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Large uraniferous springs and associated uranium minerals, Shirley Mountains, Carbon County, Wyoming--a preliminary report

By

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By J. D. Love

Abstract

Ten springs along the southeast flank of the Shirley Mountains, Carbon County, Wyoming, have water containing from 12 to 27 parts per billion uranium, have a total estimated flow of 3 million gallons of clear fresh water per day, and have a combined annual output that may be as much as 166 pounds of uranium. These springs emerge from Pennsylvanian, Permian, and Triassic rocks on the east flank of a faulted anticlinal fold.

In the vicinity of several springs, metatyuyamunite occurs locally in crystalline calcite veins averaging 3 feet in width but reaching a maximum of 24 feet. The veins are as much as several hundred feet long and cut vertically through sandstones of Pennsylvanian age overlying the Madison Limestone (Mississippian). This limestone is believed to be the source of the calcite. A 3-foot channel sample across one calcite vein contains 0.089 percent uranium. Lesser amounts of uranium were obtained from other channel samples. Selected samples contain from 0.39 to 2.2 percent uranium and from 0.25 to 0.86 percent vanadium.

Three possible sources of the uranium are: (1) Precambrian rocks, (2) Paleozoic rocks, (3) Pliocene(?) tuffaceous strata that were deposited unconformably across older rocks in both the topographically high and low parts of the area, but were subsequently removed by erosion except for a few small remnants, one of which contains carnotite.

There is apparently a close genetic relation between the uraniferous springs and uranium mineralization in the calcite veins. Data from this locality illustrate how uraniferous ground water can be used as a guide in the exploration for areas where uranium deposits may occur. Also demonstrated is the fact that significant quantities of uranium are present in water of some large flowing springs.

Introduction

Objectives

The objectives of this study are: (1) to show the possible genetic relation between the uraniferous springs and uranium minerals in calcite veins, (2) to indicate the value of uraniferous ground water as a guide in the exploration for areas where uranium deposits may occur, and (3) to demonstrate that significant quantities of uranium are present in water of some large flowing springs.

Previous investigations

No studies of the uranium deposits in this area have been published. Dobbin, Bowen, and Hoots (1929) included a generalized geologic map of the southern margin of the area in their study of the Hanna Basin. A. A. Koenig[1/] made a more detailed geologic map of the eastern part of the Shirley Mountains and adjacent areas (used in preparation of fig. 1 in this report), and his work was incorporated in a geologic map of Carbon County (Weitz and Love, 1952). Lovering (1929) studied the iron ore deposits in Precambrian rocks in the northern part of the Shirley Mountains, 6 miles to the north. The Late Cretaceous and Tertiary history of the area was described by Knight (1951).

Acknowledgments

H. H. Schneider, who discovered the metatyuyamunite in the calcite veins during the summer of 1954, and his associate, R. V. Bailey, extended many courtesies to the author in the field and assisted in sampling. The geochemical laboratories of the U.S. Geological Survey made the chemical analyses. A. D. Weeks and W. F. Outerbridge identified the uranium minerals. R. S. Houston photographed the rock specimens. Thirty chemical analyses and 4 mineral identifications were done on behalf of the Division of Raw Materials, U.S. Atomic Energy Commission.

It is a pleasure to acknowledge the cooperation of S. H. Knight, Chairman of the Geology Department, University of Wyoming, and H. D. Thomas, State Geologist of Wyoming, throughout the years of this investigation.

1/ Koenig, A. A., Jr., 1952, Geology of the Troublesome Creek Basin, Carbon County, Wyoming: unpub. M. A. thesis, Univ. of Wyo.

Geography

The Shirley Mountains are the eastern part of the Ferris-Seminoe-Shirley mountain chain that marks the southern boundary of the Granite Mountains and the northern boundary of the Hanna Basin. The northern part of the basin is dissected into rough topography with average elevations from 6,500 to 7,000 feet. The Shirley Mountains rise abruptly 1,500 to 2,000 feet above the general basin level. The elevation of the areas of most uranium mineralization and of the springs at the foot of the mountains is about 7,200 feet, but within one-fourth mile to the west, the flank of the mountains rises to 8,000 feet (see cross section, fig. 1, and fig. 3).

The area is drained by Cayton (Roaring) Creek and Smith Creek, both tributaries of Troublesome Creek, which flows south into the Medicine Bow River. There are no towns, no improved roads, and only one inhabited ranch in the area, but most of it is accessible by car. The town of Hanna, on the Union Pacific Railroad, is 17 miles by road to the south. Vegetation is sparse and bedrock is comparatively well exposed. Livestock raising is the only industry.

Geology

The Shirley Mountains constitute the southeastern portion of the broad eastward-trending anticlinal uplift known as the Granite Mountains. Precambrian rocks form the higher, more rugged portions of the Shirley Mountains. The southern flank has been thrust southward onto Cretaceous and lower Tertiary rocks in the northern part of the Hanna Basin (fig. 1). The throw of this thrust fault in the southern part of the map area is estimated by Knight (1951, p. 46) as about 17,000 feet. This is probably a minimum figure.

Figure 2 summarizes descriptions and thicknesses of the rock units shown on the geologic map (fig. 1), adapted chiefly from studies by Koenig[2], Knight (1951), Hubbell (1956), and Love (1957). Four sequences of rocks are described in more detail than is shown on figure 2 because they are important in consideration of the origin of the uranium that occurs in the rocks and water, and in evaluating the uranium potentialities of the area.

Precambrian rocks

Precambrian rocks are present in the western part of the map area. They are chiefly brown and gray coarse-grained granite intruded into and surrounding a metamorphic complex composed chiefly of gneiss and schist. Pegmatites and black mafic dikes cut the granite and older rocks. Many of the dikes and fracture systems trend approximately

2/ Koenig, A. A., Jr., 1952, Geology of the Troublesome Creek Basin, Carbon County, Wyoming: unpub. M. A. thesis, Univ. of Wyo.

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Figure 1. -- GEOLOGIC MAP AND CROSS SECTION OF SOUTHEAST MARGIN OF THE SHIRLEY MOUNTAINS, CARBON COUNTY, WYOMING

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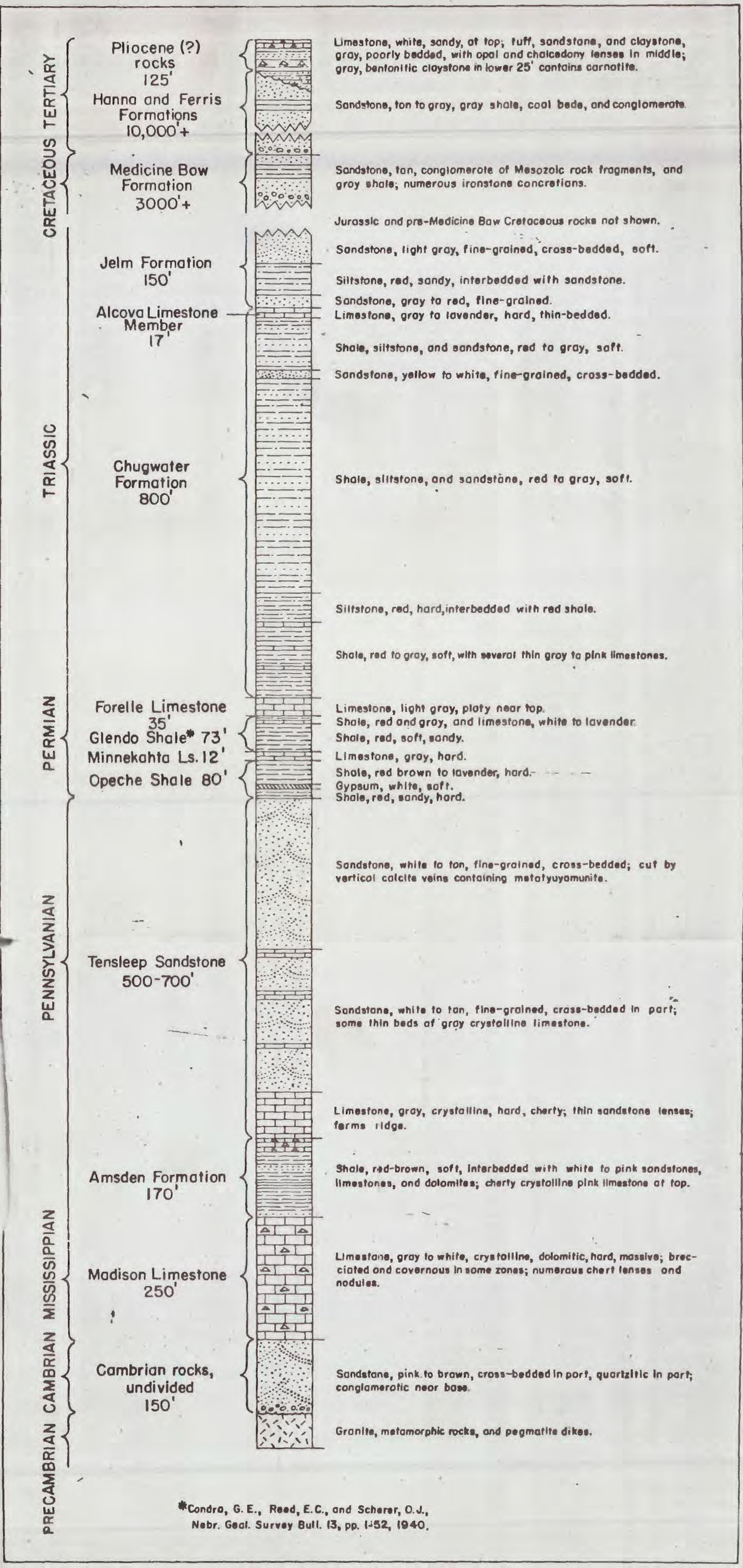

Figure 2. - - STRATIGRAPHIC SECTION OF ROCKS SHOWN ON GEOLOGIC MAP

(after A. A. Koenig and S. H. Knight)

N. 45° E. None of the Precambrian rocks of this region have been studied in detail so their economic potentialities and the relationships of the various rock types are not known. Uraninite was mined in 1954 from granite intruded into and along a graphite layer in a generally similar Precambrian complex 18 miles to the northwest (Love, 1954b, p. 229-230). Lovering (1929) studied the Precambrian rocks about 6 miles north of the map area. He reported that the chief rock type is pink coarse-grained biotite granite cut by dikes and irregular masses of aplite, aplitic syenite, pegmatites, and pegmatitic quartz containing hematite.

Madison Limestone

The Madison Limestone, of Mississippian age, is about 250 feet thick and crops out as jagged ridges near the western margin of the area (fig. 1). The formation consists almost entirely of gray to white dolomitic marine limestone that is dense, hard, massive in some places, and porous in others. Numerous chert layers and nodules are present. Thin beds of dolomite occur in some parts of the section. Pink and lavender colors are more abundant in the lower part of the formation. In this area, as throughout most of Wyoming, some zones in the Madison Limestone are readily dissolved by ground water so that numerous caves, sink holes, and porous zones are formed. On most outcrops there is extensive solution of the limestone and development of subterranean channels. It is believed that much of the calcite in the uraniferous calcite veins cutting the Tensleep Sandstone in this area was derived from the Madison Limestone.

Small deposits of malachite are present in the limestone in many parts of the Shirley Mountains.

Tensleep Sandstone

The Tensleep Sandstone, of Pennsylvanian age, is between 500 and 700 feet thick; the actual thickness is difficult to determine because of numerous small faults of unknown displacement, a lack of key beds in the upper part of the formation, and extensive crossbedding in the upper sandstones. The lithology of the lower part of the formation is summarized in figure 2. The upper 300 feet is almost entirely white, fine-grained, moderately soft and porous, crossbedded, noncalcareous sandstone that weathers tan. In the central part of the area, the Tensleep Sandstone is cut, nearly at right angles to the strike, by large and small nearly vertical veins of crystalline calcite containing metatyuyamunite. The sandstone is moderately resistant to erosion, and forms dip slopes rising 400 to 600 feet above the valley floor (see cross section, fig. 1, and fig. 3). Many springs emerge from near the top of the sandstone where the dip slope meets the valley floor.

Figure 3.--Dip slope of Tensleep Sandstone cut by uraniferous calcite veins. Height of hill above point A is 600 feet. B is Spring No. 2, C is calcite vein shown on figure 4, D is Spring No. 3, E is Spring No. 4.

Pliocene(?) rocks

Two outcrops of Pliocene(?) rocks are present in the area.

One outcrop is in section 11, T. 24 N., R. 82 W. (figs. 1, 10, 11). It consists of about 125 feet of white and light-colored tuff, limestone, conglomerate, sandstone, and claystone. The basal 30 feet is gray waxy bentonitic claystone containing abundant sand grains, interbedded with bentonitic gray sandstone. Both the sandstone and claystone contain sparsely disseminated crystals of carnotite (Love, 1955; fig. 11 this report). The middle portion of the sequence is white to light-gray porous sandy tuff and pebble conglomerate. Irregular masses and lenses of milky-white opal and chalcedony are present. The upper part of the sequence is white sandy tuffaceous limestone containing irregular masses of clear to smoky-gray chalcedony. Some yellow fluorescence is present along fracture faces. The Pliocene(?) rocks at this locality are unfossiliferous. They dip southward about 4 degrees (fig. 10) and overlie nearly vertical to overturned rocks in the Medicine Bow, Ferris, and Hanna Formations.

The Pliocene(?) rocks resemble the fossiliferous North Park Formation (latest Miocene or earliest Pliocene) of the Saratoga area (McGrew, 1951, p. 54-57), 40 miles to the south, more closely than they do the middle Miocene Split Rock Formation (Love, 1961), north and northwest of the Shirley Mountains. The North Park Formation in the Saratoga area includes light-colored tuffaceous sandstone and claystone with numerous limestone beds and deposits of chalcedony and opal. The Split Rock Formation is characterized by massive soft-gray and buff tuffaceous sandstone composed chiefly of rounded frosted quartz grains. None of this latter type of sandstone was observed in the outcrop in section 11.

Evolution of structural features

The Late Cretaceous and Tertiary structural history of the northern portion of the Hanna Basin and the southern flank of the Shirley Mountains has been described by Knight (1951, p. 45-53). The history of the Granite Mountains has been discussed by Love (1961). Items 1 to 4 in the following summary of structural events are based on Knight's studies, and the remainder are from work by the writer.

1. The first uplift of the Shirley Mountains area occurred during Medicine Bow (latest Cretaceous) time. Granite boulders in the Medicine Bow Formation indicate that the Precambrian core of the mountains had been exposed to erosion prior to the close of Cretaceous time. There is no evidence of thrust faulting.

2. The uplift of the Shirley Mountains continued slowly through Paleocene and earliest Eocene time; there is little evidence of unconformity between the Medicine Bow Formation (latest Cretaceous) and the Ferris and Hanna Formations (Paleocene and earliest Eocene).

3. The major folding and faulting occurred at the close of earliest Eocene (Hanna) time and before the deposition of the Wind River(?) Formation of early Eocene age. During this orogeny, the major folds and thrust faults of the region developed. The Precambrian, Paleozoic, and Mesozoic rocks of the Shirley Mountains were thrust southward onto vertical and overturned strata of the Medicine Bow, Ferris, and Hanna Formations along the northern margin of the Hanna Basin. Knight (1951, p. 46) estimates the throw on this thrust fault in the area shown in figure 1 as about 17,000 feet. The Paleozoic and Mesozoic rocks dip eastward into a syncline near Nelson's ranch (fig. 1), where they are involved in many complicated folds and faults.

4. The structural history during the remainder of Tertiary time can only be inferred by using data from adjacent areas. Possibly during, and definitely, in part, after the termination of the major orogeny, conglomerates, sandstones, and claystones of the Wind River(?) Formation (early Eocene) were deposited in the Hanna Basin to the south. If ever they were deposited in the map area, they were removed prior to late Tertiary time. In part, at least before Miocene time, the Shirley Mountains were cut by a network of high-angle normal faults trending generally northeastward and eastward (fig. 1). Presumably, these were formed by relaxation within the overriding thrust block after it was emplaced. Additional extensive normal faults cut Miocene rocks in the areas to the west (Weitz and Love, 1952). However, in the map area, the positions of the remnants of Pliocene(?) rocks suggest that normal faulting terminated somewhat earlier here and that this part of the Shirley Mountains, the syncline to the east, and the Hanna Basin to the south were eroded to approximately their present topographic form before Pliocene(?) deposition.

5. It is assumed that at least the limestone portion of the Pliocene(?) sequence was deposited in a horizontal position. The highest erosional remnant is now at an elevation of more than 7,900 feet. How much higher these and perhaps younger Tertiary rocks lapped up onto the flanks of the Shirley Mountains is not known. Reconstruction of the original areal distribution of these rocks is complicated by the fact that there was pronounced southward tilting of the northern margin of the Hanna Basin after deposition of the Pliocene(?) rocks. Miocene or younger deposits are present on the Seminoe Mountains, 15 miles to the west, where they can be linked with the superposition of the North Platte River. The course of this river was established across these mountains on a gently rolling upland surface at 7,400 feet, approximately 1,200 feet above the present river level.

6. The last stresses affecting the southeast flank of the Shirley Mountains were tensional and apparently occurred during Quaternary time. Networks of fissures trending N. 60° to 70° W.,

developed in the Tensleep Sandstone. These are believed to have ruptured an artesian water system, causing water to be diverted laterally along the fissures. This water must have been highly charged with calcium carbonate, probably derived from the Madison Limestone, and contained a lesser amount of uranium from an unknown source. The calcium carbonate was deposited as crystalline calcite and the uranium as metatyuyamunite within the fissures (figs. 4, 5, 6, 7).

A series of tensional movements that spread these fissures is indicated by successive vertical layers of crystalline calcite (fig. 4). Some fissures never were completely filled with calcite. One contains Pleistocene(?) brown silt in a position 100 feet or more above the adjacent valley floor (locality C in fig. 3 and fig. 4).

Uranium occurrences

Description of localities

Northwest corner sec. 31, T. 25 N., R. 81 W.--This locality is where H. H. Schneider, in 1954, discovered metatyuyamunite in calcite veins. In comparison to those in the rest of the area, the calcite veins at this locality are the most abundant, widest, cut vertically through the greatest thickness of Tensleep Sandstone, and contain the most uranium. The veins trend N. 60° to 70° W., and contacts with the Tensleep Sandstone are sharp (fig. 4). The veins differ in width; the thickest one is 24 feet wide, but contains a wedge of Tensleep Sandstone 3 feet across in the middle. This vein splits and thins drastically in short distances to the northwest and to the southeast. The average width for the veins is 3 feet. In many places, angular unoriented fragments of Tensleep Sandstone are enclosed in the calcite (fig. 5). The zone of veins extends vertically, as an anastomosing network of individual veins, through 400 feet or more of the Tensleep exposure.

Metatyuyamunite occurs as bright yellow and green coatings along planes of deposition between layers of calcite crystals (figs. 4 and 6), and also as veins filling fractures in the crystalline calcite (fig. 6). Sparse concentrations of metatyuyamunite also are present in the Tensleep Sandstone directly adjacent to some of the calcite veins (fig. 7). Most metatyuyamunite was observed in the parts of the veins that are topographically low.

The surface distribution of metatyuyamunite is so irregular that very detailed sampling would be necessary to estimate the average grade. Information gained from such intensive sampling is not meaningful, however, without subsurface data. At the time of examination, only one 20-foot adit had been driven and no wells had been drilled.

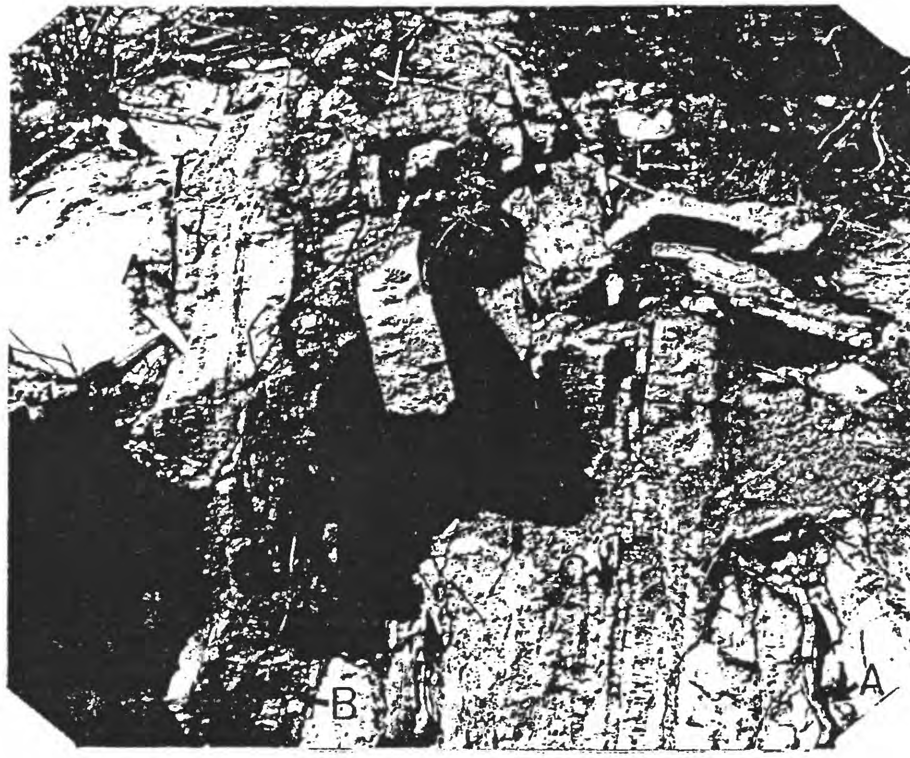

Figure 4.--Calcite vein containing metatyuyamunite at locality C shown on figure 3. A-A are contacts between vein and Tensleep Sandstone, B is a 6-inch fissure filled with unconsolidated brown Pleistocene(?) loess, C is a plane where metatyuyamunite is concentrated.

Figure 5.--Fragments of Tensleep Sandstone surrounded by crystalline calcite with some metatyuyamunite. Photomicrograph x 1.5 showing brecciated Tensleep Sandstone (A), metatyuyamunite (B), and crystalline calcite (C). Dark areas are hematite concentrations.

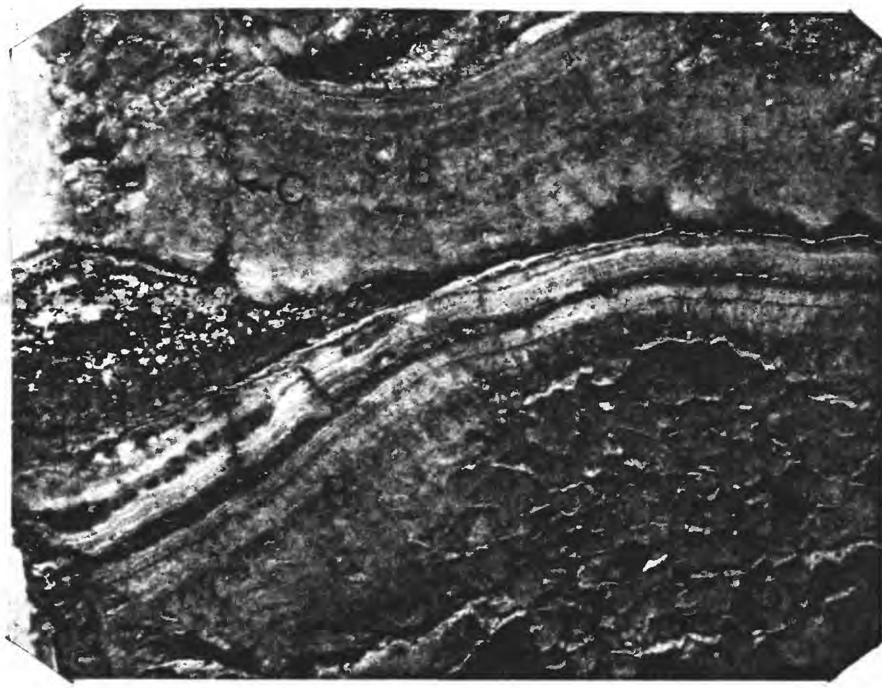

Figure 6.--Polished section of metatyuyamunite vein cutting crystalline calcite. Photomicrograph, x 1.6 showing pods of metatyuyamunite (A) in hematite, crystalline calcite (B), and small vein of metatyuyamunite (C) cutting across calcite.

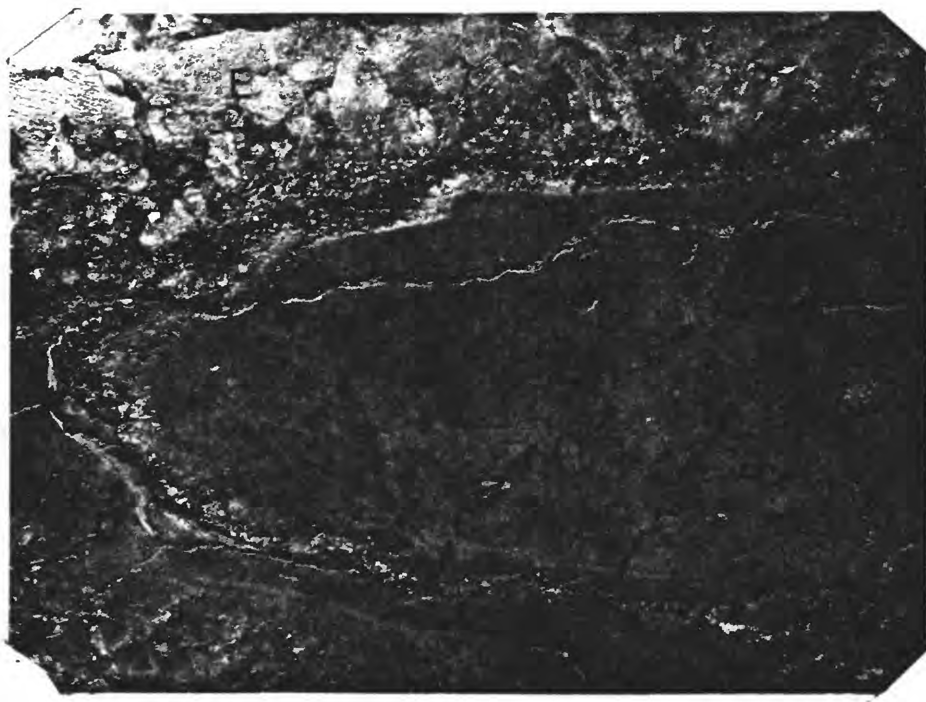

Figure 7.--Photomicrograph x 1.3 of block of Tensleep Sandstone impregnated with, and surrounded by metatyuyamunite and crystalline calcite. Tensleep Sandstone (A) has some metatyuyamunite in pore spaces (B); hematite (C), metatyuyamunite (D), and crystalline calcite (E) are indicated.

A 3-foot channel sample across one vein of crystalline calcite containing metatyuyamunite, about 200 feet northwest of Spring No. 6, contains 0.11 percent equivalent uranium, 0.089 percent uranium, and less than 0.1 percent V_2O_5. A selected sample from the most radioactive part of this vein contains 0.35 percent equivalent uranium, 0.39 percent uranium, and 0.25 percent V_2O_5.

A 3-foot channel sample of another calcite vein about 200 feet farther northwest up the hill (fig. 4) contains 0.004 percent equivalent uranium, 0.002 percent uranium, and less than 0.1 percent V_2O_5. However, a sample across 1 foot of the vein where metatyuyamunite occurs along deposition planes and crystal intersections contains 0.032 percent equivalent uranium, 0.030 percent uranium, and less than 0.1 percent V_2O_5. Numerous other calcite veins in this locality have small amounts of metatyuyamunite on surface outcrops.

The volume of crystalline calcite in these veins is tremendous. The only readily available source rock that could have supplied this much calcium carbonate is the adjacent Madison Limestone. Supporting this interpretation is the abundance of solution phenomena in this limestone along its outcrops to the west and north.

<u>SW 1/4 NW 1/4 NE 1/4 sec. 11, T. 24 N., R. 82 W.</u>--Carnotite occurs in this locality as crystal aggregates in fractures and cavities and as disseminated crystals in sandstone and claystone from 20 to 30 feet above the base of the Pliocene(?) rocks. The most abundant mineralization is in a sandy bentonitic gray claystone and bentonitic sandstone that forms a low ledge at the north end of the prominent white butte comprising the entire outcrop of the formation in this locality (figs. 10 and 11). A 1-foot channel sample of the claystone contains 0.05 percent equivalent uranium, 0.051 percent uranium, and 0.16 percent V_2O_5. Prior to the author's investigation, radioactivity had been noted, but no uranium mineralization had been discovered.

Copper occurrences

Malachite and small amounts of azurite occur in the Madison Limestone in sec. 2, T. 24 N., R. 82 W., in secs. 25 and 36, T. 25 N., R. 82 W., and in other outcrops of this formation north and northeast of the map area. These localities have been prospected, several shafts and adits have been dug, but no ore in commercial quantity has been found. Radioactivity was observed in a number of these pits. The copper minerals were deposited apparently by ground water in solution cavities in the limestone. None of the localities has been studied in detail.

Table 1.--Data on springs

(Locations are shown on figure 1. Gallons per day were computed from area of cross section of stream and estimated rate of flow, and may be subject to considerable error.)

Spring No.	Lab. Sample No.	pH	Uranium in ppb. 1954	Gallons per day	Est. output lbs. U per year	Horizon of spring	Remarks
1	141481 141483	7.5 7.5	11 12	700,000	24	Upper part of Tensleep Sandstone	
2	141480 141482	7.5 7.5	9 9	6,000	-----------	Near top of Tensleep Sandstone	
3	219622	7.9	23	32,000	2	Minnekahta Limestone	
4	219629 219630	8.1 8.1	22 22	3,000	-----------	Top of Tensleep Sandstone	Water emerges close to normal fault. In average years, flow is much larger than in 1954. Sparse metatyuyamunite in calcite veins 300 feet northwest; principal metatyuyamunite occurrences 300 feet or more southwest.
5	219627 219628	7.9 7.8	23 23	57,000	4	Top of Tensleep Sandstone	Spring is on a direct southeastward projection of one of the large calcite veins containing metatyuyamunite and apparently emerges from the lower part of this calcite-filled fissure.
6	219625 219626	7.8 7.6	23 24	646,000	46	50 feet below top of Tensleep Sandstone	Water apparently emerges from a fissure partially filled with calcite that contains sparse metatyuyamunite. Travertine deposits 10 feet or more thick have accumulated directly below point of emergence of water.
7	219623 219624	7.7 7.8	24 26 (rerun: 22.5 23.0)	646,000	47	25 feet below top of Tensleep Sandstone	Point of emergence is about 450 feet south-southeast of some of the most abundant metatyuyamunite in calcite veins.
8	219631 219632	7.9 8.0	25 23	162,000	12	Top of Tensleep Sandstone	Cayton Spring
9	219633	8.1	27	14,000	1	Upper part of Tensleep Sandstone	Point of emergence is directly east of conspicuous smooth dip slope of Tensleep Sandstone.
10	219635 219636	7.8 7.8	14 14	646,000	27	Top of Tensleep Sandstone	
11	219637 219638	7.7 7.6	18 6	88,000	3	Middle of Chugwater Formation	Water emerges at a single point on the nearly flat valley floor.
12	219639 219640	7.5 7.6	6 2	3,000	-----------	Rubble of Madison Limestone	Point of emergence is near large thrust fault. In average years, flow is much larger than in 1954.

Uraniferous springs

Twelve springs in the area were sampled (fig. 1); the data from them are summarized in table 1. Ten springs contain from 12 to 27 parts per billion uranium and have a total estimated flow of 3 million gallons of water per day. These data indicate that the annual output of elemental uranium could be as much as 166 pounds, but this figure is regarded only as a very rough approximation because of the many variables involved. It does, however, demonstrate that large flowing springs can yield significant quantities of uranium.

Nine of the springs emerge from the upper part of the Tensleep Sandstone (fig. 3 and fig. 8). Springs 5, 6, and 7 seem to be directly related to fissures that contain crystalline calcite. The pattern of deposition of calcite in these fissures indicates that they stayed open where they cut the Tensleep Sandstone, but in most places closed up in the overlying Opeche Shale and younger rocks. The tendency of these fissures to remain open in the sandstone is assumed to have been a controlling factor in the location of points of emergence of Springs 5, 6, and 7, and possibly in some of the other six issuing from the Tensleep Sandstone.

West of the most closely spaced springs, 3 to 9, inclusive, water entering the outcrops of Precambrian rocks would tend to migrate northeastward along the structural grain, and water entering the Paleozoic rocks would go eastward down dip except where blocked by faults or porosity barriers. Most of the water emerges, not along the small faults in the northwest corner of section 31, but along the much younger fissures. As stated previously, it is known that the fissures are much younger, for on the steep dip slope more than 100 feet above the present valley floor (fig. 4), some fissures are still open and others are partly filled with Pleistocene(?) silt. The fissures apparently are more effective outlets for the water than are the older fault planes.

The Geological Survey has no recorded measurements of the rates of flow of these springs. Old residents who are familiar with the springs state that the flows of the larger ones have been fairly constant for more than 50 years. Flows of Springs No. 4 and No. 12 were noticeably less than normal in 1954, which was the second of 2 dry years. The water is fresh, clear, and cool, but not cold.

Estimates of the amount of water issuing from the springs were made by the author without conventional equipment for measuring flow, and are probably subject to a large error. Except for Springs No. 3 and 9, duplicate water samples were taken for uranium analysis.

Source of uranium in calcite veins and springs

The search for uranium deposits in this area can be facilitated, in part, by an understanding of the various possibilities of origin

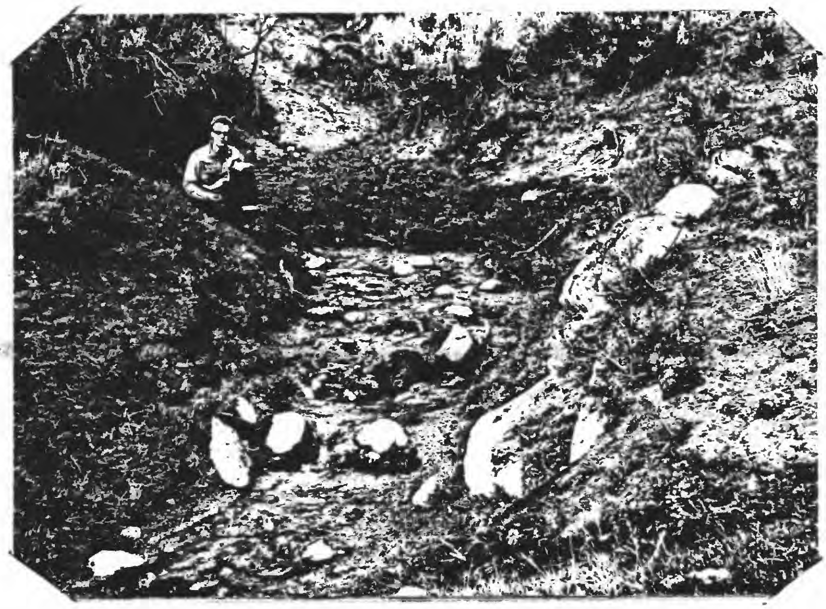

Figure 8.--Uraniferous Spring No. 7 emerging from Tensleep Sandstone. Ledge at right is topmost bed of formation. Water caontains 24 parts per billion uranium.

of the uranium in the spring water, and the reasons for the metatyuyamunite and carnotite mineralization.

Radioactivity and uranium minerals are known to be in the calcite veins through a vertical distance of 400 feet or more above the present positions of Springs 4, 5, 6, and 7. All available evidence suggests that both the crystalline calcite veins and the metatyuyamunite were deposited by ground water migrating along fissures. It is logical to assume that the springs directly associated with the uraniferous calcite veins (Springs 5, 6, and 7) were in existence all the time the land surface east of the Tensleep outcrop was being lowered 400 feet or more.

To lower the land surface 400 feet in this area would take many thousand years. Radioactivity and surface evidence of uranium minerals become progressively less as the distance above the present level of springs becomes greater. This may indicate that either less uranium was available for deposition in the calcite veins when the land surface was higher, or uranium was leached out of the calcite veins after it was once deposited. There is no evidence of extensive solution of the crystalline calcite such as would probably have accompanied leaching of the metatyuyamunite. Therefore, it is postulated that more uranium may be available to the ground water now than in times past. The relatively high amount of uranium in the water in the vicinity of the calcite veins containing metatyuyamunite (fig. 9) plus the fact that travertine is currently being deposited at Spring No. 6 indicate that the processes operating when the veins were formed are still at least partially in effect at the present time.

If the output of uranium has not increased appreciably during at least the latter part of the erosion cycle, uraniferous source rocks extensive enough and rich enough to furnish perhaps 150,000 pounds of uranium each 1,000 years must have been, and must still be available to the ground water. The three most probably source rocks are Precambrian, Paleozoic, and Pliocene(?).

Precambrian rocks as the possible source of uranium

The Precambrian rocks of the area have not been studied in detail. Some radioactivity was detected in granite half a mile west of the northwest corner of section 36, T. 25 N., R. 82 W.

Cross section A-B (fig. 1) shows the structure of the locality where the most metatyuyamunite occurs in the calcite veins. As discussed under the subject of uraniferous springs, water entering the outcrops of Precambrian rocks would migrate northeastward along the structural grain of the rocks and along fault planes. Some of it probably was deflected eastward along the faults shown in section 36

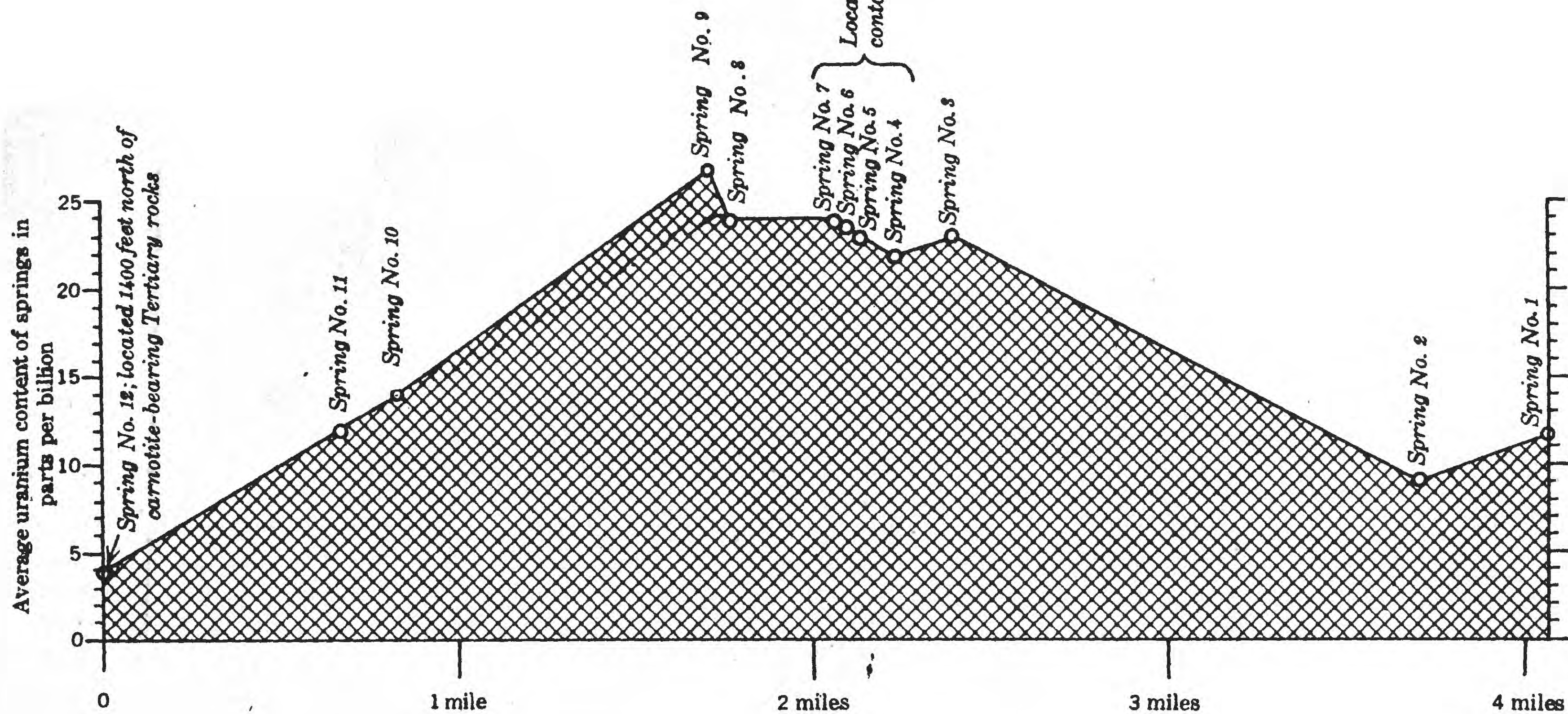

Figure 9. DIAGRAM SHOWING RELATION OF URANIUM CONTENT TO GEOGRAPHIC DISTRIBUTION OF SPRINGS

and in the northwestern part of section 31, and then entered the comparatively open fissures in the Tensleep Sandstone.

Figure 9 and table 1 show that the greatest volume of uranium available to the water is in the vicinity of the calcite veins. There is much greater diversity of rock types in the Precambrian than in the Paleozoic sequence through which the water passes. Therefore, it is possible that the variations in uranium concentration in the water, as indicated in figure 9, may be the result of variations in uranium concentration in the Precambrian rocks. These rocks are sufficiently extensive that they could easily have furnished the thousands of pounds of uranium that are thought to have been emitted with the spring water during Quaternary time.

It has been demonstrated that significant uranium deposits do occur in Precambrian rocks of this general region, for at the Little Man mine, 18 miles to the northwest of the map area, they yielded commercial quantities of uraninite during 1954 (Love, 1954b, p. 229-230). In that locality, the uraninite is in a coarse-grained gray biotite granite, weathering brown, intruded along a layer of uraninite-bearing graphite. The uraninite has a lead-alpha age of 1,800 million years (T. W. Stern, oral communication, 1957). In the zone affected by surface weathering, kasolite ($PbO.UO_3.SiO_2.H_2O$) is more abundant than uraninite. About 1.5 miles downstream from the uraninite mine is a spring emerging at the contact between Precambrian granite and Miocene sandstone. The water contains 26 parts per billion uranium, hence it is comparable in uranium content to the springs in the Shirley Mountains.

These data suggest that the Precambrian rocks of the Shirley Mountains, particularly those in and adjacent to section 36, T. 25 N., R. 82 W., could have furnished the uranium that is now in the calcite veins, and in the uraniferous springs.

Paleozoic rocks as the possible source of uranium

Except in the immediate vicinity of the calcite veins containing metatyuyamunite, the Tensleep Sandstone was not observed as having any abnormal radioactivity. A radioactivity log of 450 feet of the Tensleep Sandstone, and the entire sections of the Amsden Formation, Madison Limestone, and Cambrian rocks in the National Associated Petroleum Company, U.P.R.R. No. 1 dry hole, NE 1/4 SE 1/4 SW 1/4 sec. 13, T. 24 N., R. 80 W., 12 miles east-southeast of the Shirley Mountains, shows no abnormally radioactive zones. Similarly, 17 miles north of the Shirley Mountains area, a radioactivity log of the Stanolind Oil and Gas Co., Chalk Mountain No. 1A dry hole, SW 1/4 SE 1/4 SE 1/4 sec. 22, T. 28 N., R. 81 W., shows no zones of abnormal radioactivity in the section extending from Upper Cretaceous rocks to the Madison Limestone.

Perhaps the most cogent factor suggesting that the uranium did not come from the Paleozoic rocks is the information presented in figure 9. Nine of the 12 springs emerge from near the top of the Tensleep Sandstone, in a linear distance of 4 miles. If the source of uranium was the Tensleep Sandstone or older Paleozoic rocks, it would be logical to expect a more uniform uranium content in the water, particularly in view of the fairly uniform lithologies, plus the fact that extensive fracturing and faulting permit considerable circulation of water.

Pliocene(?) rocks as the possible source of uranium

The presence of carnotite in the Pliocene(?) rocks in sec. 11, T. 24 N., R. 82 W. (figs. 1, 10, 11), suggests that the uranium might have come from this formation. Uranium is thought to be a primary constituent in the tuffaceous rocks of the lithologically similar Moonstone Formation of Pliocene age, 60 miles to the west-northwest (Love, 1961). Carnotite is present also in the North Park Formation of the Saratoga area (Love, 1954a, p. 179; Stephens, 1959).

If the Pliocene(?) rocks or younger uraniferous strata once covered the intake area of the ground water that now emerges in Springs 1 to 12, uranium could easily have been leached downward and carried into the calcite veins. Remnants of Pliocene(?) rocks are at an elevation of 7,900 feet, whereas adjacent radioactive places in the calcite veins rarely occur at elevations above 7,600 feet. Thus it can be demonstrated that the Pliocene(?) fill extended significantly higher on the mountains than the observed uranium occurrences.

If the uranium in the calcite veins (fig. 1) had been derived from the Pliocene(?) rocks one might expect more evidence of uranium minerals in the higher, less deeply eroded portions of the veins, rather than in those at lower, more deeply eroded levels, unless extensive leaching and redeposition of metatyuyamunite took place after the original extraction from Tertiary rocks. The best mineralization, however, was observed in the topographically lower parts of the veins, and there is little evidence of extensive leaching of the calcite veins at higher elevations. These are all surface observations, and at present there is no information about the unexposed parts of the calcite veins.

It is interesting to note that the spring (No. 12) closest to the carnotite mineralization in the Pliocene(?) rocks has the lowest uranium content of any spring in the area (fig. 9). This spring is 1,400 feet north and at approximately the same elevation as the upper part of the Pliocene(?) sequence.

Figure 10.--View northwest toward carnotite-bearing Pliocene(?) rocks (A) shown on fig. 11, in sec. 11, T. 24 N., R. 82 W., at base of south flank of Shirley Mountains (B). Areal geology is shown on fig. 1.

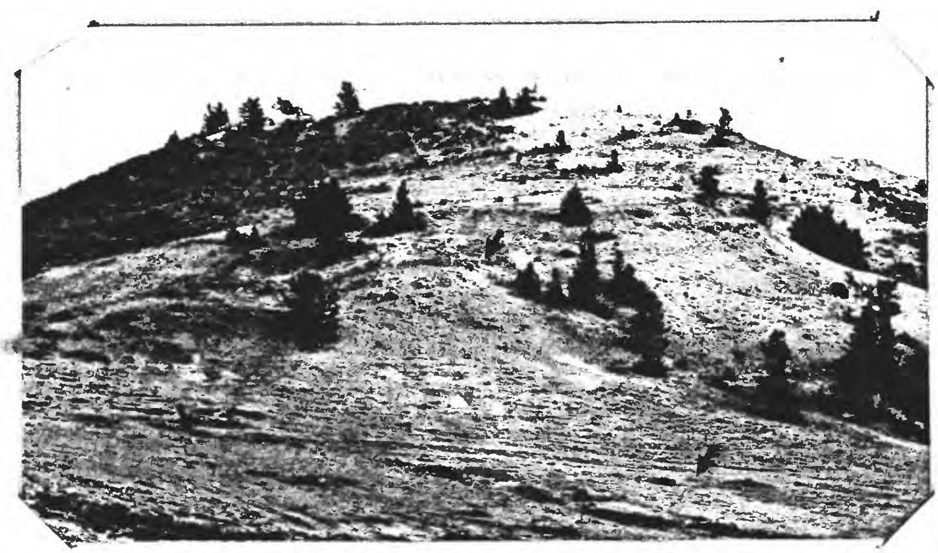

Figure 11.--North end of butte of Pliocene(?) rocks shown on fig. 10. Upper arrow indicates carnotite-bearing tuffaceous sandstone and claystone. Lower arrows mark contact with vertical strata of Medicine Bow Formation.

References

Condra, G. E., Reed, E. C., and Sherer, O. J., 1940, Correlation of the formations of the Laramie Range, Hartville uplift, Black Hills, and western Nebraska: Nebr. Geol. Survey Bull. 13, 52 p.

Dobbin, C. E., Bowen, C. F., and Hoots, H. W., 1929, Geology and coal and oil resources of the Hanna and Carbon Basins, Carbon County, Wyoming: U.S. Geol. Survey Bull. 804, 88 p.

Hubbell, R. G., 1956, Upper Triassic facies relations in northern Carbon County, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 40, p. 2743-2748.

Knight, S. H., 1951, The Late Cretaceous-Tertiary history of the northern portion of the Hanna Basin, Carbon County, Wyoming, in Wyoming Geol. Assoc. Guidebook 6th Ann. Field Conf., South central Wyoming, 1951: p. 45-53.

Love, J. D., 1954a, Uranium investigations in the Saratoga area, in Geologic investigations of radioactive deposits, semiannual progress report, Dec. 1, 1953 to May 31, 1954: U.S. Geol. Survey TEI-440, issued by U. S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge, Tenn., p. 179.

______1954b, Uranium investigations in the Shirley and Pedro Mountains, in Geologic investigations of radioactive deposits, semiannual progress report, June 1 to Nov. 30, 1954: U.S. Geol. Survey TEI-490, issued by U.S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge, Tenn., p. 227-230.

______1955, Carnotite mineralization in Upper Tertiary rocks, northeast margin of Hanna Basin, Carbon County, Wyoming, in Geologic investigations of radioactive deposits, semiannual progress report, Dec. 1, 1954 to May 31, 1955: U.S. Geol. Survey TEI-540, issued by U.S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge, Tenn., p. 209-210.

______1957, Stratigraphy and correlation of Triassic rocks in central Wyoming, in Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf., Southwest Wind River Basin, 1957: p. 39-45.

______1961, Split Rock Formation (Miocene) and Moonstone Formation (Pliocene) in central Wyoming: U.S. Geol. Survey Bull. 1121-I, 37 p.

Lovering, T. S., 1929, The Rawlins, Shirley, and Seminoe iron ore deposits, Carbon County, Wyoming: U.S. Geol. Survey Bull. 811-D, p. 203-235.

McGrew, P. O., 1951, Tertiary stratigraphy and paleontology of south-central Wyoming, in Wyoming Geol. Assoc. Guidebook, 6th Ann. Field Conf., South central Wyoming, 1951; p. 54-57.

Stephens, J. G., and Bergin, M. J., 1959, Reconnaissance investigation of uranium occurrences in the Saratoga area, Carbon County, Wyoming: U.S. Geol. Survey Bull. 1046-m, p. 321-338.

Weitz, J. L., and Love, J. D., 1952, Geologic map of Carbon County, Wyoming: Geol. Survey of Wyoming map.