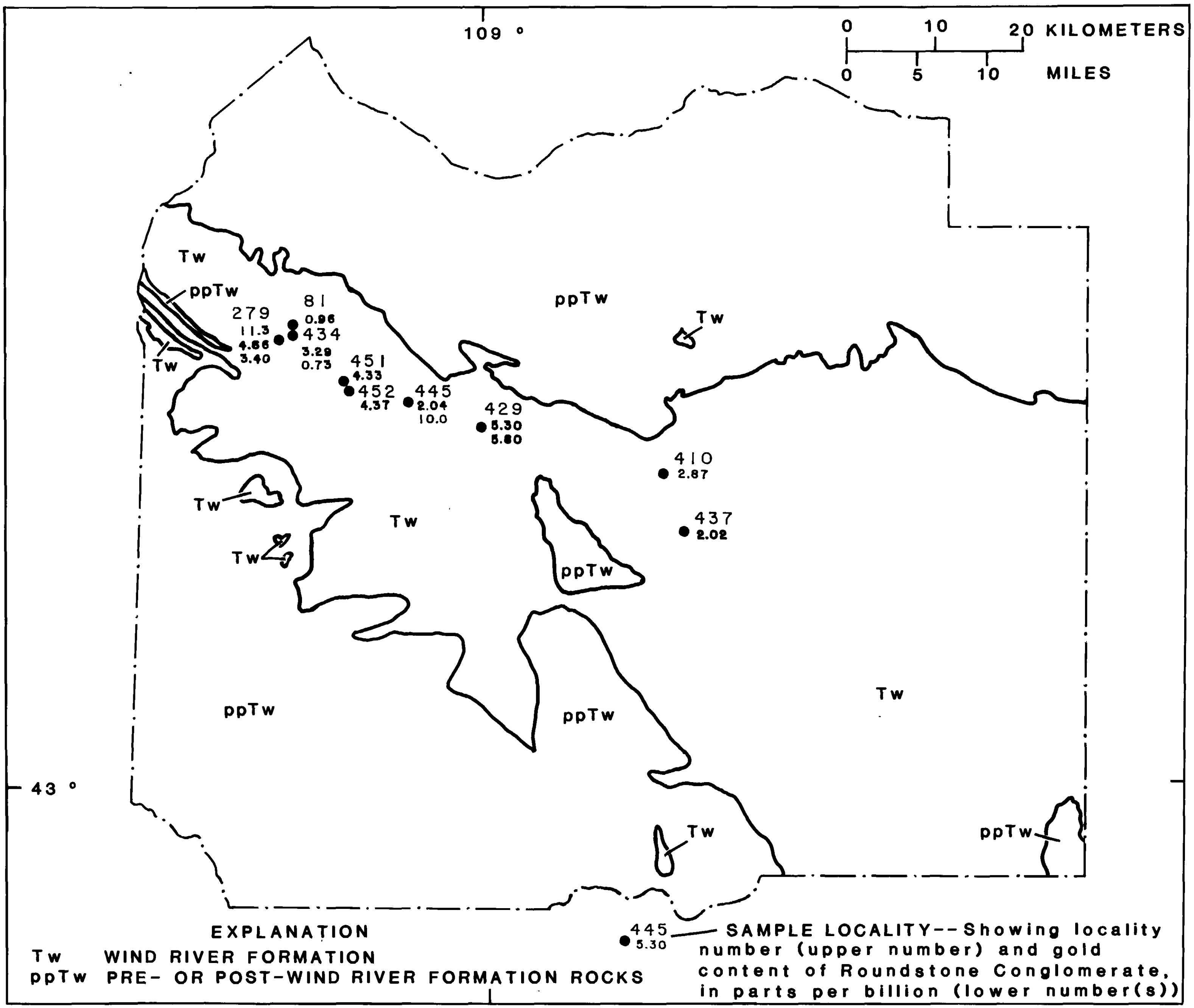

Figure 12.--Roundstone conglomerate sample localities and gold values.

The process, in its modern form, involves piling ore on plastic sheeting and irrigating the pile with cyanide solution fed through plastic pipes. The auriferous cyanide solution is then pumped through columns filled with activated granular carbon which removes the gold. The gold is removed from the carbon with a hot solution of 1 percent NaOH containing 20 percent alcohol. The gold is recovered from this solution in an electrolytic cell. The system is simple to operate; at a mine in Nevada, one man operates a stripping/recovery operation that produces over 50 ounces of gold per day (Kappes, 1978). Kappes (1978) details the entire process including estimated costs and labor requirements.

Costs of gold production could be reduced on the Wind River Reservation by first sieving the conglomerate to separate the cobbles and the sandy matrix. The matrix would contain most of the gold. The sandy matrix containing fine-grained gold could be leached rapidly and completely.

Separation of the gold by hydraulic methods might be more difficult because of lack of nearby water. Few perennial streams are near the conglomerates. Furthermore, dredges that once processed recent auriferous gravels of the Wind River near Riverton had little success. Schrader (1915) attributes this to the low ore grade and difficulty in separating gold from the fine heavy-mineral sand that comprised a large part of the ore, although more modern placer mining machinery might efficiently separate the gold from the heavy minerals.

SUMMARY

This report is focused on the gold and uranium potential of the Wind River Reservation of northwest Wyoming. Results of a paleocurrent study have defined the course of the Wind River of Eocene time and the source terranes for the rocks of the Wind River Formation.

If the premise that the uranium deposits in the early Eocene rocks of Wyoming are related to the presence of uranium-rich granitic Laramide uplifts is correct, then chemical analyses of granite samples combined with a consideration of the areas of exposed granite suggest that the Wind River Range (south) side of the basin is more favorable than the Owl Creek Mountains (north) side of the basin for the occurrence of uranium deposits. Chemical analyses of the sediments of the Wind River Formation show higher amounts of uranium on the south side of the Wind River of Eocene time.Study of sand grain size and shape showed that major streams entered the basin in Eocene time at the same places that present-day streams enter the basin from the Wind River Range. These streams deposited alluvial fan-major channel sandstones that are considered favorable exploration targets because of their association with large uranium deposits in early Eocene rocks elsewhere in Wyoming.

Anticlinal hills that rose synchronously with the Wind River Range deflected early Eocene streams and created favorable environments for the formation and preservation of uranium deposits. Anticlinal ridges may also have influenced the formation of commercial uranium deposits in the Gas Hills, Crooks Gap, and Shirley Basin districts.

A roundstone conglomerate was deposited along the course of the Wind River of Eocene time. This conglomerate was derived from older gold-bearing conglomerates of the Jackson Hole area and contains approximately the same gold values-about one and one-half dollars per cubic meter. Additional work should be done to determine if this gold is a potential mineral resource.

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