UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PHYSICAL EXPLORATION FOR URANIUM DURING 1951 IN THE SILVER REEF DISTRICT WASHINGTON COUNTY, UTAH

By

Frederick Stugard, Jr.

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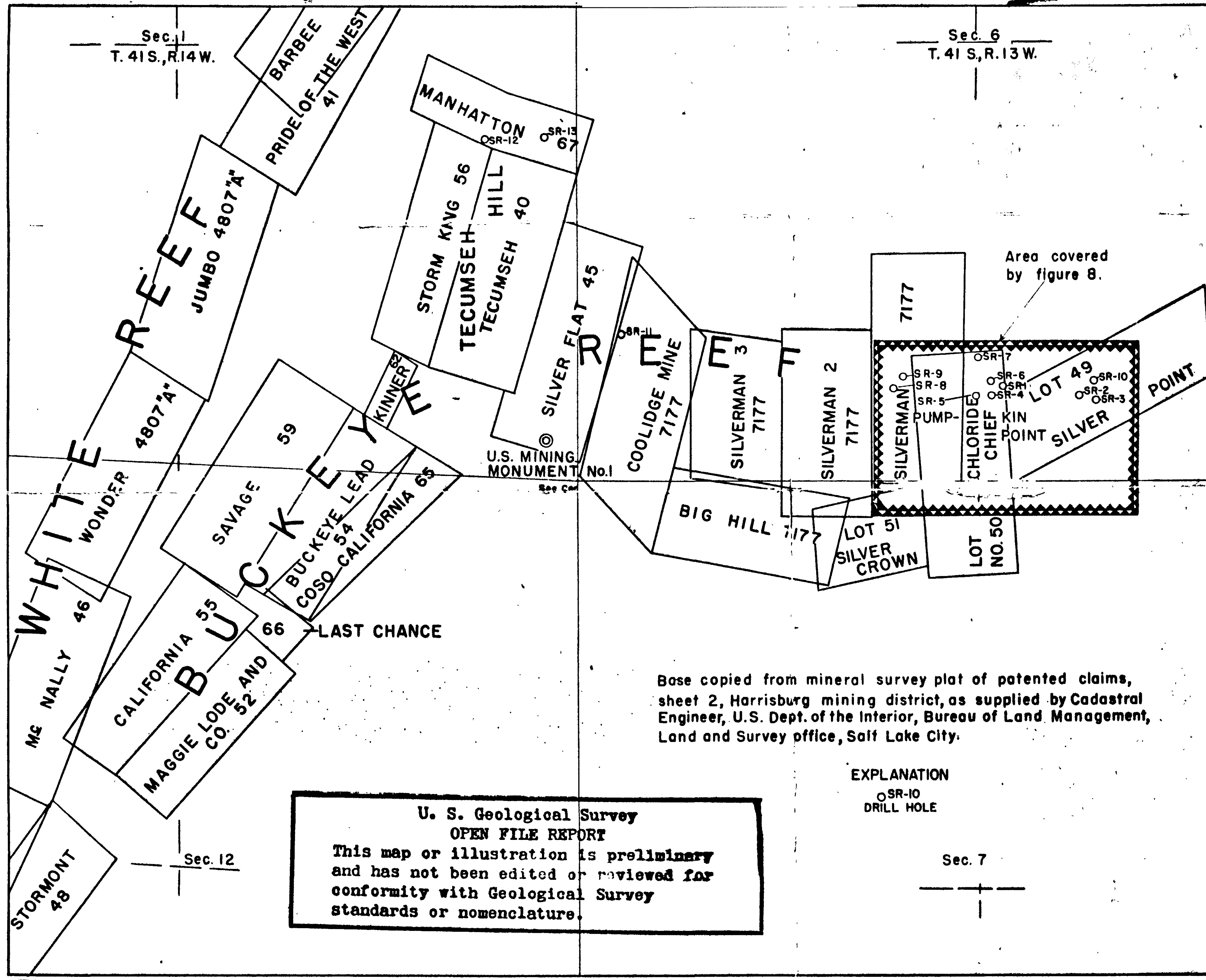
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TRACE ELEMENTS INVESTIGATIONS REPORT



U. S. Geological Survey
OPEN FILE REPORT
This map or illustration is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

FIGURE 2.-MINERAL SURVEY PLAT SHOWING LOCATIONS OF DRILL HOLES, SILVER REEF DISTRICT, WASHINGTON COUNTY, UTAH.

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PHYSICAL EXPLORATION FOR URANIUM DURING 1951 IN THE SILVER REEF DISTRICT, WASHINGTON COUNTY, UTAH

By Frederick Stugard, Jr.

ABSTRACT

During 1951 a joint exploration program of the most promising uraniferous areas in the Silver Reef district was made by the U. S. Geological Survey and the U. S. Atomic Energy Commission. A U. S. Bureau of Mines drill crew, on contract to the Atomic Energy Commission, did 2,450 feet of diamond drilling under the geological supervision of the U. S. Geological Survey. The purpose of the drilling was to delineate broadly the favorable ground for commercial development of the uranium deposits. Ten drill holes were located around Pumpkin Point, which is the northeastern end of Buckeye Reef, to probe for extensions of small ore shoots mined on the Point in fine-grained sandstones of the Chinle formation. Three additional holes were located around Tecumseh Hill to probe for extensions of the small showings of uranium-bearing rocks of Buckeye Reef.

Only one trace of uranium mineral was detected in the 13 drill holes by logging of drill cores, gamma-ray logging of the holes, and analysis of many core splits from "favorable" lithology. Extensive traversing with Geiger counters throughout the district and detailed geologic mapping of areas on Buckeye Reef and on East Reef indicate that the chances of discovering significant uranium deposits in the Silver Reef district are very poor, because of: highly variable lithology, closely faulted structure,

and obliteration of the shallow uranium-bearing lenses by silver mining. Most of the available ore in the district was in the Pumpkin Point area and has been mined during 1950 to 1953. No ore reserves can be computed for the district before further development work. The most favorable remaining area in the district is now being explored by the operators with Atomic Energy Commission supervision.

INTRODUCTION

The Silver Reef mining district (fig. 1) formerly known as the Harrisburg district, is near Leeds, about 17 miles north of St. George, in Washington County, Utah. The district includes part of T. 41 S., R. 13 and 14 W. (Salt Lake base and principal meridian); it is easily accessible by unsurfaced roads from Leeds, which is on U. S. Highway 91. The nearest purchasing depot for uranium ore is at Marysvale, about 163 miles by road from Leeds.*

The uranium deposits that were investigated are near abandoned silver mines and prospects in sandstones of the Chinle formation of late Triassic age. As shown by Butler, et al. (1920), Ball (1920), Dobbin (1939), and Proctor (1949, 1950), the Silver Reef district is on the nose of the northward-plunging Virgin anticline. The anticline has been breached by faulting and erosion; weathering has developed hogbacks, known locally as reefs, of Shinarump conglomerate and sandstone members in the Chinle formation, both of late Triassic age. The Buckeye and White Reefs on the west limb of the Virgin anticline, and East Reef, on the east limb of the anticline, are prominent features of the district.

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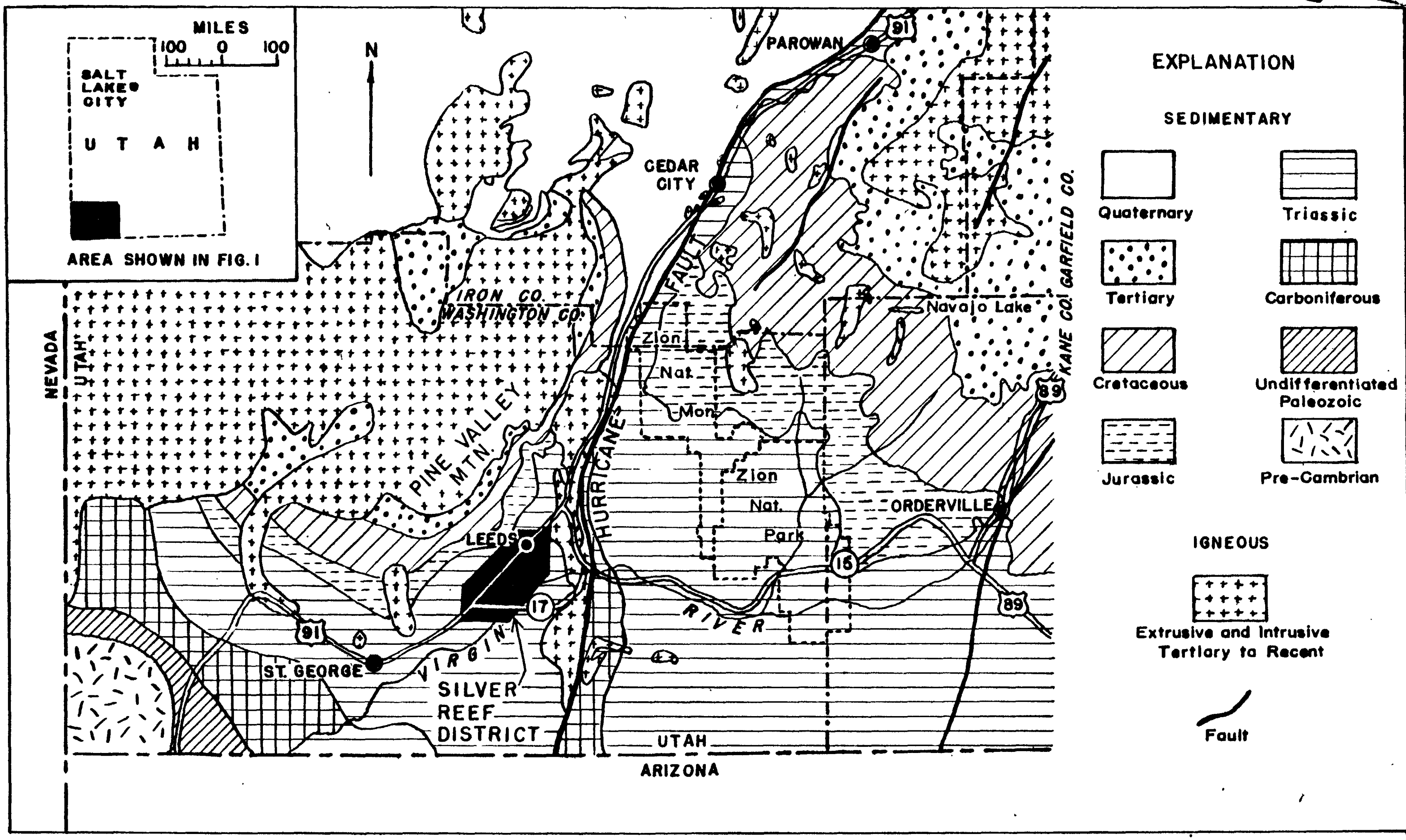

AFTER: BUTLER ET AL, U.S.G.S. PROF. PAPER 111, 1920

10 5 0 10 20 MILES

FIGURE 1.—INDEX MAP OF SOUTHWESTERN UTAH, SHOWING SILVER REEF DISTRICT

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Discovery of silver ore in 1873 resulted in the formation of the Harrisburg mining district in June 1874. The name Silver Reef was soon applied to the new district. Among the Parrusit Indians there grew within a few years a mining camp of 1,500 men, who sought the wealth so near the surface and brought a new word into the language - "chlorider". Silver chloride was found as an ore mineral in sandstones for the first time at Silver Reef.

About 7,200,000 ounces of silver, valued at about $7,800,000, were produced from the Silver Reef district between 1875 and 1909. The ore mineral was cerargyrite (silver chloride, "horn silver") that impregnated sandstone beds or "reefs". In 1881 the presence of uranium minerals in the silver workings was first recorded. Geologic attention was soon directed to the district because of the unusual mineralogy of the silver deposits.

Previous work

Previous geologic reports on the Silver Reef area include two reports made during silver mining operations (Rothwell, 1880 and Rolker, 1881), an account by Butler and Heikes (Butler, et al., 1920), an unpublished company report by Crane (1920), an unpublished geologic map and report by Sidney Ball (1920), and a district study by Proctor (1948). The early reports, by Rothwell and Rolker, give detailed information on the silver ore occurrences no longer available for observation. Butler, et al. (1920) described the geologic occurrence of the ore, the total production and the history of the now ghost district. Crane (1920) made a company report on ore reserves in the district and speculated on origin of the metal ores. Ball (1920) served as a consulting economic geologist for the company holding most of the properties in the ghost district, and made the first map showing the topography, stratigraphy, and most of the mine workings of the district. Proctor in his dissertation (1949) made a detailed study of the sedimentary rocks; his geologic map of the district, prepared with the use of aerial photographs, indicated for the first time that the multiple "reefs" of the district are probably one "reef" with repeated outcrops due to thrust faulting. A complete bibliography of previous contributory articles is given by Proctor (1949, p. 163-167).

More recently unpublished reconnaissance reports have been made on uranium potentialities of the district for three government agencies (Smith, 1940; Towle and Anderson, 1950; Stugard, 1950; Wyant, Stugard, and Kaiser, 1950; Everhart, 1950). Recommendations for physical exploration of the district for uranium were presented after further sampling of uranium ore showings (Stugard, 1951) by the Geological Survey.

Purpose of exploration

An exploration program by the U. S. Geological Survey on behalf of the Division of Raw Materials of the Atomic Energy Commission was commenced in May 1951 to delineate broadly the favorable ground for commercial development of the uranium deposits that had been studied briefly in earlier reconnaissance (Stugard, 1951). Geologic mapping and the location and logging of drill holes was done by the U. S. Geological Survey; diamond drilling was carried out by a U. S. Bureau of Mines drill crew on behalf of the Atomic Energy Commission. Field work in the area was completed in December 1951. This report summarizes results of the diamond drilling.

The coöperation of Messrs. C. C. Towle and T. P. Anderson of the Atomic Energy Commission is gratefully acknowledged, as is that of all Bureau of Mines personnel involved. Mr. R. W. Brown of Western Gold Mines Inc., has kindly permitted use of private reports on the district. Most samples were prepared and analyzed in the Denver Trace Elements laboratories of the Geological Survey; several minerals were identified in the Washington Trace Elements laboratories of the Geological Survey.

Methods of exploration

Four claims were investigated by sinking 13 diamond drill holes (fig. 2) to an average depth of 189 feet (figs. 3 to 7), the shallowest hole being 109 feet, the deepest 329 feet. Core samples were split and analyzed (1) wherever uranium minerals were noted, (2) from zones that yielded abnormal radioactivity in the hole or in the core, and (3) from zones lithologically similar to other beds in the district that contain uranium, vanadium, silver, or copper.

Gamma-ray logs were made of holes SR-1 through SR-6, and SR-9 through SR-13. Holes SR-7 and SR-8 were blocked by caved material before the logging apparatus arrived at the site. Scanning of all cores with a Geiger-Mueller counter provided an almost complete check of the gamma-ray data on the holes inasmuch as the overall core recovery in bedrock was 90.6 percent (table 1).

Figure 2 shows the locations of diamond drill holes SR-1 through SR-13. In each completed hole a standpipe was set in concrete, to mark the location for future reference.

Table 1.—Core-recovery in drilling program at Silver Reef district, Utah, 1951.

Hole	Depth of hole (feet)	Depth to bedrock (feet)	Core recovery in bedrock (percent)
SR-1	263.45	24.3	81.9
SR-2	135.20	3.9	96.4
SR-3	123.60	16.0	97.0
SR-4	109.5	21.7	96.1
SR-5	139.7	18.0	96.6
SR-6	121.2	37.5	99.8
SR-7	164.2	79.75	79.4
SR-8	197.05	47.2	94.1
SR-9	203.35	59.8	96.5
SR-10	128.5	37.5	91.1
SR-11	237.8	34.0	90.8
SR-12	329.14	43.0	94.6
SR-13	302.1	22.0	80.8

Average bedrock core recovery for 13 holes, 2,454.79 feet of drilling (2010.14 feet of bedrock) was 90.6 percent.

The first 10 drill holes around Pumpkin Point (fig. 2) were located to probe for extensions of known ore shoots; the three holes around Tecumseh Hill were planned to prospect for continuations of Buckeye Reef, on which showings of uranium minerals occur in the vicinity of old silver workings. No holes were drilled on White Reef or East Reef.

PROPERTIES INVESTIGATED

All the silver and uranium ore produced from the Silver Reef district, has come from sandstone beds, or "reefs", chiefly White Reef, Buckeye Reef, and East Reef (Proctor, 1949; Stugard, 1951). The 1951 exploration was largely directed at the exploration of the northern end of Buckeye Reef in the vicinity of Pumpkin Point (fig. 2), the only area in the district where mining has been done for uranium rather than silver. Three diamond drill holes were put down on other parts of Buckeye Reef in the Tecumseh Hill area. Exploration in the rest of the district consisted of a radioactivity reconnaissance of White Reef and geologic mapping of areas of known uranium occurrences on East Reef.

Buckeye Reef

The curved line of Buckeye Reef is generally outlined by patented claims shown in figure 2, namely the California, Savage, Kinner, Storm King, Tecumseh, Silver Flat, Coolidge, Silverman, Chloride Chief, and Silver Point claims. Water in irrigation ditches flows within several hundred feet of most of Buckeye Reef.

Location and ownership

The Chloride Chief, Silver Point, Silver Flat, and Manhatton claims were explored in 1951. These patented claims were controlled by Mr. Alex Colbath of St. George, Utah, until his death in 1952, although it is understood that sale of the properties was in progress at that time to Western Gold Mines, Inc., 42 Broadway, New York 4, New York.

Geology

The lithology of the Pumpkin Point area is represented in figures 3 through 6, and the geology in figure 8. Pumpkin Point is bounded on the south by a normal fault marked by a fault-line scarp. The area is underlain by a northerly dipping sequence of very fine-grained sandstones, siltstones, and lenses of clay-pebble conglomerate and unconsolidated clays; north of the area these rocks are covered by alluvium. The clayey materials contain casts and scanty carbonized remains of plants of Triassic age. Outcrops of the sandstone show prominent cross bedding. Dips are variable.

Thin sections from drill cores show that the sandstones are almost entirely composed of quartz with interstitial calcite. The quartz grains normally range from 0.06 mm to 0.16 mm across. Extreme grain size ranges noted are 0.04 to 0.32 mm. Very minor quantities of clays, organic material, microcline, plagioclase, muscovite, tourmalines, zircon, magnetite, hematite, and leucoxene were noted in thin sections. Core from the lower part of drill hole SR-11 displays gypsum veins. Slides of the thin limestone and chert beds from 227-foot depth in SR-11 show both of these rocks to be microcrystalline replacements of the original sandstone.

The Tecumseh Hill extension of Buckeye Reef is bounded on the east by a fault (Proctor, 1948). Prior to diamond drilling, it was assumed that the total displacement on the fault was only several feet, the displacement observed in an abandoned shaft on the Silver Flat claim. However, drill hole SR-11 was bottomed at 237.8 feet without cutting the reef-forming sandstone at the anticipated shallow depth. At 226.8 feet, the drill cut the top of a 0.5-foot layer of replacement chert and limestone. This layer can be used as an horizon marker as it crops out at approximately 100 feet above the sandstone 800 feet to the south of SR-11. The dip of the horizon marker, measured at the surface, is about 16° N. It is probable that on the east side of the fault in question, the horizon marker dips evenly about 16° from its outcrop northward past SR-11, where the horizon marker is 227 feet down. On the west side of the fault, the dip is eastward and the sandstone beds are a topographic high (Tecumseh Hill). This indicates that the dropped block east of the fault along the base of Tecumseh Hill has undergone a scissors-like movement, with the hingeline at the south end, and that the reef-forming sandstone is 330 feet below the surface at SR-11. Further north, near the end of Tecumseh Hill, the reef-forming sandstone is probably over 500 feet below the surface. The fault observed in the abandoned shaft on the Silver Flat claim can only be a minor plane of movement in the main fault zone.

Ore deposits

Carnotite, $K_2(UO_2)_2(VO_4)_2.3H_2O$, is the only uranium mineral that has been identified from the Pumpkin Point area. Uranium may be present, however, in volborthite, $Cu_3(VO_4)_2.3H_2O$, and in the small quantities of unidentified black vanadium compounds which discolor the uranium-bearing sandstones. The carnotite and the more abundant volborthite (?) occur (1) as coatings on plant fossils lying along bedding planes, (2) as local disseminations, and (3) as coatings on near-surface fractures.

Uranium-bearing rock is usually of a darker gray hue than the barren sandstone. The color difference may be due to unidentified vanadium minerals. The ratio of V_2O_5 to U_3O_8 content of the ore produced is 6.4 to 1.

Previous workings (Doyle shaft)

Abandoned silver mines and prospects, many caved or backfilled, are numerous in the Tecumseh Hill area of Buckeye Reef (fig. 2); the lack of information as to the position and extent of the underground workings made diamond drilling in that area unfeasible. In the Pumpkin Point area of Buckeye Reef (fig. 8) there are three abandoned silver prospects: the Doyle Shaft workings and two shallow unnamed shafts, approximately 300 feet north of the Doyle Shaft. The western of the two shallow shafts is now part of the No. 5 Uranium mine. The only water encountered in any workings in the Buckeye Reef is a few feet in the lowest winze of the Doyle workings.

Production record

Figure 8 shows the extent of uranium mine workings to September 1951; the workings on Pumpkin Point are the only workings in the entire district made for uranium. The production of uranium and vanadium has come entirely from No. 4 mine (fig. 8), No. 1 mine, No. 5 mine, and since 1951 from Western Gold Mines workings not shown. Each recorded shipment represented ore from two or more pits, except for the first shipment in April 1950, which came entirely from No. 4 mine after very careful hand sorting. Total production of uranium ore from the Silver Reef district has been a few hundred tons.

There is no record of any silver production from the Pumpkin Point area, including the Doyle shaft. The uranium-vanadium production from Pumpkin Point was by a former lessee, Frank Willis of Leeds, Utah, by successive sub-lessees--Frank L. Morgan of Springville, Utah, and Florencita Mining Company of Salt Lake City, Utah, and since 1951 by Western Gold Mines, Inc.

The Tecumseh Hill area supplied better than one half of the known 7,200,000 ounces of silver produced between 1875 and 1909; there has been no production since 1909.

1951 government exploration program

Colluvium was bulldozed off bedrock in 9 areas on Pumpkin Point, in an effort to find additional exposures of uranium minerals such as led to the 5 workings put down by the operators. No abnormal radioactivity and no uranium minerals were exposed by the bulldozing.

Diamond drill holes SR-1, -4, -5, -6, and -7 were put down in selected spots to search for continuations of the uranium ore lenses removed during operation of No. 5 mine by lessees. Drill holes SR-2, -3, and -10 were located to probe for possible extensions of the ore bodies mined by the operators in No. 1 mine. Drill holes SR-8 and SR-9 were sunk to search for possible down-dip or down-plunge extensions of a small, low grade showing of uranium minerals in the southwest end of the Doyle Shaft workings (fig. 9). Drill hole SR-11 was put down to explore the sandstone that forms Tecumseh Hill and was located approximately 200 feet east of the area of abandoned silver mines and prospects.

Analyses of all core-splits shown on the logs are given in table 2. No visible uranium minerals were found in any hole except SR-4, where carnotite was observed on plant fossils and in sandstone from 42.95 to 43.30 feet.

Diamond drill holes SR-1 through SR-6 were checked with Geological Survey gamma-ray logging apparatus. The results in "counts per minute" (c.p.m.) are entered directly on the core logs (figs. 3 through 6) wherever readings greater than normal background were detected. In general, 100 to 200 c.p.m. is normal background; less than 500 c.p.m. is not significant; 500 to 1,000 c.p.m. represents "weak mineralization"; 1,000 to 10,000 c.p.m. represents "strong mineralization", and more than 10,000 c.p.m. would represent "very strong mineralization". In diamond drill holes SR-7, SR-8, SR-9, and SR-10, a hand-operated gamma-ray probe showed no abnormal radioactivity to 225 feet from surface. Corresponding drill cores showed no abnormal radioactivity.

Samples of fossiliferous sandstone and shaly material coated with carnotite have in recent years been collected by several geologists from the dump of the Doyle shaft. During the 1951 exploration program, the man-way was repaired and the workings were carefully explored to find the source of the radioactive material. As indicated on figure 9, the only radioactive material in place is a lens of shaly material about a foot across, containing black plant remains, found in the western end of the workings. The air near the weakly radioactive lens contains sufficient radon to cause high readings on a Geiger-Mueller rate meter. A channel across this lens, sample FS 25-51 assayed 0.012 percent eU, .012 percent U, 0.87 percent V_2O_5, 0.60 percent Cu, and 7.40 oz. Ag per ton. Drill holes SR-8 and SR-9, placed 150 feet away, down-dip and down-plunge, show that the lens is very small and is not closely accompanied by other radioactive lenses. The most important result of the mine mapping was the clear representation of the small-scale lenticularity of the favorable beds.

The data obtained from the closely spaced drill holes around the base of Pumpkin Point indicate that if any uranium ore shoots are present beyond the base of the hill they are sparse and of small width. The crossbedded, lenticular habit of the sandstone in these deposits prevents any inference of ore bodies beyond what is in sight. No uraniferous rock of marketable grade remains in surface exposures.

Autunite has been reported by Rolker (1881, p. 24-26) to occur at the lost "Gad Shaft", As quoted by Butler, et al.(1920, p. 590) Rolker states:

> "As another matter of interest I found the seams, in which the vegetable remains are covered with autunite,[1] which is quite frequent around the Gad Shaft, and the two carbonates of copper, unproductive, with pay seams, frequently above and below them.
>
> 1 This mineral is possibly carnotite."

No autunite has been found in the district by the writer. An old claim plat of the Buckeye mine on a scale of 1 inch to 20 feet was kindly supplied the writer by Western Gold Mines, Inc., in 1951; on this plat are shown "Gads Shaft No. 1" and "Gads Shaft No. 2". This area on the Buckeye Lead patented claim (fig. 2) on Buckeye Reef was closely examined in the autumn of 1951 but no uranium minerals or abnormal radioactivity were found. No mention of uranium minerals was found in existing copies of the Silver Reef newspaper (Silver Reef Miner) for 1882.

Mining since 1951

From April 1952 to the present (May 1953), Western Gold Mines, Inc., has mined Pumpkin Point for uranium. Two new adits have been made near the No. 5 mine; these new adits are not shown on figure 8. Removal of rock has been guided by closely spaced wagon drill holes. Wherever ore has been cut by the wagon drill, the spacing has been made closer for surrounding holes. Ten-foot spacing of the holes formed the lenses or pods of ore, and five-foot spacing of holes delineated successfully the pods as they were mined. Ore along near-vertical fractures has been followed out several feet beyond the edges of the ore lenses. The ore mined has come from the same strata or "favorable horizons" mined in the earlier workings; the ore lenses are discontinuous and selective mining has followed exploration by the wagon drill. The largest ore lens mined was about 60 by 60 feet, and from less than 1 to about 3 feet in thickness. No ore reserves have been blocked out ahead of current mine workings.

It is important to note that the main ore-bearing bed has now been followed in the No. 5 mine a few feet northward of the workings shown in figure 8, and at that point is channeled out, so that the workings cut alluvium. The problem of finding further ore in that horizon now becomes to find the part of the bed not eroded.

Leeds Uranium Mine

Location and ownership

The Leeds Uranium Mine is an open cut immediately north of the village of Leeds and about 1,200 feet south of the Doyle Shaft. The owner is Walter C. Eagar of Leeds, Utah. An unsurfaced road from U. S. Highway 91 leads very close to the open cut.

Geology and structure

The Leeds Uranium Mine is in the outcrop of a block of Chinle formation, between two northeast-trending faults. The open cut is in very fine-grained yellowish sandstone in which cross bedding is shown by the undulations and the pinch-and-swell shape of dark colored layers containing carbonaceous matter and sparse casts of plant fossils.

Ore deposits

No ore is in sight at the Leeds Uranium Mine; however, the pit walls show a few partings of carbonaceous material and films of plant remains, with faint stains of volborthite. Ore examined in December 1950 prior to shipment was mostly shaly carbonaceous rock with casts of fossil plants, sporadically coated by carnotite and volborthite. The ore lens was completely removed from this pit and discovery of nearby lenses would require physical exploration.

Previous workings

The Leeds Uranium Mine (not to be confused with the abandoned Leeds mines on White Reef) is an open-cut made in 1950. Three small pits nearby had previously been made by prospectors for silver. No other workings are in the vicinity.

Production record

The only production from the Leeds Uranium Mine was one shipment on 27 June 1951 of 6.26 tons dry weight (1.5 percent moisture) to the Vitro Chemical Company buying station at Salt Lake City. The shipment assayed 0.25 percent U_3O_8 and 1.44 percent V_2O_5 at the mill.

1951 government exploration program

Reconnaissance of surrounding outcrops disclosed no abnormal radioactivity. Channel samples were taken at 10-foot intervals completely around the open cut; analyses of these and other samples are given in table 3.

Table 3.--Analyses from Leeds Uranium Mine, Silver Reef district, Washington County, Utah 1/.

Field number	Laboratory number	Material	Equivalent uranium (percent)	Uranium (percent)
FS 79-51	55528	1.4 ft., very fine-grained sandstone, pale yellowish-orange, at southeast corner of pit.	0.005	0.005
80-51	55529	3.3 ft., very fine-grained sandstone, yellowish-gray 10 ft. from previous sample.	.003	.001
81-51	55530	4.2 ft., 0.4 clay pebble conglomerate in sandstone.	.002	.001
82-51	55531	3.0 ft., pale yellowish-orange sandstone with 0.2 ft. plant remains.	.010	.003
83-51	55532	4.0 ft., very fine-grained sandstone, with partings of carbonaceous material.	.022	.014
84-51	55533	3.1 ft., very fine-grained sandstone containing 0.2 ft. clay pebble conglomerate.	.014	.011
85-51	55534	2.6 ft., very fine-grained sandstone, yellowish-gray with carbonaceous partings.	.023	.016
86-51	55535	1.8 ft., very fine-grained sandstone, yellowish-gray with limonitic staining.	.021	.004
87-51	55536	1.6 ft., clay pebble conglomerate.	.001	.001
88-51	55537	1.0 ft., very fine-grained sandstone, pale yellowish-orange. Immediately below preceeding sample.	.001	<.001
89-51	55538	3.9 ft., sandstone above clay pebble conglomerate bed, 75 ft. from pit.	.000	<.001

1/ Analyses for radioactivity by Furman; chemistry by Meadows and Mountjoy.

White Reef

White Reef is outlined by the McNally, Wonder, Jumbo, Pride of the West, and Barbee claims on figure 2. An old access road extends along the northwest base of the reef, as far as the Cobb mine (Stugard, 1951). The patented claims covering the entire White Reef were controlled by Mr. Alex Colbath until his death in 1952, at which time it is understood that sale to Western Gold Mines, Inc. was in progress.

A reconnaissance for radioactivity at White Reef was made during the 1951 exploration program. This included examination of most of the workings in the two mines still safe to enter, the Cobb mine and the Leeds mine. The only abnormal radioactivity detected in the mines accompanied several paper-thin films on plant remains in mudstone lenses within the Leeds mine.

Partial analyses of a few grams of black carbonaceous material scraped from these plant remains are given in table 4. The analyses show that this same scanty plant material contains much of the silver that is in the rock.

Tailings dumps from the long-abandoned Leeds amalgamation mill were traversed and no abnormal radioactivity was detected. The tailings from the abandoned Christy mill, sampled a year previously (Stugard, 1951), showed a uranium content of 0.009 percent.

A few rock chips with carnotite coatings were found by removal of rotted planks of old ore-loading platforms near several of the abandoned and caved silver mine shafts in back of White Reef. These rock chips, which had fallen through cracks between the boards, contain the only secondary uranium minerals observed on White Reef. Prospects for significant uranium discoveries on White Reef are considered poor, on the basis of mine examinations.

Table 4.--Analyses from White Reef, Silver Reef district, Washington County, Utah.

Field no.	Lab. no.	Material	Equivalent uranium (percent)	Uranium (percent)	V_2O_5 (percent)	Cu (percent)	Ag (oz./ton)
FS 23-51	51848 1/	Leeds mine. Scrapings of black film from plant fossils in very fine-grained sandstone; this sample contained visible malachite as well. Only several grams of material available.	0.078	0.092	0.10	29.73	963.32
FS 24-51	51849 1/	Leeds mine. Scrapings of black film from plant fossils in very fine-grained sandstone.	.043	.072	.07	2.12	55.20

1/ Analyses for radioactivity by Furman; chemistry by Boyes, Dufour, Horr.

Hot Rock No. 1 uranium prospect

The Hot Rock No. 1 uranium prospect (fig. 10) consists of abandoned, partly caved mine workings along a cliff face; originally worked for silver, the claim was relocated in 1951 for uranium.

Location and ownership

Hot Rock No. 1 prospect is in sec. 8 (?), T. 41 S., R. 14 W. This and eight adjacent mineral claims were located in 1951 by H. P. Robison, A. F. Robison, and Harold Huntsman, all of Fillmore, Utah. No development work has been performed since 1951. The validity of the claimants' mineral rights on these properties is currently in dispute.

Hot Rock No. 1 is on top of a steep hill and is relatively inaccessible as the nearest roadway is more than a mile away. There is no water near the site.

Geology and structure

The Hot Rock No. 1 prospect is on an erosional remnant of down-faulted reef-forming sandstone of the Chinle formation.

Ore deposits

The ore minerals, carnotite and volborthite, and the host rock are typically like that found elsewhere in the district. The ore minerals coat bedding planes, fracture surfaces, and sand grains in small, lenticular bodies of fine-grained sandstone. Table 5 gives analyses of selected high-grade material from the workings and the main mine dump.

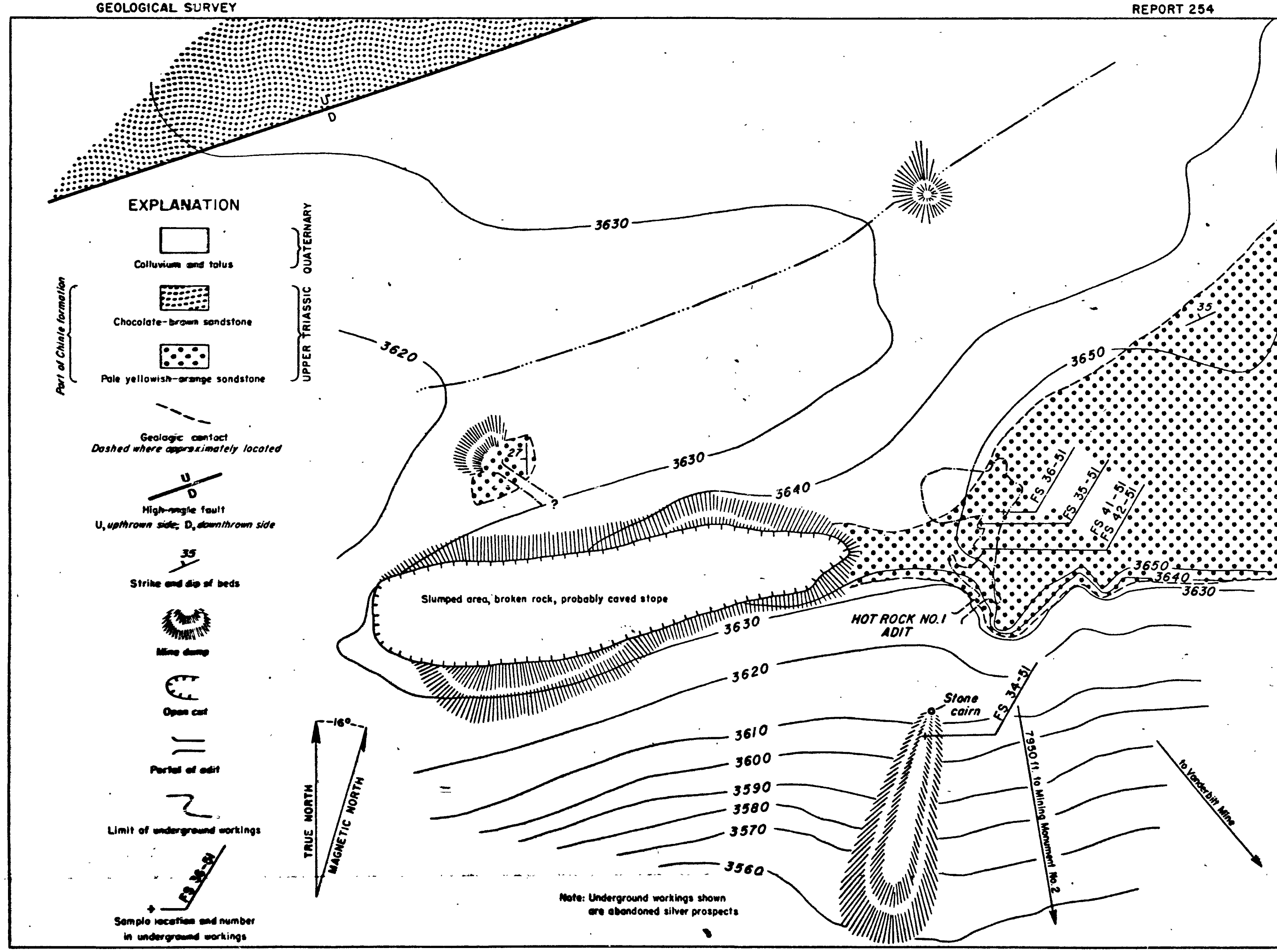

FIGURE 10–SKETCH MAP OF HOT ROCK NO. I URANIUM PROSPECT, SILVER REEF DISTRICT, UTAH

40 0 40 80 120 Feet

Contour interval 10 feet
Datum is mean sea level

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Table 5.--Analyses from Hot Rock No. 1 uranium prospect, Silver Reef district,1/ Washington County, Utah.

Field no.	Lab. no.	Material analyzed	Equivalent uranium (percent)	Uranium (percent)	V_2O_5 (percent)	Ag (oz./ton)	Cu (percent)
FS 34-51	51853	Selected high-grade grab sample from old mine dump.	0.43	.47	2.66	8.10	1.96
FS 35-51	51854	Channel sample across 1.8-foot fossiliferous bed in abandoned silver prospect.	.012	.012	.53	14.58	.38
FS 36-51	51855	Chip sample of brownish sandstone in workings, considered typical in appearance of much silver ore from the district.	.67	.60	4.51	4.30	.32
FS 41-51	52860	Channel across upper 0.7 foot of radioactive lens in silver adit.	.45	.59	2.97	5.10	1.91
FS 42-51	52861	Channel across lower 0.8 foot of radioactive lens in silver adit.	.037	.023	.67	7.00	.61

1/ Analyses by Boyes, Dufour, Furman, and Horr.

Previous workings

The abandoned silver mine workings at the Hot Rock No. 1 (fig. 10) consist of two adits and an open-cut which is probably above collapsed underground workings. The main adit, which is inclined at 30°, is in good condition except for the partially caved portal. The entrance to the main adit has been almost completely collapsed by dropped blocks along the cliff face, where prospectors had undercut the cliff. For that reason the workings could easily be blocked by further collapse of loose rock, and are unsafe. The second adit, about 150 feet northwest from the first adit, is blocked a few feet beyond the portal.

Production record

No uranium ore, and probably no silver, has been produced from Hot Rock No. 1 mine.

The sandstone that contains the ore minerals is highly lenticular, crossbedded, well-sorted, and very fine-grained. The local dip is about 35° NW. An east-trending, steeply dipping normal fault separates the prospect from the main hill to the north, and the Lucky Strike uranium prospect. The rocks are badly fractured on both sides of the fault.

1951 government exploration program

During the drilling program elsewhere in the district, the Hot Rock No. 1 prospect was mapped (fig. 10) to ascertain the practicability of further exploration.

The small ore bodies uncovered in former silver prospecting have mostly been removed, and only the two pods of uranium-bearing rock that were sampled (table 5) are in sight at present. The uranium content of the mine dump was so low that no bulk samples were taken to determine its average grade.

Lucky Strike claims

The Lucky Strike claims had been previously examined, sampled, and reported upon by Stugard, (1951). Later in 1951, the Lucky Strike claims Nos. 1, 2, and 3 were re-examined for additional exposures afforded by recent bulldozing. It was found that this work had removed most of the original uranium-bearing pods in the sandstone at Lucky Strike No. 2 but had exposed no new radioactive pods. Therefore, no additional samples were taken for analysis. Although it may still be possible to hand-pick samples of ore of marketable grade, no ore bodies can be expected because of the local close faulting of the rocks and the abrupt pinching of the lenticular bodies that contain the ore minerals.

Vanderbilt uranium prospect

The Vanderbilt uranium prospect consists of the abandoned Vanderbilt silver property relocated as a uranium-lode claim.

Location and ownership

The Vanderbilt uranium prospect is in the E 1/2 sec. 17, T. 41 S., R. 13 W. The prospect is in one of the outcrops of sandstone comprising the East Reef, the half-buried eastern limb of the Virgin anticline. It is accessible by unsurfaced road from U. S. Highway 91 at Leeds. The six claims in the Vanderbilt group were located by Waltwe C. Eagar, Leeds, Utah, and Ira L. Terry, 253 North Second West Street, Provo, Utah. Water is available at the Virgin River, 2 miles southward by unsurfaced road, at small springs about 2 miles northward, and at an abandoned two-compartment shaft, about 1,200 feet northeast of the main Vanderbilt workings. In August 1951 this shaft, which is 88 feet deep, had 22 feet of water in the bottom.

Geology and structure

The Vanderbilt mine workings are in eastward-dipping ledges of Chinle sandstone of late Triassic age, that crop out from the wind-blown sand which has buried most of the ridge. The sandstone is undulatory-and cross-bedded, and consists of two sandstone members or lentils of the Chinle formation; the lower a very fine-grained pale yellowish orange sandstone, the upper a very fine-grained red sandstone. The outcrops of red sandstone have been bleached and changed by weathering processes in irregular areas to yellowish gray and to dark yellowish orange color. Along the contact between the upper and lower sandstones lies a thin, irregular layer of clay-pebble conglomerate which has been followed downdip by the mine workings for about 190 feet. The conglomerate becomes more shaly, blacker, and richer in plant debris south of the incline.

Several feet below the first clay-pebble conglomerate is a second, thicker layer of similar composition. This second conglomerate layer in general, is entirely within the pale yellowish-orange sandstone. Along the second conglomeratic layer are mudstone pods 1 to 2 feet thick, 3 to 4 feet long; a clay analysis from one such pod is given in table 6 (sample FS 44-51).

Table 6.--Analyses from Vanderbilt uranium prospect, Silver Reef district, Washington County, Utah.

Field no.	Lab. no.	Material analyzed	Equivalent uranium (percent)	Uranium (percent)	V_2O_5 (percent)	Ag (oz. / ton)	Cu (percent)	Remarks
FS 38-51	52857 1/	Selected high grade shaly sandstone from backfill at S. entrance to Vanderbilt mine.	0.47	0.57	2.83	23.46	2.47	
FS 39-51	52858 1/	Selected highest grade sandstone from backfill at S. entrance to Vanderbilt mine.	.63	.71	3.02	6.88	2.00	
FS 40-51	52859 1/	Channel across 0.7-foot radioactive pod in working face, main room.	.04	.033	.81	136.98	2.39	
FS 43-51	52862 1/	Channel across 2.6-foot clay pebble conglomerate light brown and medium gray.	.006	.007	.04	.46	.31	
FS 44-51	66155 2/	Mudstone, greenish gray with internal slickensides, from pod 3 feet long, 2 wide and 1 thick in main room.						Contains kaolinite and hydromica (illite) in about equal proportions and a little montmorillonite.
FS103-51	56039 3/	Channel across 3.5 feet on last working face, main room.	.007	.006	.15	8.82	.19	

1/ Analyses for radioactivity by Furman, Miskowiec, Wahlberg, Huffman, Horr, Skinner.
2/ X-ray by A. D. Weeks.
3/ Analyses for radioactivity by Furman; chemistry by Meadows, Mountjoy.

Table 6.--Analyses from Vanderbilt uranium prospect, Silver Reef district, Washington County, Utah--Continued.

Field no.	Lab. no.	Material analyzed	Equivalent uranium (percent)	Uranium (percent)	V_2O_5 (percent)	Ag (oz./ton)	Cu (percent)	Remarks
FS 104-51	56040[3]/	Channel across 5.1 feet at upper end, main room.	0.003	0.003	0.07	2.02	0.25	
FS 105-51	56041[3]/	Channel across 1.6 feet in northwest corner, main room.	.003	.003	.08	.70	.92	
FS 106-51	56042[3]/	Channel across 2.4 feet on east side, main room	.012	.012	.07	.40	.70	
FS 107-51	56043[3]/	Channel across 2.3 feet on east side, lowest drift.	.008	.007	.42	16.04	1.04	
FS 108-51	56044[3]/	Channel across 7.6 feet at S. entrance Vanderbilt mine.	.015	.015	.23	1.46	.57	

Ore deposits

Cerargyrite coatings and impregnations in thin beds of shaly sandstone constituted the silver ore taken from the Vanderbilt mine. The silver ore was probably demarcated by use of assays and selection of "favorable-looking rock" because silver-chloride in the rock is often not distinguishable by eye. The main incline and most of the rooms in the mine were "dead-work" performed in order to follow an undulatory, dark gray shaly and clay pebble layer several inches thick in which the main silver concentrations occurred. This layer is mapped in the cross section (fig. 11) as the upper clay-pebble conglomerate. Very little of the ore-bearing rock is now exposed in the workings.

Carnotite and unidentified uranium minerals have been found in two places in the mine; 1) in the uppermost stope, in a dark colored sandstone lens, and 2) in the roof of the main room of the Vanderbilt mine, in the thin shaly part of the upper clay-pebble conglomerate. The uraniferous clay-pebble conglomerate lens contains no visible silver minerals but has a lithology that has come to be a typical "silver-ore appearance" for the district, and this appraisal is borne out by the assay returns on random chip samples (table 6). Analytical results on samples taken by the Geological Survey in 1951 are given in table 6.

In July 1951, the owner, Mr. Eagar, submitted a selected high-grade grab sample from the Vanderbilt mine to the Division of Raw Materials, Grand Junction Operations Office, U. S. Atomic Energy Commission and received the following assay report:

	U_3O_8	V_2O_5	$CaCO_3$
Sample CR-504	1.25 percent	3.50 percent	2.3 percent

This is the highest grade uranium sample known from the mine.

Previous workings

The abandoned Vanderbilt silver workings are shown in figure 11. These consist of several inclined shafts and a vertical shaft 10 feet deep. Two of the inclined shafts that connect with a single irregularly mined area constitute the main workings. A large room in these workings has been extended southward 4 to 5 feet during current uranium prospecting by the owners. Several hundred feet north of the area covered by figure 11, more abandoned workings are accessible in another sandstone outcrop.

Production record

Butler et al. (1920, p. 586) give the silver production of the Vanderbilt mine as 240 tons of $100 ore. The only uranium production was one shipment by the owners in 1951 to Vitro Chemical Company, Salt Lake City, Utah, of about 6 tons of ore. The mill assay of this shipment is believed to have been 0.13 percent U_3O_8. Although sold for its uranium and vanadium content, the ore is said by the operator to have been "worth more for silver than for uranium".

1951 government exploration program

A geologic map was made by plane table and alidade of the Vanderbilt uranium prospect (fig. 11). Careful reconnaissance for radioactivity and sampling of the Vanderbilt mine (table 6) were carried out, and repeated visits were made to examine new exposures afforded by the shifting of dump material and some blasting in the main room of the mine during August 1951.

The 6 (?) tons of uranium-vanadium ore shipped from the mine in the autumn of 1951 were chiefly hand-selected mine dump material and contained only a small part of newly-mined rock. The dump material sorted for the shipment was from the only part of the mine dump showing abnormal radioactivity. Only a few pounds of additional uranium ore is in sight at present, in openings 6 and 7 (fig. 11). Although a quantity of ore comparable to that already shipped may be produced by owners of the mine, the highly lenticular nature of the sandstone and the close faulting of the rock make the prospect for sizable discoveries poor. Further production will depend upon development work, as outlined in "Suggestions for prospecting" section of this report.

Requa (or Duffin) mine area

The abandoned Requa (or Duffin) mine is on a patented claim (fig. 12) in secs. 19 and 20, T. 41 S., R. 13 W., and is accessible by unpaved road. The mine is 3.4 miles from U. S. Highway 91 and 4.75 miles from Leeds postoffice. Butler, et al. (1920, p. 586) gives the past silver production of the mine as "many hundred or thousand tons of $80 to $100 ore." During 1950, selected copper carbonate ore from the Requa dump was sold to a copper smelter. This shipment, with malachite and azurite coatings on most of the rock fragments, was found by mill assay to contain $3 or $4 worth of gold per ton, and 3 or 4 ounces of silver per ton, as well as 3 or 4 percent copper, for which payment was received_/.

_/ Lavon Beatty, Toquerville, Utah: personal communication.

There has been no uranium production from the Requa mine, although several geologists have collected radioactive samples from the mine dumps.

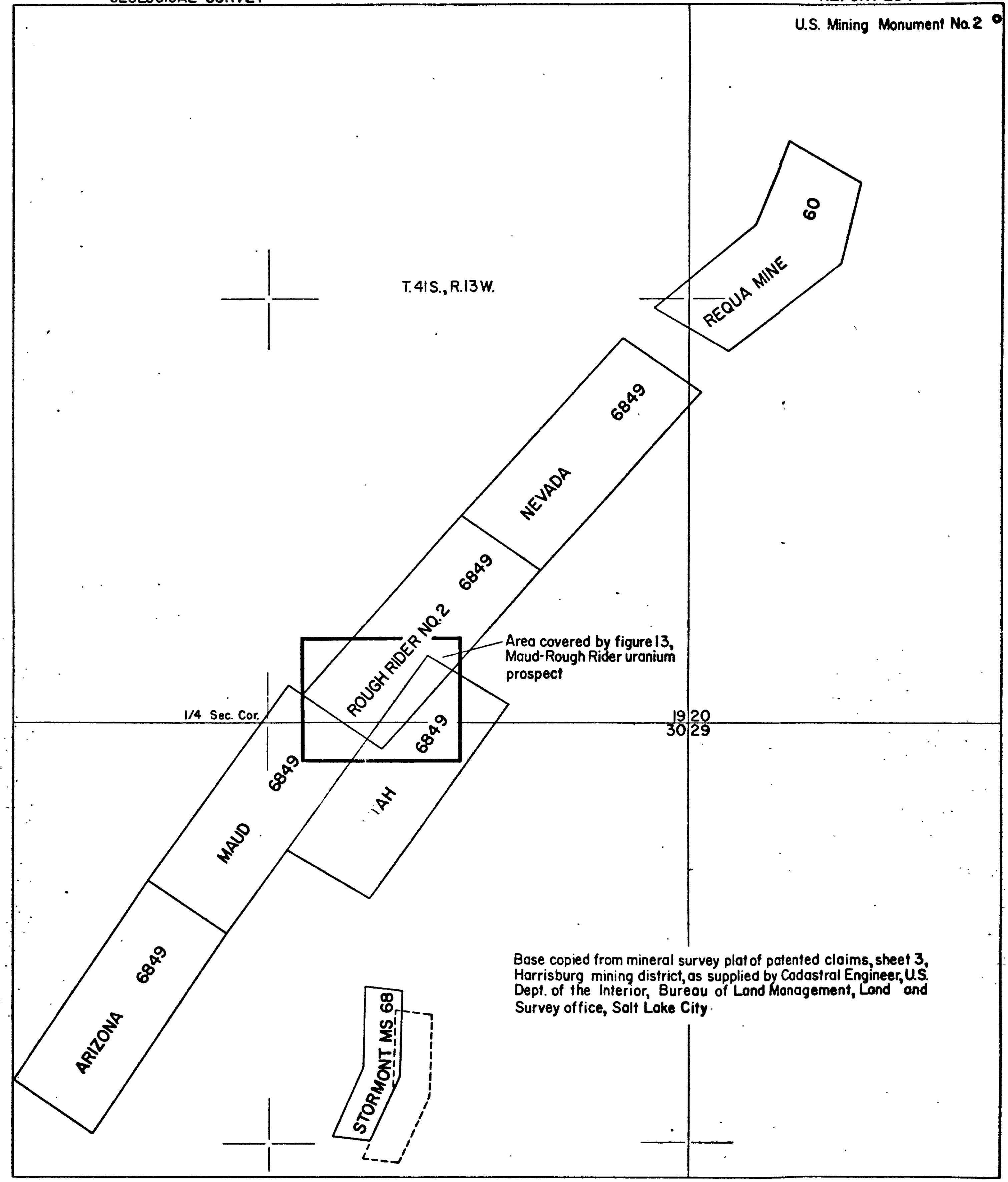

FIG. 12 - MINERAL SURVEY PLAT SHOWING LOCATION OF MAUD-ROUGH RIDER URANIUM PROSPECT, SILVER REEF DISTRICT, WASHINGTON COUNTY, UTAH

No abnormal radioactivity was detected in the underground workings or on the dumps; the underground workings are dangerously near collapse. During the 1951 government exploration program, a reconnaissance for radioactivity was made of all abandoned silver mines and prospects on East Reef. About 500 feet southwest of the main Requa mine, a room excavated for silver in the cliff face showed an abnormally radioactive lens 1.1 feet thick and 5 feet long. Most of the radioactive material was presumably removed with the silver ore, leaving only a foot-wide wall segment of the lens. A chip sample of the most highly radioactive material (FS 37-51) was analyzed and found to contain 0.23 percent eU, 0.31 percent U, 1.48 percent V_2O_5, 8.4 oz. Ag per ton, and 1.20 percent Cu. The ore mineral was principally carnotite, and the chips of sandstone resemble closely much of the rock mined for uranium on Pumpkin Point. However, on the basis of what can be seen in the workings and along the outcrops, no significant discoveries of uranium minerals near the Requa mine are expected.

Arizona, Maud, Rough Rider No. 2, Nevada, and Utah claims

These five claims on East Reef are a group of properties known to have been originally located for silver between 1886 and 1899, at which time silver ore was being treated at the Stormont Mill less than half a mile away.

Location and ownership

The Arizona, Maud, Rough Rider No. 2, Nevada, and Utah claims (fig. 13) were patented in 1925 (Mineral Survey 6849), by Harry Lapidaire, Gertrude Getz, and Sadie Alexander, of 1924 Grove Street, San Francisco 17, Calif. The claims cover East Reef southwestward across secs. 19 and 30 to the Virgin River.

An unsurfaced road leading from U. S. Highway 91 past the Vanderbilt mine to the group of patented claims and on to the Virgin River provides easy access.

Geology and structure

Lithology of the uranium-bearing parts of the Maud and Rough Rider No. 2 claims is shown in the map and section (fig. 13). The Chinle formation of late Triassic age underlies the area mapped; the Chinle here dips uniformly about 30° to the southeast and consists of thinly cross bedded siltstones, clays, and very fine-grained sandstones, mostly dark reddish brown in color. Northeast of the mapped area, a lenticular body of limestone auto-breccia is exposed near the base of the section examined. A few hundred feet southeast of the mapped area, a gradational boundary separates the Chinle formation from the Navajo sandstone, both formations being brownish-red siltstones at this locality.

Near the crest of the ridge on the northwest side, a sandstone bed crops out, pale yellowish-orange to yellowish-gray in color. Thin lenses of clay pebble conglomerate of olive gray, green, and red colors are associated with the sandstone bed. The sandstone bed with contained clay pebble conglomerate lenses, contained whatever silver was produced from the claims, and from the sandstone have come all the samples coated by uranium-vanadium minerals.

Ore deposits

The silver ore mineral in this area is presumed to have been cerargyrite, as elsewhere in the district, and although none was identified in the workings or mine dumps, small quantities of silver were found in assays of uraniferous samples.

Uranium and vanadium occur in carnotite and volborthite, found as weathered coatings on mine dump material. No uranium-vanadium minerals remain in place underground. The small size of the workings and the absence of uranium-vanadium minerals except on the mine dumps indicate that the minerals must have occurred in pods of quite small dimensions.

Previous workings

There is an almost continuous series of open-cut workings and inclined stopes along the crest of East Reef, on the Nevada, Rough Rider No. 2, Maud, and Arizona claims. All these workings were made for horn silver ores half a century ago. Most of the stopes are typified by those shown in figure 13, and are only about 3 feet high. These steeply inclined stopes are difficult to traverse and illustrate the cunning of the nineteenth century miners who by hand methods removed only the thin bed of sandstone and clay pebble conglomerate containing horn silver, possibly low-grade ore at that. In addition to the open stopes along the ridge top, two adits were cut northwestward from the road to afford a level haulageway; these later adits never produced any ore. The sandstones cut in the adit shown in figure 13 do not correlate with the sandstone mined on top of the ridge.

Production record

There has been no uranium or vanadium production from the Arizona, Maud, Rough Rider No. 2, Nevada, and Utah claims. The silver production from the Maud claim is given by Butler et al. (1920, p. 586) as $33,986 worth of $30.00 to $100.00 (per ton) ore. Production from the Rough Rider, Nevada, and Utah claims is not recorded and was probably small. It is known that the No. 3

drift (fig. 13) produced no silver and none was produced from the Breisacher Tunnel farther south on the Utah and Maud claims.

1951 government exploration program

After careful reconnaissance for radioactivity of all the mine workings in the area, a geologic map of the Maud-Rough Rider uranium prospect (fig. 13) was prepared. This map shows the location of the three dumps from which radioactive samples were taken. The results of these sample analyses are given in table 7. Radioactive material was also found on a small mine dump on the Nevada claim, about 150 feet northwest of the Nevada discovery monument. The source of dump material is believed to be a fossiliferous, lenticular sandstone and clay bed found in a nearby mine. The analyses of a sample from the dump and from the source bed are included in table 7.

SUMMARY OF URANIUM RESOURCES IN THE SILVER REEF DISTRICT

Four possible types of uranium resources have been considered in the Silver Reef district: abandoned silver mine workings, mine dumps, amalgamation-mill tailings dumps, and uranium mines or prospects.

Abandoned silver mines are mostly dry and accessible, and examination of these has disclosed significant radioactivity only in the Vanderbilt mine. The mine dumps derived from silver mines are not radioactive except for extremely rare hand specimens with scanty carnotite or volborthite coatings. The amalgamation-mill tailings dumps consist of several thousand tons of rock flour containing 0.009 percent U or less. The uranium mines have exhausted the mineral showings on which they were located, and very

Table 17.--Analyses from Maud, Rough Rider No. 2, and Nevada claims, Silver Reef district, Washington County, Utah.

Field no.	Lab. no.	Material analyzed	eU[1] (percent)	Uranium (percent)	V_2O_5 (percent)	Ag (oz./ton)	Cu (percent)	Remarks
FS 67-51[2]	54404	Grab sample of only uranium-bearing material from dump of No. 4 workings, Rough Rider No. 2 claim.	0.47	0.92	0.93	3.28		
FS 68-51[3]	54347	Grab sample of only uranium-bearing material from dump of No. 4 workings, Maud claim.	.41	.59	3.20	34.80	5.76	$CaCO_3$ - 0.26 percent
FS 69-51[4]	69223	Grab sample of grass-green crystals scraped from sandstone fragments, dump of No. 1 workings, Rough Rider No. 2 claim.	-	-	-	-	-	Yellow green to olive green mineral forming tiny crystalline plates is a copper vanadate similar to volborthite. The optical properties agree with those of volborthite, but the X-ray powder does not match the standard volborthite pattern. Qualitative spectrographic analysis showed major Cu, V, Si, minor Ba, and a trace of Al and Mg. This is probably a new mineral or a different hydration state of volborthite. Malachite and another secondary copper mineral are also present in the sample. There is a small amount of yellow uranium mineral in the sample, but not enough for spectrographic or X-ray analysis.

1/ eU = Equivalent uranium.
2/ Analyses for radioactivity by Furman; chemistry by Boyes, Skinner, Wahlberg.
3/ Analyses for radioactivity by Furman; chemistry by Boyes, Dufour, Huffman, Skinner.
4/ Mineral identification by J. N. Stitch, E. A. Cisney, M. E. Thompson.

Table 7.--Analyses from Maud, Rough Rider No. 2, and Nevada claims, Silver Reef district, Washington County, Utah--Continued

Field no.	Lab. no.	Material analyzed	eU[1] (percent)	Uranium (percent)	V_2O_5 (percent)	Ag (oz./ton)	Cu (percent)	Remarks
FS 70-51[3]	54348	Channel sample across 20 feet of south end of stope, No. 1 workings, Rough Rider No. 2 claim.	0.003	-	0.09	7.14	0.63	$CaCO_3$ - 1.9 percent.
FS 74-51[5]	54371	Grab sample of most uraniferous material in dump from No. 2 workings, Maud and Utah claims.	.28	.53	1.17	[6]	-	
FS 77-51[2]	56095	Channel sample across 1.3 ft. bed of fossiliferous, malachite-stained sandstone and clay in abandoned mine 150 feet from Nevada claim discovery monument.	.047	.050	.74	13.16	6.63	
FS 78-51[2]	56096	Grab sample of highest grade uranium-bearing rock in abandoned mine dump, 150 ft. N. 35° W. from Nevada claim discovery monument.	.50	.59	2.16	16.20	1.29	
FS109-51[7]	56045	Maud claim, 160 pound composite of 34 grab samples taken on a 6-foot grid across mine dump at No. 1 workings.	.006	.007	.09	6.16	.57	

5/ Analyses for radioactivity by Furman; chemistry by Boyes.
6/ Insufficient sample for determination.
7/ Analyses of radioactivity by Furman; chemistry by Meadows, Mountjoy, Horr, Mallory, Skinner, Wahlberg.

little additional ore is in sight. A diamond drilling program and systematic prospecting have failed to disclose further reserves, or to permit a reasonable inference of any quantity of uranium in the ground. Further ore reserves may be discovered by the wagon drilling now in progress under Atomic Energy Commission supervision. >

Ore deposits

The uranium minerals accompanying the silver deposits have mostly been removed during the silver mining operations between 1875 and 1909. Some of the uranium was discarded with waste rock and some was processed with other impurities in the silver ores.

The same ore minerals, carnotite and volborthite, are found on both sides of the district-wide anticlinal structure, and the lithology of ore-bearing pods is everywhere very similar. All occurrences are in the Chinle sandstone; the Shinarump conglomerate is barren. Uranium mineralization has occurred locally throughout the district, both along bedding planes and along joints. It is possible that additional uranium minerals may be identified by further laboratory study of the ores. The mined uranium ore shoots on bedding planes have been consistently unpredictable in shape because of the nature of the terrestrial facies involved (fig. 9). Former extensions of the upper ore shoots westward beyond the base of Pumpkin Point have been channeled out by later stream erosion. No uranium mineral concentration of mappable size is now exposed in the Silver Reef district. The largest ore body mined to date was approximately 60 feet square and 1 to 3 feet in thickness.

During 1953, wagon drilling by Western Gold Mines, Inc. on a 10-foot grid preceded mining on Pumpkin Point. The deepest wagon drill hole was about 70 feet, and the average depth about 35 feet. A Geiger-Mueller rate meter was lowered into holes to see what radioactivity existed in the holes. In this way the drifts and crosscuts were guided so as to remove the thickest parts of discontinuous ore bodies, from 9 to about 20 feet below the surface. As the ore bodies were removed, the wagon drilling was in places done on a 5-foot grid to reduce "dead work". The ore lenses or pods outlined by drilling were in several places extended by nearly vertical joints along which volborthite had been redistributed. The ore being the nearly vertical joints could not be discovered by wagon drilling and had to be followed where discovered underground. Later mining has followed the same horizon producing the 1950 and 1951 ore shipments; this horizon has been found to be intermittently mineralized from the older workings on top of Pumpkin Point to the base of the hill where it is cut out by boulder-alluvium. The mining by Western Gold Mines, Inc., removed the ore found by wagon drilling on Pumpkin Point during 1952-1953. In May 1953, production continued at a declining rate. A participating-loan by the Atomic Energy Commission stimulated a program begun in that month; the area being covered by this drilling is westward from the present workings toward Big Hill, where thicker strata overlie the "favorable horizon".

Previous workings

Abandoned silver workings, extensive and admittedly incompletely mapped (Ball, 1920, map) make drilling or mining operations impracticable over most of White Reef, the Tecumseh Hill area on Buckeye Reef, and much of East Reef. Examination for radioactivity of abandoned mine workings throughout the district failed to disclose significant radioacitivity, except for small showings in the Vanderbilt mine on East Reef.

Uranium mines

The only mines in the district made for uranium and vanadium are in the Pumpkin Point area of Buckeye Reef. This area contains the only extensive outcrops of the Chinle sandstone "favorable" beds that are not honeycombed by abandoned silver workings. Production during 1950-1953 from the adits and small open pits on Pumpkin Point has almost exhausted the carnotite and volborthite showings on which the workings were located. Ore reserves cannot reasonably be calculated in advance of more development work.

Mine and tailings dumps

In addition to the numerous mine dumps throughout the district, tailings dumps remain at the sites of several abandoned amalgamation mills which treated the silver ores. The periods of operation of the mills were as follows (Mariger, 1951, p. 87-88):

Mill	Period of operation	Location
Leeds (5 stamps)..	February 1877-1880	Quail Creek gully on west side of White Reef.
Buckeye (3 stamps).	1877 - June 1879	South of Leeds, west of U. S. Highway 91.
Barbee & Walker (5 stamps).	March 1878 - June 1878 February 1880-1898 1902-1908 (intermittently)	On east side of White Reef.
Christy (5 stamps)	January 1878 - March 1889	Between Buckeye and White Reefs, near ruins of the town of Silver Reef.
Stormont (10 stamps)	January 1878 - March 1887	On Virgin River.

The tailings from the Stormont mill washed down the Virgin River; the three sizable tailings dumps remaining today are the Leeds, the Barbee & Walker, and the Christy dumps.

Reconnaissance for radioactivity of every sizable tailings dump and mine dump in the area disclosed no abnormal radioactivity other than that shown by the few specimens containing uranium minerals (tables 5 and 6). One mine dump and one tailings dump were bulk sampled to determine average grade, with these results:

Maud mine dump (table 7) . . . . 0.007 percent U

Christy Mill tailings dump . . . . 0.009 percent U
(Stugard, 1951)

The uranium content of the Christy Mill dump is regarded as about the maximum grade expectable from mine or tailings dumps in the district, and the grade is being constantly diminished by natural leaching.

Origin of the ores

Three possible modes of origin have been considered for the uranium ores at Silver Reef:

1) detrital (syngenetic)
2) volcanic debris (syngenetic)
3) hydrothermal (epigenetic)

Minerals containing uranium and vanadium occur along certain fractures and faults and coat fossil casts found along bedding planes of some fine-grained sandstones and shales. The uranium-vanadium and silver deposits are so similar in mode of occurrence that much that has been previously written about the origin of the silver deposits should be considered in regard to uranium and vanadium.

Butler et al., (1920, pp. 155, 593) summarized the earlier theories of origin for the Silver Reef deposits. Butler cites the hypothesis of Newberry, that the silver, copper, uranium, vanadium, and selenium minerals were deposited with the sandstone from water and precipitated by the reducing action of decaying plant debris. Support for this hypothesis waned when the silver ores were found to decrease in depth, and to be discontinuous on the same stratigraphic horizons. In contrast to Newberry's hypothesis, a hydrothermal origin of the metallic minerals was proposed by Rolker, Maynard, Rothwell, and Cozin, although no intrusive igneous rock was identified as a source.

Ball (1920, p. 48) proposed that the Triassic Chinle formation was folded and faulted in mid-Tertiary time, and that circulating waters deposited chalcocite and probably argentite in middle or late Tertiary time.

The mineral bearing waters, Ball believed, probably were artesian, and deposited the metallic minerals while aseending through the "reefs" and along fractures. Erosion of the rocks at the surface later altered the original ore minerals into cerargyrite, malachite, and azurite.

Proctor (1949, p. 11) concluded that the metal content of the rocks was originally laid down in tuffs in the Chinle formation. These metals he believes were transported to the Silver Reef area and deposited there by Triassic streams which eroded the tuffs. The metals were transported either in dissolved form or as detritus, or both. The concentration of the metals in their present form then took place by the action of circulating waters and the precipitating effect of plant remains in the sediments. This hypothesis would suggest the Triassic stream channels as a loci of ore mineral deposition; for that reason the Proctor geologic map (1949, pl. 2) indicates directions of the Triassic stream flow (inferred from the truncated foreset beds of sandstone) at various localities.

The writer (Stugard, 1952) proposes a hydrothermal origin in Tertiary time for the silver, copper, uranium, vanadium, and selenium in the Silver Reef district. This is largely based upon a reinterpretation of nearby Pine Valley Mountain as a laccolithic intrusive; at the time of Proctor's work Pine Valley Mountain was considered a series of lava flows.

Granitic porphyry (rhyodacite) boulders litter the landscape in the Silver Reef district. These boulders have been considered to be transported debris from eroded lava flows by some, but the writer considers the porphyry boulders to be intrusive in origin and let down in place by weathering. The boulders are the same rock type as that in the cliffs of Pine Valley Mountain, several miles to the northwest (fig. 1). On the basis of preliminary thin-section studies the boulders of igneous rock from Pine Valley Mountain appear to be rhyodacite porphyry. The porphyritic fabric does not show flow structures such as might be expected in lava flows. The upper part of the igneous cliffs is lighter colored than the lower part, giving a suggestion of crystal settling during magmatic differentiation. The single-tier columnar jointing of the rhyodacite porphyry is clearly discernible. A geologic study of Pine Valley Mountain is needed before the intrusive origin of the porphyry can be proved, however.

In brief, the rhyodacite porphyry mass is probably an erosional remnant of a post-Wasatch laccolith related to the "Pine Valley syncline" structure in the Wasatch beds (Dobbin, 1939, p. 137 and fig. 2) that underlie the porphyry. A laccolithic habit characterizes intrusives in nearby areas. The original roof of the intrusive is not evident nor has a feeder channel for an intrusive been proven _/.

_/ During preparation of this report, a study has appeared supporting the laccolithic origin of Pine Valley Mountain: Cook, E. F., The Pine Valley laccolith, Washington County, Utah, talk before the Rocky Mountain Section, Geol. Soc. America, Butte, Montana, May 8, 1953.

On the basis of existing evidence, however, it is suggested (Stugard, 1952) that hydrothermal solutions from the consolidating rhyodacite porphyry deposited silver, uranium, vanadium, copper, and selenium minerals, which were subsequently oxidized and locally redeposited.

The process of hydrothermal deposition was probably penecontemporaneous with formation of the Virgin anticline. Later redistribution of volborthite, and to a lesser degree of carnotite, has taken place along late joints.

The possibility of a hydrothermal origin for the silver and uranium-vanadium deposits is supported by:

1) accounts of chalcocite, covellite, and pyrite in the lower parts of the silver mines; 2) the occurrence in the now abandoned mines of many areas of whitened sandstone, which may represent hydrothermally bleached rocks reported to have contained silver ore, 3) the widespread, but spotty, occurrences of ore minerals at one end of an anticlinal structure; 4) the association of minor quantities of selenium (trace to 226 ppm; Stugard, 1951), and gold with the silver deposits (cf. Requa mine, this report); and 5) the probability that intrusive igneous rock is present at Pine Valley Mountain in T. 39 S., R. 14 W.

No detrital shapes were observed in the silver and uranium-vanadium minerals, which, if originally detrital, have all been oxidized to their present composition and redistributed. No clear cut evidence of ore localization along stream channelways has been discovered by exploration to date. The solubility of uranium compounds is unfavorable for the concentration of uranium by Triassic streams. The confinement of metallic deposits to the nose of the Virgin anticline probably indicates a relationship of the deposits to structure which is more than fortuitous; if, as seems reasonably certain, the deposits are younger than some of the deformation of the rocks, the possibility of ore deposition being simultaneous with deposition of the sandstones can be ruled out.

The possibility of a volcanic origin of the deposits seems remote to the present writer, because of absence of clear evidence of volcanic activity when the sandstones were laid down. No shards have been found by the writer in the Chinle formation clays (table 6) to suggest Triassic volcanism. The bentonitic clay identified by Proctor is stratigraphically and topographically below the sandstones in which the metallic ores have been found; volcanic activity at that level must have antedated the ores by a considerable length of time. Recent basaltic lavas cap the mesas east of the Hurricane fault and make up part of the present topography along East Reef; these basalts are not accompanied by ore deposits of any kind.

CONCLUSIONS

Geologic conditions in the Silver Reef district are such that uranium ore can be produced only by the selective mining of small lenses of ore-bearing sandstones and shales. The ore has been found to date only at shallow depths analogous to the silver deposits, which were noted to decrease in richness with depth. The occurrence of uranium minerals on fracture surfaces at some distance from the main ore-bearing pods is expectable in view of the mobility of uranium compounds; no such redistribution was shown by the silver minerals during mining.

The lithology of the reef-forming Chinle sandstones is so variable that an individual bed can rarely be traced for a quarter of a mile. Therefore, favorable ground for prospecting can only be projected for short distances from any ore bodies discovered in future. Detailed exploration is needed in advance of mining operations to reduce the tonnage of waste rock removed.

Known ore deposits on Pumpkin Point may be shown to extend westward under Big Hill by further exploration in that area. This is the most favorable area for exploration in the Silver Reef district. Discovery of uranium ore bodies in the exposed rock on Tecumseh Hill, White Reef, or East Reef is unlikely. While concealed deposits may exist in buried segments of the reefs, there is no feasible method of subsurface prospecting to locate such deposits beneath hundreds of feet of colluvium.

Known pods of uranium ore in the Vanderbilt mine and Leeds Uranium Mine may also be duplicated by detailed exploration or development, and resulting discoveries in those areas. The area of possible ore deposits in these areas is somewhat more limited than the Pumpkin Point-Big Hill area, because of the closer spacing of high-angle faults.

The drill cores indicate that there is little chance of successful exploration below the sandstones, that is, in siltstones or mudstone beds of the Chinle formation. The core drilling in 1951 disclosed the lithology around Pumpkin Point sufficiently so as to provide a permament record of the strata and to show the difficulty of lithologic correlation over even short distances. The difficulties encountered in sinking diamond drill holes through boulder alluvium do not encourage further diamond drilling. Difficulty in obtaining permission to use ditch water for drilling operations during the long irrigation season also discourages further use of diamond drilling in the district. Diamond drilling is valuable to prospect for favorable lithology around uranium deposits in the district, as was done in 1951, and may disclose ore deposits, although this type of drilling is not suitable to block out ore bodies of the very small size encountered at Silver Reef.

The only development work on uranium ore bodies undertaken to date at Silver Reef by Western Gold Mines, Inc. indicates that wagon drilling is a suitable means of developing ore bodies after their discovery by other methods. Because the uranium deposits at Silver Reef are so shallow as to be above the water table, wagon drilling can be used on any uranium ore body in the district. This drilling method does not need water, which is a big advantage where the ditch water is always in short supply. The low cost per foot of wagon drilling is suitable for a close grid of drill holes to outline the small ore bodies, provided the hole is in outcrop. Wagon drilling methods are being rapidly improved at this time (Huleatt, 1952).

Logging of radioactivity of drill holes is equally applicable to diamond drill holes or to wagon drill holes, and locates the ore-bearing stratum exactly. Small Geiger-Mueller equipment can easily be used on shallow holes.

SUGGESTIONS FOR PROSPECTING

Outside the Silver Reef district, it is recommended that uranium prospecting be privately carried on by interested persons in the Chinle formation east of the Hurricane fault and in the Cenozoic formations in contact with the Pine Valley Mountain intrusive, until cheaper subsurface prospecting methods make it possible to explore below the flats within the Silver Reef district. A Geiger-Mueller or scintillation counter should also be carried along the less accessible parts of the Shinarump conglomerate outcrop which have not been completely prospected.

Within the Silver Reef district, wagon drilling on a 20-foot grid, or closer spacing, may result in the discovery of small pods of ore around the known deposits at the Leeds uranium mine, the Vanderbilt mine, and westward from Pumpkin Point. Wherever ore is discovered, a 5-foot grid should be drilled, as the present operators are doing.

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