PGJ/F-067(82)

National Uranium Resource Evaluation

TORRINGTON QUADRANGLE WYOMING AND NEBRASKA

U.S. Geological Survey
Golden, Colorado

Issue Date
September 1982

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Nuclear Energy
Grand Junction Area Office, Colorado

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NATIONAL URANIUM RESOURCE EVALUATION, TORRINGTON QUADRANGLE, WYOMING AND NEBRASKA

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Principal Investigator

With contributions from A. C. Christiansen, N. M. Denson, H. C. Granger, D. J. Hammond, F. A. Hills, J. D. Love, D. L. Macke, Mark Mercer, P. B. Mudgett, G. M. Reimer, E. S. Santos, and C. K. Sever

U.S. GEOLOGICAL SURVEY
Golden, Colorado

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION AREA OFFICE
UNDER CONTRACT NO. DE-AI13-78GJ01686

This report has not been edited for conformance with U.S. Geological Survey stratigraphic nomenclature or resource classification.

This is the final version of the subject-quadrangle evaluation report to be placed on open file. This report has not been edited. In some instances, reductions in the size of favorable areas on Plate 1 are not reflected in the text.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

Plates in accompanying packet

* This map, Geologic map of the Torrington 1° x 2° Quadrangle, southeastern Wyoming and western Nebraska, by J. D. Love, Ann Coe Christiansen, and C. K. Sever, is available as U.S. Geological Survey Miscellaneous Field Studies Map MF-1184 and may be obtained from Branch of Distribution, U.S. Geological Survey, Box 25286, Federal Center, Denver, Co 80225.

ABSTRACT

The Torrington 1°x2° Quadrangle in southeastern Wyoming and western Nebraska was evaluated to identify areas favorable for the occurrence of uranium deposits likely to contain 100 tons of uranium with an average grade of not less than 100 ppm (0.01 percent) U_3O_8. Almost all uranium occurrences reported in the literature were visited and sampled. Geochemical analyses of rock samples collected during the study were used in the evaluation. Hydrogeochemical and stream-sediment analyses were not available. Aerial-radiometric, and helium soil-gas surveys were analyzed. Much of the quadrangle is covered by Tertiary rocks. To assess the uranium potential of the Tertiary and pre-Tertiary rocks 270 well logs were studied and both contour and geologic maps made of the pre-Oligocene surface east and north of the Laramie Mountains.

Five environments favorable for uranium deposits were outlined. The first is in the coarse-grained arkosic sandstone facies of the Wasatch Formation and the Lebo Member of the Fort Union Formation in the southern Powder River Basin; this facies was once overlain by tuffaceous rocks and the arkose was derived from granitic rocks of the Laramie (and Granite?) Mountains. The second is in the Wind River Formation in the Shirley Basin, a stratigraphic and lithologic equivalent of the Wasatch. The third is the Lower Cretaceous Cloverly Formation in the northeastern part of the quadrangle; the environment favorable for uranium deposits is entirely in the subsurface and is defined by widely spaced gamma-ray logs. The fourth is in the Upper Cretaceous Lance (Laramie) Formation and the Fox Hills Sandstone in the southeastern corner of the quadrangle; the favorable environment is entirely in the subsurface. A pre-Oligocene valley crossing the favorable units created a particularly favorable environment for uranium deposits. Substantial drilling activity also suggests more widespread uranium favorability. The fifth favorable environment is in Precambrian rocks in the Laramie Mountains and Hartville uplift; fractured rocks in the favorable parts of these areas were once (and in places still are) overlain by tuffaceous rocks of the White River Formation. The areas that were once beneath the Oligocene White River contain nearly all the occurrences and have associated helium and aerial-radioactivity anomalies.

INTRODUCTION

PURPOSE AND SCOPE OF STUDY

The Torrington 1°x2° Quadrangle in southeastern Wyoming and a small area of westernmost Nebraska was evaluated to determine areas favorable for the occurrence of uranium deposits. Geologic environments (areally or stratigraphically restricted parts of a geologic unit) were placed in categories of favorable, unfavorable, or unevaluated.

Mickle and Mathews (1978) define a favorable environment as one that could contain a deposit of at least 100 short tons (all other units in this report will be metric) of U_3O_8 with an average grade not less than 100 parts per million (ppm) U_3O_8. Unevaluated geologic environments are those for which there are insufficient data for evaluation.

Evaluation of the Torrington Quadrangle was conducted by the U.S. Geological Survey (USGS) for the National Uranium Resource Evaluation (NURE) program, managed by the Grand Junction Office of the U.S. Department of Energy (DOE). The evaluation program began September, 1978 and ended March 29, 1980. Time spent in literature search, field work, evaluation of data, and in preparation of the final report totaled approximately 3 man-years by the author and other USGS personnel.

PROCEDURES

Field work consisted of examination and sampling of known uranium occurrences, sampling of geologic units not known to have occurrences, and sampling of units known to contain uranium occurrences but in areas remote from known occurrences. It was originally planned that the USGS would do detailed geochemical sampling and geologic field work in anomalous areas identified by hydrogeochemical and stream-sediment reconnaissance (HSSR) after the quadrangle-wide HSSR data and the results of the aerial radiometric survey. Unfortunately, this was not possible as the data were not available in time.

A helium soil-gas survey of about half of the quadrangle was made by G. M. Reimer of the USGS.

J. D. Love, A. C. Christiansen and C. K. Sever of the USGS compiled published larger scale maps and did reconnaissance geologic mapping and field checking of previously published maps in order to prepare the geologic map of the Torrington Quadrangle (Love and others, 1980). Pat Rohman and Dennis Laux of the USGS described and sampled many uranium occurrences. Mary Durrett coordinated the drafting. Betty Pedersen and Charlene Barnhorst typed the manuscript.

Surface Studies

There are 132 previously reported radioactive occurrences in the quadrangle; 123 of these were visited. Where necessary, the previous occurrence descriptions were modified, country rock and mineralized samples collected, and scintillometer readings made--both maximum and background away from the occurrence. These occurrences include some where no uranium concentrations were found. All occurrences are located on Plate 2. All rock-sample localities are shown on Plate 5.

Hugh Millard of the USGS analyzed 274 rock samples for uranium and thorium using neutron-activation techniques (App. C). The same samples were analyzed for 43 other elements by emission spectrography (App. B). HSSR sampling was performed by Bendix Field Engineering Corp. (BFEC). The USGS stream-sediment sampling group, which was set up to do detailed studies of anomalies did not sample in the Torrington Quadrangle because of the lack of the reconnaissance HSSR data.

A reconnaissance aerial gamma-ray and magnetic survey of the Torrington Quadrangle was done by geoMetrics, Incorporated, for the DOE. The report (geoMetrics, 1979) on this survey was not received until December 1979, too late for ground geologic or radiometric surveys to check anomalies.

Subsurface Studies

N. M. Denson and D. L. Macke studied and interpreted 270 well logs (App. D) and prepared a pre-Tertiary topographic and geologic map of the Torrington Quadrangle east of the Laramie Mountains (Pls. 10a and 10b). They also examined many gamma-ray logs for evidence of anomalous radioactivity in rocks below the pre-Tertiary unconformity.

GEOLOGIC SETTING

The Torrington Quadrangle of southeastern Wyoming (Fig. 1) has an area of about 19,000 km^2 and lies at the boundary between the Great Plains and the Southern Rocky Mountains physiographic provinces. The westernmost part of the quadrangle is in the Shirley Basin, part of the Wyoming Basins physiographic province. Altitudes range from 3,100 m at Laramie Peak in the Laramie Mountains in the southwestern part of the quadrangle to 1,250 m near the town of Torrington in the southeast corner of the quadrangle along the North Platte River.

The stratigraphy of the Torrington Quadrangle is summarized on Figure 2. The structural elements of the quadrangle and the surrounding area are shown diagrammatically in Figure 3. the major positive areas are the Laramie and Hartville uplifts. The Hartville uplift separates the Powder River Basin from the Denver (Julesburg) Basin. The Laramie Mountains, in the western third of the area, are the northern extension of Colorado's Front Range, and are the northernmost part of the Southern Rocky Mountains province.

The geologic and plate-tectonic history of the Precambrian rocks of southeastern Wyoming were discussed by Hills and Houston (1979), and it is from their paper that the following discussion is extracted. The Precambrian of the Hartville uplift and the Laramie Mountains has been divided into (1) the Archean northern metamorphic complex; (2) the Archean Laramie batholith (a granitic rock); (3) the central metamorphic complex of feldspathic gneiss and migmatite; (4) the southern metamorphic complex which is intruded by post-orogenic and anorogenic igneous rocks (the middle-Proterozoic Laramie

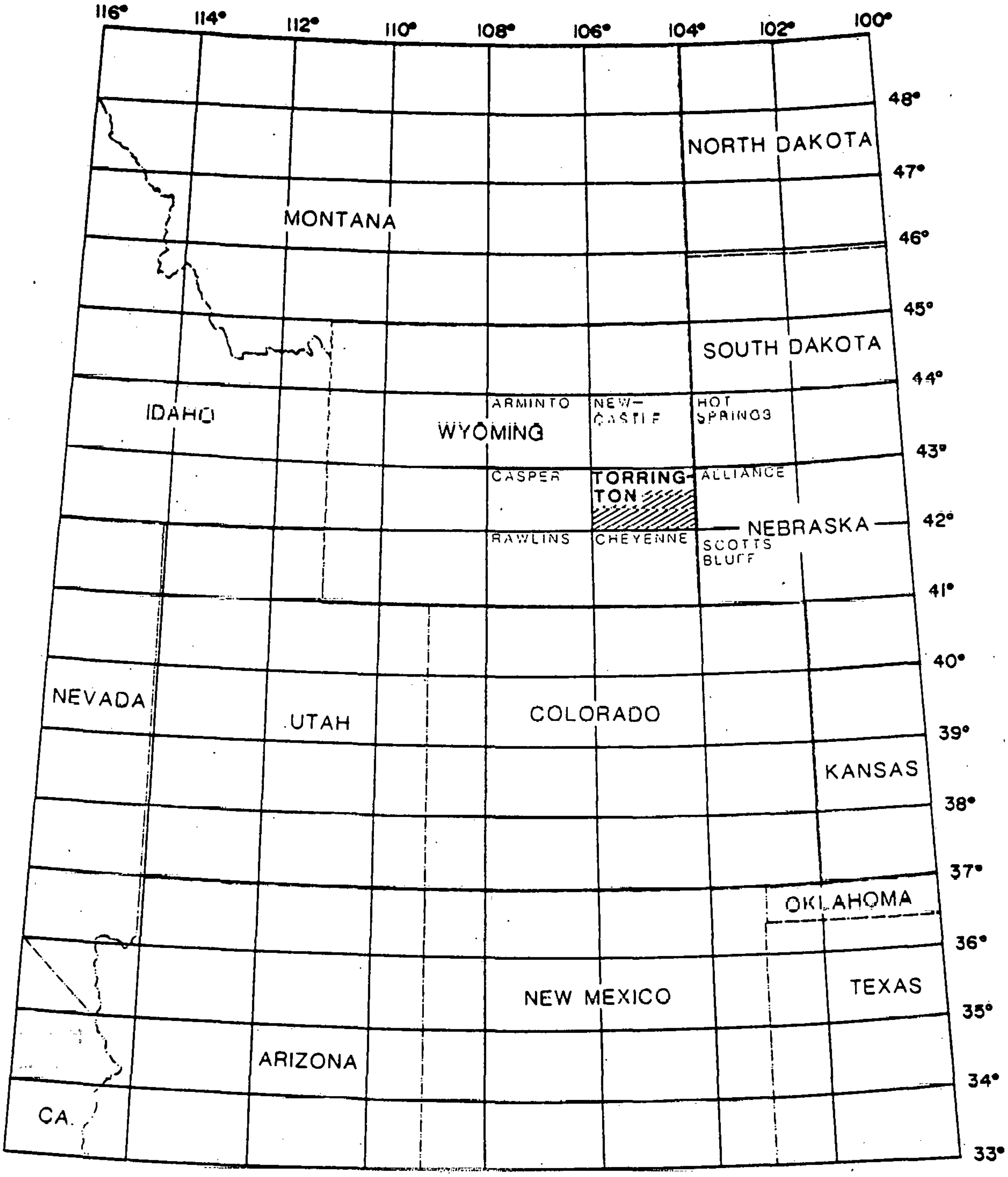


Figure 1. Location of Torrington Quadrangle.

Era	System	Series	Group or Formation		Lithologic Description
Cenozoic	Quaternary	Holocene and Pleistocene	Alluvial Deposits		Boulders, gravel, sand, silt and clay deposited by water, wind, and mass movements.
	Tertiary	Miocene	Ogallala Formation		Fine- to coarse-grained sandstone interbedded and interfingered in upper part with conglomerate, claystone, and freshwater limestone; vitric tuff beds near top. Thickness 105-185 m (345-607 ft)
			Arikaree Formation		Fine-grained poorly bedded sandstone containing abundant magnetite grains; some siltstone, limestone, tuff, and conglomerate. Thickness 0-215 m (0-705 ft)
		Oligocene	conglomerate		Conglomerate with clasts of Precambrian rocks interbedded with blocky claystone. Thickness 0-150 m (0-490 ft)
			White River Formation		Tuffaceous bentonitic claystone, breaking with a characteristic conchoidal fracture. Lenses of sandstone and arkosic conglomerate. Thickness 0-460 m (0-1,510 ft)
		Eocene	Wasatch Formation		Arkosic sandstone, lenticular conglomerates, siltstone, carbonaceous shale, and many coal beds. Some variegated mudstones. Thickness 0-610 m (0-2,000 ft)
		Paleocene	Fort Union Formation	Lebo Member	Fine- to coarse-grained sandstone interbedded with siltstone, claystone, shale, and thin coal beds. Thickness 0-760 m (0-2,490 ft)
				Tullock Member	Dominantly massive light-gray sandstone. The overlying Lebo Member is darker colored and contains more shale and claystone. Thickness 0-460 m (0-1,510 ft)
Mesozoic	Cretaceous	Upper	Lance Formation		Shale and lenticular sandstone; many thin coal beds in lower half. Thickness 610-760 m (2,000-2,490 ft)
			Fox Hills Sandstone		Sandstone and sandy shale. Thickness 45-60 m (148-197 ft)

Outcrop Columnar Section

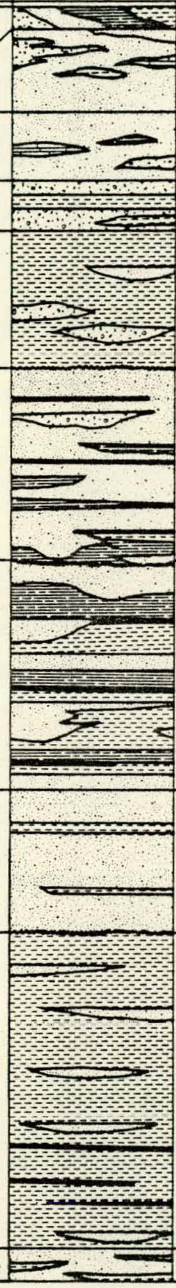


Figure 2a. Generalized stratigraphic section of the Torrington Quadrangle.

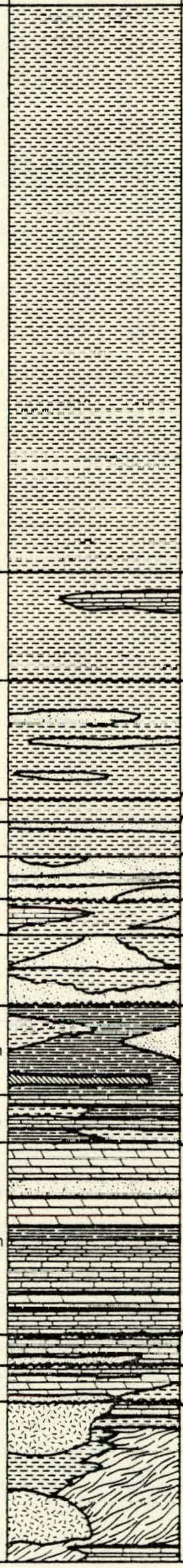
Era	System	Series	Group or Formation	Outcrop Columnar Section	Lithologic Description
Mesozoic	Cretaceous	Upper	Pierre Shale		Black concretionary marine shale with many bentonite beds. Thickness 610-945 m (2,000-3,100 ft)
			Niobrara Formation		Black concretionary shale and light colored chalky limestone. Thickness 170-180 m (558-590 ft)
			Frontier Formation		Black shales with thin concretionary sandstone. Thickness 180-215 m (590-705 ft)
		Lower	Mowry Shale		Black siliceous shale. Thickness 25-45 m (80-148 ft)
			Thermopolis Shale		Black fissile shale with thin bentonite beds. Includes Muddy Sandstone Member at top. Thickness 45-75 m (148-245 ft)
			Cloverly Formation		Shaly ferruginous sandstone, underlain by claystone. At base is sandstone with conglomerate lenses. Thickness 45-95 m (148-312 ft)
	Jurassic	Upper	Morrison Formation		Silty claystone, limestone, and lenticular sandstone. Thickness 30-90 m (98-295 ft)
		Middle	Sundance Formation		Glauconitic sandstone and shale underlain by non-glauconitic sandstone and shale. Thickness 80-145 m 260-475 ft)
	Triassic		Chuqwater Formation		Red siltstone, shale, and silty sandstone with thin gypsum partings and seams. Thickness 45-260 m (148-853 ft)
			Goose Egg Formation		Interbedded shales and siltstones, thin limestones, limestone breccias, and gypsum beds. Thickness 60-105 m (197-345 ft)
Paleozoic	Permian and Pennsylvanian		Hartville Formation		Massive limestone and dolomite, cherty in part, with some calcareous sandstone and siltstone. Locally cavernous and brecciated in upper part. Basal quartzitic sandstone. Thickness 260-375 m (853-1,230 ft)
	Mississippian		Madison Limestone		Massive cavernous cherty limestone and dolomite, arkosic sandstone present locally at base. Thickness 0-105 m (0-345 ft)
	Devonian		Guernsey Formation		Upper part is cherty coarsely crystalline limestone; lower part is thin-bedded dolomite with basal arkose. Thickness 45-75 m (148-246 ft)
Precambrian					Granites, monzonites, diorites, amphibolites, gneisses, schists, metalimestones and metashales

Figure 2b. Generalized stratigraphic section of the Torrington Quadrangle (continued).

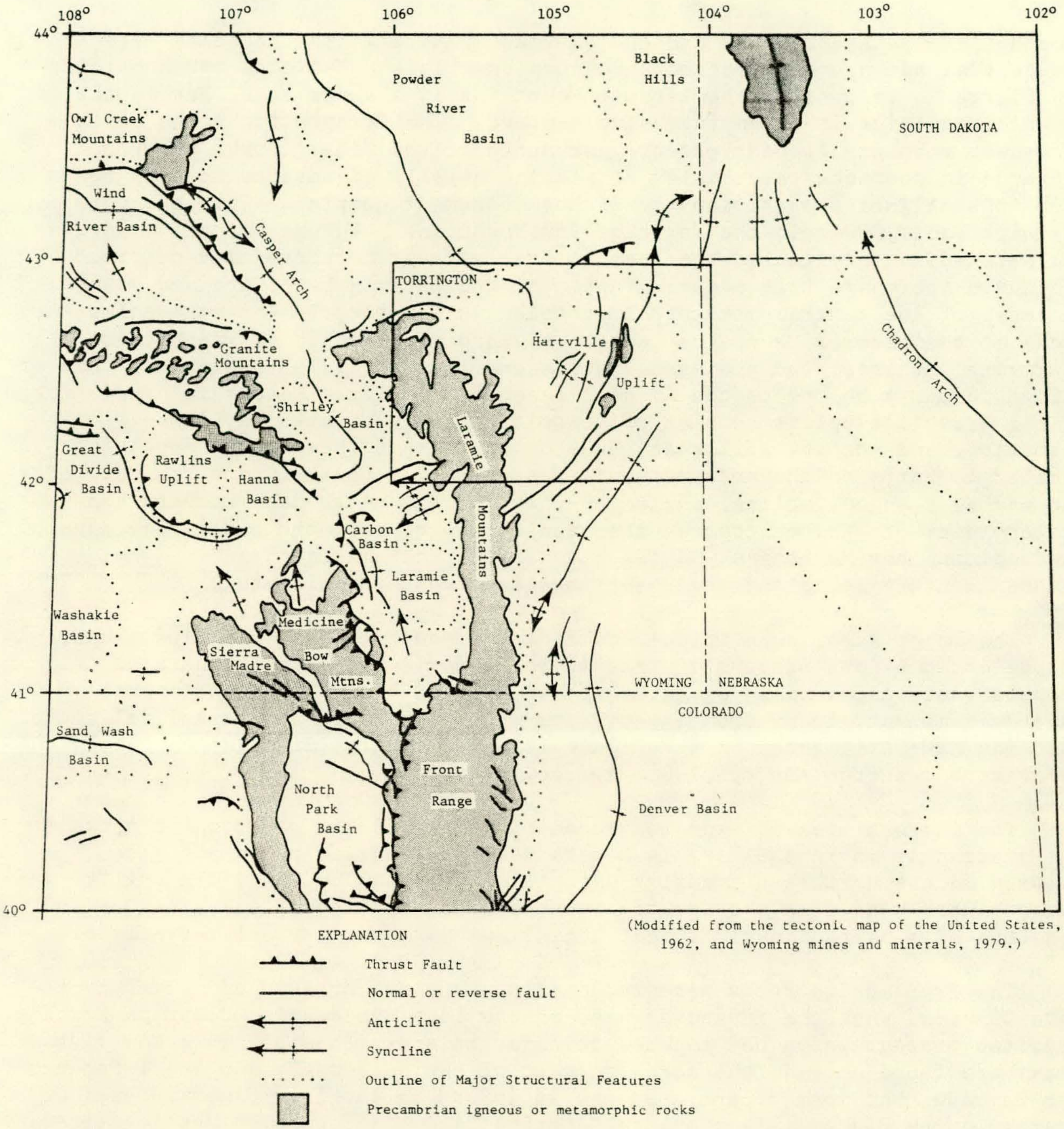


Figure 3. Major structural elements of the Torrington Quadrangle.

Anorthosite-Syenite Complex and the Sherman Granite). The boundary between the central and southern metamorphic complexes in the Medicine Bow Mountains and Sierra Madre west of the Laramie Mountains is a shear zone, but in the Laramie Mountains it is an intrusive contact. The Precambrian rocks north of the shear zone are Archean except just north of the "shear zone" where a Proterozoic supracrustal complex consisting chiefly of metasedimentary rocks lies in synclinoria overlying the Archean basement complex. This sequence is as thick as 17,000 m in the Medicine Bow Mountains. In the Laramie Mountains the metasedimentary rocks have been so strongly metamorphosed and deformed that even their age relative to granite of the Laramie batholith and granitic gneisses of the central metamorphic complex is not clear. The metasedimentary rocks of the Laramie Mountains consist of marble, quartzitie, graphite-rich quartzite, schists, and gneisses. Hills and Houston (1979) state that some or all of them may belong to the Archean basement complex. Metasedimentary rocks of the Hartville uplift consist of dolomitic marble, quartzite, iron-formation, and schist. Hills and Houston state that these rocks appear similar to parts of the metasedimentary sequence in the Medicine Bow Mountains and may be a eugeosynclinal facies of them, or may be Archean rather than Proterozoic. It is, of course, the uraniferous quartz-pebble conglomerates of the Medicine Bow Mountains and the Black Hills that makes these metasedimentary rocks and their settings important to this study.

The major shear zone in the Medicine Bow Mountains and the Sierra Madre (represented by and igneous contact in the Laramie Mountains) separates Archean gneisses overlain by late Archean (?) and early Proterozoic shallow-water sedimentary rocks from lower Proterozoic ensimatic eugeosynclinal rocks that may have originated in a volcanic island arc. The displacement along the shear zone occurred about 1,700 m.y. ago.

The largest area of exposed Precambrian igneous and metamorphic rocks in the quadrangle is in the Laramie Mountains. Precambrian rocks are also exposed in the northeast trending Hartville uplift. The Hartville uplift extends northwest from the Laramie Mountains to the Black Hills (Fig. 3) and consists of a pair of asymmetrical anticlines and an intervening syncline.

The Precambrian rocks were reduced to a surface of subdued relief by the late Cambrian when the advancing seas of the late Precambrian-Cambrian North American transgression had reached this far inland. Possible late Cambrian rocks are found only in the northern part of the quadrangle and the inference can be made that most of the area was an island in the late Cambrian sea. Nearby in the Black Hills the late Cambrian Deadwood Formation was deposited.

Lower Paleozoic rocks of the Ordovician and Silurian are also absent in the quadrangle. These rocks were either not deposited or were removed after deposition.

The Guernsey Formation is the only Devonian unit present in the quadrangle. Its thin basal arkose was assigned to the Deadwood Formation in early reports on the area but the arkose contains Devonian marine fossils. The remainder of the Guernsey consists of carbonates of both Devonian and

Mississippian age.

The Mississippian in southeastern Wyoming was generally a period of quiescence and marine carbonate deposition. The Madison Limestone, present in the western part of the quadrangle is the temporal equivalent of the upper part of the Guernsey. The upper surfaces of the Madison and Guernsey show strong subaerial karstic erosion.

Pennsylvanian rocks of the region exhibit rapid changes in depositional environments and thickness in short distances, the result of tectonic instability influencing sedimentation. Clastic rocks of the Pennsylvanian and Lower Permian Hartville and Casper Formations overlie Mississippian rocks in the area. The largely clastic aspect of these units resulted from the presence of the Frontrange and Pathfinder uplifts to the west.

The shale, limestone, siltstone, and gypsum of the Permian and Triassic Goose Egg Formation records continued tectonic instability of the region.

The Triassic Chugwater Formation is composed of shale and silty sandstone. These fine-grained red beds were deposited on a westward-sloping mudflat with scattered shallow pools of water.

Deposition of the Chugwater was followed by a long period of erosion. The marine Upper Jurassic Sundance Formation contains gray and green sandstones and shales. The overlying Jurassic Morrison Formation was deposited over a vast area of the western United States. It is a fluvial unit and contains most of the well known dinosaur beds of the Rocky Mountain region and many uranium deposits in the Colorado Plateau. The Morrison is thought to have been partly deposited by intermittent streams and partly by wind-borne dust and volcanic airfall. Lakes and swamps were also present, accounting for limestones and coaly beds in the Morrison. The rocks of the Morrison in this area are generally finer grained and contain a smaller proportion of fluvial sandstones than on the Colorado Plateau.

The base of the fluvial Lower Cretaceous Cloverly Formation is conglomeratic and sharply defines the Morrison-Cloverly contact. The conglomerate or conglomeratic sandstone, a medial shale, and an upper sandstone characterize both the Cloverly and its equivalent in the Black Hills region, the Inyan Kara Group. This interval contains uranium on the flanks of the Black Hills.

Marine shale deposition characteristic of much of the Cretaceous began with deposition of the Thermopolis Shale. The Muddy Sandstone separates the Thermopolis from the overlying siliceous Mowry Shale. The Mowry contains abundant marine fish scales. The overlying Frontier Formation, Niobrara Shale, and Pierre Shale are all dark-gray to black marine shales with subordinate thin sandstone and limestone beds.

The Upper Cretaceous Fox Hills Sandstone consists of white sandstone and gray sandy shale of marine origin. The uppermost Cretaceous unit in the Torrington Quadrangle is the predominantly fluvial Lance Formation. The Lance consists of lenticular sandstone and shale with many thin coal beds in the lower half.

The Paleocene Fort Union Formation consists of an upper Lebo Member and a lower Tullock Member. Although the Laramide Orogeny (named for the Laramie Mountains), which affected the entire Rocky Mountain chain, began as early as Late Cretaceous in many areas, there is no sedimentologic evidence for the orogeny in the Tullock Member in the Powder River Basin. Sandstone percentage does not increase toward any of the margins of the Powder River Basin (Curry, 1971) which indicates that none of the surrounding ranges, including the Laramie Mountains, had begun to rise. The Tullock contains abundant fine-grained sandstone, and subordinate amounts of thin coal and lignite beds deposited in a continental fluvial and paludal environments.

The upper Lebo Member of the Fort Union contains very thick coal beds in other parts of the Powder River Basin. The Lebo is characterized by mudstones and the sandstone percentage decreases upwards according to the basin-wide view of Curry (1971). However, thick arkosic point-bar sandstones are dominant in the upper Lebo in the southern Powder River Basin (Dahl & Hagmaier, 1976).

The early Eocene Wasatch and Wind River Formations are also fluvial, with coarse arkosic and conglomeratic sandstones, siltstones and claystones, and thin coals. The coarse clastics record continuing uplift in the Laramie and Granite Mountains. The Hartville uplift was a moderately positive feature but it contributed only a small quantity of sedimentary material to the Powder River Basin. No Paleocene or Eocene rocks are known in the Torrington Quadrangle east of the Laramie Range and, if deposited, were later removed.

Laramide uplift of the Laramie Mountains ceased before deposition of the tuffaceous fine-grained claystone of the White River Formation. Conglomeratic material along paleochannels at the pre-Oligocene unconformity suggests a moderate amount of relief at the beginning of White River time, although all but the highest portions of the mountains were finally buried by the White River Formation. A period of erosion stripped the White River from the crest of the Hartville uplift and removed some of the White River in the valleys of the Laramie Mountains. An unnamed conglomerate bed between the White River and the Arikaree may represent the deposits of the erosional period. Following this erosional period the fine sandstone and siltstone of the fluvial Arikaree Formation (Lower Miocene) was deposited.

Fluvial deposition on the plains east of the Laramie Range continued into the Upper Miocene with the deposition of more fine to coarse clastic material and fresh-water limestone beds.

The quadrangle has generally experienced regional uplift since the Miocene accompanied by removal of large volumes of the easily erodible Tertiary sedimentary rocks. Variable climate and uplift during Quaternary time has changed stream levels, producing multiple terraces and alluvial deposits. Quaternary eolian sands, loess, and playa deposits veneer large areas.

ENVIRONMENTS FAVORABLE FOR URANIUM DEPOSITS

DEFINITION OF FAVORABLE, UNFAVORABLE, AND UNEVALUATED

Under the guidelines supplied by the DOE, all ground within the quadrangle must be assigned to one of three categories: (1) Favorable, (2) Unfavorable, or (3) Unevaluated. Use of the category unevaluated is restricted to areas that were inaccessible. This category includes National Parks, National Monuments, and National Recreation Areas. The Fort Laramie National Monument is unevaluated, but it is only a few km^2 in area. The remainder of the quadrangle was evaluated.

The term favorable is applied only to formations or geologic environments (1) that can be demonstrated to have geologic characteristics similar to ground elsewhere in the quadrangle or elsewhere in the world where significant uranium resources occur, and (2) that can be demonstrated to have significant uranium mineralization, as indicated either by uranium occurrences, or by radiometric or geochemical anomalies. By analogy with the similar favorable ground elsewhere, it must be inferrable that the favorable ground in the quadrangle has the potential to contain at least 100 tons of U_3O_8 at a grade of at least 0.01 percent. Potential to contain is a key phrase in the above definition, and designation of an area as favorable does not imply that the author predicts the presence of the minimum endowment (100 tons at greater than 0.01 percent U_3O_8) in the designated area.

The term unfavorable is applied to ground where favorability, as defined above, has not been demonstrated. Designation of an area, map unit or environment as unfavorable does not imply that the author of this report predicts the absence of the minimum endowment of U_3O_8 in that area. Rather, use of the term implies only that the author has no strong, positive evidence of favorablilty.

Because time and resources available for this study were limited and the area covered is vast and geologically complex, and particularly because our understanding of the geologic factors controlling the formation and preservation of most types of uranium deposits is inadequate, much ground was of necessity classified as favorable or unfavorable based on too little information.

SUMMARY

Five areas in the Torrington Quadrangle have environments that appear to be favorable for uranium deposits. None of the areas contain mines that are currently producing uranium, but three areas have been extensively drilled, and one contains a mine that has produced 8 tons of U_3O_8 and has several abandoned mines that reported production of smaller amounts of uranium. Areas classed as favorable either have strong evidence that uranium ore-forming processes have been active, or they are geologically similar to nearby areas that have such characteristics.

AREA A, WASATCH FORMATION AND UPPER PART OF LEBO MEMBER OF FORT UNION FORMATION

Stratigraphy and Structure

The Wasatch Formation of Eocene age is unconformably overlain by the White River Formation of Oligocene age and rests on the Fort Union Formation of Paleocene age. There is a slight angular unconformity at the base of the Wasatch along the west flank of the Powder River Basin but, elsewhere, the formations are concordant and separated by an indistinct surface of erosion (Sharp and Gibbons, 1964). Throughout most of its extent the Wasatch is virtually horizontal, with dips of less than one degree to the northwest. Along the west side of the quadrangle strata dip from 2 to 7 degrees east and, northwest of the basin, as much as 25 degrees east (Childers, 1970).

The formation attains its maximum thickness in the vicinity of Pumpkin Buttes, in the Newcastle Quadrangle, and, although it must once have blanketed the area, this is the only place where the White River Formation rests on the Wasatch. Elsewhere, the upper part of the formation has been removed by erosion and, due to erosion, is absent along the east, west, and south flanks of the basin. A thickness of 480 m was measured by Sharp and others (1964) but Denson (1975) reported a maximum thickness of 570 m. In the Torrington Quadrangle it ranges in thickness from 200 m to zero at the erosional edge and averages about 85 m.

Lithology

The Wasatch Formation consists of mudstone and siltstone containing thick lenses of fine- to coarse-grained fluvial crossbedded, arkosic sandstone. Thin beds of coal and carbonaceous shale are common in some areas. A dominantly fine-grained facies flanks the basin on three sides and a dominant coarse-grained facies is present in the central and southern parts. The fine-grained facies consists of thinly interbedded siltstone, fine- to medium-grained sandstone, and coal or carbonaceous shale. Southward and toward the center of the basin, siltstone and carbonaceous shale decrease in amount; thick lenticular sandstone beds become more prominent and sandstone makes up as much as half the formation. Within the coarse-grained facies the grain size of the sandstone increases generally southward (Seeland, 1976) and, at the southern extremity of the outcrop, pebble conglomerate appears in lenses and stringers in the coarse-grained sandstone. In addition to this increase in grain size the sandstone units themselves generally thicken from north to south. Sandstone lenses as much as 45 m thick were mapped by Sharp and Gibbons (1964) at the southwest edge of the Wasatch outcrop in the Powder River Basin and 90 m of uninterrupted sandstone has been penetrated in drill holes.

The upper Lebo Member of the Fort Union Formation ranges up to 760 m and is composed of interbedded siltstone, claystone, carbonaceous shale, and coal beds with varying amounts of fine- to very coarse-grained conglomeratic sandstone. The coarse-grained and conglomeratic sandstone lenses occur in the southern and western parts of the basin. Outcrops on the east flank of the basin contain no coarse-grained sandstone so apparently a coarse- to fine-grained facies change occurs in the subsurface from west to east and from south to north much the same as in the overlying Wasatch Formation. All known uranium deposits in the Fort Union in the Torrington Quadrangle are in the upper coarse sandstones of the Lebo member. This part of the Lebo member is about 300 m thick and is lithologically indistinguishable from the Wasatch Formation.

Because uranium deposits in the Wasatch Formation and upper part of the Lebo Member of the Fort Union Formation are intimately associated with abrupt color changes, a careful description of the ranges in colors and their distribution is warranted. Most sandstone is medium to light gray in the subsurface, but weathers to dull shades of gray, yellow, or brown. In a well-defined zone along the axis of the basin, however, some of the sandstone at the surface is predominantly pale pink to grayish red and orange. Some lenses are only partly red and some are entirely drab. The red tint, where present, commonly affects a large continuous mass of sandstone. The contact of the red color within partly red sandstone lenses is generally very sharp but irregular in plan and section; contacts are generally convex into the drab sandstone. The outcropping red sandstone is restricted to an area about 110 km long and 8 to 30 km wide (Sharp and Gibbons, 1964). The long axis of the red sandstone zone closely parallels the axis of the basin and extends from the southern edge of the Wasatch sandstone about 10 km north of the North Platte River in the Torrington Quadrangle to several kilometers north of North Butte in the Newcastle Quadrangle.

Sedimentary Structures

The coarse- and fine-grained rocks of the Wasatch Formation and upper Lebo form thin to thick tabular and lenticular beds which complexly interfinger with one another on both a large and small scale. Most narrow sandstone bodies fill discrete fluvial channels cut in the underlying rocks and are roughly planoconvex in cross section. The longest sandstone bodies, which have been traced longitudinally more than 19 km, commonly have flat-lying lower contacts over much of their extent. Toward their edges these sandstone bodies become fine grained and silty. Normal to their sedimentary trend they may pinch out in several different ways, the most common of which is by the thinning of tongues away from the main part of the bodies. Sandstone lenses may decrease in thickness laterally from at least 12 m to zero in a distance of 90 m. In some localities channels are cut down through the intervening fine-grained strata and into a lower sandstone body; thus, the sandstone filling the upper channel is in direct contact with the lower one. The contact is marked in places by a reworked shaly sandstone zone as much as 1 m thick and it is impossible to delineate the contact between the two sandstone bodies where this shaly zone is absent.

The most conspicuous sedimentary structure in sandstone is cross lamination. A typical cross-laminated bed is about 50 to 60 cm thick and is overlain by as much as a dozen similar beds in a vertical distance of 6 m. Festoon crossbedding in northward-plunging troughs 0.5 to 2 m wide is not uncommon.

Another conspicuous feature of sandstone lenses is epigenetic concretions in which sand grains are tightly cemented by calcium carbonate. These are most common in thick sandstone lenses. Their shape and size range from spherical masses generally 15 to 25 cm in diameter to cylindrical masses 2 m in diameter and as much as 15 m long. In many places they are oriented parallel to crossbedding dip directions.

Depositional Environments

The rocks of the Wasatch Formation and upper Lebo Member of the Fort Union Formation are of fluvial, floodplain, and paludal origin, and were deposited in a slowly subsiding basin dominated by a warm humid climate. The facies distribution along with grain size and current direction studies by Seeland (1976) indicate that northward-flowing paleostreams deposited sand derived from a granitic source area to the south of the quadrangle. Following the deposition of most of the Fort Union Formation, the thick coarse-grained lensing sands in the southern part of the basin record renewed uplift in the source area and an increase in size and transporting power of the streams entering the basin. These streams probably were aggrading their courses fairly rapidly, perhaps rising on broad natural levees of sandy material. At times of flood the levees were breached and the lower areas on either side of the stream courses received a layer of overbank silt, clay, and some sand. Deposits of organic matter accumulated in heavily vegetated swamps that developed between stream courses.

Uranium Deposits

No producing or inactive mines are located within favorable Area A in the southern Powder River Basin in the Torrington Quadrangle but the Highland mine is only 7 km north in the Newcastle Quadrangle, and closely spaced drill holes at several locations in the Wasatch-Lebo(part) favorable area indicate the presence of important ore bodies in the subsurface. The following descriptions of ore bodies are for developed ore deposits immediately north of the Torrington Quadrangle in the Newcastle Quadrangle.

The uranium deposits in the Wasatch Formation and the upper part of the Lebo Member of the Fort Union Formation are classed as "Wyoming" roll-type deposits (Subclass 241, Austin and D'Andrea, in Mickle and Mathews, 1978) based on the following recognition criteria: (1) the tectonic setting is an intermontane basin in a mobile belt; (2) the major regional structures are Powder River Basin and adjacent Laramide uplifts; (3) the host rock for the deposits is arkosic coarse- to medium-grained sandstone with interstitial carbonaceous material and pyrite, deposited in fluvial stream channels, and forming stacked sequences of channel systems overlain and underlain by less-permeable siltstone and claystone; (4) the associated rocks are siltstone and claystone, granitic rocks of the Laramie and Granite Mountains, and the once present superjacent tuffaceous White River Formation are important possible sources of uranium; (5) pyrite of the host sandstone is oxidized and feldspars are altered; (6) primary uranium minerals include coffinite and uraninite, and vanadium-bearing uranium minerals are uncommon.

Uranium concentrations are associated with roll fronts, typically occur in the unoxidized gray sandstone, and attain their highest grade nearest to the oxidized side. From the roll front the grade gradually diminishes to background values with distance from the color boundary. Called "tails," thin zones of uraniferous sandstone, parallel to and in contact with the upper and lower bounds of the oxidized zone host unit, extend away from the main mass of ore at the front to well back into the altered side.

Although ore deposits occur at roll fronts in many places, the entire length of a particular roll front does not contain mineable concentrations of uranium. Dimensions of roll-front deposits vary greatly from one deposit to another and from place to place in the same deposit. At the Highland mine a segment of roll front 3.2 km long is continuously uranium bearing. More typical, however is the size and distribution of ore deposits along the extension of this roll front to the west as shown by Dahl and Hagmaier (1976, p. 248), where many small disconnected uranium concentrations, the longest of which is about 750 m, are present. The horizontal dimensions of the deposits perpendicular to the roll front range from less than 2 to 50 m; vertical dimensions range from less than 1 to 16 m.

The distribution of uranium in weathered near-surface deposits is very erratic and in some ways conspicuously unlike that in the deeper unweathered roll-front deposits. The deposits are closely associated with and commonly contained in iron-oxide-colored sandstone. The near-surface deposits are, very likely, remnants of roll-front deposits which have been partially destroyed and greatly modified by oxidation in the vadose zone after erosion stripped away the overlying strata and lowered the water table.

Uranium minerals in deposits below the water table are primarily coffinite, and subordinately uraninite. Above the water table carnotite and tyuyamunite are the most common minerals, but small amounts of liebigite, zellerite, uranophane, autunite, and uraninite are also present (Sharp and Gibbons, 1964). In the near-surface deposits the gangue minerals are calcite, gypsum, pyrite, hydrated iron oxides, and barite. Less common gangue minerals are manganite and pyrolusite. Below the water table, calcite, pyrite, and marcasite are the primary gangue minerals, the calcite occurring as cement in sandstone. Though small isolated concentrations of iron sulfides exceeding 5 percent are common, the overall concentration in ore is less than one percent.

Definition of favorable Area A

There are neither aerial-radioactivity anomalies in favorable Area A nor are there any helium anomalies (Pl. 7b).

Study of Landsat images in the southern Powder River Basin by Raines, Offield, and Santos (1979) revealed a major lineament down the approximate center of the basin. This lineament marks a recent tectonic feature, possibly the present axis of the basin. Most known uranium deposits in the Powder River Basin are just east of this axis. The areas of deposits were found to be in a Wasatch facies which has an intermediate sandstone-to-mudstone ratio and marked by a pattern of vegetation communities as seen on enhanced Landsat images.

The intermediate sandstone-to-mudstone- ratio facies as interpreted from the Landsat data and confirmed by subsurface information extends farther east (almost to the township 69 W.-70 W. line) than either the "red sandstone" line of Sharp and Gibbons or the eastern side of the favorable area as defined by Curry (1976) on the basis of easterly pinchouts of the extensive sand bodies of central part of the Wasatch (and Fort Union) outcrop. Another way to define the eastern limit of favorable ground is based on the Wasatch stream pattern (Seeland, 1976). Sediments having a Black Hills source were adjudged unfavorable because almost all known uranium deposits were in areas with a southern source. This area lies north of the Torrington Quadrangle. A similar area of fine-grained sediment in the Torrington Quadrangle might be attributed to the predominance of post-Precambrian detritus with a Hartville uplift source (Fig. 8 of Seeland, 1976). The inference is that not only were the streams draining the relatively low Hartville uplift of low gradient and velocity but much of their load was derived from fine-grained Paleozoic and Mesozoic rocks.

Area A (Pl. 1) contains the coarse-grained sandstone facies in the Wasatch and Fort Union. The favorable rocks extend from the surface down into the upper part of the Lebo Member of the Fort Union Formation. The outline of the area is approximately that used by Curry (1976) in his evaluation of the uranium resources in the Powder River Basin. His line generally encloses an area of coarse-grained sandstone with closely drilled patterns inferred to be ore bodies. The north edge adjoins a favorable area in the Newcastle

Quadrangle.

The size of Area A is 180 km^2. The thickness of favorable Lebo is about 300 m. The thickness of the Wasatch varies substantially because the base is a surface of erosion. Along the north boundary it may be as thick as 200 m in the western part of the area and only about 20 m in the eastern part. It also thins to zero toward the erosional edges. A very approximate average thickness of 80 m is estimated for Area A. The 80 m of Wasatch added to the 300 m of favorable Lebo results in a volume favorable for uranium deposits of 68.4 km^3.

Land status is detailed on Plate 12.

AREA B, WIND RIVER FORMATION

Stratigraphy

The Early Eocene Wind River Formation found in the Wind River and Shirley Basins is the stratigraphic equivalent of the Wasatch Formation in the Powder River Basin. Little is known about the lithology of the Wind River in the Torrington Quadrangle but, 15 km west, in the mines of the Shirley Basin in the Casper $1^\circ x2^\circ$ Quadrangle, it consists of about one-third sandstone and two-thirds siltstone and claystone (Harshman, 1972). The Wind River does not appear to coarsen as it laps eastward onto older rocks nearer the Laramie Range. The Wind River is as thick as 200 m near the mines on the Casper Quadrangle but is estimated to be less than 50 m thick in the Torrington Quadrangle.

Definition of favorable Area B

There are several factors that suggest favorability of the Wind River Formation in the Torrington Quadrangle for deposits of "Wyoming" roll-type subclass 241. The ore deposits of the Shirley Basin are of subclass 241 and are as little as 15 km to the west. The lithology and depositional environments are similar to those in the Wind River in the mine area to the west. An aerial radiometric anomaly corresponds with part of the outcrop area of the Wind River. Two helium anomalies (Pl. 7b) that may be related to uraniferous ground water also exist near the Wind River outcrops. Both granitic and tuffaceous White River Formation rocks are nearby to provide a source of uraniferous ground water.

If uranium deposits are found in the Wind River Formation in Area B in the Shirley Basin they will most probably be like the deposits now being mined 15 km west in the Wind River which are "Wyoming" roll-type deposits, (subclass 241, Austin and D'Andrea, in Mickle and Mathews, 1978). The only difference in the recognition criteria used to identify the uranium deposits in Area A (Pl. 1) and Area B (Pl. 1) is that area B ores will have, if the Shirley Basin mines are representative, uraninite as the principal ore mineral.

The outline of Favorable Area A (Pl. 1) is the mapped formational extent of the Wind River except where it extends under younger geologic units. In these subcropping areas its extent is estimated. Area A consists of three separate areas.

The size of the favorable Area B is 115 km^2. If a Wind River thickness of 25 m, one-half the maximum thickness, is used, then the volume of favorable Wind River Formation is 2.9 km^3. The volume of favorable sandstone would be one-third of this or 1 km^3.

Land status is detailed on Plate 12.

AREA C, CLOVERLY FORMATION

Stratigraphy

Cloverly Formation in southeast Wyoming is equivalent to the Inyan Kara Group in the Black Hills; they are lithologically similar and stratigraphically equivalent. The Cloverly in the Torrington Quadrangle has an upper thin-bedded, gray, shaly, ferruginous sandstone, a medial shale-siltstone-claystone unit, and a basal medium-grained gray sandstone with some chert conglomerate lenses. The Cloverly was deposited in a nearshore marine environment. The Fall River Formation, which is uranium bearing near the Black Hills, is the equivalent of the upper sandstone of the Cloverly Formation and was deposited in mixed fluvial, deltaic, and marine environments (Harris, 1976). From east to west the Fall River becomes progressively more marine. The lower sandstone unit of the Cloverly Formation is the equivalent of the basal Lakota Formation of the Inyan Kara Group. This sandstone was deposited in a warm humid climate in fluvial and lacustrine environments.

Uranium deposits and class of uranium occurrences

The Cloverly Formation is not known to be uranium bearing in the Torrington Quadrangle, but it contains uranium on the crest of Old Woman anticline in the Newcastle Quadrangle a few km north of the Torrington Quadrangle boundary. Nearer the Black Hills, the well known Inyan Kara uranium deposits have some characteristics of both channel controlled (Subclass 243) and non-channel-controlled (Subclass 244) peneconcordant sandstone deposits. The most favorable host rocks are the lower fluvial part of the lower sandstone of the Inyan Kara Group, the Lakota Formation, and the lower part of the upper sandstone, the Fall River Formation, although small occurrences are found throughout the Inyan Kara Group.

Vickers (1957) gave the first published description of a roll-type deposit in North America in the Fall River although they were not yet so-named and recognized; their existence in Area C is probable. The mixed-marine and non-marine character of the Fall River Formation and the progressive change to a more marine environment westward from the outcrop suggest that these rolls may be "Texas" roll-type deposits of Subclass 242.

Uranium minerals in oxidized deposits to the north of the Torrington Quadrangle are chiefly carnotite, tyuyamunite, and metatyuyamunite. The yellow minerals occur with variable amounts of calcite, iron oxide, carbonaceous material, and clay minerals interstitial to the quartz grains that make up the bulk of the host sandstone. Ore minerals in partly oxidized deposits are corvusite, rauvite, carnotite, and tyuyamunite, all of which occur interstitially to quartz grains. These deposits contain small amounts of calcite and pyrite. Ore minerals in unoxidized deposits are uraninite, coffinite, paramontroseite, and haggite (Gott and Schnabel, 1957). These minerals occur interstitially in sandstone and are intimately associated with calcite, pyrite, marcasite, and jordisite. Uranium, vanadium, and iron minerals occur principally as banded nodules, pods, lenses, or fracture fillings in the sandstone. Characteristically, either a core of pyrite or a core of hematite is surrounded by a mixture of vanadium and uranium minerals. Gangue minerals are iron oxides, iron sulfides, and calcite as cement in the host sandstone units.

Many deposits of uranium minerals are selectively concentrated around carbonized wood fragments and macerated plant remains. In many other deposits, in which this relation does not exist, the uranium minerals seem to have been precipitated by an ephemeral agent, probably hydrogen sulfide. Analyses of water in wells in the Inyan Kara near the Black Hills indicate the presence of as much as 150 ppm hydrogen sulfide (Gott and others, 1974). The presence of hydrogen sulfide was attributed to bacterial reduction of sulphate where sufficient carbonaceous material is available to support the bacteria.

Definition of the favorable Area C

Favorable Area C in the Cloverly Formation (Pl. 1) in the northeast corner of the Torrington Quadrangle is entirely in the subsurface and is defined by the presence or absence of anomalous gamma-ray logs. Wells with gamma ray logs are widely spaced and therefore the favorable area is not well defined. The favorable area extends into the Newcastle Quadrangle to the north and the Hot Springs Quadrangle to the northeast. The favorable part of the unit is assumed to extend to a depth of 750 m, matching the maxiumum depth of favorability used in the New castle and Hot Springs Quadrangles where there is better control. Areas where pre-Tertiary valleys containing permeable Tertiary conglomerates that cross the Inyan Kara subcrop are thought to be particularly favorable.

The southern limit of favorable Cloverly Formation rocks east of the Hartville uplift is approximate, and separates areas with no gamma-ray anomalies in scattered test wells from areas where gamma-ray anomalies are present in scattered test wells to the north. Until additional wells are drilled in the area this line will remain approximate.

Gamma-ray data from test wells is unavailable along the southern margin of the Powder River Basin. However, from east to west the medial shale and siltstone unit and upper sandstone of the Cloverly Formation probably become more marine and thus unfavorable for the occurrence of uranium deposits. This puts a very approximate western limit on Area C. It is also defined along the margin of the Powder River basin by an unmapped fault that drops the formation to depths greater than 1,500 m.

Distance from the Black Hills is another constraint on the boundary of favorable Area C. A rather complex system of ground-water movement and physical-chemical change has been suggested by Gott and others (1974). It relies on artesian water flowing outward from recharge areas in the Black Hills through carbonates underlying the Inyan Kara. The water rises under artesian pressure, enters the Inyan Kara and carries uranium- bearing water down dip. In the Torrington Quadrangle the faulting and uplift of the Hartville uplift, the faulting at the south edge of the Powder River Basin, and the Laramie Mountains uplift and its subsidiary structures all create a situation in which it is impossible to visualize a simple outward flow of water from recharge areas in the Black Hills.

The size of favorable Area C is 1,180 km^2. The thickness of the Cloverly ranges from 45 to 95 m. Using an average thickness of 70 m gives a volume of 83 km^3 of favorable rock.

Land status is detailed on Plate 12.

AREA D, LANCE (LARAMIE) FORMATION AND FOX HILLS SANDSTONE

General statement

There has been substantial company interest in finding low-grade uranium deposits in Upper Cretaceous sandstones on the east side of the Powder River Basin and in the northern Denver Basin that could be developed by solution mining. The mineralized sandstone units are the upper part of the Fox Hills Sandstone and the Lance Formation (Powder River Basin) and its stratigraphic equivalent the Laramie Formation (Denver Basin). Economic concentrations of uranium in these units are known to exist 140 km north of the Torrington Quadrangle near Moorcroft, Weston County, Wyo. and 125 km south of the Torrington Quadrangle near Grover, Weld County, Colo. Another area in which companies have drilled numerous exploratory holes to this horizon is centered 20 km south of the quadrangle in Goshen Hole. Although most drilling has been south of the quadrangle's southern boundary, exploratory drilling has extended at least as far north as the North Platte River in the southeastern part of the quadrangle.

There are no known published reports on the probable uranium deposits in the Upper Cretaceous Lance and Fox Hills Sandstones of this area, which do not crop out at the surface, but the level of interest strongly suggests that the area meets the minimum endowment criteria.

Stratigraphy and sedimentation

Ethridge, Tyler, and Thompson (1979) have discussed the stratigraphy and sedimentology of the rocks containing the Weld County, Colo. uranium deposits. They describe the Fox Hills deltaic system which makes up most of the Fox Hills and the barrier-bar system of the upper Fox Hills. The depositional setting of the Laramie (Lance) Formation is interpreted as a lower alluvial plain and upper delta-plain fluvial system with southeasterly-flowing streams.

Controls on distribution of uranium

Of more direct interest to the evaluation of the potential of the Lance and Fox Hills in the Torrington Quadrangle is a statement of Ethridge, Tyler, and Thompson (1979 p. 31) that contours on the (pre-Oligocene) surface of the Laramie Formation in Weld County, Colo., show valleys that may have localized ground-water flow patterns in the Oligocene White River Formation. Plotting of roll fronts on this paleotopographic map by Harry Dodge (oral commun., 1980) of the USGS shows a striking correlation between the location of the four largest known deposits of the Weld County area and the positions of paleostream valleys.

The pre-Oligocene paleotopographic map (Plate 10a) of the Torrington Quadrangle shows a paleostream valley trending north and northwest from near Torrington in the southeast corner of the quadrangle. The intersection of this valley with the subcrop of the Lance and Fox Hills is a particularly attractive exploration target lying near the presumed mineralization of Goshen Hole. Throughout the quadrangle, at the base of the Oligocene, a 3 to 10 m thick paleosol is found overlying bedrock on the interfluves. This paleosol generally consists of tan to gray clay where seen in outcrop, and effectively seals off the underlying rocks from contact with any uranium-bearing ground water derived from the uraniferous, tuffaceous, White River Formation. In the valleys the base of the Oligocene is marked by conglomerates rather than the clayey paleosol. The permeability of the conglomerate may have allowed easy access of uranium-bearing water to the underlying rocks.

No detailed studies or age determinations have yet been made on ores in the Fox Hills and Lance, it is possible, therefore, that the uranium is syngenetic, and if it is, then there should be no correlation between mineralization and pre-Oligocene topography. At least two epigenetic scenarios are possible and both indicate maximum favorability along paleostream axes. First, the uranium could have been carried in the water of streams draining granitic terranes such as the Laramie Mountains (or possibly both the Laramie Mountains and the Granite Mountains). The second epigenetic possibility is that uranium was leached from the tuffaceous White River Formation by ground water which would tend to flow downslope in the conglomerates of the paleostream valleys. In either case the conglomerates would provide hydrologic access to the underlying formations, which, as previously explained, are blanketed by the impermeable clays of a paleosol on the interfluves.

Drill holes for which gamma-ray logs are available were examined in the part of the southeastern corner of the quadrangle underlain by Lance (Laramie) and Fox Hills sandstones where scattered anomalies did occur. Additional gamma-ray logs were examined in the southern Powder River Basin in the northwest part of the quadrangle but no anomalies were found in the Lance and Fox Hills.

Class of uranium occurrences

Two uranium deposit types may exist in Favorable Area D. The uranium deposits that may exist in the Lance Formation in Area D in the southeastern corner of the quadrangle are classed as "Wyoming" roll type deposits (Subclass 241, Austin and D'Andrea, in Mickle and Mathews, 1978) based on the following recognition criteria: (1) The tectonic setting is a coastal plain. (2) Adjacent uplands, if they exist, would be northwest of the area. (3) The host rock for the deposits is fine- to medium-grained carbonaceous shales with coal partings present; is deposited in channels on a coastal plain; is in meandering rivers; is probably in stacked sequences of sinuous channel systems; siltstone and shale are present. (4) Siltstone is present and the unit is in contact with the coarse-grained sandstones and conglomerates at the base of the overlying tuffaceous White River Formation. (5) Alteration and mineralogy have not been described in adjacent areas.

The postulated uranium deposits in the Fox Hills Formation, also in the southeast corner of the quadrangle are classed as "Texas" roll-type deposits (Subclass 242, Austin and D'Andrea, in Mickle and Mathews, 1978) based on the following recognition criteria: (1) the tectonic setting of the Fox Hills was a coastal plain but faults are not known; (2) the host rock is a quartzose sandstone, has barrier-bar sands and fluvial sands present, and blanket sands and stacked sinuous channels probably are present; (3) silty sandstone is found near the base, no siltstones are present, and superjacent tuffs are present; (4) mineralogy and alteration, however, are unknown.

Size and volume of Favorable Area D

The northwestern boundary of Favorable Area D is the subcrop of the base of the Fox Hills Sandstone; the other edges are the quadrangle boundaries.

The size of area D is 1,250 km^2. Based on uranium deposits to the north and south of the quadrangle it can be expected that if the Fox Hills has been mineralized so was the Lance. The Fox Hills is about 60 m thick and the upper 40 m is sandstone; the Lance is more than 600 m thick and the upper 100 m is sandstone. The thickness of favorable sandstones in the Lance and Fox Hills is 140 m and the volume is 175 km^3.

Land status of area D is detailed on Plate 12.

DEPOSITS IN PRECAMBRIAN ROCKS RELATED TO THE PRE-OLIGOCENE UNCONFORMITY

General Statement

It is postulated that the Archean (and Proterozoic) igneous and metamorphic rocks of the Laramie Mountains and Hartville uplift are favorable for the occurrence of unconformity-related deposits (Class 710). This assessment is put forth in spite of the statement by Mathews (1979, p. 222) that no deposits of this class are known in the United States. Similar examples in the U.S. appear to be the Marshall Pass and Cochetopa districts of Colorado (Olson, 1976, 1979), the Stanley Uranium district (Choate, 1962) of central Idaho, and the Copper Mountain uranium deposit of Wyoming (Yellich, Kramer, and Kendall, 1978). If these deposits aren't unconformity-related then it seems likely that magmatic-hydrothermal vein deposits would be widespread in the Precambrian rocks of Wyoming and particularly in the uranium-rich rocks of the Granite Mountains. If magmatic hydrothermal deposits are not common in areas where they could be expected then this suggests that the vein deposits in the Torrington Quadrangle are unconformity related. The spatial distribution of uranium occurrences in the Precambrian rocks of the Torrington Quadrangle also supports the theory that the deposits are related to overlying tuffaceous sedimentary rocks. Nearly all of the occurrences (Pl. 2) in the Laramie Mountains lie in the postulated Oligocene trans-mountain drainageways (Pl. 1).

Smith (1954a, p. 16) made a reconnaissance study of uraniferous deposits in the Laramie Mountains and concluded that the known uranium occurrences were not large enough or consistent enough in grade to mine.

Guilinger (1956) studied the north Laramie Peak district and concluded that only the Trail Creek mine (Pl. 2, occ no. 18) shows a potential for production. Most of the occurrences are spatially related to contacts between schists and granites as at the Maggie Murphy mine (Pl. 2, occ. no. 26), where coffinite is found adjacent to a granitic-rock schist contact. The Trail Creek mine (Pl. 2, occ. no. 18) has produced a small amount of uranium ore from the junction of two nearly vertical shear zones. Limonitic coatings and 3-5 cm thick copper carbonate layers caused Guilinger (1955, p. 8) to conclude that there had been substantial ground-water movement through the shear zones.

The Albany No. 1 claim (Pl. 2, occ. no. 31) also in the Laramie Mountains, has produced 14 tons of ore containing 10 kg of U_3O_8 from a vertical fault zone in granite.

The Silver Cliff mine and the Rawhide Buttes are the two localities (Pl. 2, occ. no. 112, 118) with the most favorable past uranium production in the Precambrian of the Hartville uplift. The Silver Cliff mine (Pl. 2, occ. no. 112) has been described by Willmarth and Johnson (1954). The deposit lies along a north-trending high-angle reverse fault. The uranium minerals occur in either the fault zone or the highly fractured basal Paleozoic sandstone that lies on the footwall of the fault. Uranophane is the most abundant uranium mineral but pitchblende and gummite also occur. The production figures are questionable but the Silver Cliff mine may have produced as much as 800 tons of ore having a grade of 0.98 percent U_3O_8.

The Rawhide Buttes area (Pl. 2, occ. no. 118) is south of the Silver Cliff mine and although no production is reported, high scintillometer readings were obtained. Ore piles with about 150 tons of ore were seen. Analyses of 3 samples averaged 519 ppm uranium. The deposit is localized by intersecting fault zones in Precambrian schist. Pitchblende is probably the major uranium mineral present.

Controls on distribution of uranium

The Hartville uplift was almost certainly completely buried by Oligocene tuffaceous sediments. The Laramie Mountains are traversed by major valleys which either presently contain a portion of their originally deeper filling of tuffaceous Oligocene sedimentary rocks or which once contained Oligocene rocks. Most of the Laramie Mountains occurrences can be related to these valleys and to the pre-Oligocene unconformity.

The Laramie Mountains are an asymmetric anticlinal range. The axis of the anticline lies near the east side of the range, as do the higher peaks such as Laramie Peak. The head waters of the Laramie and North Laramie Rivers are both west of the range and many of the minor streams have head waters more than two-thirds of the way west across the width of the range. Oligocene rocks along the north-south La Prele Creek-North Laramie River valley are separated by a 10-km gap and a 60-m-high, gently sloping divide. During and after White River deposition this valley and many others throughout the Laramie Mountains probably were filled with sediments that surrounded many of the peaks and ridges of the range and formed a surface on which streams flowed from the west to east across the range. These streams had gradients of about 15 m per km, about 13 times as steep as the present gradient of the South Platte. The presumed Oligocene peaks and ridges can be seen as "islands" in Favorable Area E (Pl. 1).

Blackstone (1946, p. 254) felt that the major streams in the region were superposed over major Laramide structures from an overlying blanket of Tertiary cover. Segerstrom and others (1977, p. B12) concluded that streams in the Laramie Peak area were antecedent. Not discussed, but strongly suggestive of antecedence is the strong tendency of the stream valleys to be linear and oriented along major joint and fault directions.

The Oligocene sediments that filled these valleys have, for the most part, been removed. Uplift that initiated this erosion began in late Miocene time (Denson, 1969). The uplift could have been of anticlinal nature--as was the initial uplift of the range--but was centered west of crest of the range. Some of the streams were able to down cut and maintain their trans-mountain courses. Others were unable to cut downward rapidly enough and the flow directions in the westward segments of these were reversed.

It is difficult, if not impossible, to ascertain exactly which present-day valleys were also Oligocene valleys. In general, it is thought that the larger valleys are most likely the older valleys. On the east side of the Wind River Range the largest drainage systems were found to have existed since the Early Eocene (Seeland, 1978).

During the Paleocene and Eocene when the Laramie Mountains first rose, the drainage pattern was symmetrical about the axis of the range. It could be expected that the streams on the steeper northeast flank of the range probably cut downward and headward faster than the streams on the southwest flank. The Granite Mountains (Fig. 3) were a large, high range that began eroding to fill the Shirley Basin from the west during the Paleocene (Harshman, 1972, p. 19). By the Early Eocene, and certainly by Oligocene time, the Shirley Basin was full and streams from the Granite Mountains spilled over the much lowered Laramie Mountains divide from the Shirley Basin and flowed into the area to the east of the range.

It also may be significant that major north-south Paleocene-Early Eocene subsurface sand bodies (Elmer Santos, oral commun., 1979) in the southern Powder River Basin are perfectly alined with the R. 74 W. north-south trans-mountain drainage. The sand bodies are not only oblique to the basin axis (Fig. 3), but they are oblique to the northwesterly trending Laramie Mountains. This also suggests a genetic relationship between the drainage and the sand bodies, and furthermore, suggests that the drainages may have existed since the Paleocene.

Tuffaceous Oligocene White River sediments could have filled many of the valleys of the Laramie Mountains whether or not the major valleys contained streams flowing across the range. If they did flow across the range, then in addition to the presence of uraniferous tuff, surface water and sediment derived from the Granite Mountains would clearly add to the amount of available uranium. The favorability of the Granite Mountains as a source of uranium has been documented by Stuckless (1979).

Mafic dikes, the youngest of the Precambrian rocks of the Laramie Mountains, were emplaced along fractures, followed by scanty sulfide mineralization along some of the dikes and fractures (Segerstrom and others, 1977, p. B10). Many of the mafic dikes trend northeast as do many joints, thus causing a pronounced northeast structural and topographic grain in much of the Laramie Mountains area. Many streams follow joint- and fault-controlled valleys. In Miocene time the Laramie Peak horst formed (Segerstrom and others, 1977), and further sulfide mineralization along reactivated Precambrian faults occurred.

The presence of fractures with sulfide mineralization is important because the fracturing could have provided an entry for uraniferous water and the sulfides could then have provided the reductant necessary for the precipitation of uranium.

Because of the subdued topography on the Precambrian rocks of the Hartville uplift and the great thickness of the Oligocene White River deposited in the area they were at one time certainly covered by these tuffaceous sediments. Examination of the geologic map (Pl. 10) shows evidence for renewed uplift that removed the White River from the crest of the Hartville uplift prior to deposition of the Miocene Arikaree Formation.

Langford (1977) thought that the uraniferous lignites in North Dakota, which Denson and Gill (1956) suggested had obtained their uranium from the overlying tuffaceous Oligocene and Miocene rocks, were just as likely to have picked up uranium from the streams that shaped the unconformity. Langford (1977) pointed out that he felt that the work of Rosholt and others (1971) "casts doubt on the ability of volcanic ash to provide significant amounts of uranium through simple hydration and leaching." However, many investigators including Harshman (1972), have found elevated levels of uranium in springs issuing from the White River. These arguments are not critical because the streams that formed the pre-Oligocene valleys drained weathering granitic terranes and therefore the water had elevated uranium levels. The tuffaceous White River certainly provided a long-lived source of additional uranium. The existence of plumbing (fractures), source of uranium (tuffaceous rocks, streams containing elevated uranium levels from weathering granites), and reductants (sulfides of hydrothermal origin in fractures) all suggest that pre-Oligocene valleys are important in the localization of probable uranium deposits.

Class of uranium occurrences

Gruner and Smith (1954, p. 7) are the only known investigators who related any of the uranium vein occurrences of the Precambrian rocks of the Torrington Quadrangle to the uraniferous Oligocene sedimentary rocks of the area. Other investigators including Guilinger (1955) and Wilmarth and Johnson (1954) postulated a hydrothermal origin for the uranium, although some suggested later redistribution of the uranium by ground water.

Gruner and Smith (1954, p. 7) wrote the following about the Silver Cliff uranium deposit:

> "At the western edge of Lusk, Wyoming, a deposit containing uranophane has been known for many years. This was visited by us, incidentally, on our route from Douglas, Wyoming, to Hot Springs, South Dakota. The U is in the Cambrian basal quartzite which lies on pre-Cambrian gneisses and schists. Based on the geomorphology of the region, it is highly probable that the very resistant quartzite was a monadnock at the time when the thick Eocene White River formation began to cover

the region. During subsequent erosion the U in the White River Formation was leached downward into the Deadwood quartzite. The copper carbonates which are found in the same locality may be genetically associated with the U or may have an entirely different origin."

Recent discoveries of large amounts of uranium have been made at Copper Mountain on the southern margin of the Owl Creek Mountains on the Arminto $1^{o}x2^{o}$ Quadrangle. Uplift of the mountains along a high-angle reverse fault and subsequent collapse of the toe of the thrust created much faulting and fracturing in the Precambrian granites and metamorphic rocks (Yellich, Cramer, and Kendall, 1978). Overlying the Precambrian rocks are the arkosic sandstone, conglomerates, siltstones, and mudstones of the Late Eocene Teepee Trail Formation. The Teepee Trail consists both of locally derived clastic components and bentonitic fine-grained rocks formed from volcanic ashes from sources to the west. Meteoric waters carrying uranium from the overlying sediments picked up additional uranium in the granitic rocks. However, most of the uranium was of supergene origin (Yellich, Cramer, Kendall, 1978). The uranium was deposited in the fractured rocks where the uranium-bearing water contacted reducing hydrocarbons (from below the thrust), sulfur-bearing waters, and possibly sodium-chloride brines (Yellich, Cramer, and Kendall 1978, p. 319). Although different in detail from the simpler structural setting in the Torrington Quadrangle, the Copper Mountain deposits are basically analogous to known and postulated occurrences there. Uranium mineralization in both areas is related to meteoric water carrying uranium downward from Tertiary sediments into fractured Precambrian rocks where the uranium is precipitated.

Langford (1974, 1977) has argued for the supergene origin of many deposits previously thought to be of hydrothermal origin, for example, the pitchblende-vein deposits of the Canadian Shield. He noted that the Canadian veins are consistently associated with terrestrial sediments, an association difficult to explain by the hydrothermal theory, but easily explained if the deposits are of supergene origin.

Robertson and others (1978, p. 1414) also discussed the origin of paleosurface controlled vein deposits and concluded that the evidence favors a supergene origin. Vein deposits are likely to have formed since oxyatmoversion at about 2,200 m.y. when solution of uranium minerals became possible. After the development of land plants in the Devonian, reducing sedimentary environments became common and much of the uranium was precipitated in tabular syngenetic deposits leaving less uranium for the formation of vein deposits.

The uranium deposits of the Precambrian rocks of the Torrington Quadrangle are classed as polymetallic and monometallic unconformity-related deposits (Subclass 712 and 711, Mathews, _in_ Mickle and Mathews, 1978). Known deposits are polymetallic, but there is no geologic reason that monometallic deposits having the same genesis might not be found. These assignments are based on the following recognition criteria: (1) The tectonic setting for the

Precambrian rocks is that of a mountain range and an anticlinal, faulted uplift of moderate topographic relief rather than a shield area. (2) The major regional feature related to the ore deposits is a pre-Oligocene unconformity between a basal metamorphic and igneous sequence and an overlying tuffaceous sedimentary sequence. (3) Dominant local structures include fault, breccia, and shear zones. (4) The detailed settings of the deposits include metamorphic and igneous host rocks; metamorphic rocks that are foliated, sheared, and faulted, and granitic rocks that are sheared and faulted, and overlying sediments that are not texturally mature but do contain sandstones and conglomerates; sulfide deposits with quartz, galena, pyrite, arsenopyrite, chalcopyrite, copper carbonate, chalcocite, native silver found near the uranium ore, confinement of deposits to shear and fault zones; and post-faulting deposits which are most likely Tertiary or Recent. (5) Alteration includes hematization. (6) Uranium minerals include pitchblende and coffinite. (7) Associated elements include Co, Ni, Cu, As, Sb, Pb.

Definition of Favorable Area E

Favorable Area E is all parts of the Precambrian outcrop area in the Laramie Mountains and Hartville uplift that are thought to have bee covered by the tuffaceous sediments of the Oligocene White River. This is determined partly by the present distribution of Oligocene rocks and partly by the assumed former extent of the Oligocene which has been crudely estimated by inspection of the topographic map of the quadrangle.

Size and volume of the Favorable Area E

Favorable Area E, is 1,800 km^2 in size. Robertson and others (1978, p. 1414) stated that paleosurface related veins in most places do not extend more than 200 m below the cover rock. Since the cover rock has been removed in a substantial proportion of favorable area E (Pl. 1), allowing removal of part of the favorable Precambrian rocks, the average remaining thickness is estimated to be about 150 m, which gives a volume of 270 km^3.

Land status of Area E is detailed on Plate 12.

ENVIRONMENTS UNFAVORABLE FOR URANIUM DEPOSITS

INTRODUCTION

Finnell and Parrish (1958) point out that local concentrations of uranium occur in 34 of the 122 formations of the central Cordilleran foreland but most of the ore deposits have been found in 9 formations. Combining correlative units such as the Wasatch and Wind River, and counting as one unit the formations of the Inyan Kara Group, leaves the following four ore-bearing units occur in the Torrington Quadrangle: the Morrison Formation, Inyan Kara

Group (Cloverly Formation), Fort Union Formation, and Wasatch Formation. Three of these are favorable in the Torrington Quadrangle; the Morrison is too silty to be favorable here. This list, however, does not establish a priori evidence that any unlisted unit is unfavorable. Recent developments suggest that rocks like those of the Precambrian at Copper Mountain and the Lance and Fox Hills at various locations must certainly be added to the list of ore-bearing units.

Discussion of unfavorable units will be based on lithologic groupings as far as possible.

PRECAMBRIAN QUARTZ-PEBBLE CONGLOMERATE

Radioactive quartz-pebble conglomerate has been reported (Houston and Karlstrom, 1980) among the Precambrian metamorphic rocks in the Slate Creek area (T. 23N, Rgs. 70 and 71 N.) in the Cheyenne Quadrangle, immediately south of the edge of the Torrington Quadrangle. Little is presently known about this conglomerate, and its economic potential has not been evaluated. However, uranium mining companies and the DOE are currently studying these radioactive conglomerate occurrences.

The radioactive conglomerate of Slate Creek is one of several occurrences of radioactive conglomerate that form a trend paralleling the southeastern edge of the Archean-age Wyoming Province. Other occurrences are found in the Black Hills of South Dakota, in the Medicine Bow Mountains, and in the Sierra Madre of Wyoming. Although not exactly dated, all of these occurrences are in rocks at least 1,700 m.y. old and all are probably over 2,000 m.y. old. In the Black Hills and in the Medicine Bow Mountains, radioactive conglomerate rests unconformably upon granitic gneisses that are 2,500 to 2,700 m.y. old (Zartman and Stern, 1967; Hills and Houston, 1979). Houston and Karlstrom (1980) interpret the radioactive conglomerates in the Medicine Bow Mountains and in the Sierra Madre as late Archean or early Proterozoic fluvial deposits formed in braided-stream or river systems, and Hills and Houston (1979) interpret the succession of strata of which the conglomerates are basal members, as belonging to a miogeoclinal or coastal-plain prism formed along the southern edge of the Wyoming Province. The conglomerates are, according to these interpretations, analogous to uraniferous conglomerates of the Elliot Lake district of Ontario and of the Witwatersrand of South Africa. The trend formed by radioactive conglomerate localities in South Dakota and southern Wyoming adjoins a terrane containing anomalously uraniferous Archean granite. These uraniferous granites, exposed in the Granite Mountains, Wyoming, may be the source of the uranium in the radioactive conglomerates (Stuckless, 1979).

Uranium grades and mineralogy have not been reported where the radioactive conglomerates have been drilled in the Sierra Madre, Medicine Bow Mountains, and Black Hills. However, concentrations of greater than 100 ppm uranium and greater than 1,000 ppm thorium are reported from weathered outcrop (Hills, 1977; Houston and Karlstrom, 1980) and uranium concentrations are expected to be considerably higher in unleached rock in the subsurface. Drill core from each of these areas shows 5-20 percent pyrite in the matrix between pebbles.

Metasedimentary rocks that may correlate with formations containing radioactive conglomerate beds in nearby areas are found in the Laramie Mountains and in the Hartville uplift, in the Torrington Quadrangle, but no radioactive conglomerates have been reported. Thus, although these metasedimentary rocks are interesting exploration targets with potential to contain quartz-pebble-type uranium ore, we cannot at this time designate areas that meet the minimum DOE criteria for favorable areas. (F.A.H.)

LIMESTONES

The Guernsey Formation, Madison Limestone, and Hartville Formation are all Paleozoic marine limestones and all have low permeability and lack organic reductants. Furthermore, uranium deposits in limestone are rare and there is no evidence to the contrary in this quadrangle. Associated sandstones also lack organic matter. The ore in the quartzite at the base of the Guernsey at the Silver Cliff mine near Lusk is related to faults truncated by an unconformity and is an unusual situation not likely to occur elsewhere in the quadrangle.

SHALE, SILTSTONE, AND CLAYSTONE

Marine Black Shales

Marine black shales of Cretaceous age are common in the area, and although they do contain concentrations of uranium, the grade is much too low to meet the required endowment. The Sharon Springs member of the Pierre Shale is an example of a "Chattanooga type" low-grade uranium-rich marine black shale (Mathews and others, 1979, p. 6). The remainder of the shale in the Pierre Shale is even less favorable. The Niobrara Formation, the Frontier Formation, the Cody Shale, the Mowry Shale, and the Thermopolis Shale are all primarily black shale but are similarly unfavorable for the existence of uranium occurrences containing more than 100 tons U_3O_8 with an average grade of 0.01 percent U_3O_8.

Other lithologies occur in these black shales. Marine limestone and chalky limestone in the Niobrara are unfavorable because of their lack of porosity and reductants, and position within unpermeable shales. The Pierre Shale, Mowry Shale, Thermopolis Shale, and Frontier Formation contain sandstone beds judged to be unfavorable because of their enclosure by thick shale sequences. The Wall Creek Sandstone Member of the Frontier is adjacent to mineralized sandstones of the Wind River Formation just outside the quadrangle in the Shirley Basin but is not itself mineralized. However, there is some possibility of mineralization in these sands where they subcrop along the pre-Oligocene unconformity. There are no occurrences in any of the Cretaceous black shales in the Torrington Quadrangle.

Chugwater Formation

The Chugwater Formation, a Triassic red-bed unit, consists of siltstone, shale, silty sandstone, and gypsum rocks that are unfavorable because they have low permeability and are devoid of organic or other reductants. There are no uranium occurrences in the Torrington Quadrangle in the Chugwater Formation.

White River Formation

The Oligocene White River Formation is often invoked as a source of uraniferous ground water for mineralizing the underlying Eocene and Paleocene sandstones. The source of the uranium is tuffaceous material thought to have been derived from volcanic centers in northwest Wyoming. Much of the White River is tuffaceous siltstone and clayey siltstone deposited on a floodplain with almost no organic material. Most of the White River is impermeable and lacks reductants and is therefore an unfavorable environment in spite of the fact that there are numerous uranium occurrences in the unit. No occurrences are of high enough grade to meet the minimum requirements. Two radiometric anomalies in a basal conglomerate unit filling a paleo-valley in the pre-Oligocene surface near the Douglas Oil Field (Pl. 10a) are the most encouraging evidence for the possible occurrences of deposits in the White River. It is postulated that leaking sour gas from the Douglas Field may have reduced and precipitated uranium leached from the tuffaceous White River. This is still insufficient evidence for the existence of a deposit of minimum size and grade.

An important uranium discovery ("probable potential" of 25 million pounds of uranium oxide) in the basal Chadron (basal White River Formation) southeast of Crawford, Nebraska near Crow Butte was announced in January 1981 by Kansas-Nebraska Natural Gas Company (Chronis, 1981, Chadron Record, 1981; Crawford Clipper, 1981). Crawford is 50 Km east of the Torrington Quadrangle. The pre-Oligocene valleys shown on Plate 10a are the most likely places to find sandstones that might contain similar deposits in the Torrington Quadrangle.

SANDSTONES

Casper Formation

The Casper Formation as described by Harshman (1972) on the west side of the Laramie Mountains consists of about 200 m of mostly limestone and dolomite interbedded with sandstone and quartzite. These marine limestones and organic-free clastic portions are not favorable for the occurrence of uranium deposits of minimum grade and size though there are three occurrences in the

Casper Formation (Pl. 2, occ. nos. 8, 32, and 33,). The upper half of the Casper Formation consists of well cemented marine sandstones and quartzites. Although both are lacking in syngenetic reductants, the more porous parts of the upper Casper are slightly less unfavorable than the lower half.

Sundance Formation

The middle and upper Jurassic Sundance Formation was deposited northwest of the transcontinental arch and the lower Sundance varies from almost 100 percent sandstone of nonmarine origin in the southeastern part of the quadrangle to 50-75 percent mostly marine sandstone in the northwest part of the quadrangle. The Upper Sundance (Redwater Shale Member) is mostly marine sandy shale over the entire quadrangle (Peterson, 1972). There are no known uranium occurrences in the Sundance in the Torrington Quadrangle. No uranium deposits are listed in southeastern Wyoming in the Sundance by Finnell and Parrish (1958) but there are deposits in the Black Hills area. The marine parts of the unit are definitely unfavorable. The non-marine sandstone of the lower Sundance in the subsurface of the southeastern part of the quadrangle is less unfavorable although no anomalous gamma-ray readings were noted in the unit. If deposits were to occur they would most likely be associated with intersections of the Sundance and White River conglomerates along valleys in the pre-Oligocene unconformity surface.

Mesaverde Formation

The upper Cretaceous Mesaverde Formation occurs and crops out only in the northwestern part of the quadrangle. The Mesaverde consists of the Parkman Sandstone Member at the base overlain by an unnamed shale with the Teapot Sandstone Member at the top. The Mesaverde interfingers eastward with the Pierre Shale. These are marginal-marine deltaic sandstones (Curry 1973, 1976) and should contain some carbonaceous material. No uranium occurrences are known in the sandstones of the Mesaverde in the Torrington Quadrangle. An apparent uranium deposit has been recently discovered in the Teapot Sandstone on the Casper Arch 35 km west of the Torrington Quadrangle in the Casper Quadrangle (Griffin, BFEC, oral commun., 1979). Possibly this deposit is related to previously removed Tertiary sediments that once covered the area. In the Torrington Quadrangle, sour gas leaking from hydrocarbon reservoirs could have acted as a reductant for uranium entering these sandstones from presently or previously overlying Tertiary tuffaceous sediments. Because of a lack of positive evidence of mineralized rock on the surface or in the subsurface these sandstones must be classed as unfavorable for sandstone Class 240 deposits.

Fox Hills Sandstone (part)

The Fox Hills Sandstone is included in an area thought to be favorable for deposits of Subclass 242 in the southeastern part of the quadrangle (Pl. 1 Area D). It also contains uranium deposits two quadrangles to the north in the Gillette Quadrangle. However, it is apparently barren in the adjacent Newcastle Quadrangle to the north. No uranium occurrences were found and no analyses indicated uranium concentrations in the Newcastle Quadrangle. Elmer Santos (oral commun., 1980) postulated that the unit is unfavorable in the Newcastle Quadrangle because of the absence of favorable estuarine sandstone as found in the Fox Hills in the Gillette Quadrangle.

No occurrences were found in the Fox Hills nor did any gamma-ray logs indicate the presence of anomalies in the subsurface in the Torrington Quadrangle outside Favorable Area D. It may be that estuarine sandstones are restricted to the favorable part of the Fox Hills (Pl. 1 Area D).

Lance Formation (part)

The Lance Formation contains interbedded sandstone, shale, carbonaceous shale, and coal beds deposited in a fluvial environment. Uplift of the Granite Mountains and Wind River Range had begun (Paape, 1961) by the time of Lance deposition, but it is probable that the Laramie Range was not yet a positive feature. The uplifts that were in existence during Lance time were producing clastics from rocks only as old as the Mowry. Thus the Lance contains no arkosic sandstones. If it is mineralized it is probably because uranium-bearing ground water entered the formation from the overlying White River. The absence of significant gamma-ray anomalies and occurrences in the areas of the quadrangle underlain by the Lance but not included in Favorable Area D (Pl.1) could be caused by the past lack of a hydraulic connection with the White River. Hydraulic continuity between these rocks may have been interrupted by an impermeable pre-Oligocene paleosol developed on the Lance. Perhaps additional drilling in the vicinity of the pre-Tertiary subcrop of the Lance may find evidence to change the unfavorable classification of some areas.

Wagon Bed Formation

The Wagon Bed Formation is only present in the Torrington Quadrangle on the west side of the Laramie Mountains in the Shirley Basin. The Wagon Bed consists of about half claystone and about half clay-cemented sandstone, although in places a lacustrine limestone composes about one-fourth of the unit. Its permeability is low, it contains no carbonaceous material, and there are no uranium occurrences; it is therefore considered unfavorable.

Miocene(?) and Oligocene(?) Conglomerate

This conglomerate occurs only in three rather small areas of the quadrangle: in two valleys in the Laramie Mountains, and in an area on the southeast margin of the Hartville uplift. In both areas a wide range of locally derived clasts ranging from pebbles to boulders is present. The conglomerate is only 20 m thick near the Hartville uplift and is of unknown but not great thickness in the Laramie Mountains.

It is thought to be an unfavorable unit for finding 100-ton or larger uranium deposits because of its limited extent, complete lack of uranium occurrences, uniformly coarse-grained nature, and stratigraphic position above the White River Formation, a potential source for uraniferous ground water.

Lower Miocene rocks

The Lower Miocene rocks include the Arikaree Formation, more than 200 m of soft fine- to medium-grained sandstone with some tuffaceous beds and a few conglomerate channel deposits. Many of the occurrences in the Arikaree occur in gouge and in fractures along east- and northeast-trending faults near Shawnee (Pl. 2). One of the major differences between the Arikaree and favorable ore-bearing environments such as the Wasatch is that the Arikaree has little variation in permeability. Permeability variation is an important factor in ore localization at the Highland mine in the Fort Union Formation in the southern Powder River Basin. Dahl and Hagmaier (1976), found that ore-grade uranium occurs near the margins of sandstone bodies where they grade laterally into claystones. Coarse arkosic sandstones are absent in the Arikaree and the unit is underlain, rather than overlain, by the tuffaceous uranium-rich rocks of the White River Formation. These dissimilarities between the Arikaree and ore-bearing early Tertiary sandstones, and its lack of occurrences that suggest the presence of Wyoming roll type deposits, (Subclass 241), cause it to be classified as unfavorable for existence of 100-tons of U_3O_8 in uranium deposits with grade greater than 0.01 percent U_3O_8.

Upper Miocene rocks

The Upper Miocene Rocks include the Ogallala Formation and consist of fluvial sandstone with conglomerate, claystone, and limestone in the upper part. Although tuff beds occur in the upper part and these could have provided uraniferous ground water, a lack of occurrences and its stratigraphic position above the White River Formation indicate that deposits of more than 100 tons of U_3O_8 in deposits with a grade of more than 0.01 percent U_3O_8 are unlikely.

Quaternary clastic rocks

These are heterogeneous assemblages of unconsolidated sediment ranging from silt to giant boulders. Although some of these rocks have one of the highest uranium count rates obtained in the aerial gamma-ray survey, 42.8 counts per second (associated with Quaternary playa deposits in the Shirley Basin); and, also, one of the lowest count rates, 18.6 counts per second (on Quaternary landslide deposits (geoMetrics, 1979), no uranium occurrences are known in these units. The Quaternary rocks are, therefore, judged to be unfavorable for the presence of 100 tons of U_3O_8.

UNITS OF MIXED LITHOLOGY

Goose Egg Formation

The Goose Egg Formation of Lower Triassic and Permian age consists of red shales and siltstones, limestones, and gypsum, all of which are unlikely host rocks for uranium, and the unit is classed as unfavorable. There is one occurrence in the unit (Pl. 2, occ. no. 108) but no uranium deposits are known elsewhere (Finnell and Parrish, 1958).

Morrison Formation

The Morrison Formation of Upper Jurassic age is dominantly siltstone and claystone with interbedded thin limestone and light-colored fine-grained sandstone lenses. Uraniferous bones have been found in the sandstone and, although uranium deposits are found associated with plant fragments in the sandstone in the Big Horn Basin, carbonaceous material seems to be absent in the Torrington Quadrangle. There are no uranium occurrences in the Morrison in the quadrangle and it must be classed as unfavorable for the occurrence of 100 tons of U_3O_8.

Lebo (part) and Tullock Members of the Fort Union Formation

The upper 300 m of the Paleocene Fort Union were discussed previously and placed in the favorable category (Subclass 241). The underlying unfavorable portion of the formation includes all of the Tullock member (0-460 m) and the lower 450 m of the overlying Lebo Member. Logs of drill holes in the Tullock near the Laramie Mountains (T. 34 N., R. 75 W.) have the lowest sandstone-to-shale ratios of any place in the Powder River Basin (Curry, 1971). Only the upper 300 m of the Lebo Member contains thick arkosic fluvial sand bodies characteristic of uranium host sandstones in the Powder River Basin. The underlying 450 m contains more shale and claystone than the Tullock. Together, the Tullock and the lower 450 m of the Lebo are judged to be unfavorable for the occurrence of 100 tons of U_3O_8 with a grade exceeding 0.01 percent in Class 240, Subclass 241 because they lack the arkosic sandstone bodies characteristic of this class of deposits. The southern Powder River

Basin is part of one of the most thoroughly explored basins in Wyoming. Oil and gas, coal, and uranium have all been searched for by many companies and no significant uranium deposits have been found in the Torrington Quadrangle in these unfavorable rocks.

RESULTS OF HYDROGEOCHEMICAL AND STREAM-SEDIMENT RECONNAISSANCE

The hydrogeochemical and stream-sediment reconnaissance (HSSR) data (Shannon, 1980) for the Torrington Quadrangle were not available until July 1980, too late to be integrated into this report. Samples collected in the quadrangle included 1119 water and 756 sediment sediment samples from 1677 locations. Sediments were analyzed for uranium and thorium as well as aluminum, antimony, barium, beryllium, bismuth, cadmium, calcium, cerium, cesium, chlorine, chronium, cobalt, copper, dysprosium, europium, gold, hafnium, iron, lanthanum, lead, lithium, lutetium, magnesium, manganese, nickel, niobium, potassium, rubidium, samarium, scandium, silver, sodium, strontium, tantalum, terbium, tin, titanium, tungsten, vanadium, ytterbium, and zinc. Shannon's report also includes a sample location overlay, uranium concentration overlay for waters, conductivity overlay for waters, uranium concentration overlay for sediments, and thorium concentration overlay for sediments. All plates are at 1:250,000 scale for use with the Torrington $1^{\circ} \times 2^{\circ}$ NTMS map and the geologic map (Pl. 10, this report).

Comparison of the map showing areas favorable for uranium deposits (Plate 1) with the uranium concentration in stream sediments overlay (Shannon, 1980, Pl. 2) shows a correlation of the favorable area in the Precambrian rocks of the Laramie mountains with an area of regionally elevated uranium in sediments. The Precambrian rocks of the Hartville uplift do not cause perceptibily elevated uranium values in the sampled stream sediments. Scattered anomalously high uranium values occur in other areas of the quadrangle underlain by Tertiary sedimentary rocks, but no correlation can be made with a particular rock unit.

RECOMMENDATIONS TO IMPROVE EVALUATION

It is obvious from the geologic map (Pl. 10) that the Miocene Arikaree Formation (Tml) and Ogallala Formation (Tmu) both overlap the Oligocene White River Formation. Additional subsurface study to determine the erosional subcrop pattern of the edge of the White River would be useful. In general, increasing distance away from the edge of the White River is accompanied by increasing amounts of post-White River erosion and therefore decreased uranium potential.

Radiometric dates on as many vein deposits as possible in the Precambrian rocks of the area would be extremely useful in determining their genesis. If the dates are Oligocene or younger it would strengthen the concept of the

White River as a source rock and the proposed *per desensum* ground-water origin. Better genetic understanding would permit better definition of the distribution of the vein deposits.

Study of the clast lithology and provenance in the conglomerates of the Wasatch and Fort Union Formations in the southern Powder River Basin could provide information to unravel regional problems of sedimentology and tectonics. If the clasts are of Granite Mountains derivation then a late Laramide uplift of the Laramie Mountains is suggested because the paleocurrent directions in the ore-bearing sandstones require a southern source and the streams carrying the arkosic debris would have had to cross the northern Laramie Mountains. If this were the case then the arguments for a partial (or complete) White River source for the uraniferous ground water that mineralized the Wasatch and Fort Union in the Powder River Basin would be weakened. If all the major districts were in sediments with a Granite Mountains source then this would certainly decrease the importance of the pre-Oligocene unconformity as a guide for environments favorable for deposits.

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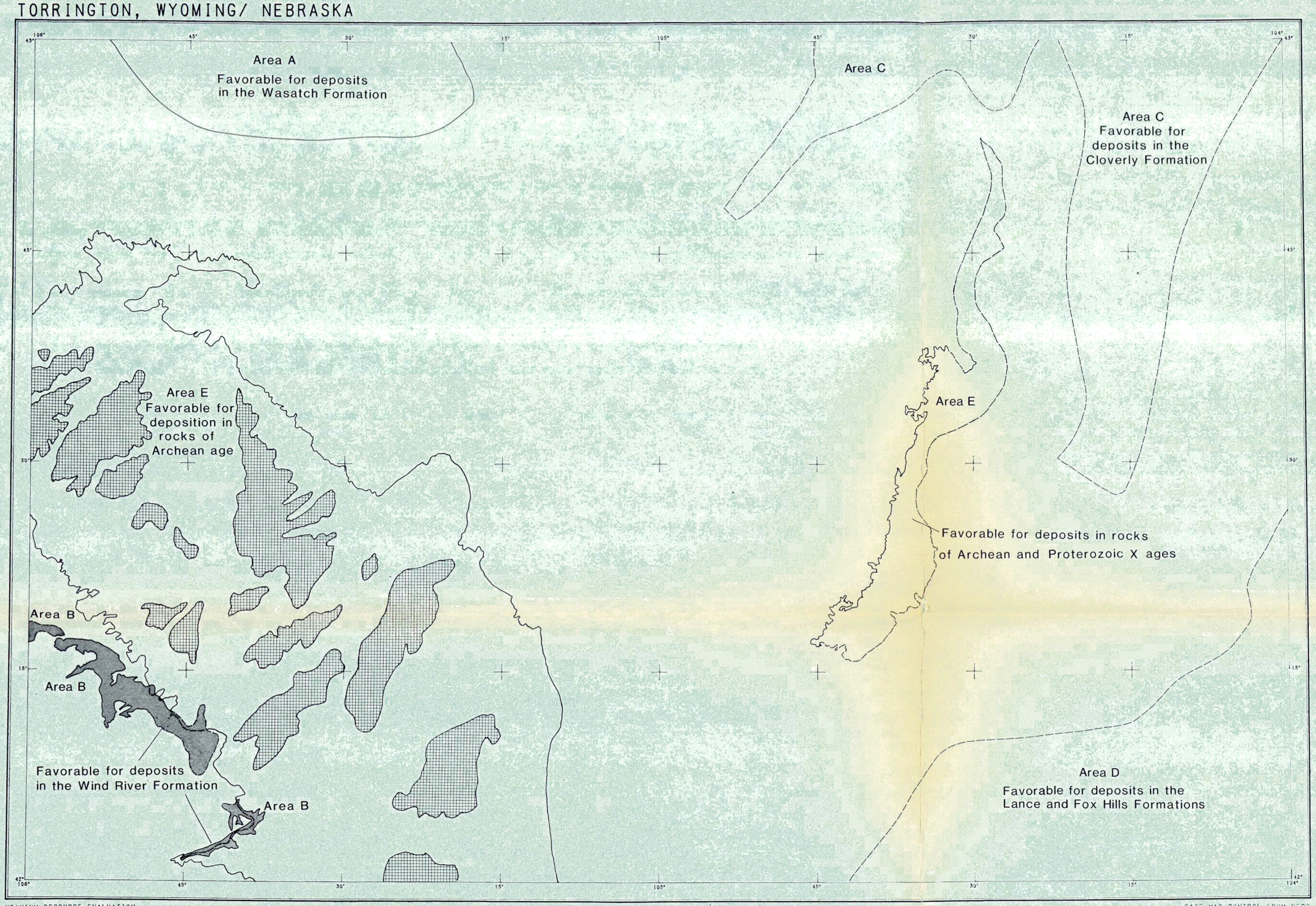


URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

EXPLANATION

Outline of areas favorable for uranium deposits

Outline of favorable area in subsurface

Favorable Area B

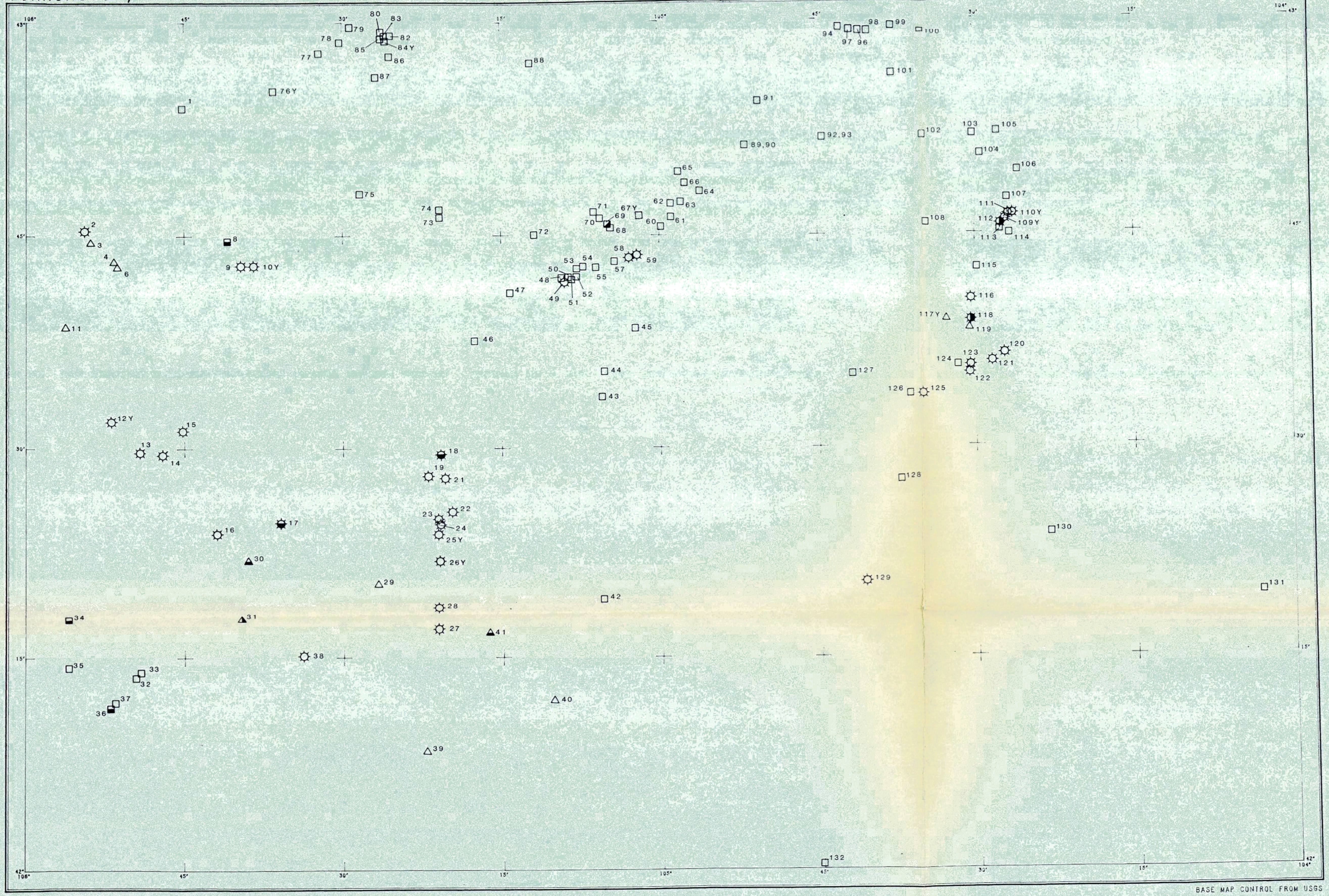
Outline of areas unfavorable for uranium deposits within Area E

PLATE 1.--AREAS FAVORABLE FOR URANIUM DEPOSITS

Compiled by David Seeland, U.S. Geological Survey

Plate 1.
1979

TORRINGTON, WYOMING/ NEBRASKA



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ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

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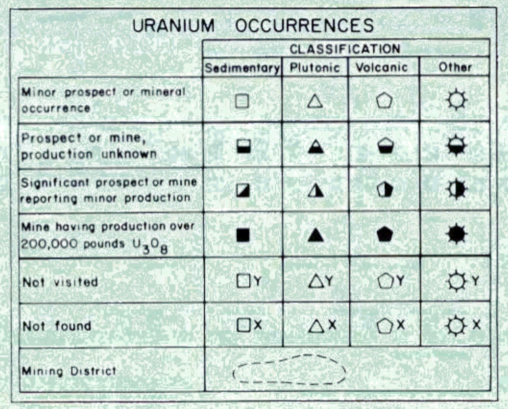
PLATE 2.--URANIUM OCCURRENCE MAP

Compiled by
David J. Hammond and Mark Mercer, U.S. Geological Survey



Uranium occurences listed in Appendix A

Plate 2.
1979

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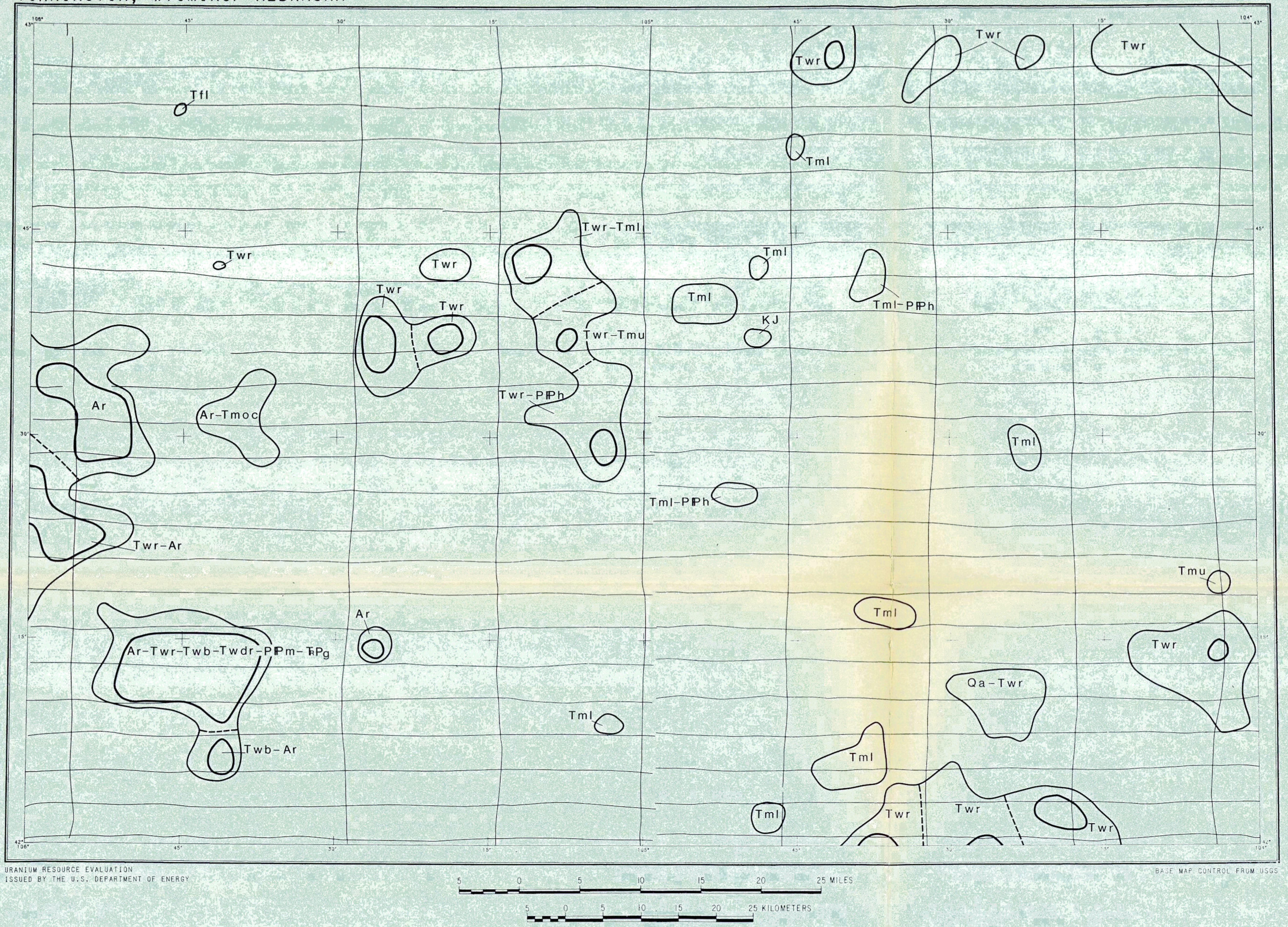


PLATE 3.--INTERPRETIVE MAP OF AERIAL RADIOMETRIC ANOMALIES

Compiled by
David Seeland, U.S. Geological Survey

EXPLANATION

Flight lines

Contour Intervals

- eU >4.3ppm(2.6% of data)
- eU >3.8ppm(12.1% of data)

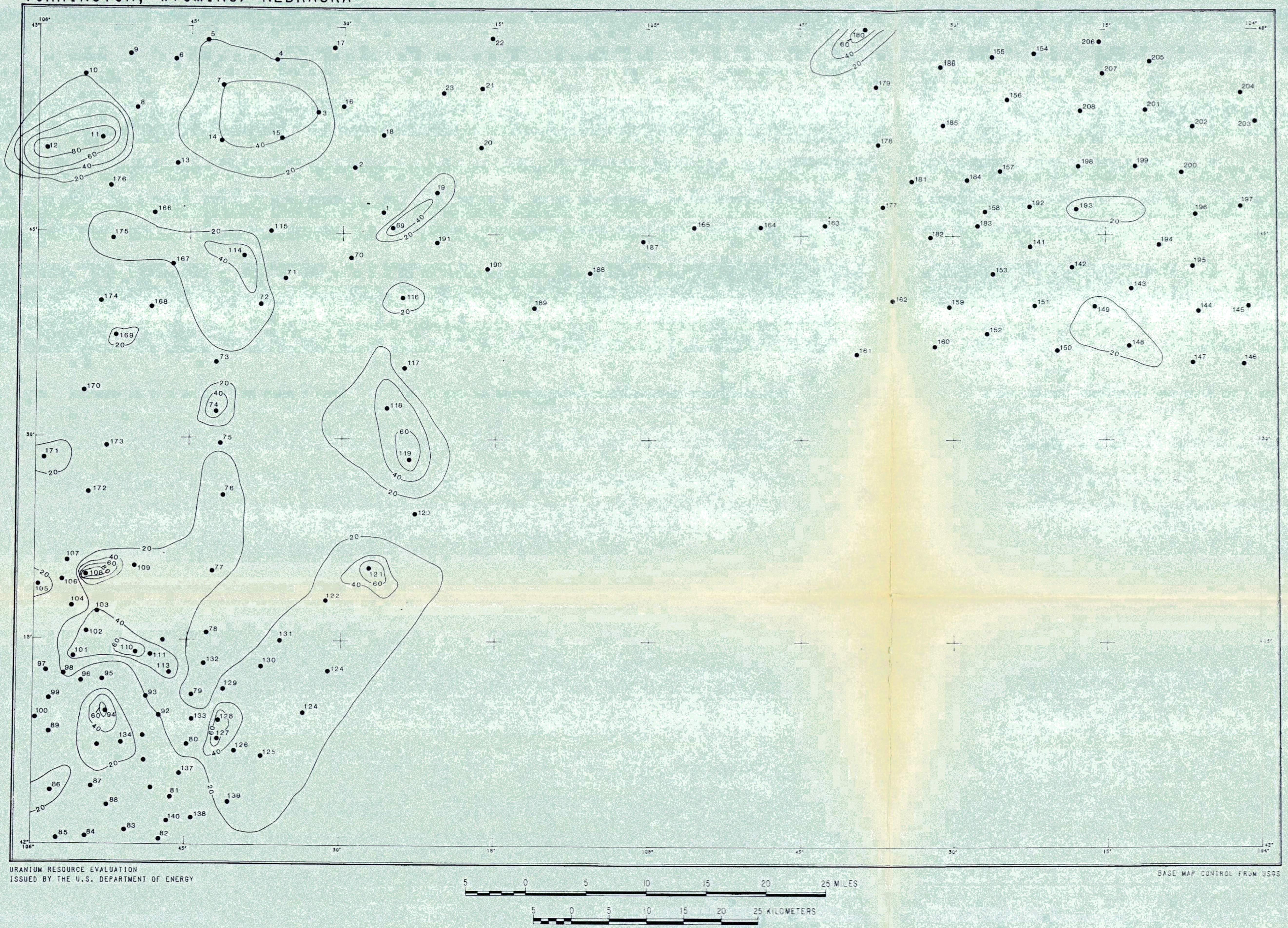
Mean eU- 2.7-3.2ppm

Lines separating components of compound highs

Rock symbols and names

- Qa – Alluvial deposits (Quaternary)
- Tmu – Upper Miocene rocks
- Tml – Lower Miocene rocks
- Tmoc – Miocene(?) and Oligocene(?) Conglomerate
- Twr – White River Formation (Oligocene)
- Twb – Wagon Bed Formation (Middle Eocene)
- Twdr – Wind River Formation (Lower Eocene)
- Tfl – Fort Union Formation-Lebo Member (Paleocene)
- KJ – Cloverly and Morrison Formations (Lower Cretaceous and Upper Jurassic)
- TRPg – Goose Egg Formation (Lower Triassic to Lower Permian)
- PIPh – Hartville Formation (Lower Permian and Pennsylvanian)
- PIPm – Casper Formation and Madison Formation (Lower Permian and Upper and Middle Pennsylvanian and Lower Mississippian)
- Ar – Archean Granite and Amphibolite

Source of data : geoMetrics Inc.,1979, Aerial gamma ray and magnetic survey, Powder River II project,Torrington Quadrangle,Wyoming and Nebraska, Final report, volume II : U.S. Department of Energy Open-File report GJBX-158 '79



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

EXPLANATION

181 Sample locality and sample number

20 Helium concentration, contour interval 20 ppb

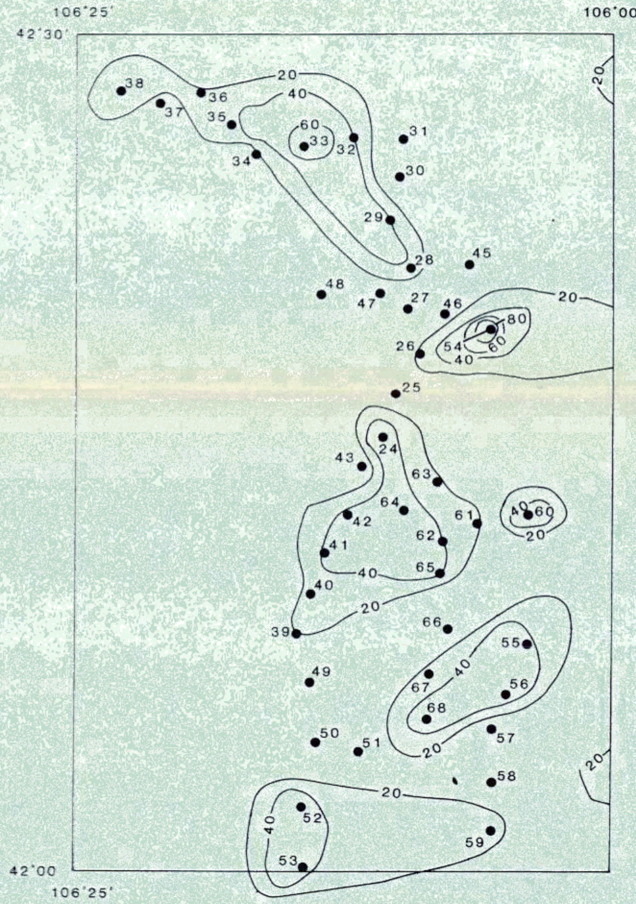
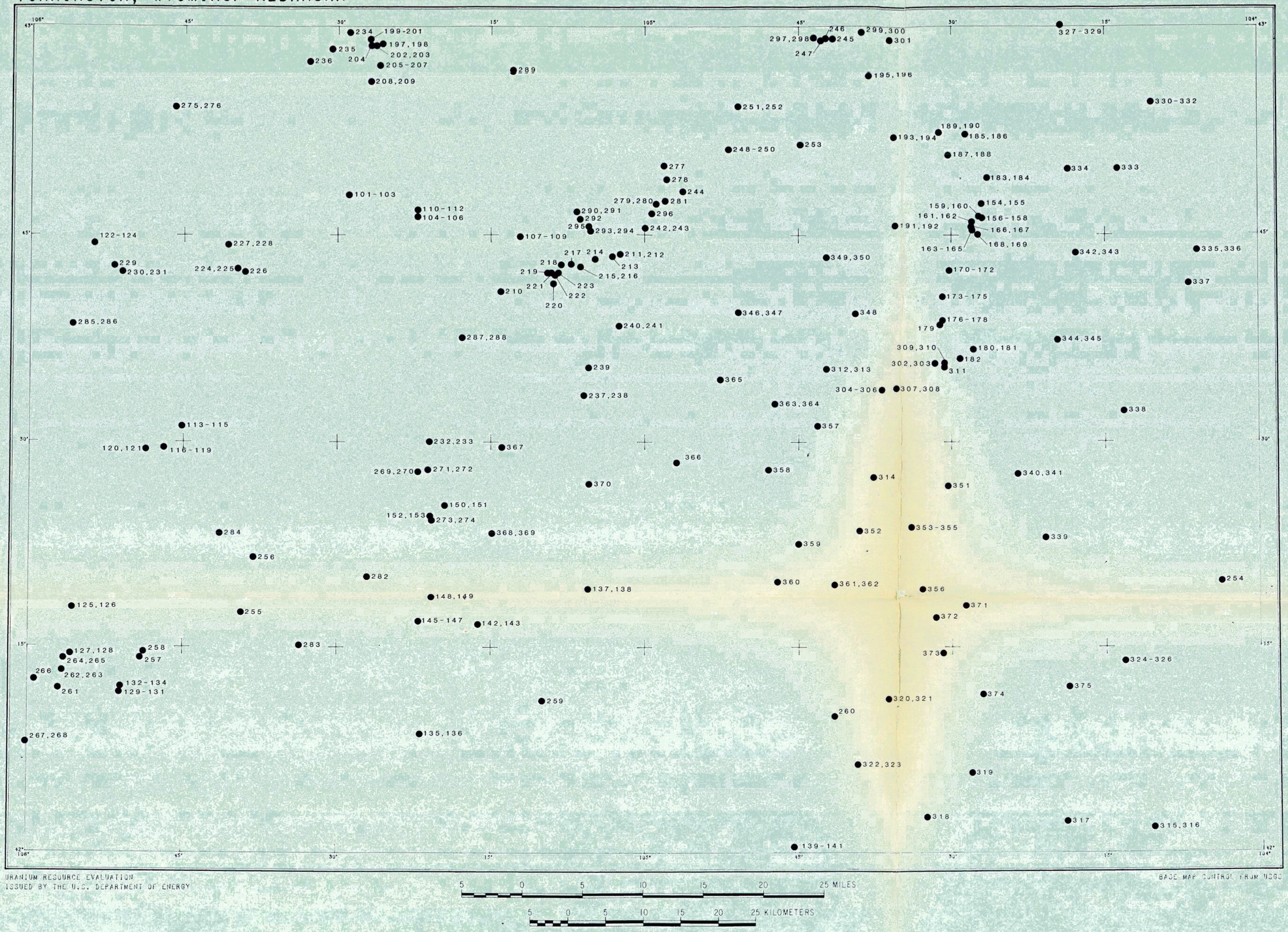


PLATE 4A.--HELIUM SOIL-GAS MAP OF THE TORRINGTON QUADRANGLE AND ADJACENT AREAS

By

G.M. Reimer, D.G. Murrey, and J.M. Been, U.S. Geological Survey

TORRINGTON, WYOMING/ NEBRASKA



EXPLANATION

● Rock sample locality

All numbers are prefixed by MDV

Analytical results are shown in Appendix B

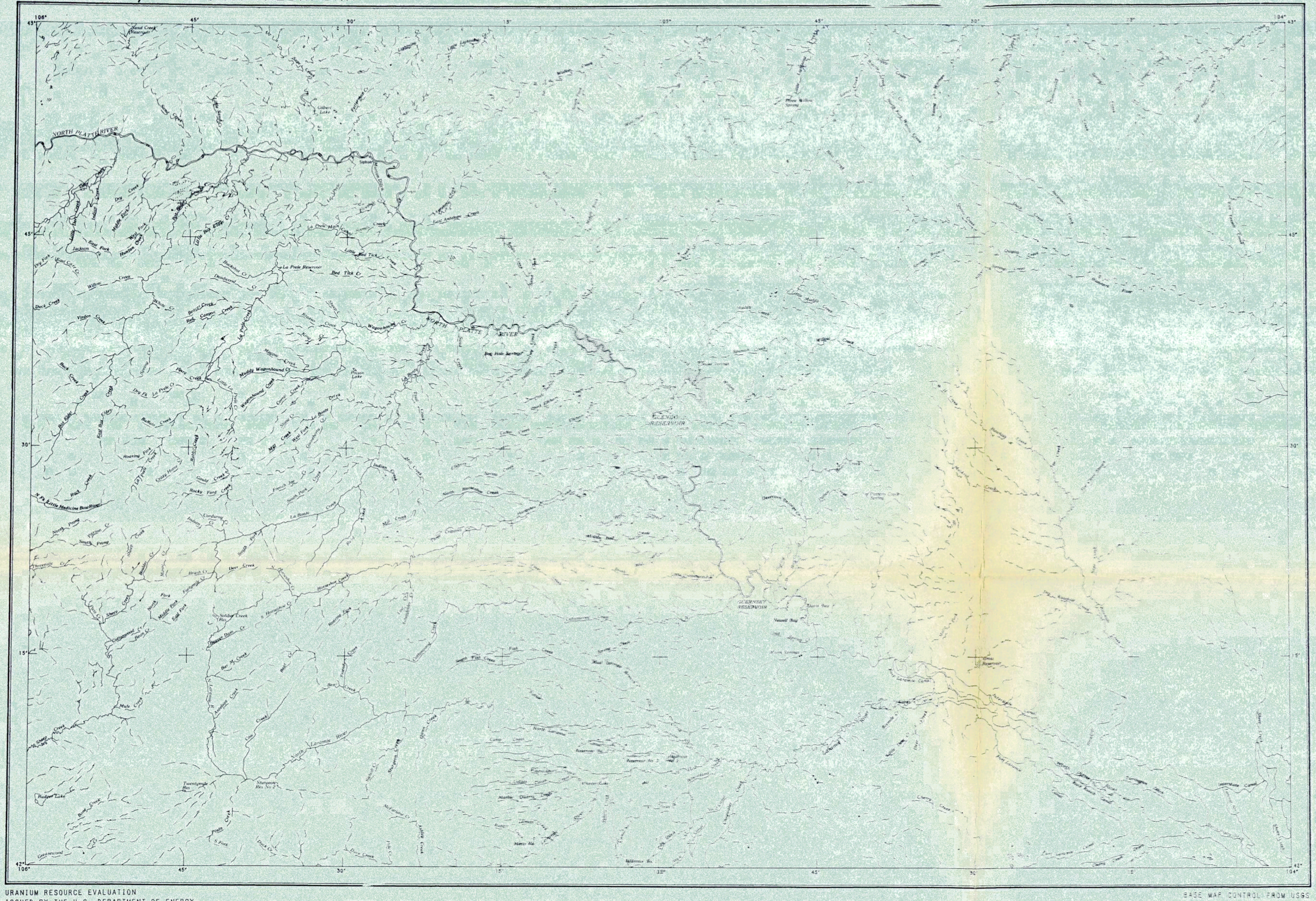
PLATE 5.--ROCK SAMPLE LOCALITY MAP

Compiled by

David J. Hammond, U.S. Geological Survey

Plate 5.
1979

TORRINGTON, WYOMING/ NEBRASKA



URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

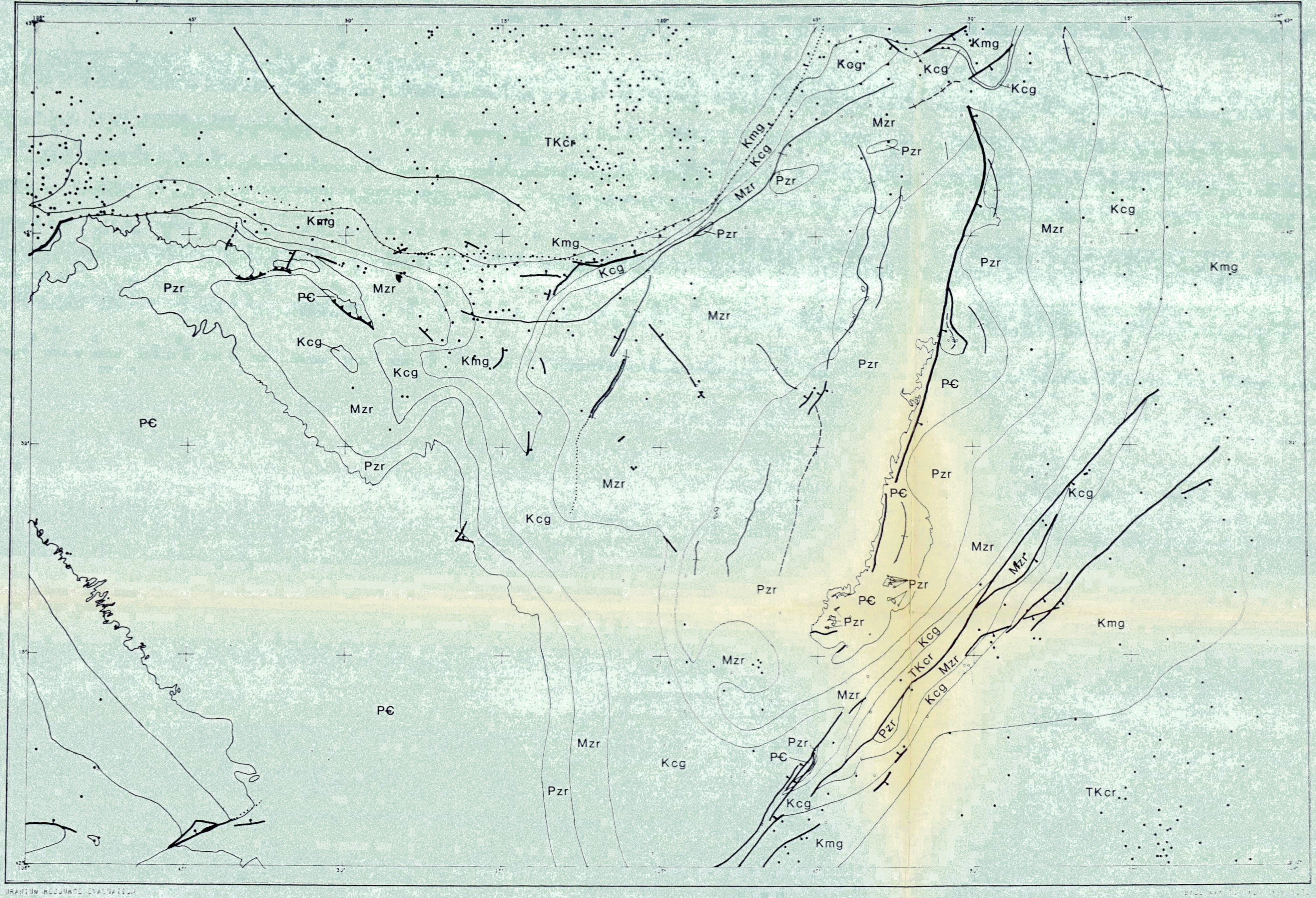
5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

PLATE 6.--DRAINAGE MAP

Plate 6.
1979

TORRINGTON, WYOMING/ NEBRASKA



5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

PLATE 10B.--PRE-OLIGOCENE GEOLOGIC MAP AND TEST WELL LOCATIONS

Compiled by

David L. Macke and Norman M. Denson, U.S. Geological Survey

EXPLANATION

- TKcr — Tertiary and Cretaceous coaly rocks: includes all pre-Oligocene rocks above the base of the Fox Hills Formation
- Kmg — Cretaceous Montana Group: from the top of the Pierre Shale to the base of the Cody Shale
- Kcg — Cretaceous Colorado Group: from the top of the Niobrara Formation to the top of the Muddy Sandstone
- Mzr — Mesozoic rocks: from the top of the Muddy Sandstone to the top of the Minnekahta Limestone (includes the upper part of the Paleozoic Goose Egg Formation)
- Pzr — Paleozoic rocks: from the top of the Minnekahta Limestone to the top of the pre-Cambrian
- P€ — pre-Cambrian rocks

- Well less than 610 m in depth
- Well greater than 610 m in depth
- Fault: dashed where approximate, dotted where concealed. Bar and ball on downthrown side
- Thrust fault: dashed where approximate, dotted where concealed. Sawteeth on upper plate
- Anticlinal axis: dashed where approximate
- Synclinal axis: dashed where approximate

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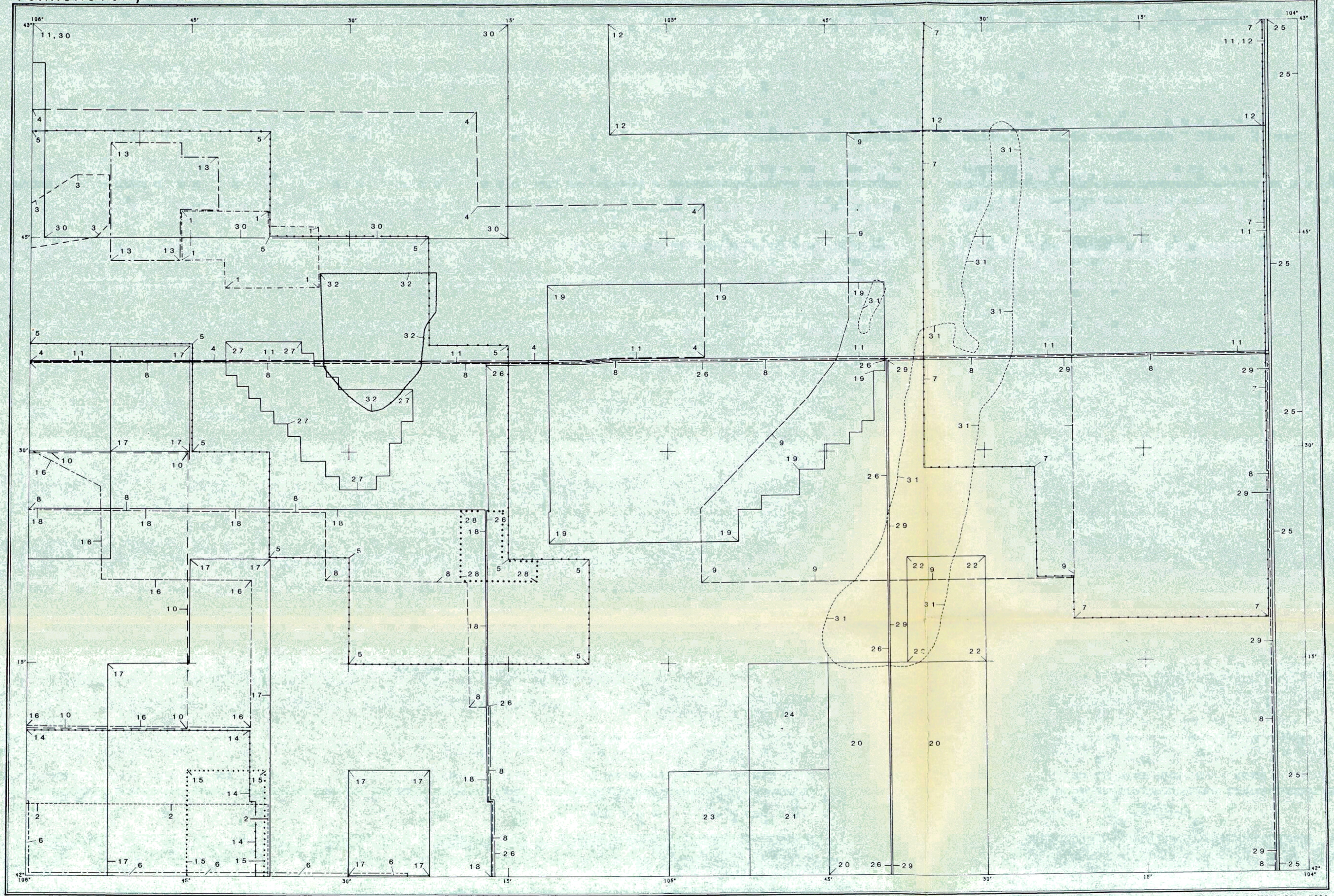

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

PLATE 11.--GEOLOGIC-MAP INDEX

Compiled by

J. D. Love, Ann Coe Christiansen, and C. K. Sever, U.S. Geological Survey

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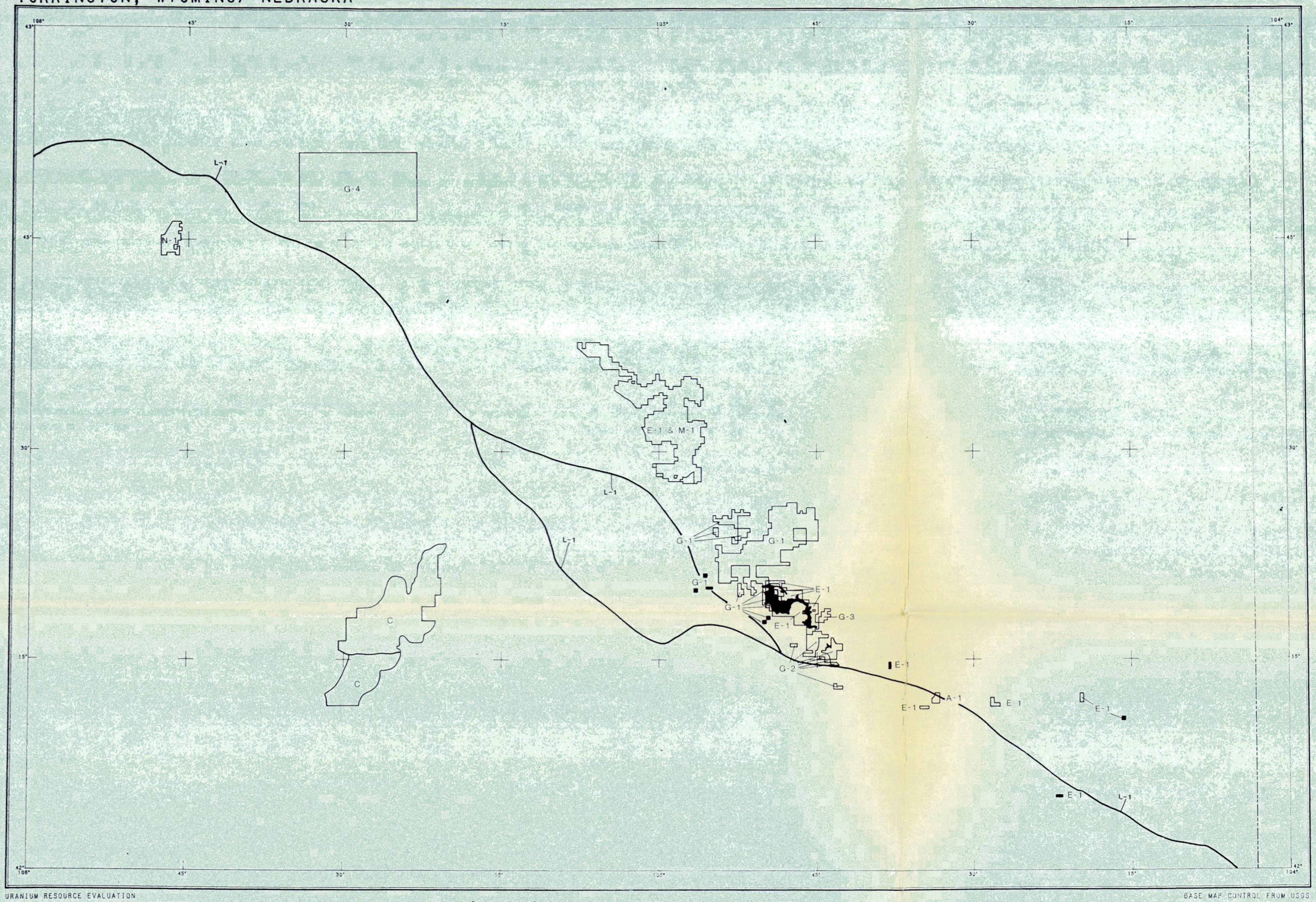

URANIUM RESOURCE EVALUATION
ISSUED BY THE U.S. DEPARTMENT OF ENERGY

BASE MAP CONTROL FROM USGS

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 KILOMETERS

PLATE 12.--GENERALIZED LAND STATUS MAP

INDEX

A. Area Managed by National Park Service
- A-1 Laramie National Monument

C. Forest Service RARE II Roadless Area

E. Bureau of Land Management Withdrawn National Resource Lands and Bureau of Reclamation Withdrawals
- E-1 Reclamation and Water Power Projects Withdrawal

G. Government Installations
- G-1 Wyoming National Guard Training Area
- G-2 Camp Guernsey
- G-3 Military Installation
- G-4 Old Fort Fetterman Military Reservation

L. National Trail
- L-1 Oregon Trail

M. State Withdrawal
- M-1 Glendo State Park

N. Other Land Categories
- N-1 Converse County Park

TORRINGTON, WYOMING/ NEBRASKA

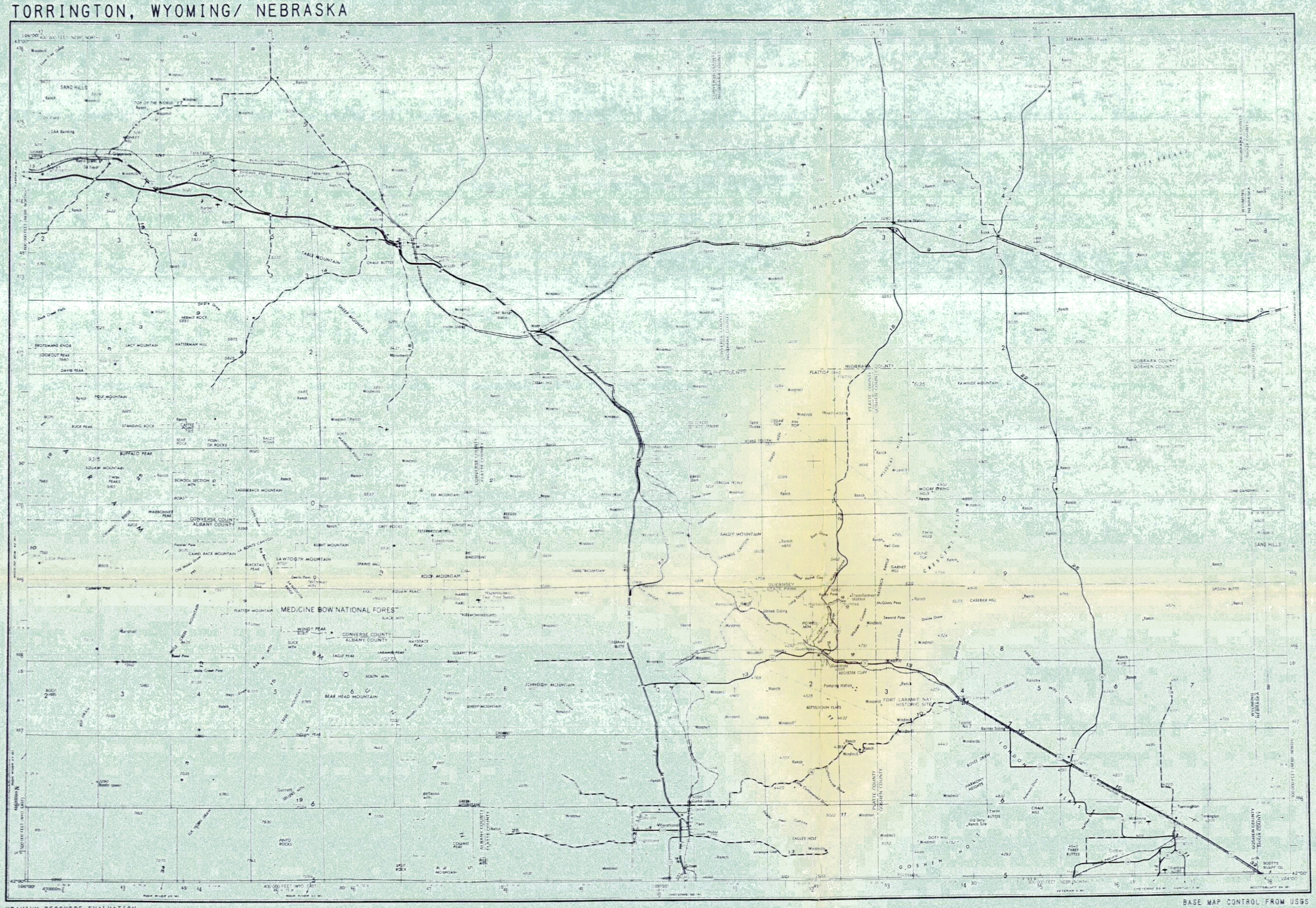

PLATE 13.--CULTURE MAP

Plate 13.
1979