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RECONNAISSANCE INVESTIGATIONS FOR URANIUM IN BLACK SHALE DEPOSITS OF THE WESTERN STATES DURING 1951 and 1952

Compiled by Donald C. Duncan

ABSTRACT

Reconnaissance examinations for uranium in 80 formations containing black shale were conducted in parts of Arizona, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Utah, and Wyoming by field parties investigating trace elements of carbonaceous rocks during 1951 and 1952. About 380 samples were collected for radioactivity tests and analyses of uranium content. Most of the black shales examined were essentially barren of uranium, but 17 formations include black shale zones containing 0.003 or more percent uranium; 4 of these deposits locally contain black shale beds containing 0.01 percent or more uranium. Of these only the phosphatic black shales of the Phosphoria appear to be sufficiently thick and extensive to be of possible economic interest. The other 13 uranium-bearing shale deposits contain 0.003 to 0.006 percent uranium.

Formations ranging in age from pre-Cambrian to Tertiary were examined. Most of the uranium-bearing black shales that were found in the investigations occur in rocks of Carboniferous and Permian ages although minor concentrations of uranium were found locally in Jurassic and Cretaceous black shales and in one Ordovician or Silurian black shale deposit.

INTRODUCTION

A reconnaissance investigation in search of uranium in black shale deposits was conducted in the Western States by geologists of the Geological Survey on behalf of the Atomic Energy Commission during the summers of 1951

and 1952. The investigations were carried on as part of a more inclusive search for uranium in several types of carbonaceous sediments. Formations containing black shale were examined, tested for radioactivity, and sampled in widely separated areas in Arizona, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, Utah, and Wyoming. The field work included reconnaissance by George O. Bachman, N. M. Denson, D. C. Duncan, J. R. Gill, W. J. Hail, J. D. Love, G. W. Moore, C. B. Read, J. I. Simmons, and J. D. Vine, under the general supervision of Norman M. Denson. The report includes detailed descriptions, a summary of results, and suggests some geologic guides for further investigation of the black shales.

Field work

The search for trace elements in black shales was conducted by geologists operating in individual general areas, as follows:

Bachman and Read examined deposits in Arizona, New Mexico, and southern Colorado.

Denson made brief reconnaissance investigations with each field party and collected subsurface data on the Pennsylvanian shales in western Nebraska.

Duncan and Simmons examined deposits mainly in Utah, Nevada, and central Idaho.

Gill and Hail examined deposits in central and western Montana in 1951, and Gill and Simmons examined deposits in central Colorado and eastern Wyoming in 1952.

Love examined deposits in Wyoming.

Moore and Vine examined deposits in northeastern Utah, southwestern Wyoming, and southeastern Idaho during 1951, and Vine examined deposits in

central Colorado during 1952.

Samples of black shale from the Tertiary sediments of eastern Utah were supplied by W. B. Cashion and from the Devonian sediments of northwestern Wyoming by W. G. Pierce, both of the Geological Survey. Data on radioactive shales extracted from preliminary reconnaissance reports of metal mining districts are also included in the report.

Field methods

Formations containing black shale were examined in detail at localities selected by the individual geologist. Generally, attempts were made to find a fresh exposure of a given shale unit or to make fresh exposures by shallow trenching. At many localities, however, the shale units are nonresistant to weathering and are covered by soil or alluvium that make complete tests or sampling impracticable. Individual shale beds were examined and were tested for radioactivity mostly with Geiger counters equipped with a small standard tube. Some field parties used a carborne counter or portable scintillation detector. In early stages of the investigation, samples were collected from shale beds that showed only slight apparent increases of radioactivity, that is, 2 or 3 scale divisions of the most sensitive scale above the normal background readings of the counter. As work progressed sampling was generally reduced to shale zones that showed apparent radioactivity with the field counters comparable to about 0.005 percent or more equivalent uranium. The field counters generally gave higher readings than the laboratory-controlled tests for radioactivity which, in turn, generally gave greater values than the chemical analyses. A special effort was made to obtain a complete series of channel samples or spot samples through the thinner shale units (less than 50

feet thick) but only selected samples of the more radioactive beds were obtained from the thicker shale units. Samples weighing 1 to 2 pounds each were collected for radioactivity measurement and chemical analysis in the Washington or Denver laboratories of the Geological Survey. For some groups of samples, chemical analyses were run only where 0.005 percent or more equivalent uranium had been determined by preceeding radioactivity measurements. For other samples, particularly those in which other valuable metals were believed present, chemical or spectrographic analyses were made to determine the nature and amount of potential byproducts such as shale-oil, vanadium, phosphate, and other uncommon materials.

Acknowledgments

Much of the material of this report is extracted from manuscript or notes of the several geologists who participated in the field examinations of the black shales. George Bachman, N. M. Denson, J. R. Gill, W. J. Hail, J. D. Love, G. W. Moore, C. B. Read, and J. D. Vine each contributed parts of manuscript and sample data that were reassembled into this report. Valuable aid in guidance to fresh shale exposures was supplied the compiler by several other geologists. Special thanks are due A. A. Baker and T. S. Lovering of the Geological Survey for guiding the writer to good exposures of black shale in central Utah; to John Weise and Walter Record of Richfield Oil Company who gave valuable guidance to shale exposures in Nevada; and to Stewart Williams of Logan, Utah, who supplied information on black shale deposits in northwestern Utah. Analyses of samples were supplied by many members of the geochemical laboratories of the Geological Survey. The results of the careful chemical analyses and radioactivity measurements by

the many chemists and physicists are a major part of the basic data of this report.

BLACK SHALES

Kinds of shale deposits examined

The term "black shale" has been applied to a large number of fine textured clastic sedimentary rocks containing organic compounds. These organic compounds impart to the rock a dark color varying from black to the darker shades of gray and brown. The term "black shale" is commonly restricted to the dark, organic rich shales of marine origin. Most of the shale deposits that are considered in this report were deposited in a marine environment, but a few of the deposits discussed herein are of non-marine origin and others were deposited in environments that are not thoroughly understood. In general, the non-marine coaly shales or carbonaceous shales associated with the coals and lignites are not included in the present report but are discussed in other reports on trace elements of coals.

In the first part of the investigation the group examined black shales known from numerous sources of literature and from unpublished information obtained informally from geologists of the Geological Survey and other organizations. A report by Beers and Heroy (1951) which reviews the geologic literature relating to black shale deposits in the United States was useful as background data in later phases of the present investigation.

The current investigations were directed primarily toward tests of thin black marine shale zones (about 100 feet or less thick) of wide aerial extent similar to some of the larger known uraniferous black shale deposits. The spacing of sampled sections was too wide, however, to find deposits of

small areal extent. Generally, thick black shale units (100 to 5,000 feet thick) were considered less favorable for containing usable concentrations of uranium, but some of the thicker shale sequences were examined as part of the inventory.

Features of known uranium-bearing black shales used in guiding search

Some features of previously described uraniferous black shale deposits (McKelvey and Nelson, 1950) were used to some extent as criteria for restricting and guiding the search. The described deposits are generally low grade, containing a few thousandths to a few hundredths percent uranium; they are generally thin units ranging from a few inches to a few tens of feet thick, in shale formations that rarely exceed 100 feet thick. Most known uraniferous marine black shales are distributed over large areas although higher grade parts may occur in areas a few tens of miles across. Most are believed to be the result of unusually slow deposition, and the uranium was presumably concentrated contemporaneously with the deposition of the enclosing muds. Phosphatic nodules, layers, or phosphorite beds are associated with some uraniferous black shales, and abnormal concentrations of other minor metals such as vanadium, copper, and nickel are associated with some uraniferous black shales. Identifiable uranium minerals in most black shale deposits are rare or absent. The uranium seems to be disseminated in the shale but associated mostly with the contained organic matter, with phosphatic material, with iron sulfide or iron oxide minerals, or in some deposits with minerals of copper, vanadium, or nickel, etc.

Stratigraphic and geographic distribution of deposits examined

Black shales are widely distributed in the Western States and include deposits ranging from late pre-Cambrian to early Tertiary in age. Shale units in the Western States approximately the same age as known uraniferous shale deposits in other regions were considered more likely to be uraniferous. Consequently the late Devonian shales, approximately correlative with the Chattanooga shale, and the shale units of Carboniferous and Permian ages, approximately correlative with other recorded uranium-bearing shales and phosphorites of the Mid-Continent and Rocky Mountain regions, were examined more closely than shale units in other parts of the stratigraphic column. In two large areas, however, most of the black shale units occurring throughout the geologic column were examined. These areas are: 1) central and western Montana, and 2) northern and central Utah. The age, name, maximum observed radioactivity and best uranium content of samples from the shale-bearing formations that were examined are shown in table 1. The locations of shale deposits examined are shown on the index map (fig. 1).

Table 1. Summary of radioactivity and uranium content of black shales in Western States

State	Age	Formation containing shale unit	Greatest radioactivity detected. Equivalent uranium (percent)	Uranium content of best sample (percent)	Remarks
Arizona	Devonian	Martin shale	0.004	<0.001	
	Cretaceous	Mancos shale	inert	not sampled	
	Cretaceous	Unnamed shale	inert	not sampled	
Colorado	Pennsylvanian	Belden shale	0.006	0.003	Coaly shale, 3 ft. thick
	Pennsylvanian	Hermosa formation	.005	.004	
	Pennsylvanian	Paradox formation	.007	.004	Black shale, 1 ft. thick in gypsum sequence
	Pennsylvanian	Weber (?) formation	0.032	0.019	Shale, 1 ft. thick, uranium hydrothermal ?
	Pennsylvanian	Unnamed formation	inert	not sampled	
	Jurassic	Pony Express limestone	0.012	0.011	Shale, 1 ft. thick, uranium hydrothermal ?
	Jurassic	Morrison formation	inert	not sampled	
	Cretaceous	Benton shale	inert	not sampled	
	Cretaceous	Dakota sandstone	0.003	not analyzed	
	Cretaceous	Laramie formation	inert	not sampled	
	Cretaceous	Lewis shale	inert	not sampled	
	Cretaceous	Mancos shale	0.003	0.001	
	Cretaceous	Mesaverde group	inert	not sampled	
	Cretaceous	Pierre shale	0.003	0.002	
	Cretaceous	Vermejo formation	.002	not analyzed	
Idaho	pre-Cambrian	Belt series	inert	not sampled	
	Cambrian	Spence shale member of Ute formation	0.003	0.0004	

Table 1. Continued

State	Age	Formation containing shale unit	Greatest radioactivity detected. Equivalent uranium (percent)	Uranium content of best sample (percent)	Remarks
Idaho (cont.)	Ordovician	Unnamed-Lower Ordovician	0.004	0.0005	
	Ordovician	Unidentified Middle or Upper Ordovician	.002	.0003	
	Mississippian	Milligen formation	.006	.002	
Montana	pre-Cambrian	Belt series (Missoula group)	.001	not analyzed	
	Cambrian or Devonian	Unidentified formation	.003	not analyzed	
	Devonian	Jefferson limestone	.003	not analyzed	
	Devonian	Three Forks shale	.004	not analyzed	
	Mississippian	Madison limestone	.005	0.003	Shale, 1/2 ft. thick in limestone
	Mississippian	Otter formation	.004	not analyzed	
	Mississippian	Heath shale	.007	0.006	4 ft. thick black shale; in dark shale sequence
	Mississippian and Pennsylvanian	Amsden formation	.002	not analyzed	
	Pennsylvanian	Quadrant formation	.003	not analyzed	
	Cretaceous	Colorado shale	.003	not analyzed	
Nebraska	Pennsylvanian	Hartville formation	.016	0.011	Shale beds, each about 1 ft. thick in limestone sequence; known only from deep drilling
Nevada	Ordovician	Vinini shale	.000	.001	
	Ordovician	Unidentified shale	.003	.001	

Table 1. Continued

State	Age	Formation containing shale unit	Greatest radioactivity detected. Equivalent uranium (percent)	Uranium content of best sample (percent)	Remarks
Nevada (cont.)	Ordovician or Silurian	Unidentified shale	0.005	0.004	A black shale zone 12 ft. thick, averaging 0.0035 percent uranium
	Mississippian	Pilot shale	.003	.002	
	Mississippian	White Pine shale	.003	.001	
	Carboniferous	Unnamed shale	.004	.002	
	Carboniferous	Unnamed shale	.005	.005	A zone 7 ft. thick averaged 0.0035 percent uranium
	Permian	Unnamed shale	.002	.002	
New Mexico	Devonian	Percha shale	.004	.002	
	Mississippian	Lake Valley limestone	.002	--	
	Pennsylvanian	Madera (Magdalena gr.)	.002	.001	
	Cretaceous	Mesaverde group	inert	not sampled	
	Cretaceous	Mancos shale	inert	not sampled	
	Cretaceous	Lewis shale	weakly radioactive	not analyzed	
Utah	pre-Cambrian	Cottonwood series	0.003	0.0011	
	Cambrian	Brigham quartzite	.005	.001	
	Cambrian	Pioche shale	.005	.001	
	Cambrian	Wheeler shale	.002	.0004	
	Cambrian	Weeks formation	.000	.0007	
	Cambrian	Orr formation	.002	.0006	
	Ordovician	Swan Peak quartzite	inert	not sampled	
	Mississippian	Madison limestone	inert	not sampled	
	Mississippian	Gardner formation	0.006	0.006	Best phosphatic shale section 19 ft. thick, aver. 0.005 percent uranium; zone irregular

Table 1. Continued

State	Age	Formation containing shale unit	Greatest radioactivity detected. Equivalent uranium (percent)	Uranium content of best sample (percent)	Remarks
Utah (cont.)	Mississippian	Chainman shale	inert	not sampled	
	Mississippian	Deseret limestone	0.002	0.001	
	Mississippian	Brazer limestone	.006	.005	Phosphatic shale beds, each about 1 ft. thick
	Mississippian	Great Blue limestone	.003	.0021	
	Mississippian	Herat shale	.002	.0008	
	Mississippian-Pennsylvanian	Manning Canyon shale	.004	.003	Best black shale zone 9 ft. thick, av. 0.003 percent uranium in thick dark shale sequence
	Pennsylvanian	Oquirrh formation	.003	.003	Shale bed about 1 ft. thick in sandy limestone
	Permian	Kirkman limestone	.000	.001	
	Permian	Park City	.005	.004	Phosphorites; covered in other investigations
	Triassic	Woodside formation	.003	not analyzed	
	Cretaceous	Mancos shale	.003	0.0002	
	Tertiary	Green River formation	.003	not analyzed	
Wyoming	Devonian	Unnamed shale	inert	not analyzed	
	Devonian	Three Forks shale	0.004	0.0005	
	Pennsylvanian	Hartville formation	.022	.019	Black shale beds, each about 1 ft. or less thick; radioactive in subsurface
	Permian	Phosphoria formation	.029	.026	Phosphorite zone about 6½ ft. thick av. 0.016 percent uranium
	Cretaceous	Belle Fourche shale	.002	--	
	Cretaceous	Fuson shale	inert	not sampled	
	Cretaceous	Mowery shale	0.001	not analyzed	
	Cretaceous	Lakota (?) formation	.005	0.005	Clay shale 1.4 ft. thick

SUMMARY OF RESULTS OF INVESTIGATIONS

During the 1951 and 1952 field seasons 80 formations containing black shale were tested for radioactivity in numerous areas in 10 western states. About 380 samples of black shale were collected and analyzed for their radioactivity or uranium content. Most of the shales that were examined were essentially barren of uranium, but 17 formations include shale units containing 0.003 percent or more uranium (table 1). The highest-grade shales include four deposits containing 0.01 percent or a little more uranium. These are 1) phosphatic shales of the Phosphoria formation of Permian age in southwestern Wyoming; 2) black shale beds, each a few inches to a foot thick, in the Hartville formation of Pennsylvanian age in the subsurface of western Nebraska and eastern Wyoming; 3) a shale zone about 1 foot thick in the Weber (?) formation of Pennsylvanian age in central Colorado; and 4) a shale zone about 1 foot thick in the Pony Express limestone of Jurassic age in southern Colorado. Both the Phosphoria and the Hartville formations were already known to be uraniferous (McKelvey, 1950, and Love, 1951).

The best samples that were obtained from other black shale zones that were examined contained as much as 0.006 percent uranium, but samples from only 11 of these deposits contained 0.003 or more percent uranium. These shale units contain too little uranium to be of commercial value at this time. Data from them, however, will be useful in the search for higher grade deposits. Arranged according to age, these uraniferous shales appear to be assignable to 7 or 8 stratigraphic zones, two of which are lateral equivalents of the higher grade deposits mentioned above.

1. Ordovician or Silurian shale:--The oldest uraniferous shale that was found is an unnamed Ordovician or Silurian shale found only at one locality

in the Toquima Range of central Nevada, where a 12-foot thick zone contained an average of 0.0035 percent uranium.

2. Early Mississippian shales:--Black shale zones of Early Mississippian age, equivalent to the upper part of the Osage of the Mid-Continent region, contain small amounts of uranium at two localities that were sampled. These include two phosphatic shale beds, each about 1 foot thick, assaying 0.005 percent uranium, in a basal black shale of the Brazer limestone in northern Utah and a phosphatic shale zone about 19 feet thick assaying 0.005 percent uranium in the upper black shale unit of the Gardner dolomite in central Utah. In the lower part of the Madison limestone of southern Montana a shale parting about ½ foot thick contains 0.003 percent uranium. The latter zone is of Kinderhook age.

3. Late Mississippian shale:--Uraniferous black shales of Late Mississippian age were found at two localities and shale possibly of this age at a third locality. A black shale unit 9 feet thick, averaging 0.003 percent uranium, was found in the lower part of the Manning Canyon shale in central Utah; a black shale zone 4 feet thick, assaying 0.006 percent uranium, was found in the Heath shale of central Montana; and a black shale zone 7 feet thick averaging 0.0035 percent uranium, was found in northern Nevada in an unnamed shale unit possibly correlative with the Manning Canyon.

4. Pennsylvanian shales:--Uraniferous shales of Pennsylvanian age were found in 7 areas. The shales are thought to be approximately equivalent to the Des Moines series of the Mid-Continent region. Shales in three of these areas contain 0.01 percent uranium or more; two are in the Hartville formation in western Nebraska and eastern Wyoming, and the other is in the Weber (?) formation of central Colorado (Singewald and Pierson, 1951). The

occurrences of lower-grade uraniferous shale include the following: In southern Colorado, shale units in the Hermosa formation contain as much as 0.004 percent uranium; in central Colorado, a black shale bed about 1 foot thick in the Paradox formation contains 0.004 percent uranium; in central Colorado, a coaly shale 3 feet thick in the Belden formation contains 0.003 percent uranium; and in central Utah, a black shale bed about 1½ feet thick in the Oquirrh formation of central Utah contains 0.003 percent uranium. These widespread occurrences of uranium in beds of approximately the same age suggest that further examination of shale units in this zone may find deposits of interest.

5. Permian shales:--Uraniferous shales of Permian age in the Phosphoria formation of western Wyoming and in the equivalent Park City formation of northern Utah were examined in only a few places. The phosphorites and associated black shales within the formations have been examined in detail in earlier trace element investigations of the Geological Survey (McKelvey, 1950) and therefore were examined only briefly in the present study. The best sample obtained from the Phosphoria in this investigation contained 0.026 percent uranium, and one sampled zone 6½ feet thick averaged essentially 0.016 percent uranium. These sample data indicate that phosphate-rich beds of the Phosphoria formation are richer in uranium than any of the other uraniferous black shale zones found in the present investigation.

6. Jurassic shale:--Uranium in black shale was found in the Pony Express limestone of Jurassic age. Deposits known from this zone include one in southern Colorado (Burbank and Pierson, 1951) and another, in the equivalent Todilto limestone in western New Mexico that is not described in this report. Although these higher grade deposits are thought to be post-sedimentary

accumulations, their occurrence in widely separated areas at approximately the same stratigraphic horizon suggests that this horizon may contain favorable host rocks for uranium deposits. The Jurassic marine shales of other areas were not examined during this investigation.

7. Lower Cretaceous shale:--A single clay shale zone about 11 feet thick in the Lakota (?) formation in northeastern Wyoming contains about 0.005 percent uranium.

SOME SUGGESTED GEOLOGIC GUIDES FOR FURTHER INVESTIGATIONS

To date much of the reconnaissance search for uranium in western black shales may be viewed as random tests of perhaps one-half of the recorded shale zones in the 10 states covered. A review and synthesis of available data on radioactive black shales undoubtedly will provide leads to better guides for prospecting and to discovery of better-grade deposits. Some lines of inquiry that appear promising are listed below:

1. Make paleogeographic studies from existing data on distribution of uraniferous shales, in an effort to determine usable criteria for recognizing favorable geologic settings of such deposits.

2. Continue search in extensions of known uraniferous shale deposits, or in their black shale equivalents.

3. Continue search for phosphatic materials in black shales, particularly oolitic or nodular phosphate rock as an indicator that uranium may be present. The search might also be extended to examining phosphatic shell, bone, and other phosphatic animal remains, particularly where they are abundant in shales.

4. Examine black shale deposits in areas near other types of uranium

deposits looking for both syngenetic and epigenetic introduced uranium.

5. Examine and interpret selected gamma-ray logs from oil company drilling for leads to uranium-bearing zones as a guide to surface studies and as a means of eliminating many of the presumably unpromising black shales that are difficult to examine thoroughly on the surface.

6. Look for black shale zones that interfinger with or are overlain by slightly radioactive volcanics or their tuffs.

7. Examine marine deposits containing black shales that appear to have been deposited during periods of extensive volcanism. Some fine-textured siliceous sediments such as cherts, radiolarites, novaculites, and diatomites interbedded with black shales perhaps were deposited where unusual amounts of siliceous volcanic materials were supplied to the ocean waters. Such deposits might be expected to contain unusual amounts of the uncommon metals, including uranium. Known uraniferous shale deposits associated with cherts include the Phosphoria formation, the Chattanooga shale, and shales in the Gardner formation.

8. Examine the possibility that sulfate deposits such as gypsum, potash salts, etc., associated with black shale provide a favorable setting for unusual amounts of uncommon metals in shales. Known shale deposits that appear to be of this type and that contain beds of shale with small amounts of uranium include shales in the Hartville formation of Wyoming and Nebraska, in the Paradox formation in Colorado, and in the Alum shales of Sweden.

9. Search for and test thin black shale zones thought to be deposited slowly or thought to be associated with disconformities.

10. Search in black shales containing unusual concentrations of other uncommon materials such as phosphorous, copper, nickel, vanadium, etc.

DESCRIPTIONS OF DEPOSITS

The following descriptions of the black shale deposits that were examined during the investigation are arranged by states, and the deposits are described in order of age from oldest to youngest. The descriptions, although showing mostly negative results, are included as a record of the nature of examinations and coverage of western black shales. Locations referred to in the text are shown on the index map (fig. 1).

Arizona

Black shale units of Devonian and Cretaceous ages were examined at localities in the eastern half of Arizona.

Martin limestone

A black shale sequence, 20 feet thick, representing the upper part of the Martin limestone of Late Devonian age, was examined and 4 channel samples cut from a continuous section in Gila County (loc. A-1). The shale, though slightly radioactive, contained essentially no uranium. The sample data are as follows:

Thickness of units sampled (feet)	Equivalent uranium (percent)	Uranium (percent)	Remarks
5	0.004	0.001	Top of shale unit
5	.003	.001	
5	.004	.001	
5	.004	.001	Base of shale unit

Cretaceous black shale

Black shales in Upper Cretaceous marine formations were examined at several localities. The shales were inert and were not sampled.

The Mancos shale was examined at the northeastern slope of Black Mesa (loc. A-2) and at Hopi Buttes (loc. A-3) in Navajo County and southeast of Tuba (loc. A-4) in Coconino County. The shale was not radioactive.

An unnamed Upper Cretaceous marine shale in the Deer Creek coal field (loc. A-5) in Pinal County was not radioactive.

Colorado

Formations containing black shale that were examined in Colorado include the Belden, Hermosa, and Paradox formations of Pennsylvanian age, the Morrison formation of Jurassic age, and the Benton shale, Dakota sandstone, Laramie formation, Lewis shale, Mancos shale, Mesaverde formation, Pierre shale, and Vermejo formation of Cretaceous age. Radioactive black shale units that were examined by other Geological Survey parties, mostly in connection with trace element reconnaissance investigations in metal mining districts, include the Weber (?) formation (Singewald and Pierson, 1951) of Pennsylvanian age and shale in the Pony Express limestone (Burbank and Pierson, 1951) of Jurassic age.

Belden shale

The Belden shale of early Pennsylvanian age is exposed in several areas in central and southern Colorado. The formation ranges from a feather edge to several hundred feet in thickness and includes gray and black shales with some limestone and sandstone. Black shale zones in parts of the Belden were tested for radioactivity at several places in Eagle, Garfield, and Gunnison Counties. At most places the shales are weakly radioactive and samples of the more radioactive shales contain 0.002 to 0.006 percent equivalent

uranium, but the uranium content of most samples is 0.001 percent or less. The greatest amount of uranium found in the Belden was in a coaly shale bed, 3 feet thick, in Gunnison County (loc. C-5). A sample of the bed contained 0.003 percent uranium. Analyses of Belden shale samples from several localities are shown in table 2.

Hermosa formation

The Hermosa formation of Pennsylvanian age was examined at two localities along the Silverton to Durango highway in San Juan and La Plata Counties. Several black shale beds in the formation are weakly radioactive and some contain a few thousandths percent uranium. Analyses of 9 samples of the Hermosa formation are as follows:

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
SAN JUAN COUNTY, Map loc. C-6				
NE-NE-29-40N-8W	85689	Channel; 1.5 ft of 3 ft black shale bed	0.005	0.004
"	85690	Channel; 1.5 ft of 3 ft black shale bed	.005	.002
"	85691	Channel; top 1¼ ft of 5 ft black shale bed	.005	.002
"	85692	Channel; 2nd 1¼ ft of same bed	.004	--
"	85693	Channel; 3rd 1¼ ft of same bed	.004	--
"	85694	Channel; basal 1¼ ft of same bed	.006	0.003
LA PLATA COUNTY, Map loc. C-7				
SW-SW-35-37N-9W	85696	Grab; 4 ft black shale	0.003	--
"	85697	Grab; 11 ft black shale	.003	--
"	85698	Grab; 5 ft black shale	.005	0.002

Table 2.--Analyses of samples from the Belden shale, Colo.

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
EAGLE COUNTY, Map loc. C-1					
7-5S-86W	73722	Channel; 1 ft black shale most radioactive bed.	0.006	0.001	Probably part of shale unit represented by sample 76817.
"	76813	Channel; 5 ft gray and black shale; top of sampled zone.	.004	0.001)	
"	76814	Channel; 6 ft gray shale	.003	.001)	Continuous section in
"	76815	Channel; 6 ft gray shale	.004	.000)	middle part of forma-
"	76816	Channel; 4½ ft gray shale	.002	.000)	tion
"	76817	Channel; 3½ ft black shale	.003	.001)	
"	76818	Channel; 2½ ft black and gray shale base of sampled zone.	.003	.001)	
"	76825	Channel; 1½ ft black shale from 200 ft thick shale exposure	.001	.000	Representative bed in lower part of formation.
5-4S-86W	76819	Channel; 1 ft black shale in gypsum-shale sequence.	.004	.001	Upper part of Belden or base of Paradox.
17-4S-86W	76827	Channel; 1 ft black shale	.003	.001	Upper part of Belden shale.
GARFIELD COUNTY, Map loc. C-2					
31-4S-90W	76822	Channel; 1½ ft black shale	.002	.001	
Map loc. C-3					
12-5S-87W	76812	Channel; 1 ft black shale	.004	.001	Basal limestone-shale part of formation.
Map loc. C-4					
4-3S-91W	76824	Grab; black shale	.000	.000	
GUNNISON COUNTY, Map loc. C-5					
SW¼15-14S-84W	85682	Channel; 3 ft black coaly shale	.005	.003	
"	85683	Grab; black shale	.001	.000	

Paradox formation

A sequence of gypsum and black shales assigned to the Paradox formation of Pennsylvanian age, or the approximately equivalent lower part of the Maroon formation, is exposed in several structurally complex areas in central and western Colorado and eastern Utah. At most places exposures of the gypsum and black shale sequence is complexly folded and complete sections of the sequence are difficult to find.

The black shales of the Paradox formation were examined in Eagle and Garfield Counties near the towns of Gypsum and Glenwood Springs. Some thin black shales were radioactive in both areas. The maximum equivalent uranium content was 0.007 percent, and the maximum uranium content was 0.004 percent. Samples collected from the black shales of the Paradox formation and their analyses are shown in table 3.

Weber (?) formation

Shale partings, each a few inches thick in the Weber (?) formation of Pennsylvanian age contain small amounts of uranium in the lower levels of the Eclipse mine in the Leadville district, sec. 19, T. 9 N., R. 79 W., Lake County, Colo. (loc. C-9) (Singewald and Pierson, 1951). A chip sample of one of the most radioactive shale partings, about 1 foot thick, approximately 320 feet above the Leadville limestone, contained 0.032 percent equivalent uranium and 0.019 percent uranium. Singewald and Pierson thought that the uranium was probably of hydrothermal origin, but that possibly it might be syngenetic in the enclosing sediments. Although the deposit in the Eclipse mine apparently is too small to be of commercial importance, the occurrence is of interest as a possible guide to further search for low-grade uranium

Table 3.--Analyses of samples from the Paradox formation, Colo.

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
EAGLE COUNTY, Map loc. C-1					
1-2S-84W	76839	Grab; green micaceous shale at top of gypsum sequence	0.005	0.003	
19-3S-85W	76830	Grab; black shale at top of gypsum sequence	.002	.002	
33-4S-84W	76808	Channel; 3 ft black shale	.002	.001	Upper 9 ft of 20 ft thick black shale exposure in upper part of Paradox formation.
"	76809	Channel; 3 ft black shale	.001	.001	
"	76810	Channel; 3 ft black shale	.002	.001	
20-4S-85W	73720	Channel; 4 ft black shale in gypsum sequence	.004	.001	
2-4S-86W	73721	Channel; 1 ft of 4 ft black shale in gypsum sequence	.003	.002	
"	76836	Channel; top 2 ft of same 4 ft black shale	.004	.001	
"	76837	Channel; bottom 2 ft of same black shale	.004	.001	
9-4S-86W	76828	Grab; black coaly shale	.004	.003	Lower part of gypsum sequence
"	76829	Grab; black scaly coating on gypsum cliff	.002	.000	200 ft stratigraphically above preceeding
31-4S-86W	76834	Channel; top 1 ft of 3 ft black shale in gypsum	.004	.003	Basal part of gypsum sequence
"	76835	Channel; bottom 2 ft of same bed	.004	.003	
6-5S-86W	73718	Channel; 2 ft thick black shale in gypsum	.005	.002	Lower part of gypsum sequence
"	73719	Channel; 1 ft of 3 ft thick black shale in gypsum sequence	.007	.003	

Table 3.--Continued

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
GARFIELD COUNTY,					
Map loc. C-2					
25-4S-91W	76821	Grab; black shale middle of gypsum sequence	0.004	0.003	Middle of gypsum sequence
2-5S-91W	76820	Channel; 1 ft black shale	.005	.003	Upper part of gypsum sequence
Map loc. C-8					
7-7S-88W	76832	Grab; black shale	.003	.004	
NE36-7S-88W	76833	Grab; black shale in gypsum sequence	.003	.003	

deposits. The shale partings are lateral equivalents of and interfinger with the slightly radioactive shales of the Belden-Paradox sequence in Eagle County. Prospecting in the intermediate areas might result in the discovery of low-grade uranium deposits of larger size than those in the Weber (?) formation.

Unnamed Pennsylvanian shale

A black shale zone of Pennsylvanian age similar to shales of the Belden formation is exposed in La Veta Pass in the northern part of Costilla County. The exposures were examined with carborne counter and in places with the portable Geiger counter. The shale was inert and was not sampled.

Pony Express limestone

A shale bed 1 foot thick in the Pony Express limestone of Jurassic age is adjacent to a metaliferous vein deposit in the Pony Express mine, sec. 19, T. 44 N., R. 7 W., Ouray County, Colo. (loc. C-10). A sample of the shale contained 0.012 percent equivalent uranium and 0.01 percent uranium.

The uranium is thought by Burbank and Pierson (1951) to be of hydrothermal origin, and the mineralization to be of Tertiary age. The deposit is presumably too small to be of economic interest. Although the Pony Express limestone and correlative units such as the Todilto limestone probably have been examined and tested for radioactivity at many places, the carbonate-shale sequence, which is extensively exposed in southern Colorado (Wanaka marlstone) and northern New Mexico (Todilto limestone) may provide a favorable environment for other local uranium deposits and the outcrop band might be worthy of further radioactivity reconnaissance surveys. In several places

the formations contain dark shale units which might contain uranium, either of syngenetic or epigenetic origin.

Morrison formation

Shale zones in the Morrison formation of upper Jurassic age were not radioactive where examined in exposures near Iola, Cebolla, and Sapinero along the Gunnison River in Gunnison County.

Cretaceous shales

Numerous black shale zones in marine sedimentary rocks of Cretaceous age were examined and tested for radioactivity in the course of reconnaissance search for uranium in coal and lignite of several Colorado coal fields. Most of the Cretaceous marine black shales are inert and were not sampled. Thin beds of weakly radioactive shale containing 0.002 to 0.003 percent equivalent uranium were found, however, in the Dakota sandstone, the Mancos shale, the Pierre shale, and the Vermejo formation. Shales that were examined in other Cretaceous formations, including the Benton shale, Laramie formation, Lewis shale, and Mesaverde group were essentially non-radioactive. Only the sampled localities of Cretaceous shales in Colorado are shown on the map (fig. 1). These localities and numerous other areas in Colorado, where Cretaceous shales are non-radioactive and not sampled, are discussed below.

Benton shale.--Benton shale was examined at several localities in Fremont, Pueblo, and Huerfano Counties. The shales were inert and were not sampled.

Dakota sandstone.--Black shales in the Dakota sandstone that were examined at several places in Delta, Montrose, Gunnison, La Plata, Montezuma, Huerfano, Pueblo, and Fremont Counties were non-radioactive and were not sampled. A weakly radioactive black shale was found at one locality in Archuleta County. Analyses of samples of a 3-foot thick black shale bed are given below:

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
Map loc. C-11				
NW-NW-9-35N-5W	85701	Upper 1½ ft black shale	0.003	--
"	85702	Lower 1½ ft black shale	.001	--

Laramie formation.--At several localities in Park County, shales in the Laramie formation were non-radioactive and were not sampled.

Lewis shale.--At several localities in Archuleta and La Plata Counties, the Lewis shale was not radioactive and was not sampled.

Mancos shale.--The Mancos shale was non-radioactive where tested with a carborne counter near Cortez and Mancos in Montezuma County, near Durango in La Plata County, and several places in Archuleta County. Portable Geiger-counter tests indicate that the shales of the formation are inert at several places in Gunnison, Delta, Montrose, and San Juan Counties.

Thin beds of weakly radioactive black shale in the lower part of the Mancos shale were sampled in Eagle and Garfield Counties. The sampled beds contained essentially no uranium as indicated below:

Locality (Sec., Tp., R.)	Sample number	Kind of sample and position in section	Equivalent uranium (percent)	Uranium (percent)
EAGLE COUNTY, Map loc. C-12 10-4S-83W	76811	Grab; black shale 150 ft above base of Mancos	0.003	0.000

Locality (Sec., Tp., R.)	Sample number	Kind of sample and position in section	Equivalent uranium (percent)	Uranium (percent)
EAGLE COUNTY, Map loc. C-12 (cont.)				
17-2S-84W	76838	Channel; 1 ft black shale 150 ft above base of fm.	0.002	0.001
GARFIELD COUNTY, Map loc. C-13				
16-5S-91W	76823	Grab; black shale about 500 ft above base of formation	.002	.000

Mesaverde group.--Marine black shales in the Mesaverde group were inert and were not sampled at several localities where they were examined in Gunnison, Delta, Montrose, San Juan, La Plata, and Montezuma Counties.

Pierre shale.--Black shale beds in the Pierre shale were not radioactive and were not sampled at numerous localities where they were examined in Park, Pueblo, Fremont, El Paso, Douglas, Elbert, Arapahoe, Adams, Morgan, Weld, Boulder, and Larimer Counties. One shale exposure in the SW¼ sec. 23, T. 31 S., R. 69 W. (loc. C-14), Las Animas County, was weakly radioactive. A sample (Lab. no. 85714) representing the upper foot of a 30-foot black shale zone contained 0.003 percent equivalent uranium.

Exposures of the Pierre shale near the contact with a basaltic dike were examined and sampled by Bachman and Read (1952) in Huerfano County (loc. C-15). A sample of the shale adjacent to the basalt contained 0.002 percent equivalent uranium and 0.002 percent uranium.

Vermejo formation.--Black shales in the Vermejo formation are not radioactive and were not sampled where they were examined at several localities in Huerfano, Pueblo, and Fremont Counties. One thin black shale bed was weakly radioactive at an exposure in the SW¼ sec. 19, T. 31 S., R. 65 W. in

Las Animas County (loc. C-16). A sample (Lab. no. 85713) of the bed, 0.8 feet thick, contained 0.002 percent equivalent uranium.

Idaho

Black shale zones in south-central and southeastern Idaho were examined for radioactivity by Duncan and Simmons in September 1952. Attention was directed mainly toward marine black shales of Paleozoic age. Other black shale zones in the state have not yet been examined so the inventory is incomplete.

The ages and stratigraphic relationships of shale units that were examined in Idaho are shown in the following table:

PALEOZOIC	Mississippian	Milligen formation
	Ordovician	Unnamed Ordovician shale
		Unnamed Lower Ordovician shale unit
	Cambrian	Spence shale member of Ute formation
PRE-CAMBRIAN	Belt series	Unnamed thin shale unit

Belt series

A gray argillite about 150 feet thick in the pre-Cambrian Belt series is exposed along U.S. Highway 93 near the mouth of the Pasimeroi Creek near Ellis, Lemhi County, Idaho (loc. I-1). The argillite is essentially non-radioactive and was not sampled.

Ute formation

The Spence shale member in the basal part of the Ute formation of Middle Cambrian age is exposed in several places in southeastern Idaho and adjacent parts of northern Utah. The member is a black, fissile, richly

fossiliferous shale about 30 feet thick. The shale was tested for radioactivity and sampled at two places along roadcuts on the east side of the Bear River, about 2 miles south of Cleveland in Franklin County, Idaho. Shale beds of the Spence member are slightly radioactive, but their uranium content is negligible, as shown by the following sample data:

Location (Sec., Tp., R.)	Sample number	Kind of sample and thickness of bed sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
FRANKLIN COUNTY, Map loc. I-2					
6-13S-41E	74115	Channel; top 2' 10"	0.002	0.0002	Abandoned pit E. of highway
"	74116	Channel; 2' 8"	.002	.0002	
"	74117	Channel; 2' 2"	.003	.0002	Incomplete exposure of Spence shale
"	74118	Channel; base 2' 0"	.002	.0001	
7-13S-41E	74119	Channel; base 4'	.002	.0002	
"	74120	Channel; 4'	.003	.0003	Complete
"	74121	Channel; 4'	.003	.0002	exposure
"	74122	Channel; 4' 9"	.002	.0004	of Spence
"	74123	Channel; 4'	.003	.0003	shale in
"	74124	Channel; top 3'	.003	.0003	roadcut.

Ordovician black shale

Black shale zones of Ordovician age were examined at two localities in central Idaho.

An unnamed formation of Early Ordovician age that is exposed along the highway on Trail Creek, 11 miles northeast of Ketchum, Blaine County, includes a carbonaceous argillite zone about 100 feet thick (Umpleby, Westgate, and Ross, 1930, pl. 1).

Field tests of the argillite indicated weak radioactivity for much of the exposed section. Analyses of two channel samples, taken across the most

radioactive zone, 7 feet thick, are as follows:

Map locality	Sample number	Kind and thickness of sample	Equivalent uranium (percent)	Uranium (percent)
I-3	74140	Channel; 3.5 ft black fissile shale	0.004	0.0003
"	74141	Channel; 3.5 ft black fissile shale	.004	.0005

A black shale exposed in T. 8 N., R. 23 E., Custer County is mapped as Ordovician on the Idaho state geologic map. About 300 feet of the shale is well exposed in Lone Cedar Canyon on the east side of the Lost River Valley, 4 miles north of Mackay Reservoir, and is weakly radioactive. Two samples collected from the most radioactive beds yielded the following analyses:

Map locality	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
I-4	74125	Chip sample; 1 ft black shale	0.002	0.0002
"	74126	Chip sample; 6 ft of black shale	.002	.0003

Milligen formation

The Milligen formation of Mississippian age is widely distributed in the Wood River region, in the Bay Horse region and Lost River region, Custer and Blaine Counties, central Idaho. The formation consists of a sequence of black carbonaceous shale with some limestone and quartzite zones, and in places impure coals, and is approximately 3,000 feet thick. The formation was examined at places in both Custer and Blaine Counties, and 8 samples from different parts of the formation in Custer County were collected. Weak radioactivity was detected with the Geiger counter in some of the beds sampled, but most of the formation appeared to be non-radioactive. As no

complete well-exposed section of the formation was found, the tests are considered incomplete but perhaps representative of the formation.

Results of analyses of samples collected from the most radioactive parts of the black shale of the Milligen formation are shown below:

Locality (Sec., Tp., R.)	Sample number	Thickness sampled (ft)	Equivalent uranium (percent)	Uranium (percent)	Remarks
CUSTER COUNTY, Map loc. I-5					
10N-22E	74127	1	0.001	0.0003	Black shale lower slope
3 miles northeast of Dickey	74128	grab	.003	.002	Carbonized tree trunk
"	74129	grab	.002	.0002	Black shale
"	74130	1-1/2	.002	.0002	Black shale
"	74131	1	.003	.0002	Brown siliceous shale
Map loc. I-6					
30-11N-17E	74137	2-1/2	.003	.0004	Most radioactive bed in 200 ft shale exposed
Map loc. I-7					
25-11N-17E	74138	1	.003	.002	Most radioactive black shale in 80 ft sandstone-shale sequence.
"	74139	4	.006	.002	Graphitic shale, most radioactive bed in about 200 ft sandstone-shale exposure.

Montana

Black shale zones in rocks ranging in age from pre-Cambrian to Upper Cretaceous were examined at one or more localities in Montana. Except for the black shales of the Phosphoria formation (Butler and Chesterman, 1945), an effort was made to obtain a complete census of the better known outcropping

black shale zones of Paleozoic formations in the region. Particular attention was directed toward black shales of Devonian and Carboniferous age (table 4). The examination of pre-Paleozoic and of Mesozoic black shale zones in the region was less complete.

The black shale units sampled are described below from the oldest to youngest. Laboratory analyses include equivalent uranium for all samples, but the uranium content was determined chemically only for samples that contain 0.005 percent or more equivalent uranium.

Missoula group

An unidentified formation in the Missoula group of the Belt series of pre-Cambrian age contains some black shale. The shale units examined were inert when tested with the field counter.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
RAVALLI COUNTY, Map loc. M-1				
24-6N-18W	66732	3' channel in 3' bed	0.001	--
"	66733	Upper 2.1' of 4.2' bed	.001	--
"	66734	Lower 2.1' of 4.2' bed	.001	--
"	66735	3' channel of 3' bed	.001	--

Unidentified formation

An unidentified formation consisting mainly of limestone, that is either Cambrian or Devonian in age was examined in Granite County. A shale parting in the limestone yielded the following analysis:

Table 4.--Shale-bearing formations that were examined in central and western Montana. Formations containing black shale zones are marked with an asterisk.

				Number of samples
MESOZOIC	CRETACEOUS	Upper	Colorado fm.*	6
		Lower	Kootenai fm.	
	JURASSIC	Upper and Middle	Morrison fm.	
			Ellis fm.	
PALEOZOIC	PENNSYLVANIAN		Quadrant fm.*	3
	MISSISSIPPIAN	Upper	Amsden fm.*	1
			Heath shale*	13
			Otter fm.*	2
			Kibbey sandstone	
		Lower	Madison limestone*	4
	DEVONIAN	Upper	Three Forks shale*	5
		Middle	Jefferson limestone*	2
	CAMBRIAN	Upper	Pilgrim limestone	
		Middle	Park shale	
			Meagher limestone	
			Wolsey shale	
			Flathead quartzite	
PRE-CAMBRIAN	PRE-CAMBRIAN	BELT series	Unidentified fm.* in Missoula group	4

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
GRANITE COUNTY, Map loc. M-2				
10-12N-14W	66695	0.5' channel in 0.5' bed	0.003	--

Jefferson limestone

The Jefferson limestone of Devonian age consists chiefly of several hundred feet of limestone and dolomite. There are also some beds of dark gray shaly limestone or siltstone. No radioactivity above background was detected in the formation with the field counter.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
LEWIS AND CLARK COUNTY, Map loc. M-3				
32-33-13N-1W	66696	Upper 10' of 20' bed	0.003	--
"	66697	Lower 10' of 20' bed	.002	--

Threeforks shale

The Threeforks shale of Late Devonian age is widespread throughout western Montana. It is about 250 feet thick at Three Forks and contains a few thin beds of gray and black shale in addition to varicolored clays, sandstone, and limestone. Geiger-counter readings of the sampled beds were one and one-half to two times background.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
GALLATIN COUNTY, Map loc. M-4				
SW¼ 25-2N-2E	66759	1.5' channel in 1.5' bed	0.004	--
"	66761	4.3' channel in 4.3' bed	.003	--
Map loc. M-5				
1-2N-2E	66762	Grab sample	.004	--
Map loc. M-6				
27-2N-6E	66764	Upper 4.1' in 8.2' bed	.004	--
"	66765	Lower 4.1' in 8.2' bed	.003	--

Madison limestone

The Madison limestone of Mississippian age is composed chiefly of limestone, but throughout much of its extent in Montana there is a thin bed of black shale near its base. Geiger-counter readings for the black shale units sampled were not above background.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
MADISON COUNTY, Map loc. M-7				
14-1N-2W	63276	2.5' channel in 2.5' bed	0.002	--
GALLATIN COUNTY, Map loc. M-4				
SW¼25-2N-2E	66760	0.4' channel in 0.4' bed	.005	0.003
Map loc. M-6				
27-2N-6E	66763	2.7' channel in 2.7' bed	.004	--

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
GALLATIN COUNTY, (Cont.)				
Map loc. M-8				
6-15N-4W	66766	2' channel in 2' exposure	0.003	--

Otter formation

The Otter formation of Mississippian age consists of green claystone, limestone, sandstone, and a few thin beds of gray and black shale. The formation has a maximum thickness of 375 feet. It is exposed in central Montana in the Big Belt, Little Belt, and Big Snowy Mountains. The two shale units in the formation that were sampled showed little radioactivity above the background of the field counter.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
FERGUS COUNTY,				
Map loc. M-9				
8-13N-21E	66715	8' channel in 8' bed	0.002	--
Map loc. M-10				
14-12N-16E	66717	Grab sample	.004	--

Heath shale

The Heath shale of Upper Mississippian age is mainly black marine shale and is one of the thickest black shale units of Paleozoic age in Montana, attaining a maximum thickness of about 350 feet near the Big Snowy Mountains in central Montana. Geiger counter readings at all but one of the localities where the Heath shale was examined indicated that the shales were not

radioactive. One channel sample representing 4 feet of a 6-foot bed collected at locality M-15, Fergus County, contained 0.006 percent uranium.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
MEAGHER COUNTY, Map loc. M-11				
14-9N-10E	66703	Top 2.5' of 5' bed	0.003	--
"	66704	Bottom 2.5' of 5' bed	.002	--
FERGUS COUNTY, Map loc. M-12				
35-14N-19E	66705	Middle 5' of 12' outcrop	.001	--
"	66706	Bottom 5' of 12' outcrop	.001	--
"	66707	Top 5' of 12' outcrop	.004	--
Map loc. M-13				
14-14N-19E	66708	Middle 3' in 5' outcrop	.003	--
Map loc. M-14				
21-28, 14N-19E	66719	4' channel in 7' of 16' bed	.002	--
"	66710	4' channel in 9' of 16' bed	.002	--
Map loc. M-15				
24-14N-20E	66711	4' channel in 6' outcrop	.007	0.006
Map loc. M-16				
NE¼26-14N-20E	66712	3.2' in upper part of 12' bed	.003	--
"	66713	5.0' in lower part of 12' bed	.002	--
Map loc. M-17				
34-14N-20E	66714	Grab sample	.001	--
Map loc. M-18				
11-12N-21E	66716	4' channel in 6' bed	.002	--

Amsden formation

The Amsden formation of Mississippian and Pennsylvanian age consists mainly of sandstones, sandy limestones, and some red shales, but in places the formation contains a few thin discontinuous black shales. The bed from which a sample was collected is probably only local in extent. This bed is a black, silty, blocky argillite, overlain by light gray siltstone. The Geiger-counter reading was not above background.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
FERGUS COUNTY, Map loc. M-19				
10-12N-16E	66718	3.5' bed	0.002	--

Quadrant formation

In the area from which the three samples from the Quadrant formation of Pennsylvanian age were collected, the formation contains about 40 feet of interbedded light and dark gray shale and some red silty shale. Geiger-counter readings were not above the background.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
MADISON COUNTY, Map loc. M-20				
17-10S-3W	63268	3.0' in upper part of 40' zone	0.002	--
"	63269	4.0' in middle part of 40' zone	.003	--
"	63270	3.0' in lower part of 40' zone	.002	--

Colorado group

The Colorado group of Late Cretaceous age contains several hundred feet of black or gray marine shale, as well as siltstone and sandstones. The lower part of the sequence contains phosphorite nodules in places. Six samples were collected from three localities. Geiger-counter readings for these were not above the background reading.

Locality (Sec., Tp., R.)	Sample number	Thickness sampled	Equivalent uranium (percent)	Uranium (percent)
PARK COUNTY, Map loc. M-21				
6-2S-12E	62051	1.1'	0.003	--
Map loc. M-22				
24-3S-7E	62058	4.0'	.002	--
LEWIS AND CLARK COUNTY, Map loc. M-23				
15N-4W	66746	0-25' in 100' thick zone	.002	--
"	66747	25-50' in 100' thick zone	.002	--
"	66748	50-75' in 100' thick zone	.002	--
"	66749	75-100' in 100' thick zone	.003	--

Unidentified formation

A thin shale zone in rocks thought to be of Late Cretaceous age was examined in sec. 33, T. 5 N., R. 11 W., Deer Lodge County (loc. M-24). The shale unit, 2.9 feet thick, appeared to be slightly radioactive with field counter. A laboratory radioactivity test of a channel sample (No. 63967) taken across the entire bed, contained 0.002 percent equivalent uranium.

Nevada

Several black shale zones are recorded in the stratigraphic sequence in Nevada. These range from Cambrian to Tertiary in age, but the most extensive are of Paleozoic age. Most of the better known shale zones of Paleozoic age, recorded in central and northeastern Nevada, were examined at one or more localities.

Vinini shale

A black shale-bearing sequence of Early and Middle Ordovician age, the Vinini formation, possibly as much as 2,000 or 3,000 feet thick, is exposed in several places in east-central Nevada. The shales are generally complexly deformed. Shales underlying the surface of a large thrust sheet along Vinini Creek in the Roberts Mountains area, Eureka County, had contained 0.003 to 0.008 percent equivalent uranium in earlier examinations (Harder and Wyant, 1944), but the area was not revisited in the current investigation. Exposures of the Vinini as a whole are generally poor, but good exposures of parts of the formation were examined at two localities in Eureka County. Geiger-counter readings of the partial sections examined and laboratory analyses of random samples revealed no radioactivity or uranium content as indicated below:

Locality (Sec., Tp., R.)	Sample number	Kind of sample	Equivalent uranium (percent)	Uranium (percent)	Remarks
EUREKA COUNTY, Map loc. N-1					
19-23N-52E	53633	Grab	0.000	0.001	Black siliceous shale in quarry; about 2' of beds in about 250' of exposed section.

Locality (Sec., Tp., R.)	Sample number	Kind of sample	Equivalent uranium (percent)	Uranium (percent)	Remarks
EUREKA COUNTY, (Cont.) Map loc. N-2					
21-22N-52E	53634	Grab	0.000	0.001	Siliceous shale. Top of formation.

Unnamed Early Paleozoic shale

Two black shale units of Early Paleozoic age were examined in south-central Nevada. These shale units are perhaps younger than the Vinini shale and may be of Ordovician or Silurian age. Shales at the two localities examined were slightly radioactive, but the uranium content of the more radioactive beds sampled was too low to be of economic interest. One of the black shale units, probably of Middle Ordovician age, crops out in the Monitor Range, 1.5 miles north of the forks of Ryegrass and Copenhagen Canyons in unsurveyed T. 15 N., R. 49 W., Eureka County, (loc. N-3). The exposed shale zone is about 15 feet thick and is about 20 feet below the base of the Eureka quartzite. A channel sample (No. 53643) through 2-1/2 feet of black shale contained 0.003 percent equivalent uranium and 0.001 percent uranium. The other black shale sequence of Ordovician or Silurian age is exposed along the eastern front of the Toquima Range, 0.2 mile south of the mouth of Ikes Canyon in T. 14 N., R. 46 E., Nye County. The exposed shale zone, about 150 feet thick, is complexly folded. Results of laboratory analyses of 3 samples taken from the more radioactive parts of the shale are shown below:

Locality (Tp., R.)	Sample number	Kind of sample and thickness represented	Equivalent uranium (percent)	Uranium (percent)	Remarks
NYE COUNTY, Map loc. N-4					
14N-46E	53644	Channel, 5 feet	0.002	0.003	12' zone near top sequence
"	53645	Channel, 7 feet	.005	.004	
"	53646	Chip, 2 feet	.002	.003	Near base of sequence

Pilot shale

The Pilot shale of Mississippian age is a dark gray, brown, and black shale unit, about 400 feet thick, as exposed east of Newark Pass, approximately in unsurveyed sec. 5, T. 19 N., R. 55 E., White Pine County (loc. N-5). The shale which is poorly exposed, was tested with Geiger-counter in a series of shallow pits, and two samples of the weakly radioactive shale were collected and analyzed, with the following results:

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness represented	Equivalent uranium (percent)	Uranium (percent)	Remarks
WHITE PINE COUNTY, Map loc. N-5					
5-19N-55E	53637	Channel, 5 feet	0.002	0.002	Base of formation
"	53638	Channel, 5 feet	.003	.001	Top of formation

White Pine shale

The White Pine shale, black shale as much as 2,500 feet thick and mostly of Late Mississippian age, is extensively exposed in Elko, Eureka, and White Pine Counties.

The formation was examined and tested with Geiger-counter at several localities, and although parts of the shale are slightly radioactive, the random samples collected from the more radioactive beds contained negligible amounts of uranium upon chemical analysis, as indicated below:

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness of beds sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
EUREKA COUNTY, Map loc. N-6					
12-19N-54E	53635	Chip, 5 feet	0.002	0.001	
WHITE PINE COUNTY, Map loc. N-5					
5 & 6-14N-55E	53636	Chip, 5 feet	.003	.001	Black shale 500' below top of fm.
"	53639	Chip, 5 feet	.003	.001	Base of White Pine
EUREKA COUNTY, Map loc. N-7					
19-20N-53E	53642	Chip, 2 feet	.003	.001	Black shale overlying alaskite sill

Unnamed Carboniferous black shale

Black shale zones that were examined in northern Elko County are similar in general aspect to Mississippian and Pennsylvanian shale-bearing formations in other nearby areas and perhaps are the same age.

A black shale, several hundred feet thick, is incompletely exposed near the abandoned Rio Tinto copper mine near Mountain City in the northern part of Elko County. The shale is host rock of a large copper sulfide deposit in the Rio Tinto mine. Examination of the shale in roadcuts and

mine dumps indicated only a small amount of radioactivity. Results of laboratory analyses of samples of the more radioactive shales are as follows:

Locality (Sec.,Tp.,R.)	Sample number	Kind of sample and thickness of beds sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
ELKO COUNTY, Map loc. N-8					
13-45N-53E	53630	Dump	0.004	0.002	Copper prospect
12-45N-53E	53631	Channel, 2 feet	.003	.001	Most active shale in 50' of exposed sections in roadcut.

A black shale and interbedded sandstone zone several hundred feet thick is exposed along roadcuts in Taylors Canyon on Nevada Highway 11, T. 39 N., Rs. 52 and 53 E. (loc. N-9). Rocks of the zone were tested with Geiger-counter, and two thin shale zones were found to be weakly radioactive. Samples collected from the most radioactive rocks yielded the following analyses:

Locality (Sec.,Tp.,R.)	Sample number	Kind of sample and thickness of beds sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
ELKO COUNTY, Map loc. N-9					
30-39N-53E	53632	Chip, 2 feet	0.005	0.005	Roadcut; random sample in same exposure as 73104 and 73109.
"	73104	Channel, 2 feet	.002	.0018	Top of exposed shale. Black soft shale.
"	73105	Channel, 3 feet	.003	.0019	Black and dark gray shale
"	73106	Channel, 3.3 feet	.002	.0020	Black shale and tan siltstone
"	73107	Channel, 4 feet	.005	.0037	Black shale
"	73108	Channel, 3 feet	.003	.0033	Black shale

Locality (Sec.,Tp.,R.)	Sample number	Kind of sample and thickness of beds sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
ELKO COUNTY, (Cont.) Map loc. N-9					
30-39N-53E	73109	Channel, 3.2 feet	0.003	0.0019	Dark gray and tan shale. Base of shale exposure
24-39N-52E	73102	Chip, 3 feet	.002	.0006	Black shale dike in siliceous shale
"	73103	Channel, 3.2 feet	.001	.0006	Dark gray and brown siliceous shale host rock, 3 ft away from 73102.

A black shale several hundred feet thick exposed on the west side of Goose Creek valley in the northeastern part of Elko County (loc. N-10) is perhaps of Carboniferous age. Exposures of the shale in sec. 27, T. 47 N., R. 69 E. were examined along the unconformable contact with overlying tuff deposits of Pliocene age. A grab sample (No. 76326) of hard blocky black shale from the exposure contained 0.002 percent equivalent uranium and 0.0004 percent uranium.

Permian black shale

A thin black shale unit of Permian age in the Eureka district, Eureka County, Nev. was examined and found to be essentially non-radioactive. A grab sample (No. 53640) from the shale, collected from a roadcut, approximately in unsurveyed sec. 36, T. 19 N., R. 53 E. (loc. N-11) contained 0.002 percent equivalent uranium and 0.002 percent uranium.

New Mexico

Black marine shales of Devonian, Mississippian, Pennsylvanian, and Cretaceous ages were examined and sampled at several localities in New Mexico (Bachman and Read, 1952).

Percha shale

The Percha shale, a black petroliferous shale of Late Devonian age, was examined and sampled at two localities in New Mexico. Slight radioactivity was detected at one locality in Otero County, but the uranium content of the shale was negligible as indicated by the following sample data:

Locality	Sample number	Thickness of beds sampled (feet)	Equivalent uranium (percent)	Uranium (percent)	Remarks
OTERO COUNTY, Map loc. NM-1					
Alamo Canyon	63056A	10	0.000	--	Base of Percha
"	63057	Grab	.004	0.002	Calcareous shale 15' above base.
"	63058	1-1/2	.004	.002	Calcareous zone about 22' above base.
"	63059	3	.003		Lower half of 6' thick shaly unit.
"	63060	3	.002		Upper half of 6' thick shaly unit.
"	63061	Grab	.001		Nodular unit; below contact with Lake Valley limestone (Miss.)
SOCORRO COUNTY, Map loc. NM-2					
Rhodes Pass, San Andres Mountains	63062	10	.001		20 ft above base
	63063	20	.001		Above sample 63062
	63064	10	.001		Above sample 63063

Lake Valley limestone

The Lake Valley limestone of Mississippian age overlies the Percha shale and was examined at Rhodes Pass, San Andres Mountains, Socorro County (loc. NM-2). A single sample (No. 63065) collected from a thin calcareous shale zone contained 0.002 percent equivalent uranium.

Madera formation

A black shale zone, about 1,500 feet thick in the Madera formation of Pennsylvanian age, was examined in Mora County at a locality 1.9 miles east of Taos-Mora County line on New Mexico State Highway No. 3 (loc. NM-3). A grab sample (No. 613064) of one of the more radioactive shale beds, 4 inches thick, contained 0.002 percent equivalent uranium and 0.001 percent uranium. Other parts of the formation tested were less radioactive and were not sampled.

Cretaceous marine shales

In the course of examining Cretaceous coal-bearing areas for radioactive materials in New Mexico, several marine black shale zones in the Mancos and Lewis shales and the Mesaverde group of Late Cretaceous age were also examined in reconnaissance. Field radioactivity tests were made with carborne counters supplemented by spot tests with standard portable Geiger-counters. At the several localities where the Cretaceous marine shales were tested, the shales were essentially non-radioactive and were not sampled.

Mancos shale.--The Mancos shale, consisting mostly of dark gray and black marine shales and ranging from about 300 to 2,500 feet thick, is

extensively exposed in central, western, and northern New Mexico. Localities where the formation was examined include exposures near Rio San Antonio (loc. NM-4), near the towns of Chama (loc. NM-5), Lumberton (loc. NM-6), and Canjilon (loc. NM-7) in Rio Arriba County; near Cuba on the upper Rio Puerco (loc. NM-8) and along Ceja del Rio Puerco (loc. NM-9) in Sandoval County; along the Rio Puerco (loc. NM-10) in Bernalillo County; along the upper part of Rio Salado (loc. NM-11) and west of the Rio Grande near Carthage (loc. NM-12) in Socorro County; near Capitan (loc. NM-13) in Lincoln County; and at several localities between Gallup and Shiprock (loc. NM-14) along the west side of the San Juan Basin in San Juan County.

Mesaverde group.--Marine dark gray and black shale zones are interbedded with the coal-bearing nonmarine sandstone and shales of the Mesaverde group in the western part of the San Juan Basin (loc. NM-14), San Juan County. The marine shales were tested at several places and found to be non-radioactive.

Lewis shale.--The Lewis shale is extensively exposed in northwestern New Mexico. The formation includes black shale zones that were tested for radioactivity near Cuba (loc. NM-8), Sandoval County, and near Fruitland (loc. NM-15) in San Juan County. No radioactivity was detected. Immediately south of Chaco Canyon National Monument, San Juan County (loc. NM-16), the Lewis shale may be slightly radioactive as indicated by scintillation-detector readings.

Utah

Black shales were examined in several areas in the northern half of Utah. The following table shows the approximate age relationships of the formations and general areas in which the formations were examined.

Age	Western Utah	Central Utah	Northern Utah	Eastern and northeastern Utah
Eocene		Green River fm.		Green River fm.
Upper Cretaceous				Mancos shale
Triassic				Woodside shale
Permian				Park City fm.
Permian (?)		Kirkman ls.		
Pennsylvanian and Permian		Oquirrh fm.		
Pennsylvanian and Mississippian	Manning Canyon sh.	Manning Canyon shale		Unnamed shale unit
Mississippian	Oquirrh Mtn. ls. (Herat shale member)	Great Blue Deseret ls. Madison, Gardner	Brazer ls. Madison	
Ordovician			Swan Peak quartzite	
Cambrian	Orr fm. Weeks fm. Wheeler fm. Pioche sh.	Pioche shale Brigham qtzite.		
Pre-Cambrian		Big Cottonwood series		

Big Cottonwood series

A series of pre-Cambrian quartzite and metamorphosed shale beds are exposed along Big Cottonwood Canyon, T. 2 S., R. 2 E., Salt Lake County, Utah (Crittendon, et al. 1952, p. 3; Calkins and Butler, 1943, pl. 5). The series contains a dark gray argillite zone about 500 feet thick which was examined in exposures along the highway 3 miles above the mouth of Cottonwood Canyon, in sec. 20, T. 2 S., R. 2 E. (loc. U-1). Geiger-counter readings across the shale zone showed slight radioactivity. A grab sample (No. 73090) collected from the most radioactive bed detected, represented a 1-foot dark gray argillite and contained 0.003 percent equivalent uranium and 0.0011 percent uranium.

Brigham quartzite

A gray micaceous shale zone 7-1/2 feet thick in the upper part of the Brigham quartzite of Early Cambrian age is exposed in a roadcut near the mouth of Ogden Canyon in sec. 24, T. 6 N., R. 1 W., Weber County (loc. U-2). A channel sample (No. 52726) taken across the top 6 feet of the shale bed contained 0.005 percent equivalent uranium and 0.001 percent uranium.

Another exposure of the Brigham quartzite, several hundred feet thick, in sec. 20, T. 10 S., R. 1 E., Utah County (loc. U-3), was examined and tested for radioactivity with a Geiger-counter; some of the quartzitic sandstone beds are weakly radioactive. Analytical results of two samples of the most radioactive beds are as follows:

Locality (Sec., Tp., R.)	Sample number	Kind of sample	Equivalent uranium (percent)	Uranium (percent)
UTAH COUNTY, Map loc. U-3				
20-10S-1E	73080	Grab, brown quartzite	0.002	0.0009
"	73081	Chip, 1-1/2 ft. gray shaly sandstone	.004	.0008

Pioche shale

The Pioche shale of Early Cambrian age crops out in several of the mountain ranges of northern and western Utah and eastern Nevada. The unit normally consists predominantly of brown-weathering micaceous and siliceous shale or argillite, but in places it contains some medium- to dark-gray shales. The Pioche shale ranges from about 200 feet thick to as much as 500 feet thick. The formation is weakly radioactive in the few localities where it was examined, but random samples collected from the more radioactive beds contained negligible uranium upon chemical analysis.

A gray and brown micaceous shale unit about 500 feet thick, assigned to the Pioche shale, crops out near the mouth of Ogden Canyon in sec. 24, T. 6 N., R. 1 W., Weber County (loc. U-2). The lower 300 feet of the shale was tested and weak radioactivity was detected throughout the exposure. Analyses of samples collected from two of the more radioactive beds are as follows:

Locality (Sec., Tp., R.)	Sample number	Kind of sample	Position in formation	Equivalent uranium (percent)	Uranium (percent)
WEBER COUNTY, Map loc. U-2					
24-6N-1W	52727	Channel; 1 ft	175' above base	0.005	0.001
"	52728	Channel; 3 ft	218' above base	.003	.000

A section of the Pioche shale was examined near the Marjum Pass road at the west face of the House Range, Millard County, Utah, in unsurveyed T. 18 S., R. 14 W. (loc. U-4). The field counter indicated that the shale is in part weakly radioactive. A chip sample (No. 73100) representing 2 feet of a green, micaceous shale zone contained 0.004 percent equivalent uranium and 0.001 percent uranium.

Wheeler formation

The Wheeler formation of Middle Cambrian age consists of alternating shale and limestone about 570 feet thick where it is exposed in the House Range of western Utah. The formation is well exposed along the highway at Marjum Pass in unsurveyed T. 18 S., approximately along Range line of 13 and 14 W., Millard County, Utah (loc. U-5), where the lower 300 to 400 feet of the formation is predominantly alternating gray and black shale. Weak radioactivity was detected in some of the black shales, although most of the formation is non-radioactive. A sample from one of the more radioactive zones yielded the following results.

Locality (Sec., Tp., R.)	Sample number	Kind of sample	Equivalent uranium (percent)	Uranium (percent)
MILLARD COUNTY, Map loc. U-5				
18S-13,14W	73099	Chip, black, fissile shale representing about 5 feet of beds in a black shale zone 25 feet thick.	0.002	0.0004

Weeks and Orr formations

The Weeks and Orr formations of Late Cambrian age crop out in the southern part of the House Range, Millard County, Utah. These formations are about 3,000 feet thick that consist mostly of thin-bedded gray to black limestone. Each contains dark gray and black shale zones which range from several feet to about 235 feet thick. The formations are cut by a granitic intrusive rock near the head of Weeks Canyon (unsurveyed Tps. 18 and 19 S., Rs. 13 and 14 W.), where several small contact metamorphic deposits of scheelite are mined. The formations were examined at places adjacent to the granite contact and in Weeks Canyon and Orr Ridge, a few miles east of the granite contact. Weak radioactivity was noted within the granite near the sedimentary contact in Weeks Canyon and in a small granitic dike intruding limestones of the Weeks formation above the granite. Less radioactivity was detected in the black shale beds and limestones. Analyses of samples collected from granite, limestone, and shale in the area are as follows:

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
MILLARD COUNTY, Map loc. U-6				
18 & 19S, 13 & 14W.	73093	Granite, chip sample, several exposed faces, head of Weeks Canyon	0.005	0.001
"	73094	Granitic dike, grab sample	.007	.0006
"	73095	Black arenaceous limestone, 2' bed from 30' above nearest exposed granite (Weeks formation)	.000	.0007

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
MILLARD COUNTY, (Cont.) Map loc. U-6				
18 & 19S., 13 & 14W.	73096	Black shale, 1 ft thick chip sample, Weeks formation, 1/2 mile east of granite contact	0.001	0.0006
"	73097	Tan shale, chip sample of 1 ft thick zone, near top of 235 ft shale unit in Orr formation	.002	.0006
"	73098	Black fissile shale, chip sample through 1-1/2 ft of beds about 70 ft below top of 235 ft shale unit in Orr formation	.002	.0005

Swan Peak quartzite

The Swan Peak quartzite of Ordovician age crops out in southeastern Idaho and northern Utah, and equivalent sediments are recorded in western Utah. The formation, composed mostly of quartzite, contains some thin beds of phosphatic shale near Fish Haven in southeast Idaho (Mansfield, 1927, p. 57). One section of the Swan Peak was examined in Green Canyon, 1.4 miles east of Logan, T. 12 N., R. 1 E., Cache County, Utah (loc. U-7). There, rocks assigned to the Swan Peak quartzite include an olive drab-weathering shale about 50 feet thick underlying thin-bedded quartzites. The shale is poorly exposed, and the weathered slope was not radioactive. Three pits dug at intervals across the shale slope exposed brown silty shale which also was not radioactive. No samples were taken.

Madison limestone

The Madison limestone of Early Mississippian age is widely exposed in central, northern, and eastern Utah. The formation consists mostly of limestone with chert layers and nodules but in places contains thin black shale zones, some of which are reported to contain thin phosphatic layers.

A black shale zone is reported in the basal part of the Madison limestone, in Logan Canyon, T. 12 N., R. 2 E., Cache County (loc. U-8). Rocks in the area were examined, but exposures were poor. No radioactivity was detected with the counter, and no samples were taken.

Thin dark shale zones in the upper part of the Madison formation are exposed in City Canyon, T. 1 N., R. 1 E., Salt Lake County (loc. U-9) where the formation was examined. No radioactivity was detected.

Gardner dolomite

The Gardner dolomite of Early Mississippian age, approximately the lateral equivalent to the Madison limestone, is exposed in the Tintic mining district near Eureka, Juab County, Utah (loc. U-10). A zone of black shale and interbedded dolomite about 160 feet thick makes up the top part of the Gardner, and similar black shales alternating with dolomite and limestone continue upward into the lower part of the overlying Pine Canyon limestone of Late Mississippian age. This black shale near the Gardner-Pine Canyon boundary apparently thins northward but may correlate in part with the basal black shale of the Deseret limestone and with thin phosphatic shales in the upper part of the Madison limestone of nearby areas. The Gardner shales have not been traced south and west of the Tintic district, but phosphatic black shales reported by A.E. Granger

(personal communication) in the Canyon Range, near Leamington, about 30 miles south of Eureka, are presumably approximately the same stratigraphic zone. The shale zone near Leamington was searched for but not found.

The individual black shale zones in the Gardner-Pine Canyon sequence range in thickness from a few inches to about 30 feet. They are poorly exposed or concealed at the surface in the Tintic district but have been penetrated by numerous underground mine workings and drill holes. The belt of outcrop of black shale extends about 3 miles north-south in sections 7, 18, 19, and 30, T. 10 S., R. 2 W., and terminates to the north and south against igneous rocks that include both flows and intrusives.

Weak radioactivity was discovered in the basal black shale of the Gardner by geologists of the Longyear Drilling Company in an exploration drift extending north from the Chief Consolidated Mine. Two muck-pile samples, weighing 25 pounds each, collected from the drift were orally reported by R. C. Gebhardt of the Longyear Company to have been analyzed by the Bureau of Mines laboratory in Salt Lake City. The following analyses were obtained:

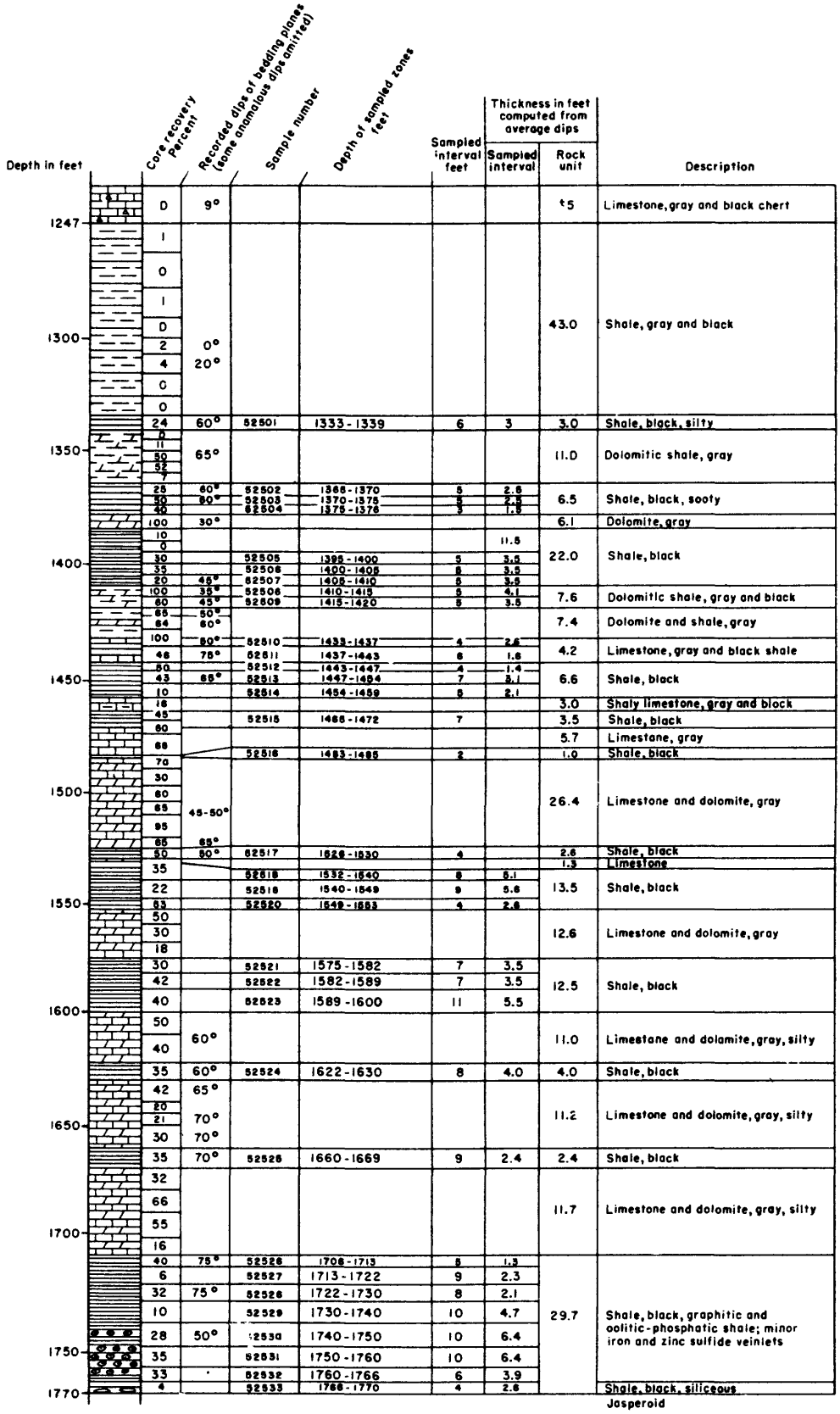
	V_2O_5 (percent)	Uranium (percent)
Lot 1	1.16	0.005
Lot 2	0.34	0.003

The Longyear Drilling Company's core drill hole 1-A (loc. U-10) put down vertically from surface, penetrated the steeply dipping and perhaps crumpled shale zone that was sampled underground. The part of drill core containing black shale was examined by Duncan, a series of core samples was taken and analyzed for uranium and other trace elements. A detailed log of the hole through the black shale zone is shown graphically in

figure 2; an interpreted stratigraphic section of the lower part of the same zone is shown in figure 3. In general, shales in the lower 115 feet of the section contain 0.002 percent uranium or more. The best zone of minable thickness assayed 0.004 to 0.006 percent uranium, averaging about 0.005 percent through the basal 19.3 feet of black shale section (sample numbers 52530 to 52533). Phosphorous and vanadium in the same part of the section may be in sufficient quantities to be of future commercial interest. Core recovery was low from the black shale beds penetrated in drilling and a sample section of the more radioactive shale zone was obtained from nearby mine workings as a check of the core samples. The black phosphatic shale exposed in the 1,600 foot level of the Chief Consolidated mine (mine coordinates 8700 E., 5400 N.), was examined and sampled. The shale zone representing the basal part of the black shale sequence was cut by a fault at the top of the exposure. Radioactivity measurements with the Geiger-counter at the shale exposure were several times greater than the radioactivity measurements of the shale in the laboratory. As the field counter continued to indicate uniform radioactivity along the mine drift away from the source of air current, it is assumed that the unusually strong radioactivity is due, in large part, to radon evolving from the black shale. Analyses of a series of channel samples taken across the shale show negligible amounts of uranium as indicated below.

Analyses of channel samples of basal part of the black shale of the Gardner limestone, taken from 1,600 foot level of Chief Consolidated mine, sec. 18, T. 10 S., R. 2 W., Juab County (loc. U-10).

Sample number	Thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
73082	2 ft	0.002	0.0018	Base of sampled section, black shale

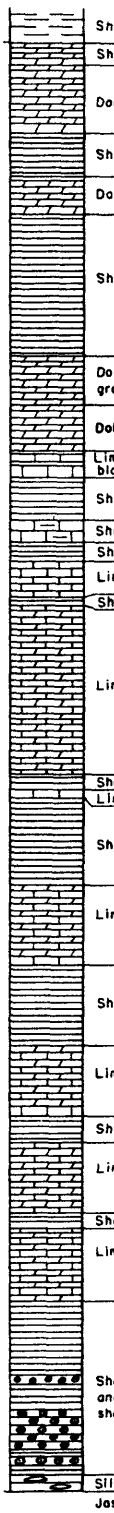


Depth in feet	Core recovery Percent	Recorded dips of bedding planes (some anomalous dips omitted)	Sample number	Depth of sampled zones feet	Sampled interval feet	Thickness in feet computed from average dips: Sampled interval	Thickness in feet computed from average dips: Rock unit	Description
1247	D	9°					5	Limestone, gray and black chert
	1							
	0							
	1							
	D						43.0	Shale, gray and black
1300	2	0°						
	4	20°						
	0							
	0							
	24	60°	52501	1333 - 1339	6	3	3.0	Shale, black, silty
	0							
1350	11							
	50	65°					11.0	Dolomitic shale, gray
	52							
	7							
	25	60°	52502	1366 - 1370	5	2.6		
	50	60°	52503	1370 - 1375	5	2.5	6.5	Shale, black, sooty
	40		52504	1375 - 1378	3	1.9		
	100	30°					6.1	Dolomite, gray
	10					11.5		
	0							
1400	30		52505	1395 - 1400	5	3.5	22.0	Shale, black
	35		52506	1400 - 1405	5	3.5		
	20	45°	52507	1405 - 1410	5	3.5		
	100	35°	52508	1410 - 1415	5	4.1	7.6	Dolomitic shale, gray and black
	60	45°	52509	1415 - 1420	5	3.5		
	65	50°					7.4	Dolomite and shale, gray
	64	60°						
	100	80°	52510	1433 - 1437	4	2.8	4.2	Limestone, gray and black shale
	48	75°	52511	1437 - 1443	6	1.8		
	50		52512	1443 - 1447	4	1.4	6.6	Shale, black
1450	43	85°	52513	1447 - 1454	7	3.1		
	10		52514	1454 - 1459	5	2.1		
	16						3.0	Shaly limestone, gray and black
	45		52515	1466 - 1472	7		3.5	Shale, black
	60						5.7	Limestone, gray
	88							
	70		52516	1483 - 1485	2		1.9	Shale, black
	30							
1500	60						26.4	Limestone and dolomite, gray
	68	45-50°						
	95							
	65	85°						
	50	80°	52517	1528 - 1530	4		2.6	Shale, black
	35						1.3	Limestone
			52518	1532 - 1540	8	5.1		
	22		52518	1540 - 1549	9	5.8	13.5	Shale, black
1550	83		52520	1549 - 1553	4	2.6		
	50							
	30						12.6	Limestone and dolomite, gray
	18							
	30		52521	1575 - 1582	7	3.5		
	42		52522	1582 - 1589	7	3.5	12.5	Shale, black
	40		52523	1589 - 1600	11	5.5		
1600	50							
	40	60°					11.0	Limestone and dolomite, gray, silty
	35	60°	52524	1622 - 1630	8	4.0	4.0	Shale, black
	42	65°						
	20							
	21	70°					11.2	Limestone and dolomite, gray, silty
1650	30	70°						
	35	70°	52526	1660 - 1669	9	2.4	2.4	Shale, black
	32							
	66						11.7	Limestone and dolomite, gray, silty
	55							
1700	16							
	40	75°	52526	1706 - 1713	8	1.3		
	6		52527	1713 - 1722	9	2.3		
	32	75°	52528	1722 - 1730	8	2.1		
	10		52529	1730 - 1740	10	4.7	29.7	Shale, black, graphitic and oolitic-phosphatic shale; minor iron and zinc sulfide veinlets
	28	50°	52530	1740 - 1750	10	6.4		
1750	35		52531	1750 - 1760	10	6.4		
	33		52532	1760 - 1766	6	3.9		
1770	4		52533	1766 - 1770	4	2.6		Shale, black, siliceous Jasperoid

LOG OF PART OF LONGYEAR DRILLING CO. CORE DRILL HOLE 1A TINTIC MINING DISTRICT, SEC. 7, T. 10 S., R. 2 W., JUAB COUNTY, UTAH SHOWING LITHOLOGY, STRUCTURAL DATA, AND SAMPLED PARTS OF THE GARDNER AND PINE CANYON FORMATIONS

Prepared by D.C. Duncan. Data in part from drilling records of E.J. Longyear Co.

FIGURE 2



Depth in feet	Rock type	Computed thickness feet	Laboratory sample number	% eU	% U	% V_2O_5	% P_2O_5
	Shale, gray						
1333	Shale, black	3.0	52501	.001	.001	0.45	3.00
	Dolomitic shale, gray	11.0					
	Shale, black	2.5	52502	.000	.001	0.21	0.80
		2.5	52503	.001	.001	0.18	0.58
		1.5	52504	.001	.001	0.13	0.85
	Dolomite, gray	6.1					
	Shale, black	11.5	No samples				
		3.5	52505	.000	.001	0.17	1.65
		3.5	52506	.001	.001	0.20	1.95
		3.5	52507	.000	.001	0.18	1.45
	Dolomitic shale, gray and black	4.1	52508	.001	.001	0.14	1.01
		3.5	52509	.001	.001	0.12	0.85
	Dolomitic shale, gray	7.4					
	Limestone, gray and black shale	2.6	52510	.002	.001	0.23	1.65
		1.6	52511	.003	.001	0.54	5.90
	Shale, black	1.4	52512	.001	.001	0.33	4.55
		3.1	52513	.001	.001	0.40	3.86
		2.1	52514	.004	.001	0.41	5.60
	Shaly limestone	3.0					
	Shale, black	3.5	52515	.003	.001	0.40	4.90
	Limestone, gray	5.7					
	Shale, black	1.0	52516	.002	001	0.31	3.90
	Limestone and dolomite, gray	26.4					
	Shale, black	2.6	52517	.004	003	0.19	10.10
	Limestone	1.3					
	Shale, black	5.1	52518	.002	.002	0.23	10.70
		5.8	52519	.004	.003	0.47	8.10
		2.6	52520	.005	.002	0 57	6.45
	Limestone and dolomite, gray	12.6					
	Shale, black	3.5	52521	.003	.003	0.40	9.80
		3.5	52522	.002	.002	0.15	1.05
		5.5	52523	.001	.001	0.17	1.84
	Limestone and dolomite, gray	11.0					
	Shale, black	4.0	52524	.003	.002	0 17	6.50
	Limestone and dolomite, gray	11.2					
	Shale, black	2.4	52525	.002	.002	0.40	3.70
	Limestone and dolomite, gray	11.7					
	Shale, black, graphitic and oolitic-phosphatic shale	1.3	52526	.002	.002	0.36	1.70
		2.3	52527	.003	.003	1.02	6.30
		2.1	52528	.005	.003	1.22	5.20
		4.7	52529	.002	.003	0.51	7.35
		6.4	52530	.006	.005	0.27	15.25
		6 4	52531	.006	.004	0.37	15.25
		3.9	52532	.005	.005	0.14	23.62
1770	Siliceous shale, black	2.6	52533	.006	.006	0.36	0.65

Jasperoid and gray silicified limestone not sampled

Vertical scale: 1 inch = 20 feet

COMPUTED STRATIGRAPHIC SECTION THROUGH SAMPLED ZONE IN THE GARDNER AND PINE CANYON FORMATIONS, PENETRATED IN LONGYEAR DRILLING CO. CORE DRILL HOLE 1A, SEC. 7, T. 10 S., R. 2 W., JUAB COUNTY, UTAH, SHOWING URANIUM, V_2O_5, AND P_2O_5 CONTENT OF BLACK SHALE ZONES

Prepared by D.C. Duncan

FIGURE 3

Sample number	Thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
73083	4 ft 8 in.	0.000	0.0007	Black jasperoid
73084	2 ft 3 in.	.003	.0022	Black shale, oolitic and phosphatic
73085	1 ft 9 in.	.002	.0020	Black shale, oolitic and phosphatic
73086	2 ft 2 in.	.001	.0015	Black shale
73087	2 ft 2 in.	.002	.0017	Black shale, top of continuous sampled section.
	13 ft	Not sampled		Brecciated dark gray and black limy chert; probably faulted.
73088	6 ft	.002	.0017	Black shale
	10 ft	Not sampled		Light gray limestone, cut by fault at top
73089	3 ft	.004	.0038	Black siliceous shale with white clay bands. Top of sampled section.

As there appears to be little correlation between the uranium content of the two sampled sections of the lower part of the Gardner shale, and as the uranium content is generally small, it appears that the deposit is too low grade and irregular to be of economic interest in the forseeable future.

Deseret limestone

The Deseret limestone of Late Mississippian age is exposed in north-central Utah, where it overlies the Madison limestone and is overlain by the Humbug formation. In most places the base of the Deseret limestone is marked by a black shale zone ranging from about 6 to 25 feet thick. The basal black shale locally contains phosphorite layers a fraction of an inch to a few inches thick. The shale generally weathers red on outcrops but in the fresher exposures the shales are black. The shale zone at the base of the Deseret limestone was examined at 3 localities in north-central Utah, but no radioactivity was detected.

The shale assigned to the lower part of the Deseret limestone was sampled in the portal of a prospect adit on the north side of a dry gulch in the SE¼ sec. 15, T. 9 S., R. 2 W., Utah County (loc. U-11). One sample (No. 52494) taken across 11 feet of red-weathering shale beds contained 0.002 percent equivalent uranium and 0.001 percent uranium.

The black shale which is 24 feet thick at the base of the Deseret limestone in City Canyon, about 6.1 miles by road northeast of the State Capitol Building in T. 1 N., R. 1 E., Salt Lake County (loc. U-9) was examined. Samples of the shale from a trench about 200 feet above stream level were analyzed as follows:

Sample number	Kind of sample	Thickness (feet)	Equivalent uranium (percent)	Uranium (percent)	Description of rock
					Top: Gray dolomitic limestone; unit not sampled.
52431	Chip	12	0.000	0.001	Dark gray fine shaly limestone, few black chert nodules and few thin layers oolitic shale.
52432	Channel	4	.001	<.001	Dark gray dolomitic limestone grading downward to sandy shale.
52433	Channel	4	.001	.001	Dark gray and brown silty shale oolitic and presumably phosphatic.
52434	Channel	4	.002	.001	Dark gray and brown silty shale, some oolitic and presumably phosphatic.
					Base: Dolomitic limestone, massive, gray. Madison unit not sampled.

Another section of the basal shale of the Deseret was examined at Doughnut Falls, sec. 19, T. 2 S., R. 3 E., Salt Lake County (loc. U-12). No radioactivity was detected and the shale was not sampled.

Brazer limestone

The Brazer limestone of Late Mississippian age is extensively exposed in northern Utah. A black shale zone at the base of the Brazer limestone, probably equivalent to the basal shale of the Deseret limestone, was examined and sampled in Ogden Canyon, Weber County, Utah. The shale unit, about 15.7 feet thick, is exposed in an abandoned roadcut on the north side of the Ogden River, about 1/4 mile west of the Pine View Reservoir Dam in T. 6 N., R. 1 E. (loc. U-13). The shale unit contains thin phosphorite layers which contain as much as 0.005 percent uranium.

Analyses of channel samples across the black shale at locality U-13 are given in the following table:

Sample number	Thickness (feet)	Equivalent uranium (percent)	Uranium (percent)	V_2O_5 (percent)	P_2O_5 (percent)	Remarks
						Top: Gray limestone, massive with light gray weathering chert nodules; not sampled.
	0.3					Shale, black; not sampled
	1.0					Siliceous limestone, black; not sampled.
52729	1.4	0.006	0.005	0.13	15.25	Phosphatic black shale, oolitic.
52730	1.0	.006	.002	.04	6.00	Shale, brown
52731	1.5	.003	.001	.02	0.77	Mudstone, brown; shale, black
52732	1.4	.001	.000	.04	0.20	Siliceous dolomite
52733	1.1	.005	.005	.18	17.30	Phosphatic black shale, oolitic.
52734	3.5	.002	.002	.03	6.25	Alternating black siliceous shale and oolitic shale.
52735	5.5	.002	.002	.18	5.15	Siliceous shale, black, massive, thin oolitic shale layers at top, middle, and base.
						Base: Dark gray massive ls. (Madison); not sampled.

Although two phosphatic shale beds, each a little more than 1 foot thick, contain 0.005 percent uranium, the beds are too thin and too low grade to be of economic interest.

Great Blue limestone

The Great Blue limestone, of Mississippian age, is exposed in Salt Lake, Utah, and Tooele Counties and contains some dark gray to black shale zones in the middle and lower parts of the formation. The Long Trail shale member in the middle part of the formation is exposed in the Oquirrh Range. Shale units that were tested in the Great Blue were essentially non-radioactive, and the uranium content of samples was negligible.

The Great Blue limestone is about 2,800 feet thick along the Wasatch Mountain front near Provo, Utah County (loc. U-14) and was non-radioactive when tested with a field counter. Shales in the lower part of the section were incompletely exposed, though the middle and top parts were adequately tested with the Geiger-counter. Two grab samples were collected and analyzed, as follows:

Sample number	Kind of sample	Equivalent uranium (percent)	Uranium (percent)
52221	Dump sample, black shale	0.000	0.001
52088	Grab sample, black shaly limestone	.000	.001

A section of the Long Trail shale member of the Great Blue limestone was examined in sec. 30, T. 9 S., R. 2 W., Utah County (loc. U-15). Channel samples of the lower 50 feet of the Long Trail shale member, and random samples in the upper sandy part of the member contained negligible uranium as is shown below:

Sample number	Kind of sample and thickness in feet	Equivalent uranium (percent)	Uranium (percent)	Remarks
52435	Channel; 4	0.003	0.001	Base of continuous section
52436	Channel; 7	.003	.001	
52437	Channel; 7-1/2	.003	.001	
52438	Channel; 7-1/2	.002	.001	
52439	Channel; 7-1/2	.001	.001	
52440	Channel; 7-1/2	.002	.001	
52441	Channel; 7-1/2	.000	.000	Top of continuous channel section
52442	Channel; 4	.000	.001	Higher shale bed
52493	Channel; 2	.001	.001	Higher shale bed

Black shale in the Great Blue limestone was examined in sec. 32, T. 6 S., R. 3 W., Tooele County (loc. U-16), about 5 miles south of the town of Mercur. A prospect adit in the shale-limestone sequence entered along a calcite vein flecked with sulvanite and its olive-green oxidation products. The calcite vein material, sulvanite, copper-vanadium oxide, and adjacent black shale were non-radioactive. A 2-foot channel sample of the black shale adjacent to the vein contained 0.002 equivalent uranium and 0.0021 percent uranium.

The Long Trail shale member was sampled at its only good surface exposure in the Ophir-Mercer area at the head of Long Trail gulch. The lower half of the shale unit was not exposed. Analyses of channel samples of the exposed beds were as follows:

Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)	Remarks
52495	Channel; 2.8 ft	0.001	<0.001	Continuous channel section of upper part of the Long Trail member.
52496	Channel; 2.3 ft	.002	< .001	Base underlain by igneous rock sill.
52497	Channel; 1.8 ft	.002	< .001	
52498	Channel; 2.4 ft	.002	< .001	
52499	Channel; 2.1 ft	.002	< .001	

Herat shale member of the Ochre Mountain limestone

The Ochre Mountain limestone of Late Mississippian age is exposed at several places in the Gold Hill district in the western part of Tooele County. The formation consists mostly of thick-bedded limestone and is estimated to be about 4,500 feet thick. A black shale unit near the middle is called the Herat shale member and ranges from a few inches to 50 feet in thickness. The shale was examined at the entry of the Herat mine near Clifton (Nolan, 1935, pl. 1), approximately in unsurveyed sec. 25, T. 8 S., R. 17 W., Tooele County (loc. U-18), where a sequence of dark-gray and black shales about 20 feet thick is exposed. One sample (No. 73092) of the most radioactive shale bed that was detected, which was 1 foot thick, contained 0.002 percent equivalent uranium and 0.0008 percent uranium.

Chainman shale

The Chainman shale of Mississippian age crops out in several of the desert ranges in eastern Nevada and western Utah. The unit ranges from a few hundred feet to possibly as much as 1,000 feet in thickness. It contains dark-gray to black shales rich in carbonaceous matter. The Chainman shale was examined at Skunk Springs, in the central part of the Confusion Range, Millard County, Utah (loc. U-19) and found to be non-radioactive.

Manning Canyon shale

The Manning Canyon shale of Late Mississippian and Pennsylvanian age is a gray to black shale ranging in thickness from about 1,100 to 1,650 feet in exposures in western and central Utah. The formation was examined and exposed beds tested for radioactivity in three areas, namely, along

the Wasatch Mountain front, a few miles east and northwest of Provo, Utah County; in Soldier Canyon of the Oquirrh Range, and in the Deep Creek Range, Tooele County.

The Manning Canyon shale was examined near Provo in secs. 3, 4, 16, 21, and 22, T. 6 S., R. 3 E., on the north side of Rock Canyon, in roadcuts on the ridge east of Pole Canyon and in quarries along the Provo River (loc. U-20). The most uraniferous black shale zone found in the Manning Canyon is a zone 9 feet thick in the lower part of the formation. This zone contains 0.003 percent uranium according to assays of channel samples across the zone. (See table 5.)

Table 5.--Analyses of samples of the Manning Canyon shale near Provo, Utah

Locality (Sec.,Tp.,R.)	Sample number	Thickness (feet)	Equivalent uranium (percent)	Uranium (percent)	Remarks
Map loc. U-20					
17-5S-2E	52222	Grab	0.001	0.001	Shale under thrust fault in upper part of formation.
22-6S-3E	52227	4	.001	.002	Top of formation; black shaly limestone.
"	52228	6	.002	.001	Black shale 120 ft below top of formation.
"	52229	4	.001	.001	Gray, tan, and black shale; 250 ft below top.
"	52230	3.5	.002	.001	Black and gray shale, 450 ft below top of formation
"	52231	4	.002	.001	Black shale, 610 ft below top of formation.
21-6S-3E	52072	3.5	.004	.002	Black shale, roadcut est. 100 ft above base of formation.
"	52073	4	.002	.001	Black shale, roadcut est. 130 ft above base of formation.

Table 5.--Continued

Locality (Sec.,Tp.,R.)	Sample number	Thickness (feet)	Equivalent uranium (percent)	Uranium (percent)	Remarks
16-6S-3E	52074	2	0.003	0.002	Top: Continuous sample section about 340 ft above base of formation.
"	52075	5	.003	.003	
"	52076	4	.003	.003	
"	52077	4	.002	.002	Base
"	52078	4	.002	.002	Black shale, about 500 ft above base.
4-6S-3E	52079	3	.002	.001	Black shale, 750 ft above base.
"	52080	3	.001	.001	Black shale, 780 ft above base.
"	52081	2	.001	.001	Black shale, 850 ft above base.
"	52083	4.5	.001	.001	Brown shale, 840 ft above base.
"	52084	4	.001	.001	Brown shale, 840 ft above base.
"	52085	3	.001	.001	Brown shale, 840 ft above base.
"	52086	3	.000	.000	Black silty limestone; limestone marker, 810 ft above base.

A good exposure of the Manning Canyon shale in Soldiers Canyon, in sec. 33, T. 4 W., R. 4 W., Tooele County, Utah (loc. U-21), was examined but found to be non-radioactive with a field counter. The Manning Canyon shale is about 1,140 feet thick here and it consists of alternating gray, brown, and black shale with some interbedded sandstone and limestone. Two samples were analyzed, as follows:

Locality (Sec.,Tp.,R.)	Sample number	Thickness of beds sampled	Equivalent uranium (percent)	Uranium (percent)	Remarks
TOOELE COUNTY, Map loc. U-21					
33-4S-4W	52500	2.5 ft	0.001	0.000	Black shale, 220 ft above base of fm.
"	52725	3.0 ft	.001	.001	Black shale, 460 ft above base of fm.

A section of the upper part of the Manning Canyon shale was examined in T. 8 S., R. 18 W. (unsurveyed) along the county highway 3.7 miles south of Gold Hill in the western part of Tooele County, (loc. U-22). About 150 feet of dark gray to black shale containing a few thin black limestone beds crops out in roadcuts and in adjacent slopes and is essentially non-radioactive with a field counter. The most active bed detected, a black dolomitic limestone 1 foot thick was sampled (No. 73091) and contained 0.002 percent equivalent uranium and 0.0017 percent uranium.

Unnamed Late Mississippian and Pennsylvanian black shales

A black shale unit of Late Mississippian age is exposed along the south flank of the Uinta Mountains. The unit ranges from about 25 to 250 feet in thickness. Apparently it is approximately equivalent to the lower part of the Manning Canyon shale of the Wasatch Mountains and Oquirrh ranges. The unit was examined at several localities in Duchesne and Uintah Counties, but it was so poorly exposed at most places that sampling was difficult. Laboratory tests of 5 samples collected from the black shale zone showed equivalent uranium ranging in amount from 0.001 to 0.003 percent. Sample data are as follows:

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)
UINTAH COUNTY, Map loc. U-23			
UINTA MERIDIAN 11-2N-1W	64969	Black shale, grab sample	0.001
WASATCH COUNTY, Map loc. U-24			
SLM, 30-3S-9E .	64971	Black shale; base; grab sample	.003

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)
DUCHESNE COUNTY, Map loc. U-25			
UM,36-2N-8W	64972	Black shale; upper part; grab sample	0.003
"	64973	Black shale; middle part; grab sample	.001
"	64974	Black shale; lower part; grab sample	.002

Rocks consisting of black shale and black shaly limestone are present in the overriding block of the Uinta thrust fault on the north flank of the Uinta Mountains, NE¼ sec. 30, T. 3 N., R. 23 E., Daggett County, Utah (loc. U-29). The rocks contain fossils of Late Mississippian or Early Pennsylvanian age. A sample of the fossiliferous black shaly limestone contains 0.001 percent equivalent uranium and 0.001 percent uranium.

Oquirrh formation

The Oquirrh formation of Pennsylvanian and Permian age consists mostly of marine sandy limestone and sandstone and includes a rock sequence on the order of 20,000 feet thick in the Oquirrh Range and southern Wasatch Mountains of central Utah. The lower part of the formation is predominantly limestone but contains many thin interbeds of black shale, ranging from a few inches to 5 or 10 feet thick. Several of these black shale beds were examined in exposures near Provo. The shales were apparently non-radioactive with the field counter. One of the two random samples collected contained 0.003 percent uranium.

Locality (Sec., Tp., R.)	Sample number	Kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
UTAH COUNTY, Map loc. U-26				
1-9S-3E	52226	Channel, 1½ ft black shale	0.003	0.003
Map loc. U-27				
33-5S-3E	52087	Channel, 3½ ft black shale	.000	.000

Kirkman limestone

The Kirkman limestone, probably of Permian age, is composed of fine-grained limestone, gray and black, laminated, petroliferous, limestone and locally contains phosphatic oolites. It crops out in a small area in the southern Wasatch Mountains of central Utah. The maximum observed thickness of the formation is 1,600 feet. A sequence of black and gray limestone beds a few hundred feet thick in the upper part of the formation was examined at Hobble Creek in sec. 24, T. 7 S., R. 4 E., Utah County (loc. U-28) and found to be non-radioactive. One grab sample (No. 52223) of the finely laminated petroliferous limestone collected from the representative bed in the formation contained no equivalent uranium and 0.001 percent uranium in laboratory analyses.

Park City formation

The Park City formation of Permian age is exposed in several areas in central and northeastern Utah. It is the approximate equivalent of the Phosphoria formation of southeastern Idaho and southwestern Wyoming. The formation was not examined in the course of this investigation in central Utah, as it had been studied in detail in another recent investigation of

the Geological Survey (McKelvey, 1950). A phosphatic shale zone at the base of the Park City formation was examined in Brush Creek, sec. 15, T. 2 N., R. 22 E., in Daggett County, Utah (loc. U-29). Laboratory analyses of a channel sample (No. 64966) across 2 feet of phosphatic shale contained 0.005 percent equivalent uranium, 0.004 percent uranium, and 18.1 percent P_2O_5.

Woodside formation

The Woodside formation, chiefly intertonguing marine and nonmarine red-beds of Triassic age, is 750 to 1,000 feet thick and is composed mostly of shale, siltstone, and sandstone in central and northern Utah. The Woodside overlies the Park City and Phosphoria formations and is probably a lateral equivalent of the Moenkopi formation of southern Utah. A grab sample (No. 64970) of dark shale from the base of the formation in sec. 26, T. 1 N., R. 9 W., U.S.B.L., in Duchesne County (loc. U-30) contained 0.003 percent equivalent uranium.

Mancos shale

The Mancos shale of Late Cretaceous age is exposed in many places in eastern Utah and adjacent areas. The formation ranges in thickness from about 3,000 to 5,000 feet and is composed mostly of gray to dark-gray marine shales but includes some zones of black shale and carbonaceous shales, the latter of which are associated with nonmarine sandstone tongues. The marine beds include some thin, lighter-colored bentonite layers. The Mancos is incompletely exposed at most outcrop localities although zones of shale several hundred feet thick, particularly in the upper part of the

formation, are well exposed in slopes below the sandstones of the Mesaverde group.

A partial section of the Mancos was examined at intervals through approximately the upper 3,000 feet of the formation along Soldiers Creek, Tps. 13 to 15 S., R. 11 E., in Carbon County. Geiger-counter tests indicate that most of the black shales are essentially non-radioactive, but the shales adjacent to some thin, light-colored bentonite zones are slightly radioactive. Laboratory tests of one grab sample (No. 74114) representing about 1 foot of black shale below a thin bentonite bed in sec. 3, T. 15 S., R. 11 E., Carbon County (loc. U-31) contained 0.003 percent equivalent uranium and 0.0002 percent uranium.

Green River formation

The Green River formation in eastern Utah and western Colorado is an extensive lake basin deposit of Eocene age containing a sequence of oil shales, interbedded and intertongued with tuffaceous sediments and sandstone. The formation ranges from a few hundred feet to about 5,000 feet thick in Colorado and Utah and contains oil shales ranging from a few feet up to 2,000 feet in thickness. The richest oil-shale zone, "Mahogany ledge", which is of potential interest as a source of synthetic liquid fuel, was sampled as several localities in Uintah County, Utah. The same stratigraphic zone in Duchesne County was non-radioactive and was not sampled. Several zones of green and gray to brown shales were examined along U. S. Highway 50, west of Soldier Summit in Utah County. The field-counter tests and the laboratory analyses of the shale beds did not reveal any radioactivity or uranium. The shale and limestone, rich in organic matter

in other parts of the formation, were not completely tested, however, in the current investigation.

About 200 feet of green shales, representing the upper part of a shore phase of the Green River formation, was examined with a Geiger-counter in secs. 26 and 27, T. 9 S., R. 4 E., Utah County (loc. U-32). No radioactivity was detected. A grab sample (No. 52225) representing about 1 foot of green shale contained 0.000 percent equivalent uranium and 0.001 percent uranium.

The better exposed parts of the Green River formation along Soldier Creek west of Soldier Summit in T. 10 S., Rs. 5, 6, and 7 E., Utah County, were examined and tested with a Geiger-counter. The beds examined included thin oil-shale zones, tuffaceous sandstones, and marlstones all of which were non-radioactive and were not sampled.

A zone about 150 feet thick in the upper part of the Green River formation contains oil shale and was examined along State Highway 53, in T. 11 N., R. 15 E., Duchesne County (loc. U-33). The oil shales and interbedded tuffaceous sandstones were not radioactive and were not sampled.

Parts of the rich oil-shale zone, the Mahogany ledge, were sampled by W. B. Cashion of the Geological Survey at 8 localities in the eastern part of Uintah County (loc. U-34). Forty-four channel samples from 8 localities collected primarily to determine potential oil yield of the shale were also tested for radioactivity in the laboratory and contained equivalent uranium in amounts ranging from less than 0.001 percent to 0.003 percent as shown in table 6.

Table 6.--Analyses of channel samples of the Mahogany oil shale ledge in the Green River formation, Uintah County, Utah

Locality (Sec., Tp., R.)	Sample number	Thickness of beds	Equivalent uranium (percent)	Remarks
UINTAH COUNTY, Map loc. U-34				
36-12S-24E	72290	5 feet	0.002	Top
"	72291	5 feet	.001	
"	72292	5 feet	.001	Continuous section
"	72293	5 feet	.001	
"	72294	5 feet	.001	Base
"	72295	5 feet	.001	Base
"	72296	5 feet	.002	Continuous section
"	72297	5 feet	.003	Top
28-9S-25E	72298	5 feet	.001	Base
"	72299	5 feet	.001	
"	72300	5 feet	.001	
"	72301	5 feet	.001	Continuous section
"	72302	5 feet	.001	
"	72303	5 feet	.001	
"	72304	5 feet	.001	
"	72305	5 feet	.001	
"	72306	5 feet	.001	Top
21-13S-25E	72316	5 feet	.001	Base
"	72317	5 feet	<.001	Continuous section
"	72318	5 feet	.002	Top
16-10S-25E	72319	5 feet	.003	Base
"	72320	5 feet	.002	
"	72321	5 feet	.002	
"	72322	5 feet	<.001	
"	72323	5 feet	<.001	Continuous section
"	72324	5 feet	<.001	
"	72325	5 feet	.001	
"	72326	5 feet	.001	
"	72327	5 feet	<.001	
"	72328	5 feet	<.001	
"	72329	5 feet	<.001	Top
25-11S-25E	72330	5 feet	.002	Base
"	72331	5 feet	.001	Continuous section
"	72332	5 feet	<.001	Top

Table 6.--Continued

Locality (Sec., Tp., R.)	Sample number	Thickness of beds	Equivalent uranium (percent)	Remarks
8-13S-25E	72333	5 feet	0.001	Top
"	72334	5 feet	.001	Base
4-13S-23E	72335	5 feet	.001	Top
"	72336	5 feet	.001	
"	72337	5 feet	<.001	Continuous section
"	72338	5 feet	<.001	
"	72339	5 feet	<.001	Base
9-13S-24E	72340	5 feet	.001	Top
"	72341	5 feet	.001	Continuous section
"	72342	5 feet	.001	Base

Wyoming and Western Nebraska

Unnamed Devonian shale unit

A lens of Devonian black shale about 20 feet thick crops out in Cottonwood Canyon, on the west flank of the Bighorn Mountains in sec. 34, T. 57 N., R. 93 W., Big Horn County, Wyo. (loc. W-1). The Devonian black shale sequence and adjacent dolomite zones of the underlying Bighorn dolomite of Ordovician age and of the basal part of the overlying Madison limestone of Mississippian age were found to be non-radioactive in a brief examination by J. D. Love.

Two samples, each representing about 6 inches of section, were taken near the top of the black shale section and analyzed, with the following results:

Lab. No.	Uranium (percent)	Equivalent uranium (percent)	Percent by weight			Sp. Gr. of oil at 60°/60° F.	Oil yield (gals. per ton)
			Oil	Water	Gas (loss)		
72411	--	<0.001	1.4	1.0	1.6	0.903	3.7
72412	--	< .001	1.3	1.2	1.0	0.905	3.5

Threeforks formation

Six grab samples of black shale and black argillaceous limestone in the Threeforks formation of Late Devonian age were collected by W. G. Pierce from two localities in Park County, Wyo. The samples were obtained from several representative black shale and limestone beds in the formation but were collected without radiation-detecting equipment. Some of the samples were slightly radioactive, but they contained essentially no uranium as shown below:

Locality	Laboratory sample no.	Kind of sample and kind of rock	Equivalent uranium (percent)	Uranium (percent)
PARK COUNTY, Map loc. W-2				
East side of	106209	Grab; black shale	<0.001	--
Tepee Creek	106210	Grab; black argillaceous limestone	.002	--
North fork of	106211	Grab; black shale	.002	--
Crandall Creek	106212	Grab; black shale	.004	<0.0005
between Tepee	106213	Grab; black shale	.002	--
and Tough Creeks	106214	Grab; black shale	.002	--

Pennsylvanian black shales

Thin beds of black shale in the Hartville formation of Pennsylvanian (Des Moines) age contain uranium in amounts ranging from a few thousandths percent to 0.019 percent, based on analyses of core chips from wells drilled for oil and gas in eastern Wyoming (Love, 1951). Since 1951, other data obtained by Denson, Gill, and Love from test wells in eastern Wyoming and western Nebraska and surface examination of exposures of the Pennsylvanian rocks on the Hartville uplift, in Platte, Goshen, and Niobrara Counties, Wyo., have added to knowledge of the distribution of

uranium in the shales.

The radioactive black shales are known mostly from subsurface data where the shales occur in Divisions III, IV, and V of the Hartville formation. From the incomplete data available, rocks of the Hartville change in character from east to west, and the black shales known in the subsurface are not present in the surface exposures of the formation on the Hartville uplift.

Careful surface examination at several places on the Hartville uplift resulted in finding only one weakly radioactive silty carbonaceous shale bed, 1 foot thick, in Division IV or V of the Hartville formation. A channel sample (D-71208) of the bed exposed on the east shore of the Guernsey Reservoir 5 miles northeast of the town of Guernsey (loc. W-3) contained 0.003 percent equivalent uranium and 0.001 percent uranium.

The Pennsylvanian black shales have been recognized in 9 well sections located in a crescent-shaped area nearly 100 miles long, extending southeastward from Little Buck Creek in Wyoming to Harrison, Neb., and thence southward to Jay Em in Wyoming. The eastern, northern, and southern limits of the radioactive black shales are not known. Analyses of selected chips from cores of 2 wells in Wyoming and 1 in Nebraska are shown in table 7.

Table 7.--Analyses of core chips of the Hartville formation from wells drilled for oil and gas in Nebraska and Wyoming

Locality (Sec., Tp., R.) Well name	Lab. No.	Depth in feet	Thickness of rock sampled (inches)	Kind of rock	Equivalent uranium (percent)	Uranium (percent)
GOSHEN COUNTY, WYOMING, Map loc. W-4						
14-28N-63W		2230	?	Shale, black	0.005	0.005
Ohio Oil Co.,		2290	?	Shale, black	.013	.012
Waggoner No. 1		2322	?	Shale, black	.022	.019
		2323	?	Shale, black	.018	.014

Table 7.--Continued

Locality (Sec., Tp., R.) Well name	Lab. No.	Depth in feet	Thickness of rock sampled (inches)	Kind of rock	Equivalent uranium (percent)	Uranium (percent)
NIOBRARA COUNTY, WYOMING, Map loc. W-5						
26-36N-64W Continental Oil Co., E.L.C.U.B., No. 14		5998	?	Shale, black	0.019	0.018
SIOUX COUNTY, NEBRASKA Map loc. Nb-1						
NW¼27-30N-56W	51599	6498	2 in.	Shale, gray	.003	.001
California Oil	51600	6502	2 in.	Limestone, black	.001	.001
Co.,R.A. Mann	51601	6504	2 in.	Limestone, gray	.001	.001
"	51602	6509	2½ in.	Dolomite	.000	.001
"	51603	6520	2½ in.	Limestone, black	.001	.001
"	51604	6531	2½ in.	Gypsum	.000	.001
"	51605	6544	2½ in.	Shale, black	.008	.003
"	51606	6568.5	2½ in.	Shale, black	.008	.004
"	51607	6569.5	2½ in.	Shale, black	.011	.007
"	51608	6570	1 in.	Shale, black	.006	.004
"	51609	6582	2½ in.	Shale, black	.003	.002
"	51610	6587	2 in.	Shale, black	.005	.003
"	51611	6589	1½ in.	Shale, black	.005	.003
"	51612	6598	2 in.	Shale, gray	.005	.002
"	51613	6600	1½ in.	Shale, black	.002	.001
"	51614	6607.5	2 in.	Dolomite, shaly	.000	.001
"	51615	6618.5	2 in.	Shale, black	.004	.003
"	51616	6624	2 in.	Shale, black	.012	.011
"	51617	6629	1 in.	Shale, black	.006	.003
"	51618	6630.5	1 in.	Shale, black	.000	.001
"	51619	6632	2 in.	Limestone, gray	.000	.001
"	51620	6635	12 in.	Shale, black	.011	.007
"	51621	6669	1 in.	Shale, black	.004	.001
"	51622	6671	2 in.	Shale, black	.013	.011
"	51623	6681.5	2½ in.	Shale, black	.007	.003
"	51624	6685	2 in.	Gypsum	.000	.001
"	51625	6698.5	5 in.	Shale, black	.005	.002
"	51626	6705	2 in.	Shale, black	.008	.004
"	51627	6707	2 in.	Shale, black	.005	.002
"	51628	6730	2 in.	Shale, black	.004	.001
"	51629	6743	4 in.	Shale, black	.016	.011

Radioactivity logs indicate that as many as 8 radioactive zones, each about 10 feet thick, are present in the lower part of the Hartville formation near the Wyoming-Nebraska state line, but the detailed core study by N. M. Denson of one well (fig. 4) shows that the black shale zones are thinner than the gamma-ray logs indicate. From available data the black shale layers containing more than 0.01 percent uranium seem to range from about 1 inch to 1 foot in thickness, but other shale beds, ranging from 1 to 8 feet thick, seem to contain 0.003 to 0.007 percent uranium.

Phosphoria formation

The Phosphoria formation of Permian age has been tested for radioactive materials in western Wyoming in earlier Geological Survey investigations (McKelvey, 1950) and was not systematically tested in the present investigation. A few samples of phosphate rock were collected, however, from 3 localities in Lincoln and Teton Counties. These samples contained uranium in amounts ranging from 0.004 to 0.026 percent. The sample data are shown below. One series of channel samples from a phosphorite zone 6 feet 8 inches thick, taken at Rocky Point, contained an average of nearly 0.016 percent uranium.

Locality (Sec., Tp., R.)	Sample number	Thickness represented	Equivalent uranium (percent)	Uranium (percent)	P_2O_5 (percent)	Remarks
LINCOLN COUNTY, Map loc. W-6						
Rocky Point, near Cokeville	64975	22 in.	0.015	0.012	32.8	Continuous section, 6' 8" thick.
"	64976	12 in.	.017	.014	30.7	
"	64977	16 in.	.029	.024	26.6	
"	64978	30 in.	.016	.015	26.3	

Locality (Sec., Tp., R.)	Sample number	Thickness represented	Equivalent uranium (percent)	Uranium (percent)	P_2O_5 (percent)	Remarks
LINCOLN COUNTY, (Cont.) Map loc. W-7						
21-23N-116W	64979	50 feet	0.007	0.004	14.6	Quealy phosphate mine
"	64979a	Grab	.029	.013	31.9	
"	64980	Grab	.019	.026	21.4	
"	64981	Milled sample	.015	.018	24.3	
TETON COUNTY, Map loc. W-8						
32-39N-116W Snake River Canyon	64845	Grab	.024	.018	19.9	

Cretaceous black shales

Cretaceous black shale-bearing formations were examined at numerous localities in Niobrara, Weston, and Crook Counties in eastern Wyoming, but were not radioactive to a field counter and were not sampled at most places. The formations that were examined include the Belle Fourche shale, Fuson shale, Graneros shale, Lakota (?) sandstone, Mowry shale, and Pierre shale. Analyses are as follows:

Locality (Sec., Tp., R.)	Sample number	Formation, kind of sample and thickness	Equivalent uranium (percent)	Uranium (percent)
NIOBRARA COUNTY, Map loc. W-9				
SW¼23-37N-62W	78523	Belle Fourche shale, 2.9 ft channel, black shale	0.002	--
"	78524	Mowry shale, 0.5 ft channel, black shale	.001	--
WESTON COUNTY, Map loc. W-10				
SW¼31-48N-62W	98539	Lakota (?) sandstone, 1.4 foot channel, clay shale	.005	0.005

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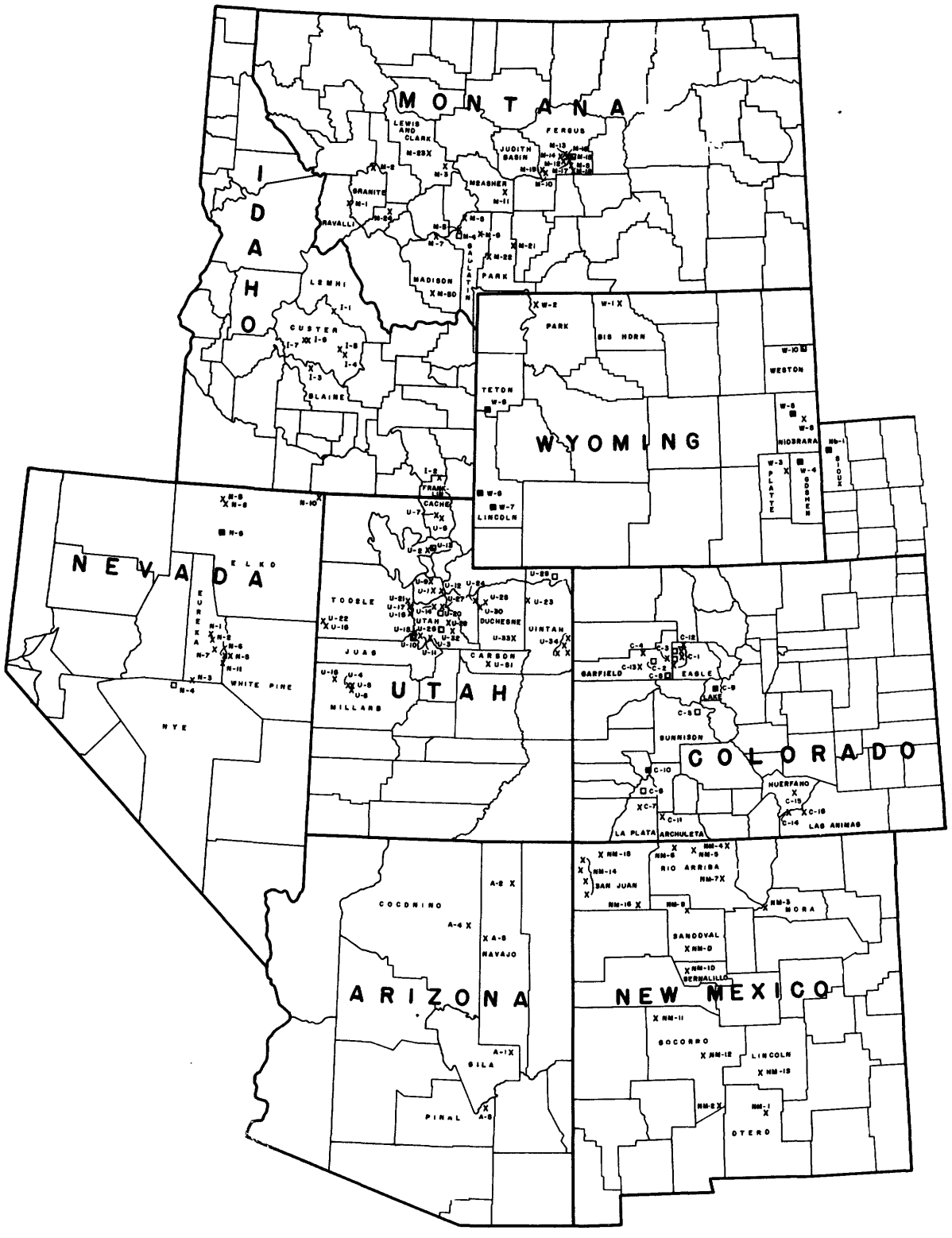

EXPLANATION

- ■ Black shale containing 0.01% uranium or more
- ■ Black shale containing 0.005% to 0.09% uranium
- □ Black shale containing 0.003% to 0.004% uranium
- X Black shale containing less than 0.003% uranium
- M-8 Locality number referred to in text

FIGURE 1.--INDEX MAP SHOWING URANIUM CONTENT OF BLACK SHALE SAMPLED IN WESTERN STATES DURING 1951 AND 1952

0 50 100 150 200 miles
SCALE

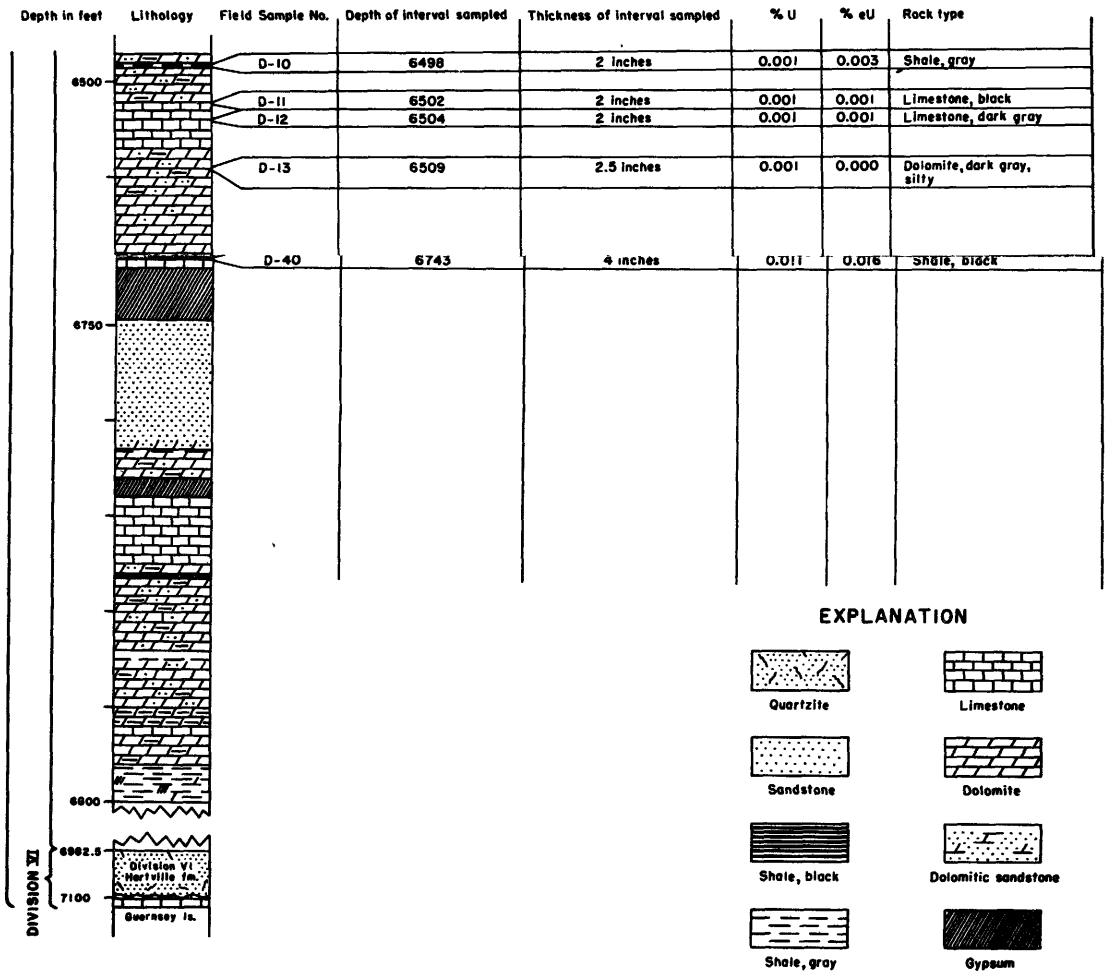

FIGURE 4.--STRATIGRAPHIC SECTION SHOWING URANIUM CONTENT OF BLACK SHALES IN LOWER PART OF THE HARTVILLE FORMATION, CALIFORNIA OIL COMPANY'S R. A. MANN TEST WELL, NW 1/4 SEC. 27, T. 30 N., R. 56 W., SIOUX COUNTY, NEBRASKA

By Norman M. Denson