(200)
T67r
No. 112

FOR OFFICIAL USE ONLY

THIS DOCUMENT CONSISTS OF 30 PAGE(S)
NO. 6 OF 16 COPIES, SERIES A

See maps

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON

ES-122

USGS-TEIR-112

(USGS-CPPER-1)

CARNOTITE RESOURCES
in the
CHARLES T. AREA AND VICINITY
San Miguel County, Colorado

By A. L. Bush

COLORADO PLATEAU PROJECT EXPLORATION REPORT 1

MARCH 1950

U. S. GOVERNMENT PRINTING OFFICE 858002

FOR OFFICIAL USE ONLY

MFC-20911

maps to accompany this report are filed in the DRM map file

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CARNOTITE RESOURCES IN THE CHARLES T. AREA AND VICINITY, SAN MIGUEL COUNTY, COLORADO

By Alfred L. Bush

COLORADO PLATEAU PROJECT EXPLORATION REPORT 1

MARCH 1950

USGS - Colorado Plateau Project
Exploration Report 1, March
1950.
Consisting of 30 pages
Copy No. 6 of 16 copies
Series A
Issued to (See below)

The distribution (Series A) of this report is as follows:

Copies 1 and 2 . . . . AEC, Washington (J. C. Johnson)

Copies 3 through 7 . . . . . AEC, New York (P. L. Merritt)

Copy 8 . . . . AEC, Denver, Colorado (C. C. Towle, Jr.)

Copy 9 . . . . AEC, Spokane, Washington (E. E. Thurlow)

Copy 10 . . . . AEC, Grand Junction, Colorado
(W. G. Fetzer)

Copies 11 through 16 . . . . U. S. Geological Survey
(Including Master Copy.)

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

TABLES

CARNOTITE RESOURCES IN THE CHARLES T. AREA AND VICINITY

SAN MIGUEL COUNTY, COLORADO

By Alfred L. Bush

ABSTRACT

Between November 1947 and September 1949, the United States Geological Survey, at the request of the Atomic Energy Commission, conducted an exploratory drilling program in the Charles T. area and vicinity. The purpose of the exploration was to discover new carnotite deposits to support milling operations on the Colorado Plateau, and to appraise the uranium and vanadium resources of the area explored.

The Charles T. area and vicinity is in the western part of San Miguel County, Colorado. It comprises the Ownbey, Easton B., Charles T., and Golden Rod groups of claims and the adjacent ground.

Production from 1914 to November 1, 1949, totalled about 11,000 short tons of ore, with an average grade of about 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5.

The carnotite deposits lie near the top of the Salt Wash sandstone member of the Morrison formation. The ore minerals, carnotite and a micaceous vanadium mineral, occur mainly as impregnations in sandstone. The ore deposits are commonly tabular layers of mineralized sandstone, but locally thicken into pod-like masses called "rolls". In general the long dimensions of the layers are parallel to the bedding, but in detail the layers cut across the bedding in many places. Most of the ore has been produced from rolls.

The ore minerals are believed to have been deposited from ground-water solutions during a period of active circulation shortly after deposition of the ore-bearing sandstone.

Certain lithologic features, characteristically associated with ore deposits, are considered to be guides to ground favorable for ore deposits. These features include alteration of mudstone associated with the sandstone; the presence of cross-bedded, medium-grained, thick, light-brown sandstones; and concentrations of carbonized plant fossils.

Geological Survey exploration comprised three stages of drilling: 1) wide-spaced holes, to obtain geologic information for determining the favorability of the ore-bearing sandstone; 2) moderately spaced holes in favorable ground to discover ore deposits; 3) closely spaced holes, to outline approximately the ore deposits found in the other stages of drilling.

Seven hundred and forty-two holes were completed, totalling 40,989 feet of drilling. Three major belts of favorable, semi-favorable, and unfavorable ground were defined by the drilling. Mineralized rock was cut in 110 holes, in 10 major and 28 minor deposits. Approximately 1 ton of indicated ore was found for each 3.7 feet of hole drilled. No large-tonnage, low-grade ore deposits were found.

Reserves are classed as indicated, inferred, or potential, depending upon the amount of information available for each deposit. Reserves are further classified according to three grade cut-offs for mineralized rock 1 foot or more thick, and one grade cut-off for mineralized rock less than 1 foot thick.

Indicated reserves total 14,000 short tons of ore, with an average grade of 0.16 percent U_3O_8 and 1.7 percent V_2O_5, equivalent to 44,800 pounds of U_3O_8 and 476,000 pounds of V_2O_5. Inferred reserves are estimated to be 4,000 short tons of ore, with an average grade of about 0.22 percent U_3O_8 and 2.1 percent V_2O_5, equivalent to 17,600 pounds of U_3O_8 and 168,000 pounds of V_2O_5. Potential reserves, whose existence is predicted on geologic evidence alone, are estimated to be in the order of 1,500 to 3,000 short tons, with an estimated grade of 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5, equivalent to 6,000 to 15,000 pounds of U_3O_8 and 60,000 to 120,000 pounds of V_2O_5.

Most of the reserves are expected to be in essentially tabular layers, commonly with one or more contained rolls. The bulk of the production is expected to be from these rolls.

No further diamond drilling is recommended in the Charles T. area and vicinity. The exploration is complete within the scope desired by the Atomic Energy Commission. On the other hand, the undrilled northern half of the Golden Rod group is believed to contain several small deposits that do not now warrant diamond-drilling, with a total of 500 to 1,000 short tons of ore. These deposits lie 1 to 25 feet below the surface, because the upper part of the ore-bearing sandstone has been removed by recent erosion. Future exploration by industry, using jackhammer-drilling or wagon-drilling, is recommended. The ground south of the Charles T. area and vicinity is considered to be unfavorable, and no intensive exploration is recommended.

INTRODUCTION

Purpose of work

Exploration was undertaken by the Geological Survey, at the request of the Atomic Energy Commission, to discover carnotite deposits and to appraise the uranium and vanadium resources in the Charles T. area and vicinity. This area contains deposits from which there has been some important production and affords a large acreage suitable for exploration by shallow diamond-drilling.

Location

The Charles T. area and vicinity is in the western part of San Miguel County, Colorado (fig. 1), in sections 14, 15, 16, and parts of sections 10 and 11, T. 43 N., R. 19 W., of the New Mexico principal meridian. The Charles T. area and vicinity includes the Ownbey, Easton B., Charles T., and Golden Rod claim groups (fig. 2). Altitudes range from 7,100 feet to 7,350 feet. The area is 42 miles from the Atomic Energy Commission mill at Monticello, Utah, and 47 miles from the Vanadium Corporation of America mill at Naturita, Colorado.

Previous Exploration

In 1943 the Geological Survey and the Bureau of Mines diamond-drilled parts of the Charles T. and Ownbey groups, in the vicinity of known deposits, to develop reserves of carnotite ores for newly opened mills on the Colorado Plateau.

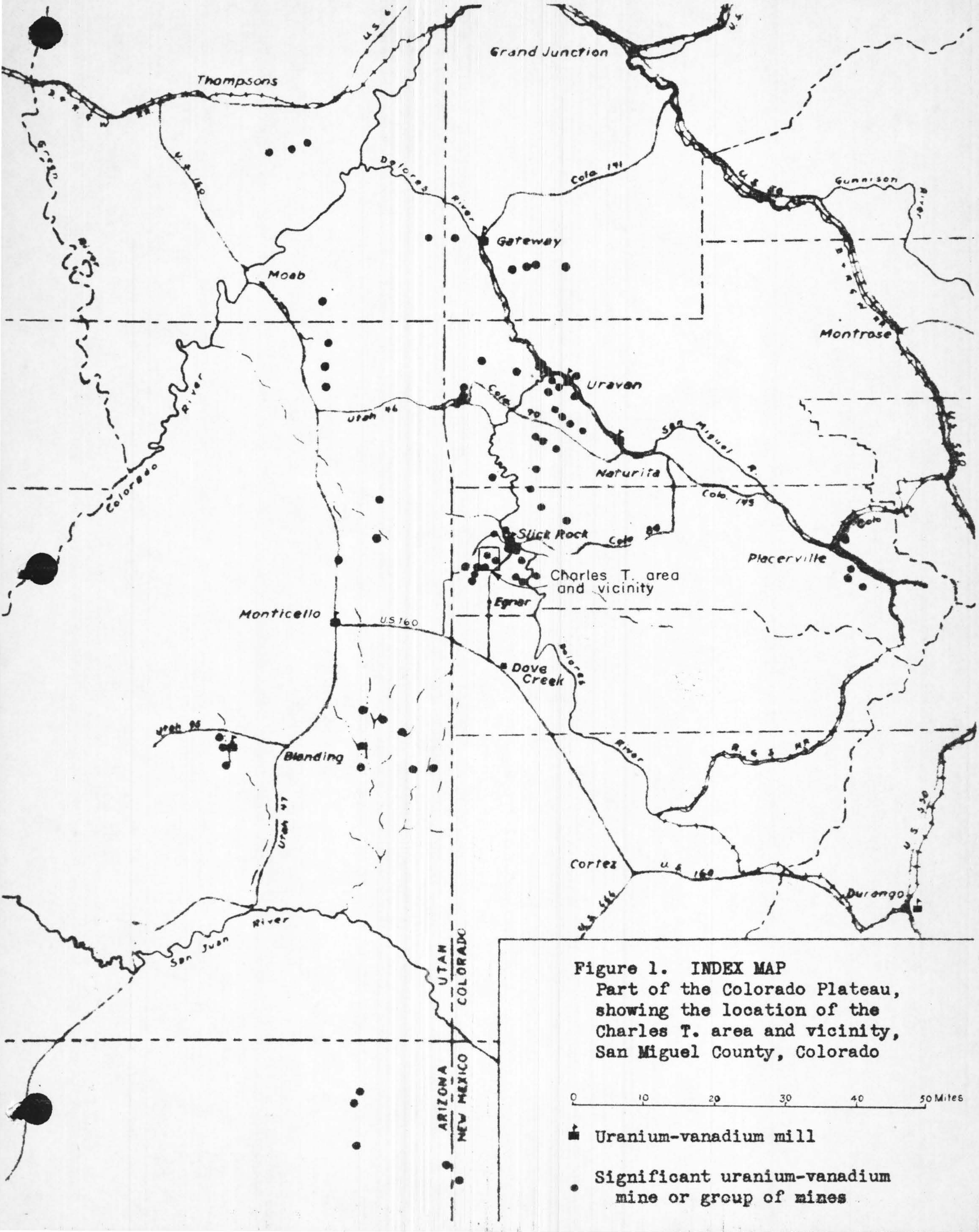

Figure 1. INDEX MAP
Part of the Colorado Plateau, showing the location of the Charles T. area and vicinity, San Miguel County, Colorado

Uranium-vanadium mill

Significant uranium-vanadium mine or group of mines

History and Production

From 1914 to 1923, the carnotite deposits were mined for their radium content. Mining was resumed in the late thirties, for the vanadium content of the ores, and continued to the end of the ore-buying program of the Metals Reserve Company in early 1944. Production was resumed in 1949, for uranium and vanadium, under the ore-buying program of the Atomic Energy Commission. The production data for the several groups in the Charles T. area and vicinity (table 1) is indicative of the trend of production and the relative importance of the groups.

GEOLOGY

The sedimentary beds exposed in the Charles T. area and vicinity are of Mesozoic age. These beds are nearly flat-lying. They are on the crest of a broad, northwest-trending arch, whose axis approximately bisects the Charles T. area and vicinity.

Ore-bearing sandstone

The carnotite deposits are in sandstone lenses near the top of the Salt Wash sandstone member of the Morrison formation. Younger beds of Morrison age overlie the sandstone in the central and southern parts of the Charles T. area and vicinity. The approximate outcrop of the top and the base of the ore-bearing sandstone lenses are shown on figure 3. Structure contours on the base of the ore-bearing sandstone lenses are also shown. These lenses are a few hundred to several thousand feet long. The total thickness of the ore-bearing sandstone ranges from

Table 1.--Production in the Charles T. area and vicinity[1]

Year	Ownbey group			Easton B. group			Charles T. group			Golden Rod group[2]		
	Short tons	Percent		Short tons	Percent		Short tons	Percent		Short tons	Percent	
		U_3O_8	V_2O_5		U_3O_8	V_2O_5		U_3O_8	V_2O_5		U_3O_8	V_2O_5
1914-1934	0			0			300[3]	No data	No data	0		
1935-1939	0											
1940	1,000[3]	No data	No data									
1941	1,400	No data	No data	230	No data	No data	1,867	0.25	2.50	1,133	No data	1.50
1942	1,682	No data	1.75									
1943	730	0.21	1.88	6	No data	No data	1,607[4]	0.25[3]	2.25	88	No data	No data
1944	218	No data	1.99	0			0			0		
1945-1948	0			0			0			0		
1949[5]	302	0.20	1.88	467	0.42	2.29	0			0		
Totals	5,332	0.20[3]	2.00[3]	703	0.25[3]	2.20[3]	3,774	0.25[3]	2.30[3]	1,221	0.15[3]	1.50[3]
Grand total	11,030 short tons of rock, average grade 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5.											

1/ Source: U. S. Geological Survey files, compiled from the records of North Continent Mines, Inc., Vanadium Corporation of America, Metals Reserve Company, and the Atomic Energy Commission.

2/ Includes production from the Snyder claims (Keystone, Santa Marie, and Rainbow).

3/ Estimated.

4/ May include some tonnage from the Sunflower claim.

5/ Period ending October 31, 1949.

20 to 78 feet, and the average thickness is about 45 feet. In places along the northern part of the Charles T. area and vicinity, erosion has reduced the residual thickness to less than 5 feet. Mudstone beds underlie the ore-bearing sandstone.

Lithology.--The sandstone lenses are fine- to medium-grained, and consist of well-sorted and well-rounded quartz grains, with some interstitial argillaceous material. The rock is moderately cemented by calcareous material. The sandstone lenses are cross-laminated, with both foreset (high-angle) and bottomset (low-angle) cross-bedding. Parts of individual lenses, however, are essentially massive and structureless.

Thin, interbedded mudstone lenses and mudstone "trash pockets" are common. The trash pockets are characterized by mudstone galls and pebbles, and by carbonized plant fossils. At the time of deposition the mudstones were red or red-brown. Some of the interbedded mudstone lenses, galls, and pebbles, and parts of the mudstone underlying the ore-bearing sandstone, have been partly or wholly altered to shades of gray, green, and light brown. The exact process of alteration is not fully understood, but it may represent a change in the state of oxidation of iron compounds, or a base exchange in the clay minerals.

The lithologic associations suggest that the ore-bearing sandstone was deposited by broad, meandering streams, on a surface of low relief.

ORE DEPOSITS

Mineralogy

The ore minerals impregnate sandstone, occur as coatings on the sand grains, and may completely fill interstices between the grains. The principal ore minerals are carnotite and a micaceous vanadium mineral whose identity is not definitely established. The gangue minerals are quartz, clay minerals, and calcareous cement.

The V_2O_5 content of the deposits ranges from less than 0.10 percent to more than 9.0 percent, with an average grade, in the ore bodies that have been mined, of about 2.0 percent. The U_3O_8 content also varies widely; the average grade as determined from production has been about 0.20 to 0.25 percent.

Character of ore deposits

For the purpose of this report, the term "ore deposit" is used synonymously with "mineral deposit", to designate the entire mass of mineralized sandstone, including the material too low grade or too thin to mine, as well as the minable material. The term "ore body" is used to designate the minable masses of mineralized rock.

The deposits are irregular in size, shape, thickness, and distribution (figs. 2, 4, 5, 6, 7, 8, 9, and 10). In general the long dimensions of the deposits are parallel to the bedding, but in detail they cut across it in many places. The limits of mineralized rock may be well- or poorly-defined. The well-defined limits usually cut across the bedding in smooth surfaces, and enclose pod-like or sinuous, elongate masses of ore, commonly called "rolls". Tabular deposits with one well-defined limit, at top or base, are common. Where the limits are poorly defined, the grade and thickness of mineralized rock commonly decreases outward from the central part of the deposit. The ore bodies, or masses of mineralized rock of minable grade and thickness, are commonly smaller than the mineral deposits in which they lie.

These deposits lie at several stratigraphic positions within thick parts of the ore-bearing sandstone. In general, those near the top of the sandstone are small and high grade, whereas those near the center and at the base are larger and somewhat lower grade. However, there are no large-tonnage, low-grade ore deposits in the Charles T. area and vicinity.

In the vicinity of the ore deposits, the mudstone lenses within the ore-bearing sandstone, and the upper part of the mudstones that underlie the ore-bearing sandstone, are characteristically altered from red or brown to gray or green. In general, the intensity of this alteration appears to decrease away from the ore deposits.

The ore bodies range from small masses a few feet across, containing less than one hundred tons of ore, to large tabular layers several hundred feet across, containing several thousand tons of ore. The thickness ranges from less than 1 foot to 8 or 9 feet. The largest mined ore body in the Charles T. area and vicinity (Hawk mine, Ownbey group, fig. 5) is 300 feet long, 125 feet wide, and is 1 to 4 feet thick. The largest roll deposit (Charles T. mine, Charles T. group, fig. 4) is 190 feet long, 10 to 25 feet wide, with a maximum thickness of about 17 feet. The average roll is probably one-fifth to one-third as large as this roll.

Uranium is more soluble than vanadium in the ground water, and has migrated for short distances beyond the original limits of some of the deposits. In a few places, sparsely disseminated carnotite extends a short distance above, below, or to the sides of more strongly mineralized layers. Carnotite is also concentrated as films along joints which cut the mineralized layers.

Origin

Ground-water solutions, which flowed through the thick, central parts of the sandstone lenses, are believed to be the media from which the ore minerals were precipitated. It is believed that the ore minerals were precipitated from the solutions at a time of active circulation, shortly after the deposition of the sandstone lenses, and probably before complete consolidation had taken place. Slight changes in the composition of the solutions may have caused the precipitation. These solutions may also have caused the alteration of the mudstone interbedded with, and underlying, the ore-bearing sandstone, in the vicinity of the ore deposits. Thus the altered mudstone is a usable guide to ground favorable for ore deposits.

GUIDES TO ORE AND SUGGESTIONS FOR PROSPECTING

Certain lithologic features are characteristic of the ore-bearing sandstone in the vicinity of ore deposits in the Charles T. area and vicinity. Away from ore deposits, the same features may be present to a lesser degree, or be entirely absent. The following "guides to ore" are guides to ground thought to be favorable for the presence of ore deposits, rather than guides to ore itself.

1. In the vicinity of most ore deposits, the ore-bearing sandstone is underlain by one foot or more of altered mudstone.

2. Many of the ore deposits lie near the feather edges of altered mudstone lenses within the ore-bearing sandstone, or near concentrations of altered mudstone pebbles and galls.

3. The ore-bearing sandstone, in the vicinity of most of the deposits, has an original thickness of 35 to 50 feet (fig. 3).

4. Concentrations of carbonized plant fossils are present in and near many of the ore deposits.

5. Sandstone with foreset (high-angle) cross-bedding appears to be more favorable ground for deposits than structureless or tangentially (low-angle) cross-bedded sandstone.

6. Almost all of the known ore deposits are in pale-brown and light-brown sandstone. Only a few small deposits are in red or red-brown sandstone.

7. Most of the ore deposits, both large and small, are in medium-fine- and medium-grained sandstone.

GEOLOGICAL SURVEY EXPLORATION

General plan

The drilling was planned principally to explore for ore deposits, rather than to develop known ore deposits by close-spaced drilling. The drilling mainly followed the three stages outlined below, although some deviations from the general plan were made because of difficult access during the winter and spring months.

In stage 1, holes were drilled on centers of 800 to 1,000 feet, to obtain geologic information regarding the thickness and character of the ore-bearing sandstone, in order to determine the favorability of the ore-bearing sandstone for the presence of ore deposits. Although it was not expected that many ore deposits would be discovered in this stage of the drilling, four deposits were cut by drill holes.

In stage 2, holes were drilled in the more favorable ground on approximately 200-foot centers. This spacing was selected because the known deposits, from which there had been significant production, had one horizontal dimension of about 200 feet or more. It is unlikely that deposits of this size or larger were missed in this stage of the drilling.

In stage 3, four offset holes were drilled at a distance of about 50 feet around most discovery holes, to determine the trend and the extent of the deposit. If any of these holes cut mineralized sandstone, other holes were drilled on about 100-foot centers to determine the trend and approximate outline of the deposit.

Drilling specifications required good core recovery, and core was taken as often as every 6 inches when drilling mineralized rock, to insure accurate footages and good recovery. All core was logged visually by the geologist, and logged radiometrically with a Geiger-Mueller counter in the laboratory. All mineralized core was assayed chemically for U_3O_8, V_2O_5, and $CaCO_3$. The drill hole assay data are shown in table 2.

Results

Drilling began in the Charles T. area and vicinity on November 10, 1947, and was completed on September 13, 1949. The drilling was recessed for eight weeks from March to May 1948, and for six months from February to August 1949. Seven hundred and forty-two holes were completed, totalling 40,989 feet of drilling. This drilling was divided as follows: stage 1) 120 drill-holes, 6600 feet; stage 2) 422 drill-holes, 23,400 feet; stage 3) 200 drill-holes, 11,000 feet. The average core recovery for all holes drilled was about 80 percent. The average depth of hole was about 55 feet, and the range in depth was from 24 feet to 160 feet.

Three major belts of favorable, semi-favorable, and unfavorable ground were defined by the drilling. These are shown on figure 2.

Mineralized sandstone was cut in 110 holes. The drilling resulted in the discovery of 6 major and 27 minor deposits, and extended 4 major and 1 minor known deposits. The drill holes and the ground underlain by carnotite-bearing rock are shown on figures 4, 5, 6, 7, 8, and 9. The reserve blocks and the tonnages of ore indicated or inferred for the several grade and thickness cut-offs are discussed in the section on reserves. The reserves are tabulated in table 3. Approximately 1 ton of indicated ore, 1 foot or more thick, of 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5, was found for each 3.7 feet of hole drilled. In comparison, approximately 1 ton of indicated and inferred ore, 1 foot or more thick, of 0.02 percent or more U_3O_8 or 0.2 percent or more V_2O_5, was found for each 1.2 feet of hole drilled.

RESERVES

The terms "indicated" and "inferred" reserves are applied to the uranium- or vanadium-bearing material in the deposits that are known from exposures in natural outcrops, mine workings, or drill holes. These reserves are subdivided by thickness and grade cut-offs, and the method used in calculating them is explained below. The tonnage and grade of the indicated and inferred reserves, for each reserve block, are given in table 3. The ground containing the reserve blocks is shown on the maps, figures 4 to 9.

In addition to the known deposits, it is believed that there are other deposits which have not yet been found. These additional deposits are predicted solely on the basis of interpretation of geologic evidence, for there is no physical proof of their existence. The term "potential" reserves is applied to the mineralized material in these deposits.

Indicated and inferred reserves

Reserve classes.--Known reserves are classed as indicated and inferred. Owing to the erratic variations in thickness and grade of carnotite ore within short distances, and the general lack of abundant sample data for individual reserve blocks, the amount of reserves that can be calculated with a small limit of error, and thus can be classed as measured, is so small as to be nearly negligible; therefore, reserves of this class are included with indicated reserves.

It is believed that the calculated tonnage of indicated reserves in any single reserve block may be as much as 100 percent too low or as much as 50 percent too high. The limit of error of total tonnage for several blocks, however, is apt to be considerably lower, perhaps not over 25 percent. The limit of error in the tonnage figures for inferred reserves, of course, is apt to be higher than for the indicated reserves. The possible limit of error in the calculated or estimated grade for both indicated and inferred reserves probably is somewhat smaller than the possible limit of error in the tonnage figures.

The indicated and inferred reserves are subdivided into groups according to a thickness cut-off and several grade cut-offs. Reserves are not classified in this report according to their availability for mining. In an effort, however, to obtain reserve figures that would express as nearly as possible the tonnage and grade of the material that might actually be mined from these deposits under current conditions, consideration was given to the 1949 mining and milling practices in selecting the thickness and the highest grade cut-offs.

Indicated reserves _/ are those for which the grade is computed

---

_/ The definitions used here for indicated and inferred reserves are abstracted from the definitions adopted by the Bureau of Mines and the Geological Survey in April 1943.

---

from drill-hole samples, exposures in mine workings and natural outcrops, and production data, and for which the tonnage is computed by projection for a reasonable distance on geologic evidence from points of exposure (drill holes, mine workings, and natural outcrops).

Inferred reserves are those for which quantitative estimates are based largely on broad knowledge of the geologic character of the deposits and for which there are few samples or measurements.

Thickness cut-off.--Although mining practices vary from place to place in the region as well as with individual operators, with the present price schedules most ore bodies of average grade are being mined to where they pinch to a layer about 1 foot thick. Layers of ore less than 1 foot thick are mined in places if the grade of the ore is high. Reserves, therefore, are classified by thickness as those that are 1 foot or more thick and those that are less than 1 foot thick.

Grade cut-off.---The deposits contain two metals of value, uranium and vanadium, and these metals occur in an average ratio of about 1 part U_3O_8 to 8 or 10 parts V_2O_5. Within the deposits, however, these metals are so erratically distributed that a single sample, such as obtained from a drill hole, is not necessarily representative of the grade or metal ratio of ore near the point sampled. Knowing this by experience, the miner will drive to a drill hole that shows a good vanadium value, even though the uranium content of the sample might be negligible. Thus the material in the vicinity of this sample must be classed as an ore reserve, even though the sample shows a value for only one metal. Furthermore, with the present price schedules for ore, the vanadium content of ore containing the normal metal ratio is as valuable to the miner as is the uranium content. Thus both metals must be considered in reserve appraisals and in selecting a grade cut-off.

Reserves 1 foot or more thick are classified by three grade cut-offs. The highest cut-off used -- 0.10 percent U_3O_8 or 1.00 percent V_2O_5 -- corresponds to the Atomic Energy Commission purchase cut-off for uranium and the Monticello, Utah mill cut-off for vanadium. Reserves are also figured on a lower cut-off -- 0.05 percent U_3O_8 or 0.50 percent V_2O_5 -- on the possibility that conditions in the future might require or permit the mills to accept lower grade ore. The calculation of reserves at a still lower cut-off -- 0.02 percent U_3O_8 or 0.20 percent V_2O_5 -- has little or no immediate value, but it is done to obtain a better idea of the tonnage of this weakly mineralized material and the amount of metal contained in it. In the Charles T. area and vicinity, the reserves calculated at the lowest grade cut-off contain only 20 to 30 percent more U_3O_8 and 30 to 40 percent more V_2O_5 than the reserves calculated at the highest grade cut-off.

Reserves less than 1 foot thick are grouped in one class and a grade-times-thickness factor is applied. The class is calculated at a cut-off equivalent to a 1-foot layer containing 0.10 percent U_3O_8 or 1.0 percent V_2O_5.

Calculation of tonnage.--The methods used for calculating the volume, and hence tonnage, of a deposit 1 foot or more thick differ with the geologic interpretation of the form of the deposit. Some deposits are roughly tabular or lenticular so that projections can reasonably be made between drill holes, and the average thickness of the ore samples can be assumed to be the average thickness of the deposit. Other deposits consist of small bodies of ore of minable thickness connected by layers of mineralized sandstone that are too thin to mine. Reserves are estimated by assuming that each drill hole in ore indicates a single minable body that is comparable in tonnage to the average size of the ore bodies that have been mined nearby, or that the deposit contains a comparable tonnage per unit area to that of a deposit that has been mined nearby.

By definition, the tonnage of indicated reserves "is computed by projection for a reasonable distance on geologic evidence." In most places in the Charles T. area and vicinity indicated reserves are projected between drill holes and other sample points that are not more than 100 feet apart, though in a few places they are projected between points as much as 150 feet apart. Similarly, indicated reserves are not projected more than 25 feet beyond sample points, where the edge of the deposit has not been located. Reserves are classed as inferred rather than indicated if the projection exceeds these lengths. Inferred reserves are projected to the assumed limits of the deposit, as determined by geologic evidence and interpretation.

Although a single drill hole in ore obviously permits the designation of some tonnage of indicated reserves, there is no reasonable basis for projecting an indicated reserve block more than a few feet from a single hole. Rather than calculating such an indicated block separately, or assigning a small but arbitrarily selected amount of indicated reserve to a single hole, the reserve block is projected to its assumed limits and the ore calculated and classed as inferred.

A factor of 14 cubic feet per ton is used to calculate tonnage.

Calculation of grade.--The grade of indicated reserves in a single block is calculated by weighting the assay grades by lengths of the samples. If the deposit has been partly mined, the grade of the ore produced is also considered in establishing the grade of the adjoining reserve block. In reserve blocks containing only one or two drill holes, however, if the core assays (table 2) are appreciably higher than the average grade of the ore mined nearby, it is assumed that the drill penetrated abnormally high-grade parts of the body, and an estimated grade is given (table 3). Although the grade of the samples is given in table 2, the grade assigned to a block containing inferred reserves (table 3) is obtained from the records of production from nearby mines or from the district as a whole.

Strict grade cut-offs are used in calculating reserves more than 1 foot thick. Except as noted in the following paragraph, no material belonging to a class with a lower cut-off grade is included with material of a higher cut-off class, even though the weighted average grade of the whole is above the cut-off grade of the higher class.

Where a layer of waste not more than 1 foot thick lies between two layers of ore, the three layers totalling 1 foot or more thick, the waste is included in the reserve calculations, thereby increasing the thickness of ore and decreasing the grade proportionately, and the ore is classed according to the grade of the weighted average. For example, if two layers of ore each 6 inches thick and containing 0.30 percent U_3O_8 are separated by 1 foot of waste, the three layers are calculated together, yielding 2 feet of ore averaging 0.15 percent U_3O_8. In mining, although some of the waste might be picked out by hand, most of it would go to the mill with the ore.

If the waste is more than 1 foot thick, it would probably be blasted separately from the ore layers in mining, and thus ore layers more than 1 foot apart, with waste between, are calculated as separate ore bodies.

Layers of ore less than 1 foot thick are classed as reserves only if the grade-times-thickness factor shows at least as much U_3O_8 or V_2O_5 as a 1-foot thick layer containing 0.10 percent U_3O_8 or 1.0 percent V_2O_5. The actual thickness and grade of the sample, however, rather than the weighted factor, are used in calculating tonnage and grade of these reserves.

In order to prevent duplication in the computation of the reserves, strict care must be exercised in assigning sample intervals to the class of ore equivalent to one foot of 0.10 percent U_3O_8 or 1.0 percent V_2O_5. A sample is used in computation of reserves less than 1 foot thick only if it cannot be used in any one of the three grade classes of reserves one foot or more thick.

Potential reserves

Few potential reserves are calculated for the Charles T. area and vicinity. As this area was the first of the exploratory drilling projects, more effort was made to investigate the three types of ground favorability than has been done elsewhere. As a result, a large part of the Charles T. area and vicinity, which had been classed as "semi-favorable" on the basis of widely spaced drilling (fig. 2), was rather intensively drilled at an approximate 200-foot spacing. As no deposits were cut in this phase of the exploration, it is believed that there are no large deposits in the "semi-favorable" ground. Small deposits may be present, but their number is considered to be few. In the southern part of the Charles T. area and vicinity, favorable lithologic features are partly or wholly absent, and the ground is considered unfavorable for the discovery of large deposits. A few small deposits may be present. One to two thousand short tons of rock, with an estimated grade of 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5 are estimated to be present, probably in small (10- to 100-ton) bodies. The northern part of the Golden Rod group lies in a belt of favorable ground, but little exploration was conducted because the ore-bearing sandstone is thin, as the upper part of the ore-bearing sandstone has been removed by recent erosion. It is estimated that about 500 to 1,000 short tons of rock, with an estimated grade of 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5, are present, probably in small (10- to 100-ton) bodies. This area is described more fully in the section on recommendations for future work. These estimates are based on an appraisal of the geologic evidence, and a study of the calculated grade and size of the known deposits.

RESERVE BLOCKS

Masses of mineralized rock that constitute an indicated or inferred reserve, as defined by the thickness and grade cut-offs, are called reserve blocks (see table 3). The geometric limits of the reserve blocks are determined by the rules used in calculating reserves (see pp. 18 to 24). The exact positions of the blocks are not shown on the detailed maps, though the carnotite-bearing ground that contains the blocks is designated by block numbers on the maps (see figs. 4, 5, 6, 7, 8 and 9). Where mineralized layers overlap, even though they contain two or more masses of reserves, a single block number is assigned, and the total tonnage of these masses, as well as their average weighted grade, is shown on table 3.

Description

Most of the production in the Charles T. area and vicinity has been from deposits containing large rolls. There are, however, more tabular or blanket-like deposits than roll deposits.

Most of the deposits contain less than 1,000 tons of reserves each. In general, they are small tabular layers of mineralized sandstone, or small, flat or steeply dipping rolls. The tabular layers contain small ore bodies, either as rolls, or as local thickenings or pods that are above specified thickness and grade cut-offs. These deposits are not confined to any stratigraphic horizon within the ore-bearing sandstone. Several of these small deposits are shown in the geologic sections (fig. 10).

The major deposits in the Ownbey and Easton B. groups are tabular layers of mineralized rock (sections A-A' through H-H', fig. 10). Thick tabular ore bodies, usually bounded by a well-developed roll surface at the top, are connected by thin or weakly mineralized layers. Some of the deposits, although essentially tabular in form, transgress the bedding of the ore-bearing sandstone (sections A-A', G-G', and H-H', fig. 10). This transgression is most pronounced in Block 19 (fig. 5; also sections G-G' and H-H', fig. 10). In the Michael Bray mine, a 27° incline cuts a mineralized layer close to the surface, and follows the south-dipping layer to a depth of 15 feet (section H-H', fig. 10). South and southwest of the workings, the dip of the mineralized layer continues, but is less steep. At its southwest end, the deposit lies at the base of the ore-bearing sandstone. Two or three rolls, similar to the roll exposed in the Michael Bray mine, are believed to occur in the deposit (sections G-G' and H-H', fig. 10). An inferred reserve of 600 short tons has been assigned to the rolls assumed to be present (table 3). The roll in the Frankie mine (fig. 5 and section B-B', fig. 10) is exceptional in that the ore body, as mined, was nearly as large as the ore deposit that contained it. Mineralized rock too low in grade to be minable, does not extend for more than a few feet from the roll except along the trend of the body.

The major deposits in the Charles T. group are of two types (fig. 4, and sections I-I' through O-O', fig. 10). Most of the production has been from large, roll-type deposits, with connecting tabular layers (Blocks 26 and 29, fig. 4, and sections L-L', M-M', and N-N', fig. 10). The connected, well-developed rolls in the Charles T. mine (Block 26) are 190 feet long, 10 to 25 feet wide, and as much as 17 feet thick. South and east of the Charles T. mine, layers of mineralized sandstone were cut by diamond-drill holes at several stratigraphic horizons within the ore-bearing sandstone. It is believed that rolls connect these mineralized layers, between drill holes BM 915 and BM 920 or BM 921, and between BM 912 and CT 493 (section M-M', fig. 10). A total of 1,000 short tons of inferred ore is estimated for these rolls (table 3). Two newly discovered deposits appear to be tabular layers of mineralized sandstone, without rolls (Blocks 20 and 23, fig. 4, and sections I-I', J-J', and K-K', fig. 10).

In the Golden Rod group, and in the area between the Charles T. and Golden Rod groups (figs. 7, 8, and 9), production has been small and has come from small, flat or steeply dipping rolls, and from small, essentially tabular deposits. However, the newly discovered deposit on the Golden Rod No. 3 and adjacent claims (Block 45, fig. 8) is considered to be a major deposit. The deposit, essentially a tabular layer, transgresses the ore-bearing sandstone (sections P-P', Q-Q', and R-R', fig. 10). Because of the similarity between this deposit and the deposit in Block 19 (fig. 5), at least one roll and perhaps three rolls are believed to be present. These rolls lie within the layer, or connect it with smaller tabular layers that are included in Block 45. It is believed that the rolls lie between drill holes CT 659 and CT 660 or CT 662, between CT 647 and CT 652, and between CT 631 and CT 632 (Block 45, fig. 8, and sections P-P', Q-Q', and R-R', fig. 10). As each roll may contain 100 to 500 short tons of mineralized rock, 1,000 short tons of inferred ore are included in the reserve estimates (table 3).

RECOMMENDATIONS FOR FURTHER WORK

No additional diamond-drilling is recommended for the Charles T. area and vicinity. The exploration, within the scope thought to be desired by the Atomic Energy Commission, is considered to be completed.

In the northern part of the Golden Rod group, the upper part of the ore-bearing sandstone has been removed by recent erosion. The remaining thickness of rock (15 to 25 feet) can be explored more economically by jackhammer-drilling, or by wagon-drill methods, than by diamond-drilling. As a result, no exploration of the Golden Rod No. 1, Fraction No. 4, and Golden Rod No. 2 claims was undertaken. The southern half of the Golden Rod No. 3 claim was drilled adequately, but no drilling was done in the northern half. A few holes were drilled in the Golden Rod claim, principally for geologic information.

Evaluation of this drilling, and the presence of small deposits, indicate that the northern part of the Golden Rod group lies in a belt of favorable ground. It is believed that the chances of finding several small deposits by jackhammer-drilling, or wagon-drill methods, are good. It is recommended that this drilling be done by the claim operators.

Only a few deposits are known for several thousand feet south of the Charles T. area and vicinity. In addition, the ground in the southern part of the Charles T. area and vicinity is considered dominantly unfavorable. Therefore, the ground immediately south of the Charles T. area and vicinity is not believed to be worthy of intensive exploration.

SUMMARY

Exploration in the Charles T. area and vicinity has resulted in the discovery of 6 major and 27 minor deposits, and has extended 4 major and 1 minor known deposits. An indicated reserve of 14,000 short tons of ore, with an average grade of 0.16 percent U_3O_8 and 1.7 percent V_2O_5, equivalent to 44,800 pounds of U_3O_8 and 476,000 pounds of V_2O_5, is calculated in ore bodies 1 foot or more thick, containing 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5. An inferred reserve of 4,000 short tons of ore, with an average grade of about 0.22 percent U_3O_8 and 2.1 percent V_2O_5, equivalent to 17,000 pounds of U_3O_8 and 168,000 pounds of V_2O_5, is estimated, in ore bodies 1 foot or more thick, containing 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5. Potential reserves of 1,500 to

3,000 short tons of ore, with an average grade of about 0.20 to 0.25 percent U_3O_8 and 2.0 percent V_2O_5, equivalent to 6,000 to 15,000 pounds of U_3O_8 and 60,000 to 120,000 pounds of V_2O_5, are estimated. There are no large-tonnage, low-grade ore deposits in the Charles T. area and vicinity.

According to the criteria being used by the Geological Survey to guide exploration, the southern part of the Charles T. area and vicinity is classed as unfavorable, a central belt of semi-favorable ground lies north of the unfavorable ground, and the western and northern parts of the Ownbey, Easton B., Charles T., and Golden Rod groups are favorable.

The most significant of the "guides to ore" appears to be the amount of alteration of the mudstone unit that underlies the ore-bearing sandstone, and the presence and alteration of thin mudstone lenses within the ore-bearing sandstone.

No further exploration by diamond-drill methods is recommended in the Charles T. area and vicinity. It is believed that jackhammer-drilling, or wagon-drilling, in the northern half of the Golden Rod group, will result in the discovery of several small deposits, containing 500 to 1,000 short tons of ore.