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Uranium Occurrences in Bucks County, Pennsylvania, and Hunterdon County, New Jersey

By F. A. McKeown, P. W. Choquette, and R. C. Baker

Trace Elements Investigations Report 414

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Geology and Mineralogy

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Series A

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

URANIUM OCCURRENCES IN BUCKS COUNTY, PENNSYLVANIA, AND HUNTERDON COUNTY, NEW JERSEY*

By

F. A. McKeown, P. W. Choquette, and R. C. Baker

June 1954

Trace Elements Investigations Report 414

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By F. A. McKeown, P. W. Choquette, and R. C. Baker

ABSTRACT

Eleven occurrences of uraniferous argillite in the Lockatong lithofacies and five occurrences of uraniferous sandstone in the Stockton lithofacies, both of Triassic age, are known in Bucks County, Pa., and Hunterdon County, N. J. Most of the occurrences were discovered by the Geological Survey, though prospectors found several.

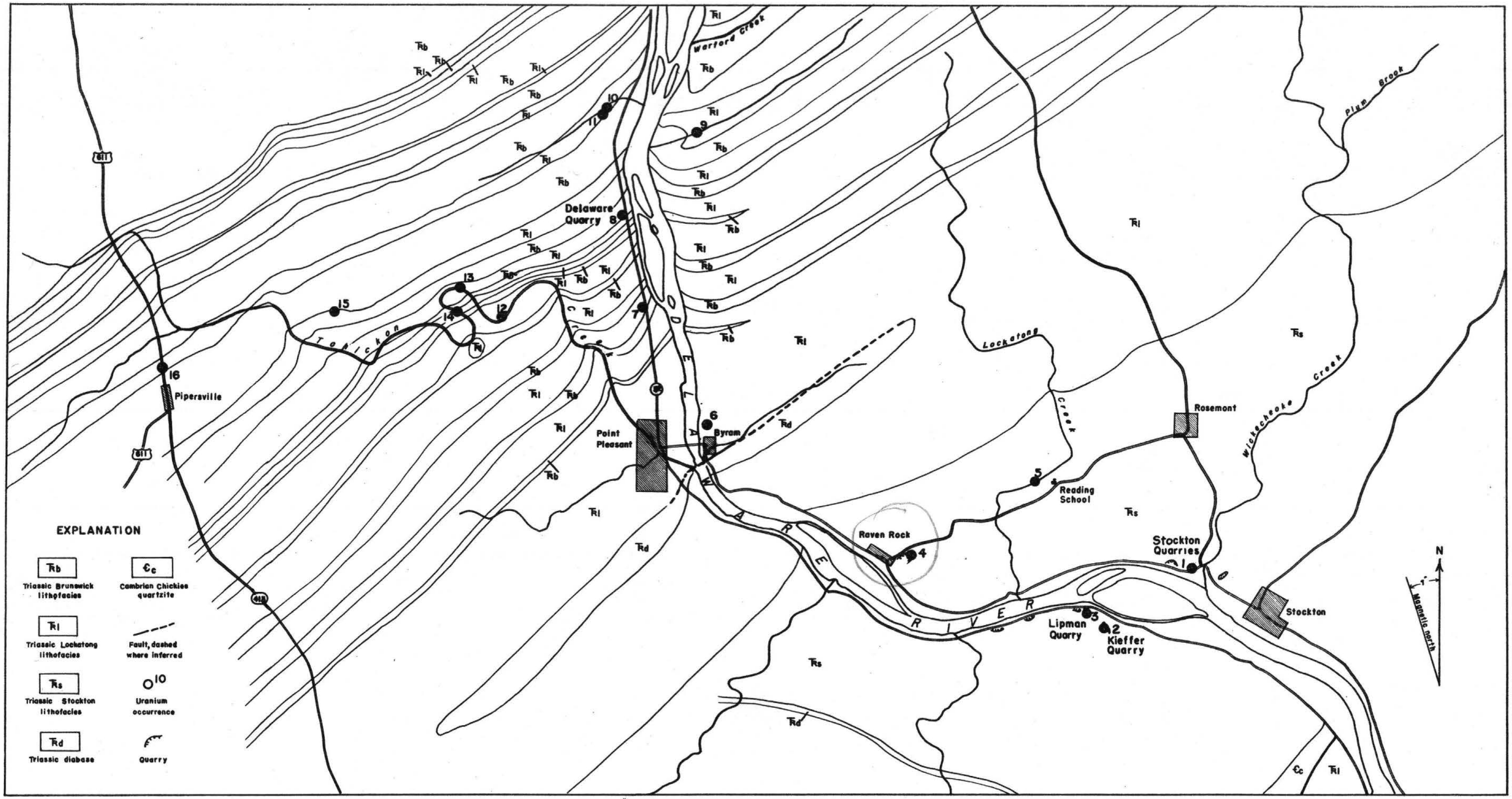
The Delaware quarry, Bucks County, Pa., was mapped and sampled in detail because the best exposed and most uraniferous argillite known crops out there. Sketches of two sandstone occurrences were made. Two stratigraphic sections of part of the Stockton formation were made in an unsuccessful effort to find key beds to which the uranium occurrences might be referred. The argillite occurrences contain as much as 0.034 percent uranium but commonly contain only about 0.010 percent uranium. They are known to extend for several hundred feet along the strike and may possibly extend several thousand feet, but less than a mile. They range from about 1 to 6 feet in thickness.

The sandstone occurrences are characterized by the presence of pyrite or limonite and the alteration of feldspar to clay. The most uraniferous parts of the sandstone contain mud pebbles or lenses. The sandstone with

mud pellets generally contain from 0.01 to 0.03 percent uranium, but selected parts of the pellets contain as much as 0.29 percent uranium. The known occurrences are small, about 1 to 2 feet thick and 20 to 30 feet long. None of the argillite or sandstone occurrences are now of economic importance.

INTRODUCTION

Eleven occurrences of uraniferous argillite and five occurrences of uraniferous sandstone are known in Bucks County, Pa., and Hunterdon County, N. J. (fig. 1). Uraniferous rock from the area was first known to the U. S. Geological Survey when Wilfred Carr of the Survey collected several samples of uranium-bearing sandstone and argillite from near Stockton, N. J., in 1948 (personal communication). Later in the same year, after the highway had been widened, Donald H. Johnson (personal communication) of the Survey found torbernite at the same locality. Since then Johnson (1950) and Stewart (1951) have examined the Stockton locality and made a radioactivity survey with car-mounted equipment along some of the roads in part of southeastern Pennsylvania and western New Jersey. In the spring of 1953 the writers found uraniferous argillite near Pipersville, Pa., and uraniferous sandstone at Raven Rock, N. J. These occurrences, plus: a) the similarity of some of the sandstone in the Triassic formation to the Shinarump conglomerate, which contains many uranium deposits in Colorado, Arizona and Utah; b) the presence of copper at many places in Triassic rocks in Pennsylvania and New Jersey; and c) the conclusions of Stewart (1951, p. 10) provided a reasonable basis for examining in greater detail the area between Stockton, N. J., and Pipersville, Pa.



Scale 1:31680

0 1/2 1 2 miles

Geology after B. Willard et al, Geologic map of Bucks County, Pennsylania 1950 and McLaughlin 1945 with additions by F. A. McKeown, P.W. Choquette, and R.C. Baker 1953

Figure 1 Map showing geology and locations of uranium occurrences in part of Bucks County, Pa., and Hunterdon County, N. J.

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Concurrent with the writers' reconnaissance Mr. Joseph Busik of Point Pleasant, N. J. and Mr. Richard Spurgeon of Lansdale, Pa., were prospecting in the same area. They found uraniferous argillite in the Delaware quarry, which is owned and operated by Mr. Busik.

The areas of outcrop that are directly along strike from known occurrences of uranium were searched intensively. In addition, many of the streams and roadcuts were traversed on foot with Geiger or scintillation counters. Stratigraphic sections (fig. 2) were measured at Stockton and in the vicinity of the Kieffer and Lipman properties (figs. 4 and 5) in an effort to find key beds to which the uranium occurrences could be referred. Delaware quarry was mapped at a scale of 1:360 (fig. 3) because the highest grade uraniferous argillite found in this study is best exposed there. An unsuccessful attempt was made to correlate thin (less than 20' thick) lithologic units within the Lockatong formation from the west side of the Delaware River to the east side.

Radioactivity measurements were made with both a scintillation counter and a Geiger counter. The background radiation as measured was about 0.02 milliroentgens per hour. For low levels of radioactivity 0.01 mr/hr is very roughly equivalent to 0.001 percent equivalent uranium. Thus in this report where an outcrop is said to measure 0.1 mr/hr the reader may interpret the measurement in terms of percent equivalent uranium by subtracting background (0.02 mr/hr) and dividing by 10.

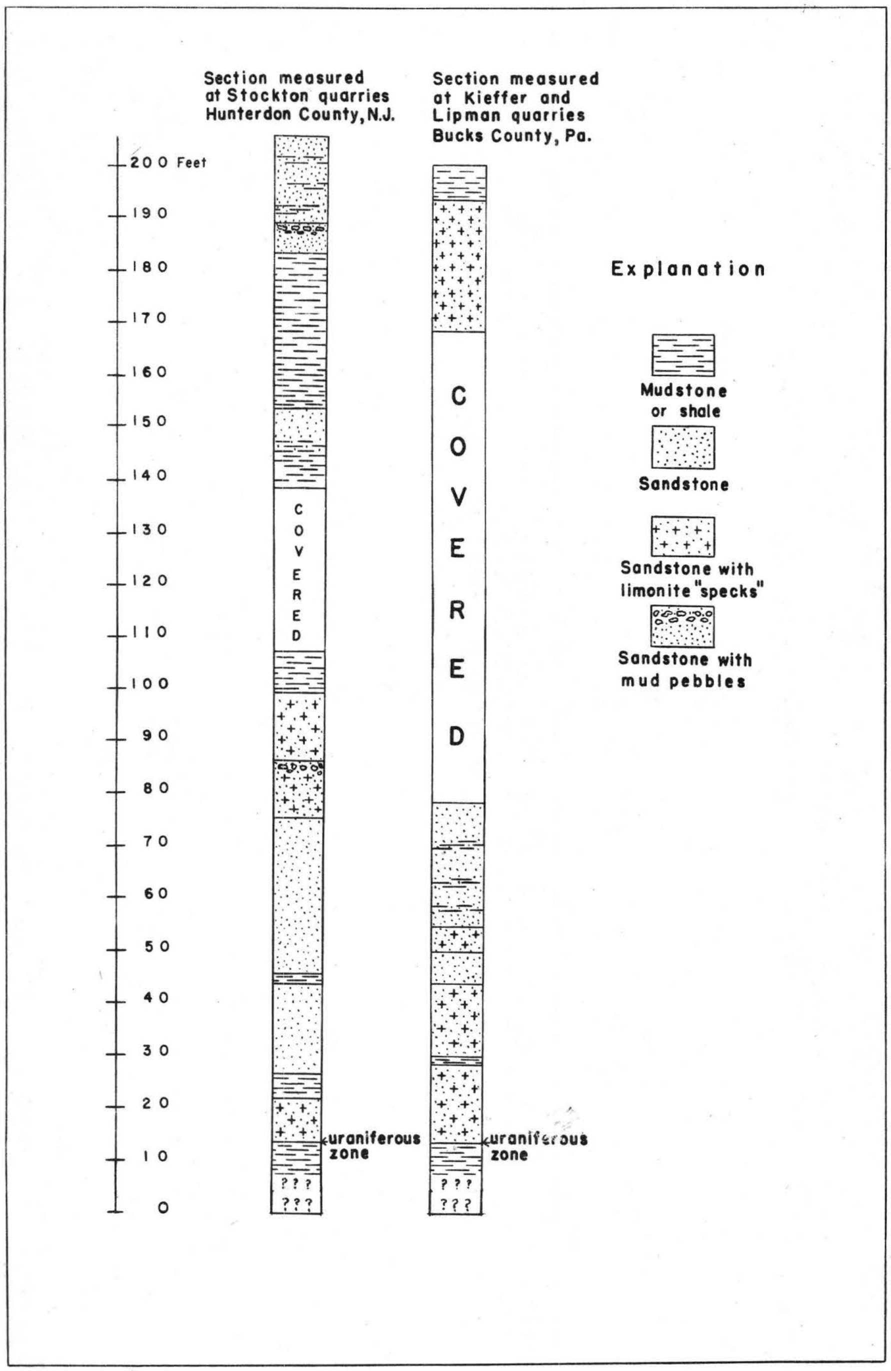

Figure 2 Sections of the Stockton lithofacies

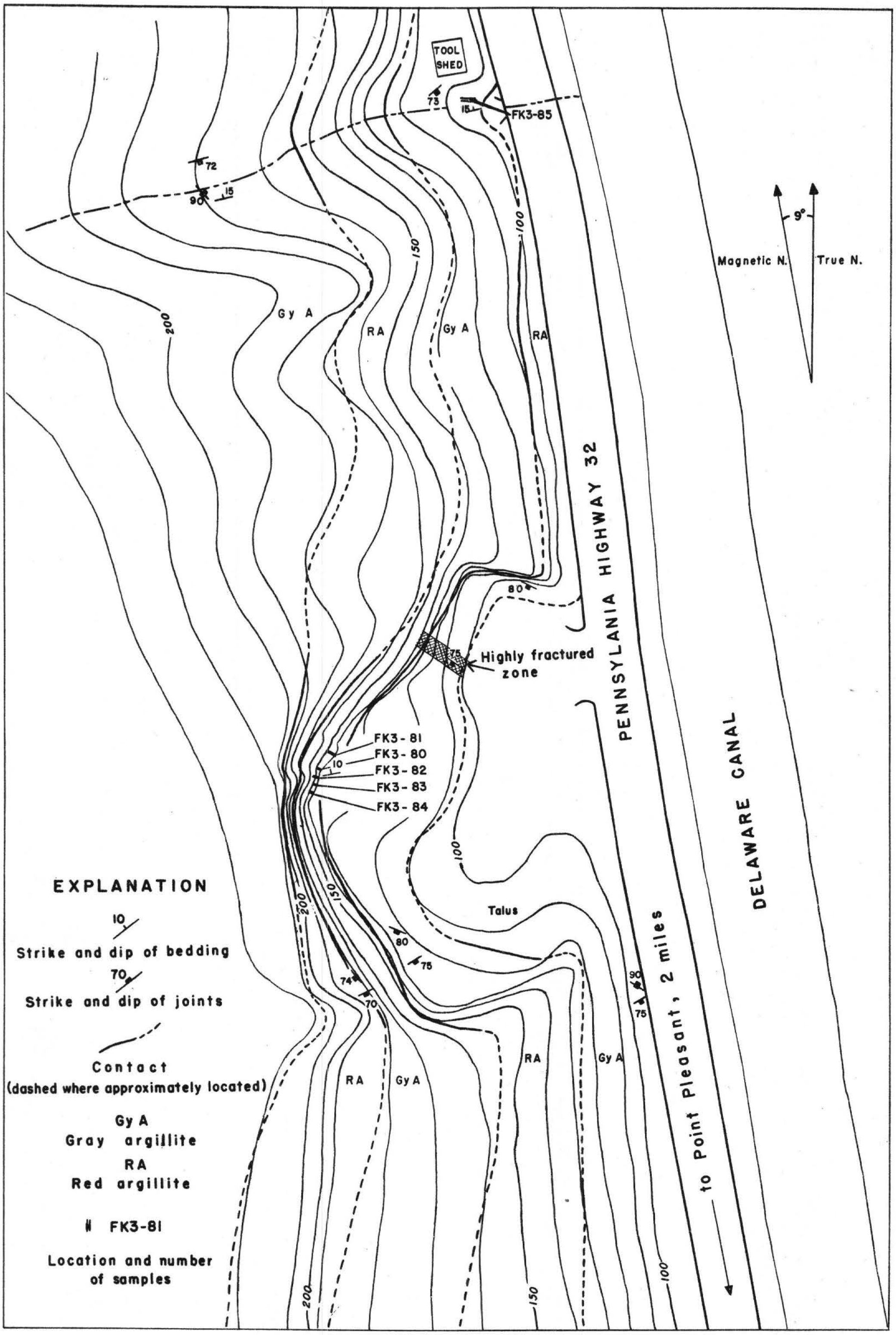

FIGURE 3 DELAWARE QUARRY, BUCKS COUNTY, PA.

Scale 1:360

0 30 60 90 120 Feet

Datum mean sea level
Contour interval 10 feet

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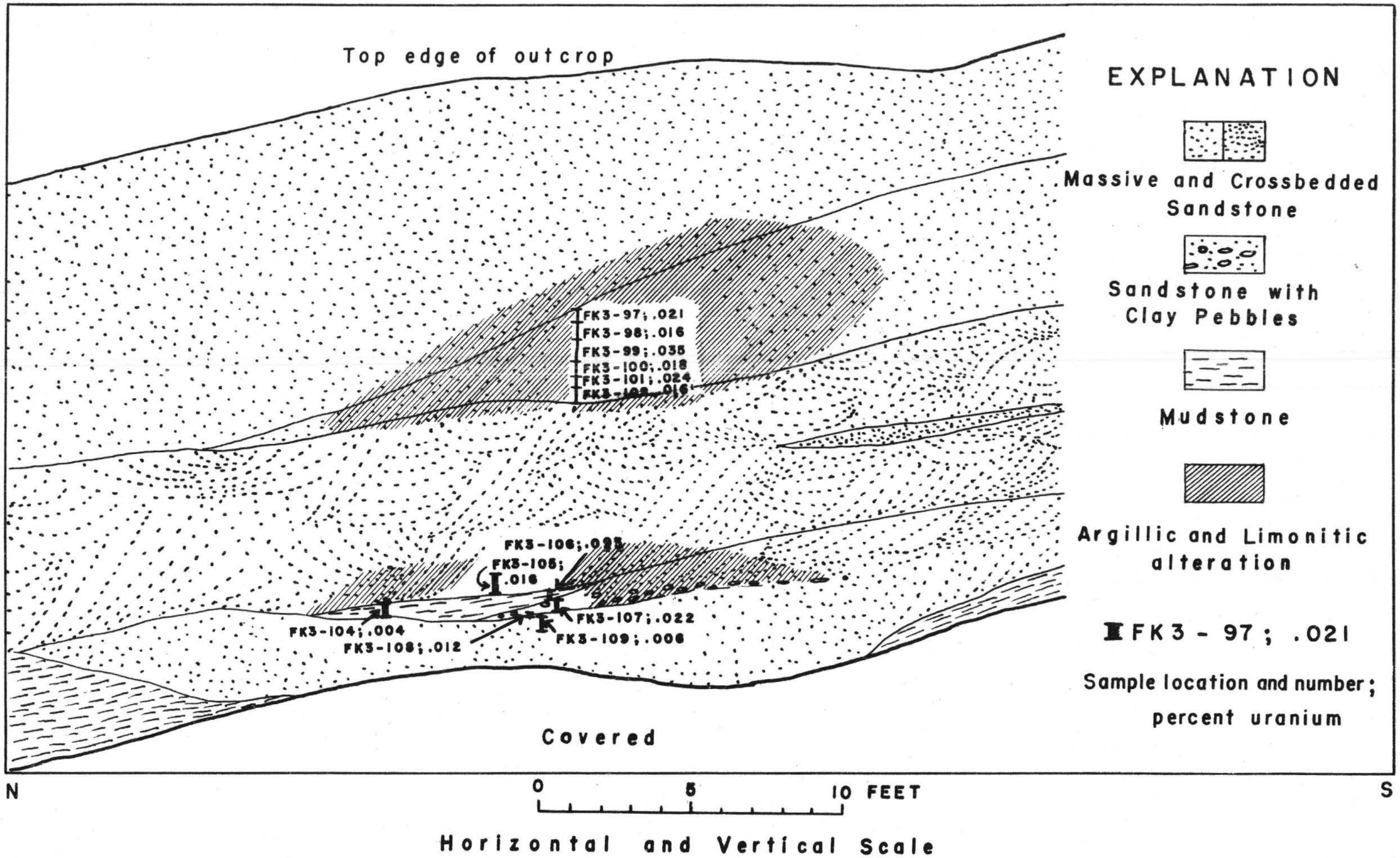

Figure 4 Sketch of outcrop of uraniferous sandstone on C.M. Kieffer property near Center Bridge, Bucks County, Pa.

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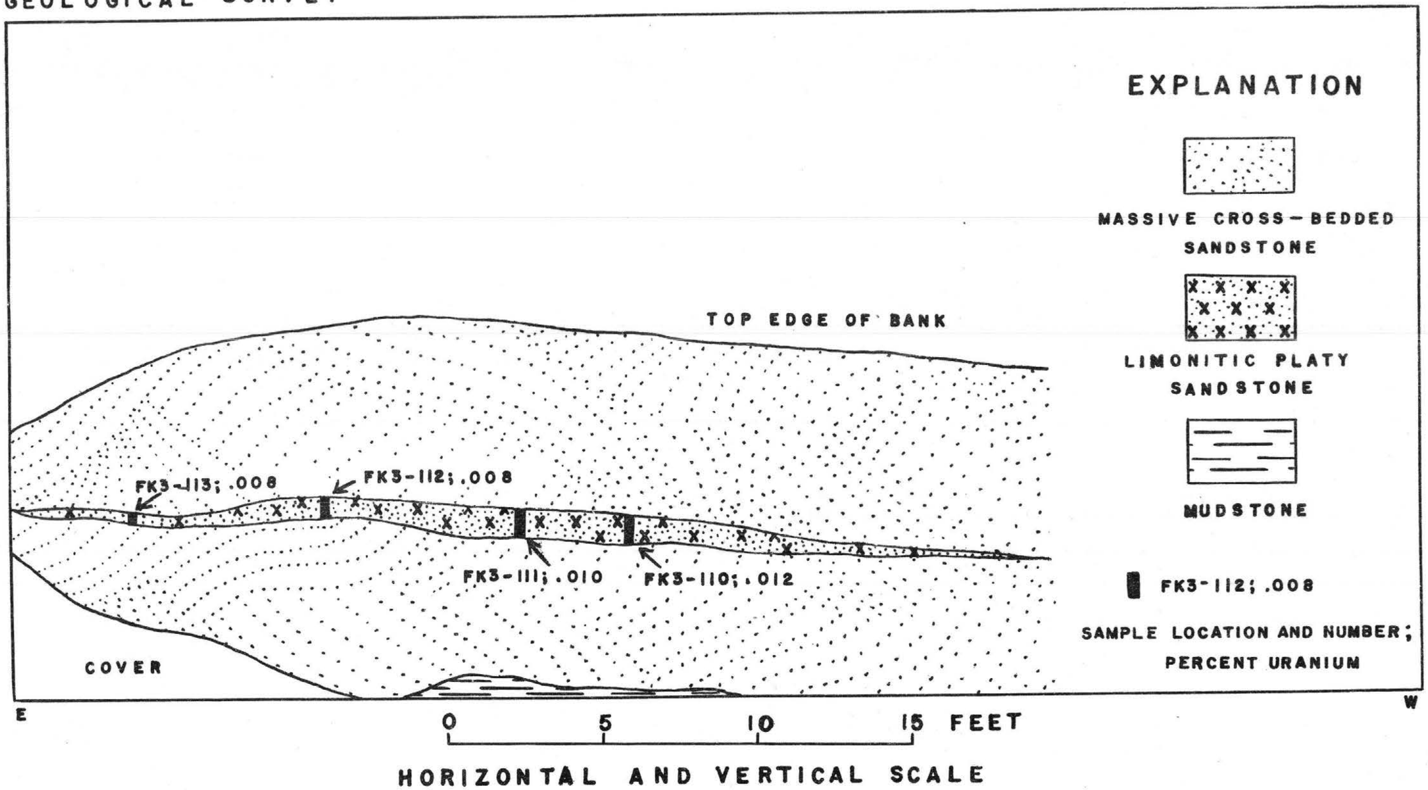

FIGURE 5 SKETCH OF OUTCROP OF URANIFEROUS SANDSTONE ON HARRY LIPMAN PROPERTY NEAR CENTER BRIDGE, BUCKS COUNTY, PA.

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GEOLOGY

The area in Bucks County, Pa., and Hunterdon County, N. J., that is relevant to this report is underlain by sedimentary rocks of the Newark group and diabase sills and flows of Triassic age. The sedimentary rocks of the Newark group in Pennsylvania and New Jersey have long been divided into three formations: Stockton sandstone, Lockatong argillite, and Brunswick shale (Kümmel, 1940, p. 102).

The "Geologic map of New Jersey" (Lewis and Kümmel, 1931) shows that within the area underlain by Triassic rocks, the Stockton formation underlies most of the southern part, the Lockatong formation is in the middle, and the Brunswick formation underlies the northern part. The Stockton formation is characteristically a sandstone, the Lockatong is mostly argillite, and the Brunswick is mostly shale. All three types of rocks, however, are found in each of the formations and, as fossils are scarce, establishment of formation contacts is difficult.

Detailed studies by McLaughlin (1944, 1945, and 1949) and McLaughlin and Willard (1950) led them to believe that "the Newark is not a group of three distinct formations successively deposited, but rather a series of interfingering, in part contemporaneously-formed, continental facies." (McLaughlin 1949, p. 43). The term lithofacies rather than formation is used by McLaughlin and others on their recent "Geologic map of Bucks County, Pa." (Bradford and others, 1950). It will also be used in this report because the writers believe this interpretation of the Triassic rocks is more realistic.

Stockton lithofacies

The Stockton lithofacies consists of interbedded conglomerate, arkosic sandstone, and red shale; sandstone predominates. In the Stockton area much of the sandstone has specks of limonite about 1/16-inch in diameter scattered through it. Microscopic examination of several thin sections of sandstones shows about 50 percent quartz, 20 percent microcline and plagioclase feldspars, and 20 percent clay matrix. The clay matrix is commonly stained with limonite. Pyrite, muscovite, and zircon are accessory minerals.

In general, the sandstones are fine-to coarse-grained, though more commonly medium-grained and well indurated; they are white, tan, brown, and reddish-brown. Clay pebbles are common though not abundant; they are most common in coarse-grained sandstone or fine-grained conglomerate. Red shale and fine-grained red sandstone are common in the upper part of the Stockton lithofacies.

Lockatong lithofacies

The Lockatong lithofacies is made up of black, dark gray, and red argillite. The black and gray varieties are commonly shaly or flaggy and finely laminated. Some of the lamellae are about 0.1 mm thick, and consist of pyrite. Red argillite ranges from very homogeneous, massive, hard rock to very thin-bedded soft rock which is typical of the Brunswick lithofacies; both the red and gray argillites, however, are characteristically thick bedded. Some beds, such as the red argillite at Delaware quarry, may be as much as 30 feet thick. Transition zones between red and gray argillite are commonly chocolate brown, weather to a buff color, and contain mudcrack layers and intraformational conglomerate. The conglomerate consists of angular pieces of gray argillite in a red matrix. McLaughlin (1944, p. 63) refers to it as "grey in red breccia" and notes that such breccias are always gray in red, never red in gray.

McLaughlin (1945, p. 107) reports argillaceous limestone in the lower part of the Lockatong lithofacies. At the Delaware quarry a very peculiar bed in the transition zone between the lower red argillite unit and underlying gray argillite was noted by the writers. The fresh surfaces of this bed appear to be gray argillite. Weathered surfaces, however, show that the gray argillite has many small (0.5 to 2 mm thick) veins of tan material. The weathered outcrop looks somewhat like a breccia or intraformational conglomerate. Microscopic examination shows that the tan material is dolomite and the gray material is argillite.

Brunswick lithofacies

The Brunswick lithofacies is most commonly found in the area 5 to 10 miles north of Point Pleasant, Pa. It is typically poorly laminated red shale interbedded with gray or green shale and red sandstone. Along the northwestern border of the area underlain by Triassic rocks, the Brunswick lithofacies contains some very coarse conglomerates.

URANIFEROUS SANDSTONE OCCURRENCES

Stockton quarries

The first uranium occurrence in the Triassic rocks of New Jersey and Pennsylvania known to the U. S. Geological Survey is in the vicinity of the Stockton quarries (locality 1, fig. 1). The quarries are about 1 mile north of Stockton along New Jersey Highway 29, between Stockton and Raven Rock, Hunterdon County, N. J. The uranium occurrence is not in any of the quarries; it is a zone of decomposed arkosic sandstone in a bank on the southeast side of the road directly across from the quarries. The decomposed uraniferous rock is probably in place and the underlying rock may, therefore, be uraniferous. Several other radioactive zones were found in the wooded area between the road and a large water-filled quarry about 200 feet southeast of the road. These are approximately 200 feet southwest along strike from the decomposed sandstone zone. Lack of outcrops precludes further inferences about the relationship of the radioactive zones to each other.

The quarries on the northwest side of the road were tested with Geiger and scintillation counters; the more accessible parts of the large quarry southeast of the road were also tested. No radioactive rock was found in either of them.

Stratigraphic sections (fig. 2) were measured at the Stockton quarries and at quarries and outcrops directly along strike across the Delaware River where several other occurrences of uraniferous rock (the Kieffer and Lipman properties, as discussed below) were found. Although the uraniferous zones are at or near the contact of limonite sandstone with mudstone and appear to be at essentially the same horizon, the overlying strata cannot be correlated. The inference from field observations and the sections in figure 2 is that sandstone and mudstone units have strike lengths of less than 1 mile.

The uranium at Stockton is in limonite-specked arkosic sandstone and on joint surfaces of red-brown mudstone. Mudstone and very fine-grained sandstone crop out next to the zone of decomposed arkosic sandstone, but no uranium minerals have been found on the outcrops. The zone of decomposed radioactive rock is about 15 feet long and 10 feet wide. Torbernite is rarely found on joint planes of the mudstone and on other but random surfaces or disseminated in pieces of the sandstone. Most of the radioactive rock has no megascopic uranium minerals. Microscopic examination of the sandstone shows about 50 percent quartz, 40 percent feldspar, 10 percent limonite and clay, and traces of a fibrous, pleochroic (yellow to straw yellow) mineral which is probably uranophane. Much of the quartz is strained and fractured. Plagioclase, perthite, and a little microcline make up the feldspars. Mortar structure is common.

About 100 feet southeast of the decomposed sandstone zone, outcrops of sandstone in the face of a quarry are bleached to light gray. Though the rock is obviously altered, the cause is not apparent. No significant fracturing, faulting, or mineralization has been observed, and despite its proximity to the occurrence of uranium minerals, the rock in this bleached zone is not radioactive.

Kieffer quarry

An abandoned quarry (locality 2, fig. 1) in a wooded area about 1 mile west of Center Bridge, Bucks County, Pa., is on property owned by Charles M. Kieffer. The Kieffer quarry may be reached by going 0.3 mile to the south along a secondary road off Pennsylvania Highway 32, 1 mile west of Center Bridge. The quarry is about 300 feet southeast of the secondary road.

Sandstone and a little red shale and mudstone are exposed in the quarry. The sandstone is medium grained, cross-bedded, yellow-white on fresh exposures and weathers to tan or brown. Most of it has "specks", 0.05 to 0.20 inch in diameter, of disseminated limonite. Bedding ranges from about 1 foot to as much as 15 feet in thickness. Though cross-bedding is common, the rock when quarried breaks out in thick units along prominent bedding planes and joints.

The sandstone is disconformably underlain by red-brown mudstone. The disconformity appears to be the result of channeling in the mudstone. One channel (?), about 25 feet wide, is 5 to 10 feet below the two most radioactive zones in the quarry (fig. 4). Another, about 100 feet wide and very poorly defined, is about 50 feet north of the smaller channel.

The two most radioactive zones in the quarry lie one above the other (fig. 4). One is associated with a lens of red mudstone with argillic and limonitic alteration around it; the other is massive sandstone with argillic and limonitic alteration. Two other small zones, 5 to 10 feet long, of radioactive sandstone are located about 100 and 150 feet, respectively, north of the zones shown in figure 4. The zones of uraniferous sandstone are rich with limonite and clay. The limonite is believed to be the result of oxidation of pyrite, which is rarely observed in the highly altered zones, and the clay minerals have resulted from decomposition of feldspar. Siderite, which might also oxidize to limonite, has not been observed.

A thin section of the sandstone from the uraniferous altered zone contains about 50 percent quartz, 45 percent clay and limonite, 5 percent feldspar, and traces of pyrite and zircon. The quartz is angular to subangular; some is corroded and much is fractured. Clay and limonite appear to replace quartz along grain boundaries. Some of the limonite has a cubic habit and probably is pseudomorphous after pyrite. Most of the feldspar is albite; a little microcline is also present. Both albite and microcline are commonly partly altered to clay.

Torbernite (?) is disseminated in part of the lens of red mudstone. No uranium minerals were observed in the sandstone. The secular equilibrium of uranium in sandstone is different than the secular equilibrium of uranium in mudstone. All samples of sandstone (FK3-97,-98,-99,-100,-101,-102, and -104) have an equivalent-uranium content that is higher than, or nearly equal to the uranium content. Samples of mudstone or sandstone containing mud pebbles (FK3-105,-106,-107, and -108) generally have a higher uranium content than equivalent-uranium content.

Lipman quarry

A large quarry (locality 3, fig. 1) on property owned by Harry Lipman is located about 1,500 feet northwest of the Kieffer quarry. The Lipman quarry can be entered directly from Pennsylvania Highway 32, 1.3 miles west of Center Bridge.

Yellow to red-brown medium- to fine-grained sandstone that grades upward into red mudstone is exposed in the quarry. The sandstone in the lower part of the quarry is medium grained and contains "specks" of disseminated limonite. Red mudstone, which is probably the same mudstone exposed in the Kieffer quarry, underlies the sandstone.

Uranium occurs in the southwest face of the quarry in a slightly altered zone of platy sandstone, about 1 foot thick and 25 feet long, (fig. 5). The zone is about 4 feet above the sandstone-mudstone contact. In contrast to the rock at the Kieffer quarry, clay is less abundant and mud lenses and pebbles are absent. Analyses of the sandstone (samples FK-3-110,-111,112,-113, and -114) show that the equivalent uranium content is greater than the uranium content. This conforms with the observation regarding secular equilibrium and lithology noted from the samples collected at the Kieffer quarry.

Raven Rock quarry

The Raven Rock quarry (locality 4, fig. 1) is at Raven Rock, Hunterdon County, N. J. It is about 500 feet long and 200 feet wide. Fine-to medium-grained sandstone was quarried from it for building stone for many years, but the last large operation was for riprap. This shattered the quarry face so that the quarry is no longer suitable for the economic removal of building stone. Local quarrymen, however, still occasionally take out a very small quantity.

Approximately 60 feet of rock is exposed in the quarry. Forty feet consists of thick-bedded, massive, light gray to white medium-grained sandstone that breaks cleanly along joint planes and bedding planes. This sandstone grades upward into purple fine-grained sandstone and purple siltstone and is underlain by red shale. In places the white sandstone has prolate spheroidal kidney-shaped zones, 5 to 10 feet long, that are rich in pyrite. About midway between the top and bottom of the 40-foot unit of light colored sandstone is a discontinuous zone, about 1 foot thick, of pyrite-rich rock. This zone is marked by limonite staining along a slight disconformity throughout the quarry.

Radioactive rock has been found at three sites in the quarry, only one of which is in place. The outcrop site is at the top edge of the center of the east face of the quarry. A zone of clay and clayey sandstone about 10 feet long and as much as 1 foot thick has a radioactivity as much as 0.15 mr/hr in places. Several pieces of very radioactive rock have been found in talus on the quarry floor below the radioactive outcrop. Part of a clay pebble in one of the pieces contained 0.28 percent uranium (FK3-5). A thin section of this sample shows--in addition to clay--pyrite, limonite after pyrite, a few grains of quartz, and a few grains of a bright yellow mineral that is probably uranophane. Though the radioactive talus was directly below the radioactive outcrop, the talus may not have fallen from this outcrop. Approximately half way down the face of the quarry a fractured zone may be the original site of the radioactive talus.

The third occurrence of radioactive rock is road metal in and along the road into the quarry. Several zones up to 10 feet in length measure as much as 0.25 mr/hr in places.

Reading School

The Reading School occurrence (locality 5, fig. 1) is along the south bank of Lockatong Creek, a quarter of a mile west of the school. This school is along the road halfway between Raven Rock and Rosemont.

White medium-grained sandstone crops out along the Lockalong Creek. As the strike of the sandstone is parallel to the creek and the dip is about 15° to the northwest, only a very small stratigraphic thickness of the rock is exposed, probably less than 5 feet. A zone of the sandstone ranging from several inches to about 1 foot in thickness is highly pyritiferous. This zone can be traced discontinuously for about 250 feet along strike. About 75 percent of the zone is radioactive. In places the radioactivity is as much as 1.2 mr/hr, although 0.1 to 0.2 mr/hr is more common.

Examination of four thin sections shows that the sandstone is made up of about 50 percent quartz, 20 percent feldspar, 20 percent clay and limonite and 10 percent pyrite, mica, and zircon; pyrite is much more abundant than either mica or zircon. The quartz is commonly fractured or strained; the feldspars, which are plagioclase and a little microcline, generally show some alteration to clay. Much of the pyrite is euhedral and occurs as cubes modified with pyritohedron faces.

Two grab samples (FK3-115 and-119) were taken at the most radioactive outcrops in the stream bed. They assayed 0.044 and 0.006 percent uranium, respectively.

URANIFEROUS ARGILLITE OCCURRENCES

Locality 6

The radioactivity of several outcrops (locality 6, fig. 1) along the east side of the river road, 0.2 mile northwest of Byram, N. J., measures as much as 0.1 mr/hr in places. The radioactive rock is dark gray argillite, metamorphosed almost to hornfels by a diabase sill about

0.5 mile southeast of this locality. Exposures of radioactive rock are poor. Large outcrops of gray argillite are exposed on a hillside about 200 feet northeast of the road. None of these rocks, however, is radioactive.

Locality 7

Locality 7 (fig. 1) includes two occurrences of radioactive dark gray to black argillite 0.7 mile south of Delaware quarry along Pennsylvania Highway 32. The occurrences are about 100 feet apart stratigraphically. The lower occurrence is a massive unit of dark gray argillite 21 feet thick; the upper 8 feet of this unit grades into red argillite. The dark gray argillite measures as much as 0.1 mr/hr in places; the average radioactivity, however, is about 0.04 mr/hr.

The upper occurrence of radioactive rock is fissile dark gray to black argillite with a few brown silty laminations. A 6-foot zone of this rock has a radioactivity ranging from 0.1 to 0.18 mr/hr.

Locality 8, Delaware quarry

The Delaware quarry (locality 8, fig. 1) is located 2 miles north of Point Pleasant, Bucks County, Pa., along State Highway 32. It is about 200 feet wide and cut back about 100 feet into the side of a hill (fig. 3). It is owned and quarried for building stone by Joseph Busik of Point Pleasant. The presence of uranium in some of the rock was known by Mr. Busik before the writers visited the quarry. According to Mr. Busik, a sample of the most radioactive rock was assayed by a commercial assayer and contained 0.1 percent uranium.

Because the quarry contained the best exposure and most radioactive argillite known in the area, it was mapped at a scale of 1:360 (fig. 3) and the accessible radioactive outcrops of argillite sampled in detail.

The quarry is in red and gray argillite which is part of the "Double Red" unit of McLaughlin (1944, p. 65). McLaughlin reports the thicknesses of the rocks in this unit to range as follows: red argillite, 22 to 33 feet; black argillite, 29 to 36 feet; and red argillite, 34 to 45 feet. Though the thicknesses of the red and gray rock units shown in figure 3 do not exactly agree with the thicknesses of the same units measured at several places by McLaughlin, the location and relative thicknesses of underlying and overlying strata indicate with little doubt that the rocks at the Delaware quarry are in the "Double Red" unit. The red argillite units are massive and even-grained. In general they break in the direction of bedding and of the two main sets of joints in the area. Where it does not break in these preferred directions, it has a conchoidal fracture. The transition zones between gray and red argillite are usually about 5 feet thick. The gray units are massive to shaly and have a more heterogeneous composition. They are commonly very finely laminated with alternating dark gray and light gray or tan layers. Fine-grained sandstone, siltstone, and shale with mud-cracked layers may all be found in units 3 feet thick or less. Some of the layers are contorted and broken, presumably by movement when the sediment was still unconsolidated.

The structure at the quarry is typical of the area. Bedding strikes about N. 85° E. and dips 10° -15° NW. Two sets of joints are prominent; one strikes about N. 50° E. and dips 75° SE, the other strikes N. 50° W. and dips 75° SW. A highly fractured zone about 15 feet wide in the north face of the quarry (fig. 3) suggests incipient faulting; no displacement was noted, however, at this zone.

The uraniferous rock in the quarry is a zone of medium to dark gray, massive to shaly argillite. The most radioactive outcrop is about 40 feet above the floor in the center of the west wall of the quarry. By chance this part of the zone was the most accessible as well as the most radioactive; it was therefore sampled in detail. Five channel samples, each consisting of 6 or 7 parts, were taken within a dip length of about 25 feet. (See samples FK3-80 through FK3-84 with letter suffixes, table 1; figure 3 shows location.)

The inaccessible parts of the black argillite zone were tested for radioactivity by lowering a Geiger tube on the end of 85 feet of cable down the side of the quarry face at three places. This showed that about 30 feet south of sample locality FK3-84 the zone is not radioactive. At the two places it was tested north of the sample locality, the zone was slightly, but distinctly, radioactive.

An outcrop of the zone on the south top edge of the quarry is not radioactive. Outcrops, along the road between the quarry and the tool shed several hundred feet north of the quarry and in the stream bed just below the tool shed, are slightly radioactive. A sample (FK3-85) taken in the stream bed contains 0.009 percent equivalent uranium and represents a thickness of 5 feet. The highly fractured zone in the northwest wall of the quarry is not radioactive at the level of the quarry floor. Attempts to test it higher up were unsuccessful.

Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent) 1/	Equivalent Uranium (percent) 2/
FK3-3	1, Stockton	grab	---	Iron-stained, coarse-grained arkosic sandstone.	0.035	0.056
FK3-5	4, Raven Rock	do.	---	Part of very radioactive red and gray clay pebble	.29	.28
FK3-6	4	do.	---	Pink, fine-grained sandstone.	.031	.034
FK3-7	4	do.	---	Iron-stained sandstone with gray and red clay pebbles	.016	.017
FK3-8	15	channel	1 ft	Dark gray shaly argillite	.002	.004
FK3-9	15	do.	1 ft	do.	.004	.007
FK3-10	15	do.	1 ft	do.	.007	.010

1/ Uranium analyses by Audrey Smith, Esma Campbell and Blanche Ingram, U. S. Geological Survey

2/ Radioactivity analyses by Benjamin McCall and Julius Goode, U. S. Geological Survey

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-11	15	do.	14 inches	do.	0.003	0.006
FK3-12	15	do.	18 inches	do.	.001	.004
FK3-13	15	do.	18 inches	do.	---	.012
FK3-79	15	grab	---		---	.007
FK3-80 A	8, Delaware quarry	channel	1.1 ft	Medium gray massive argillite	---	.003
FK3-80 B	8	do.	1.1 ft	do.	---	.004
FK3-80 C	8	do.	.8 ft	Dark gray to black shaly argillite	---	.008
FK3-80 D	8	do.	.8 ft	Black shaly argillite	---	.004
FK3-80 E	8	do.	1.2 ft	Dark gray massive argillite	---	.013
FK3-80 F	8	do.	1.0 ft	Medium to light gray argillite	---	.012
FK3-80 G	8	do.		Medium to light gray argillite, few sandy laminae	---	---
FK3-81 A	8	do.	1.1 ft	Medium gray, massive argillite	---	0.002
FK3-81 B	8	do.	1.1 ft	do.	---	.003
FK3-81 C	8	do.	.8 ft	Dark gray to black, shaly argillite	---	.002

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-81 D	8, Delaware quarry	channel	0.8 ft	Black shaly argillite	---	0.011
FK3-81 E	8	do.	1.2 ft	Dark gray massive argillite	---	.029
FK3-81 F	8	do.	1.0 ft	Medium to light gray	---	.016
FK3-81 G	8	do.	1.0 ft	Medium to light gray argillite	---	.010
FK3-82 A	8	do.	1.1 ft	Medium gray massive argillite	0.034	.031
FK3-82 B	8	do.	1.1 ft	do.	.014	.014
FK3-82 C	8	do.	.8 ft	Dark gray to black, shaly argillite	.030	.033
FK3-82 D	8	do.	.8 ft	Black shaly argillite	.029	.028
FK3-82 E	8	do.	1.2 ft	Dark gray massive argillite	.011	.013
FK3-82 F	8	do.	1.0 ft	Medium to light gray argillite	.008	.011

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-82 G	8, Delaware quarry	channel		Medium to light gray argillite, few sandy laminae	0.002	0.004
FK3-83 A	8	do.	1.1 ft	Medium gray massive argillite	.001	.003
FK3-83 B	8	do.	1.1 ft	do.	.001	.004
FK3-83 C	8	do.	.8 ft	Dark gray to black, shaly argillite	.001	.004
FK3-83 D	8	do.	.8 ft	Black shaly argillite	.013	.018
FK3-83 E	8	do.	1.2 ft	Dark gray massive argillite	.016	.016
FK3-83 F	8	do.	1.0 ft	Medium to light gray argillite	.012	.013
FK3-83 G	8	do.		Medium to light gray argillite, few sandy laminae	.010	.013
FK3-84 A	8	do.	1.1 ft	Medium gray massive argillite	---	.005
FK3-84 B	8	do.	1.1 ft	do.	---	.016

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-84 C	8, Delaware quarry	channel	0.8 ft	Dark gray to black, shaly argillite	---	0.005
FK3-84 D	8	do.	.8 ft	Black shaly argillite	---	.012
FK3-84 E	8	do.	1.2 ft	Dark gray massive argillite	---	.010
FK3-84 F	8	do.	1.0 ft	Medium to light gray argillite	---	.019
FK3-84 G	8	do.	1.0 ft	Medium to light gray argillite, few sandy laminae	---	---
FK3-85	8	grab	5.0 ft	Dark gray argillite	---	0.009
FK3-87	9	do.	---	Pyritiferous black shaly argillite	---	.008
FK3-90	4, Raven Rock	do.	---	Pyrite-rich sandstone	0.003	.004
FK3-97	2, Kieffer quarry	channel	0.5 ft	Medium-grained limonitic arkosic sandstone	.021	.022
FK3-98	2	do.	.5 ft	do.	.016	.015

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-99	2, Kieffer quarry	channel	0.8 ft	Medium-grained limonitic arkosic sandstone	0.035	0.031
FK3-100	2	do.	.5 ft	do.	.018	.021
FK3-101	2	do.	.3 ft	do.	.024	.066
FK3-102	2	do.	.5 ft	do.	.016	.054
FK3-104	2	do.	5 ft	Purple-gray mudstone	.004	.006
FK3-105	2	do.	.8 ft	Medium-grained limonitic arkosic sandstone in contact with mudstone lens	.016	.010
FK3-106	2	do.	.1 ft	Dark purple mudstone under FK3-105	.095	.047
FK3-107	2	do.	.3 ft	Sandstone lens with clay pebbles, within mudstone lens and subjacent to FK3-106	.022	.014
FK3-108	2	do.	.2 ft	Purple mudstone	.012	.010
FK3-109	2	do.	.5 ft	Medium grained arkosic sandstone with "specks" of limonite	.006	.004

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Table 1.--Assay data for samples of Triassic rocks from Hunterdon County, N. J., and Bucks County, Pa.--Continued

Sample number	Locality	Type of sample	Length of sample	Description	Uranium (percent)1/	Equivalent Uranium (percent)2/
FK3-110	3, Lipman quarry	channel	1.0 ft	Fine-grained, arkosic platy, limonitic sandstone	0.012	0.025
FK3-111	3	do.	.8 ft	do.	.010	.056
FK3-112	3	do.	.4 ft	do.	.008	.029
FK3-113	3	do.	.4 ft	do.	.008	.023
FK3-114	3	do.	.5 ft	Medium-grained, arkosic sandstone with "specks" of limonite; subjacent to FK3-112	.001	.002
FK3-115	5, Reading School	grab	---	Fine-grained, arkosic, pyritiferous sandstone	.044	.044
FK3-119	5	do.	---	do.	.006	.035

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The observable extent of the zone of radioactive argillite, therefore, as shown by outcrop measurements of radioactivity and samples, is from approximately the center of the quarry northward about 230 feet to the stream. The most radioactive part of the zone is black fissile argillite. No uranium minerals have been observed. Pyrite is common, though not abundant, as coatings on joints and as finely disseminated euhedral grains in the gray and black argillite. One patch of malachite about the size of a fifty-cent piece was found in a block of the red massive argillite about 10 feet below the radioactive zone. It was not radioactive.

Locality 9

Outcrops of argillite (locality 9, fig. 1) in the first creek south of Warford Creek, about 2.5 miles north of Byram, N. J. are radioactive.

A bed of black, fissile pyritiferous, argillite about 2 feet thick measures as much as 0.15 mr/hr and averages about 0.1 mr/hr. A sample FK3-87) contained 0.008 percent equivalent uranium. The black argillite grades upward into nonradioactive gray argillite that in turn grades into a sequence of red argillite about 60 feet thick. About 10 feet of gray argillite with mud-cracked layers overlies the red sequence. Another thick sequence of red argillite overlies the mud-cracked gray beds. None of the rock above the 2-foot black bed is radioactive.

Localities 10 and 11

Uraniferous argillite occurrences at localities 10 and 11 (fig. 1) are 0.1 and 0.2 mile respectively upstream from State Highway 32 in the stream 1 mile north of Delaware quarry. The more easterly occurrence is a zone of black argillite about 2 feet thick whose radioactivity measures from 0.1 to 0.2

mr/hr. Mud-cracks filled with grey argillite are common in this zone. The uraniferous rock contains a few laminae, about 0.5 mm thick, of pyrite.

Localities 12, 13, and 14

Three uraniferous argillite occurrences are located along Tohickon Creek, starting from the first bridge west of the Delaware River across the Creek, about 2 miles northwest of Point Pleasant, Pa. The first occurrence (14) is about 0.5 mile downstream from the bridge; the second (13) is about 0.75 mile downstream from the bridge; and the third (12) is 500 feet downstream from 13. (See fig. 1.)

At locality 14 the radioactive rock is a black argillite, 2 to 3 feet thick, which measures 0.12 mr/hr. Two feet of black argillite at locality 13 measures 0.08 mr/hr; mud cracks are abundant about 4 feet below this rock. Slightly radioactive red argillite occurs at locality 12, where a 2-foot stratigraphic thickness measures 0.05 mr/hr. The rock overlying and underlying this 2-foot zone measures about 0.02 mr/hr.

Locality 15

Outcrops of argillite (locality 15, fig. 1) in a dirt road 1.5 miles northeast of Pipersville and 0.3 mile north of Tohickon Creek, Bucks County, Pa. have a radioactivity of about 0.1 mr/hr. The outcrops are near the edge of the road and very poorly exposed. The radioactive zone is part of a unit of gray argillite and siltstone of unknown thickness. It appears to be about 4 feet below a unit of red argillite. About 3 feet of the gray argillite is radioactive; a grab sample (FK3-79) of it contains 0.007 percent equivalent uranium.

Locality 16

A section, about 15 feet thick, of dark gray to black argillite and shale (locality 16, fig. 1) is exposed by a roadcut along U. S. Highway 611, a quarter of a mile northwest of Pipersville, Bucks County, Pa. The rocks strike N. 50° E. and dip 10° NW. Near the middle of the section a 2- to 4-foot zone of shaly and massive argillite is radioactive. This zone crops out continuously for about 400 feet along the dip of the beds. Samples (FK3-8 through FK3-13) from the radioactive zone range from 0.001 to 0.007 percent uranium and average 0.004 percent uranium over a thickness of 4 feet.

CONCLUSIONS

None of the occurrences of radioactive rock described in this report are now of significant economic importance; all are too small and too low in uranium content. Other occurrences are likely to be found, but the data are too few to predict their nature and location. Some inferences may be made, however, from the nature of the known occurrences and their comparison to similar uranium deposits elsewhere in the United States.

The uranium in the argillite may be syngenetic. This origin is suggested by: a) the homogeneous distribution of uranium in certain dark gray or black units; b) the wide lateral distribution (at least several hundred feet, possibly thousands of feet) of uranium in any particular unit as compared to a limited vertical distribution (less than 10 feet); c) no observable relation between uranium content and structure; and d) a low uranium content (generally about 0.010 percent). The chief differences between the uraniferous argillite and typical uraniferous black shale occurrences, such as the Chattanooga shale, Nonesuch shale, or the alum shale of Sweden, are that the argillite is nonmarine and probably contains less carbonaceous or bituminous matter (judging from its color); and its lithologic units, both uraniferous and nonuraniferous, are much less extensive.

The uranium in sandstone of the Stockton lithofacies is associated with euhedral pyrite and argillic and limonitic alteration. As these features are epigenetic, the uranium is inferred to be epigenetic. The intensity and localization of the alterations suggest that hydrothermal solutions may have been the transporting agent of the uranium and pyrite.

Analogy with other uranium deposits in sandstone elsewhere in the United States, most of which are in Colorado and Utah, may be the best way to evaluate the Stockton occurrences. Several geologic features generally found with sandstone deposits of this type are: a) the common occurrence of mud pebbles and lenses, and pyrite or limonite b) the concentration of uranium at or near disconformities, many of which are stream channels; c) the general occurrence of an impermeable shale mudstone, or similar rock, as the underlying stratum; and d) the fact that the host rock is commonly a sandstone of fluvial origin. The Stockton uranium occurrences, however, lack carbonaceous material or significant quantities of copper or vanadium which are two important features in the sandstone type deposits of the Colorado Plateau. This lack of elements commonly associated with uranium suggests that mineralization was weak. Although the role that carbonaceous matter plays in the deposition of uranium is only in the realm of theory, its presence and abundance at so many deposits in western United States make it empirically an important guide. Because it is generally sparse in the Triassic rocks of New Jersey and Pennsylvania, and because copper and vanadium are lacking at the Stockton occurrences described herein, it is believed unlikely that any high-grade uranium deposits occur in the Stockton formation.

LITERATURE CITED

Bradford, W., McLaughlin, D. B., Watson, E. H. and others, 1950, Geologic map of Bucks County, Pa.: Pennsylvania topographic and Geologic Survey, Scale 1:62,500

Kummel, H. B., 1940, The geology of New Jersey: Dept. of Conservation and Development, State of New Jersey, Bull. 50, Geologic series.

Lewis, J. V. and Kummel, H. B., 1931, Geologic map of New Jersey: New Jersey Geol. Survey, Scale 1:250,000.

McLaughlin, D. B., 1944, Triassic stratigraphy in the Point Pleasant district, Pennsylvania: Pa. Acad. Sci. Proc. v. 18.

______________, 1945, Type sections of the Stockton and Lockatong formations: Pa. Acad. Sci., Proc., v. 19.

______________, 1949 Triassic facies in the Delaware Valley: Pa. Acad. Sci. Proc., v. 23.

McLaughlin, D. B., and Willard, Bradford, 1950, Triassic facies in the Delaware Valley: Pa. Acad. Sci. Proc., v. 23.

UNPUBLISHED REPORTS

Johnson, D. H., 1950, A torbernite deposit near Stockton, Hunterdon County, New Jersey: U. S. Geol. Survey Trace Elements Memo. Rept. 125.

Stewart, R. H., 1951, Radiometric reconnaissance examination in southeastern Pennsylvania and western New Jersey: U. S. Geol. Survey Trace Elements Memo. Rept. 255.