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Carnotite Resources of the Calamity Group Area, Mesa County, Colorado

Trace Elements Investigations Report 146

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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CATEGORY V (Colorado Plateau)

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CARNOTITE RESOURCES OF THE CALAMITY GROUP AREA, MESA COUNTY, COLORADO

By

Harold K. Stager

June 1951

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CARNOTITE RESOURCES OF THE CALAMITY GROUP AREA, MESA COUNTY, COLORADO

By

Harold K. Stager

ABSTRACT AND SUMMARY

The Calamity group area, which includes 28 unpatented Government claims and enclosed fractions of public domain, lies along the east rim of Calamity Mesa, Mesa County, Colo. From 1915 through 1944, about 10,000 tons of carnotite ore, averaging about 1.0 percent U_3O_8 and 2.50 percent V_2O_5, was produced from mines in this group (tons in this report are short tons). Production from this area from August 1949 to January 1, 1951, totaled 8,100 tons of ore with an average grade of 0.36 percent U_3O_8 and 1.66 percent V_2O_5, containing about 58,600 pounds of U_3O_8 and 268,600 pounds of V_2O_5.

Most of the carnotite deposits in the area are in a broad sandstone lens near the top of the Salt Wash sandstone member of the Jurassic Morrison formation.

The deposits are mainly impregnations of sandstone by carnotite and a vanadium-bearing micaceous mineral. Commonly, the deposits are irregular tabular layers, or pod-like or crescentic masses ("rolls") connected by thin layers of mineralized rock. The rolls in the area have a dominant northeasterly trend. Sedimentary features probably controlled the flow of the mineral-bearing ground-water solutions and

the localization of the deposits.

Altered mudstone within, and at the base of the ore-bearing sandstone, and concentrations of carbonized plant fossils are the most useful criteria for evaluating the favorability of sandstone for ore deposits.

From June 17, 1948 to January 10, 1949, the U. S. Geological Survey drilled 622 diamond-drill holes, totaling 41,296 feet, in the Calamity group area. As a result of this drilling, 26 carnotite deposits were found.

The indicated and inferred reserves of carnotite-bearing material, and the pounds of contained U_3O_8 and V_2O_5 are summarized in table 1. At the highest thickness and grade cut-offs (1 foot or more thick and 0.1 percent U_3O_8 or 1.0 percent V_2O_5), indicated and inferred reserves total 47,100 tons, averaging 0.33 percent U_3O_8 and 1.52 percent V_2O_5. Of this total, 39,800 tons of reserves, averaging 0.34 percent U_3O_8 and 1.52 percent V_2O_5, was discovered by U. S. Geological Survey drilling. Potential reserves, whose existence is based on geologic evidence alone, are predicted to total about 15,000 tons, averaging about 0.30 percent U_3O_8 and 1.5 percent V_2O_5.

No additional exploration by the Geological Survey is planned, as the Government claims have been leased by the Atomic Energy Commission to the U. S. Vanadium Co. (formerly the U. S. Vanadium Corp.). Additional exploratory drilling by the claim operators is recommended, however, particularly in the favorable ground in the central part of the area.

Table 1.--Summary of reserves, Calamity group area, Mesa County, Colorado

		Grade cut-off	Reserve tonnage	Percent		Pounds contained [1]	
				U_3O_8	V_2O_5	U_3O_8	V_2O_5
One foot or more thick	Indicated	0.10% U_3O_8 or 1.0% V_2O_5	33,300	0.34	1.53	226,500	1,019,000
One foot or more thick	Indicated	0.05% U_3O_8 or 0.5% V_2O_5	45,400	0.26	1.29	236,000	1,171,000
One foot or more thick	Inferred	0.10% U_3O_8 or 1.0% V_2O_5	13,800	0.30	1.5	83,000	414,000
One foot or more thick	Inferred	0.05% U_3O_8 or 0.5% V_2O_5	19,500	0.25	1.2	97,500	468,000

[1] Rounded figures, U_3O_8 to nearest 500 pounds, V_2O_5 to nearest 1,000 pounds.

INTRODUCTION

The Calamity group area is in secs. 2, 10, 11, 14, and 15, T. 50 N., R. 18 W., New Mexico principal meridian. It consists of 28 unpatented Government claims and enclosed fractions of public domain along the east rim of Calamity Mesa, Mesa County, Colo. (figs. 1, 2, and 3). Altitudes in the Calamity group area range from 6,300 to 6,700 feet. The area is covered with a sparse to thick growth of juniper, pinon pine, and other low scrubby brush. Water is scarce except after rain storms or during the melt of snow in winter and spring.

Most of the mines and claims in the Calamity group area are accessible by a network of truck trails that connect with Colorado Highway 141 by 3 unimproved roads. One of these roads extends 30 miles across Outlaw and Blue Mesas to Colorado Highway 141 at Mesa Creek, 10 miles northwest of Uravan. Another extends about 20 miles, with grades as steep as 24 percent, to Colorado Highway 141 at a point 4 miles northeast of Gateway. A third road, completed in 1950, extends via Indian Creek to the Forest Service road that traverses the Uncompahgre Plateau, and joins Colorado Highway 141 at a point 15 miles southwest of Whitewater. The unimproved roads require frequent filling and grading, and haulage in winter is particularly difficult except when the ground is frozen.

Carnotite was discovered on Calamity Mesa about 1911 and the first organized mining commenced in 1914. Only high-grade carnotite

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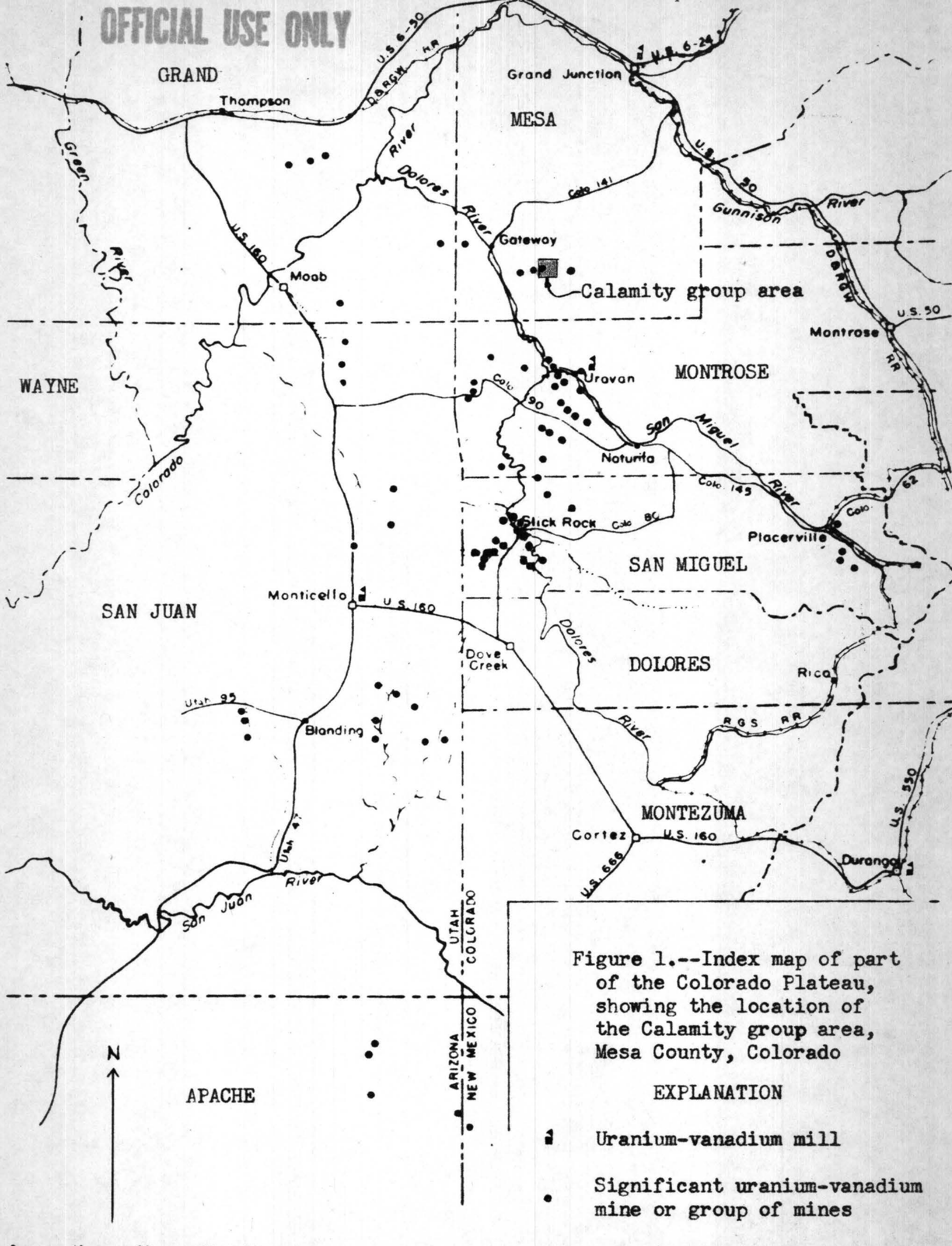

Figure 1.--Index map of part of the Colorado Plateau, showing the location of the Calamity group area, Mesa County, Colorado

EXPLANATION

Uranium-vanadium mill

Significant uranium-vanadium mine or group of mines ore was mined until 1938, when the increased demand for vanadium caused renewed activity in the district. Production for the period from 1914 to 1944 totaled about 10,000 tons of ore (table 2). As a result of Geological Survey exploration, mining was resumed in August 1949, and the production from then until January 1, 1951, totaled 8,100 tons of ore (table 3), including several hundred tons of hand-sorted and screened backfill and dump material from old workings.

During 1921 and 1922, the Radium Co. of Colorado drilled several hundred diamond-drill holes in the Calamity group area. Much of the information gained by this early drilling cannot be used, however, because many holes cannot be found or identified by number or because the records are mixed.

In 1943, when the Geological Survey and the Bureau of Mines cooperated in a drilling project to develop vanadium ore for wartime needs, 141 holes were drilled on the Calamity group _/. The location

_/ Fischer, R. P., Duncan, D. C., Stokes, W. L., and Rominger, J. F., Federal exploration for vanadium in southeastern Utah and southwestern Colorado: U. S. Geol. Survey manuscript rept., pp. 28-37, 1944.

Huleatt, W. P., Hazen, S. W., Jr., and Traver, W. M., Jr., Exploration of vanadium region of western Colorado and eastern Utah: U. S. Bur. Mines, Rept. Inv. 3930, pp. 13-15, 1946.

of these holes and the assay data are shown on figures 2, 3, and 4 and table 4. Reserves found by this drilling are given in table 5, as calculated by the Geological Survey from the Bureau of Mines assay data.

Table 2.--Production of carnotite ore from the Calamity group area, 1914-44

Period	Ore (short tons)	Grade in percent U_3O_8	Grade in percent V_2O_5
1915-38	3,000 a/	2.25 b/	2.75 b/
1939	908	0.30 a/	2.25 a/
1940	519	0.30 a/	2.25 a/
1941	874	0.30 a/	2.25 a/
1942	1,159	0.30 a/	2.25 a/
1943	2,703	0.28	2.68
1944	933	0.30 a/	2.62
Total or averages	10,096	1.00 a/	2.50 a/

a/ Estimate.

b/ Estimate based on oral communication from J. E. Weston, Climax Uranium Co.

Table 3 --Production of carnotite ore from the Calamity group area, 1949-50. _/

Claims	Ore (dry short tons)	Content of U_3O_8		Content of V_2O_5	
		Percent	Pounds	Percent	Pounds
Calamity No. 1	492	0.25	2,465	1.47	14,487
Calamity No. 2	968	0.16	3,010	1.58	30,615
Calamity No. 9	110	0.39	855	1.54	3,391
Calamity No. 13	973	0.33	6,433	1.39	26,942
Calamity No. 17	1,139	0.51	11,658	1.81	41,213
Calamity No. 18	745	0.31	4,593	1.34	19,945
Calamity No. 21	1,431	0.38	11,022	1.78	51,069
Calamity No. 27	2,242	0.41	18,528	1.81	80,966
Totals and averages	8,100	0.36	58,564	1.66	268,628

_/ From August 1949 through December 1950, inclusive.

The Geological Survey began diamond-drill exploration of the Government claims on Calamity Mesa in June 1948, and exploration was carried on simultaneously in the Calamity group area and on the Maverick group area until January 1949. This report summarizes the results of the exploration in the Calamity group area only. Results of the exploration on the Maverick group area were presented in a separate report _/. The Geological Survey drilled 622 diamond-

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_/ Stager, Harold K., Carnotite resources of the Maverick group area, Mesa County, Colorado: U. S. Geol. Survey Trace Elements Investigations Rept. 117, June 1950.

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drill holes, totaling 41,296 feet, in the Calamity group area.

The primary purpose of the exploratory drilling by the Geological Survey was to discover deposits and appraise the carnotite reserves in the Calamity group area. Preliminary results of this work were discussed in a previous report _/. Exploration by the Geological

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_/ Stager, Harold K., Carnotite deposits on Government-owned claims, Calamity Mesa, Mesa County, Colorado: U. S. Geol. Survey Trace Elements Memorandum Rept. 79, May 1949.

Survey was discontinued after completion of about 80 percent of the drilling planned, when the Government claims were leased to the U. S. Vanadium Co. by the Atomic Energy Commission.

GEOLOGY

Rocks exposed in the Calamity group area consist of sedimentary beds of the Morrison formation of Jurassic age. These beds dip about 3° SW.

The Morrison formation probably was deposited by shallow streams of low gradient that meandered across flood plains in a broad basin of low relief. The formation is divided into the Salt Wash sandstone member and the overlying Brushy Basin shale member. The Brushy Basin shale member consists of varicolored shales and lenticular beds of light-colored sandstone, which are partly conglomeratic. It crops out in steep slopes that are accessible to drill rigs only with difficulty.

The Salt Wash sandstone member is composed of lenses of light-colored sandstone interbedded with dominantly red mudstone. Most of the carnotite deposits in southwestern Colorado are in sandstones near the top of the Salt Wash member. In the area surrounding the Calamity group these sandstones form discontinuous, though broad lenses. All of the large known deposits in the area are contained in a single sandstone lens, called the "ore-bearing sandstone." The sandstone ranges from 30 to 80 feet in thickness and averages about 55 feet thick. The approximate outcrop of its top and base is shown on figures 2 and 3. A bench has developed on the sandstone over most of the area, so that most of the ground is easily accessible to drill rigs, and it is possible to test the sandstone with relatively shallow holes drilled from the surface.

The ore-bearing sandstone generally is cross-bedded or irregularly bedded. It is dominantly medium- to medium-fine-grained, though in places it is fine-grained. It is mainly light- to pale-brown, speckled with small spots (1 to 2 mm in diameter) of limonite stain, but in places it has a light reddish cast or is red-brown.

The sandstone contains some mudstone, which occurs as thin lenses and seams, and as irregular lenses of mudstone-pebble conglomerates. Fossil plant remains are common, especially in close association with the ore deposits. The plant remains consist of fragments of fossil tree trunks and branches, reeds, and leaves, as well as finely divided particles.

The mudstones that lie above and below the ore-bearing sandstone, as well as the mudstone pebbles and lenses within the sandstone, are dominantly red. Field relations suggest that this was their original color. Near ore deposits, however, the mudstone within the ore-bearing sandstone and the upper few inches to few feet of mudstone beneath the ore-bearing sandstone are altered to gray (the so-called "blue-clay" of the miners). This alteration of color apparently was caused by the mineral-bearing solutions that formed the deposits, or by other solutions that followed the same channels as the mineral-bearing solutions, because the alteration was most intense around the ore deposits. In the Calamity group area, the thickness of altered mudstone averages 3.5 feet in holes that cut mineralized rock, and 1.5 feet in holes that cut only barren sandstone. For this reason, the thickness of the altered mudstone is useful as a guide to sandstone that possibly might contain ore deposits.

A general discussion of the geology and character of the carnotite deposits of southwestern Colorado and adjoining states is given by Fischer _/.

_/ Fischer, R. P., Vanadium deposits of Colorado and Utah, a preliminary report: U. S. Geol. Survey Bull. 936-P, 1942.

ORE DEPOSITS

The ore consists mainly of sandstone impregnated with uranium- and vanadium-bearing minerals. In addition to the sandstone type of ore, some of the fossil plant remains have been replaced with rich concentrations of ore minerals, and the mudstone pebbles within the ore have a high vanadium content.

Carnotite ($K_2O.2UO_3.V_2O_5.2H_2O$) is the principal uranium-bearing mineral. It is yellow and occurs disseminated in the sandstone or as a replacement of fossil wood.

The principal vanadium-bearing mineral is finely divided and micaceous, and is generally referred to as "roscoelite." It occurs as an aggregate of minute flakes coating the sand grains and filling the interstices between the grains. This mineral gives the sandstone a gray to dark-greenish-gray color, which is darker where the vanadium content is greater.

Carbonaceous material is common. It consists of fragments of fossil tree trunks and branches, reeds, leaves, and finely divided particles as well as masses of coaly material several inches thick.

In the ore deposits, some of this carbonaceous material contains considerable amounts of uranium- and vanadium-bearing minerals, either as replacements, or as coatings in open fractures.

The ore deposits occur in irregular tabular or lens-shaped masses. The tabular layers lie nearly parallel to the sandstone bedding, although they do not follow the bedding in detail. The thicker parts of the tabular layers may form pod-like or elongate crescent-shaped masses, called "rolls". These rolls range from 10 to 100 feet or more in length and from 5 to 15 feet in thickness. The rolls and fossil logs have a dominant northeasterly trend (figures 2 and 3). An ore deposit may comprise one or more rolls, commonly connected by thin, tabular layers of mineralized rock. The thin layers that connect the rolls, although commonly of high grade, are usually too thin to be mined at a profit. In places mineralized layers too thin or too low in grade to be mined also extend outward from a few feet to nearly 100 feet from ore bodies. These extensions, and the thin layers that connect the rolls, increase the size of the drilling target and serve as a guide to ore bodies that might be present.

The deposits in the Calamity group area are noted for the abundance of fossil trees that are richly replaced by uranium- and vanadium-bearing minerals.

The ratio of uranium to vanadium is higher than in most deposits on the Colorado Plateau, which in general averages about 1 part U_3O_8 to 8 or 10 parts V_2O_5. The average grade of the ore produced from August 1949, when mining was resumed, through December 1950, was 0.36 percent U_3O_8 and 1.66 percent V_2O_5, a ratio of about 1 part U_3O_8 to 4.6 parts V_2O_5. This ratio ranges progressively within the Calamity group area from 1:3.5 in the northern part (Calamity No. 17 claim) to 1:10.5 in the southern part (Calamity No. 2 claim).

The known ore deposits in the area are close to the surface, owing to erosion of much of the overlying material. Some mining has been done by open-pit methods. Deposits that crop out along the rims have been developed by adits and drifts. Other deposits found by drilling are mined by shallow shafts and inclines. The maximum depth of deposits in the area is about 65 feet below the surface.

There are no large-tonnage, low-grade deposits in the area. A deposit thick enough to be mined (about 1 foot or more thick) generally is of minable grade and the entire deposit can be classed as "ore" and mined to its limits. The limit between high-grade ore and barren sandstone is commonly clearly defined -- a face of good ore 5 feet thick may change to barren rock in a horizontal distance of 1 foot.

Sedimentary features apparently controlled the localization of the deposits, which probably were precipitated from ground-water solutions that migrated principally along the thicker and more permeable parts of the beds shortly after the sands accumulated. The light-brown color of the sandstone and the gray or green color of the mudstone in the vicinity of the ore deposits may be effects of the mineralizing solutions. Precipitation of the ore minerals probably resulted from changes in composition of the solutions, perhaps in the environment of decaying plant material.

GUIDES TO ORE AND SUGGESTIONS FOR PROSPECTING

The following geologic features are listed in their order of usefulness as guides to ore and to sandstone that possibly might contain ore deposits. Most of these features are subtle and should be evaluated together in appraising the ground being prospected, and no single one is sufficiently well defined to be used alone. A more detailed discussion on the guides to ore deposits is given by Blackman _/.

_/ Blackman, Doris H., Geologic guides to carnotite deposits on the Colorado Plateau: U. S. Geol. Survey Trace Elements Memorandum Rept. 170, August 1950.

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1. The upper few feet of mudstone beneath the ore-bearing sandstone, and the mudstone pebbles and seams within the ore zone, have been altered from red to gray in the vicinity of ore deposits, and the amount of altered mudstone generally decreases outward from the deposits.

2. Carbonized plant remains are more abundant near deposits than in ground away from them. In most places where abundant carbonaceous material was cut by the drill, an ore deposit was found nearby.

3. The sandstone in the vicinity of deposits is dominantly light-brown, with little or none of the reddish cast that is common a few hundred feet away from deposits.

Using these criteria as guides, it is possible to evaluate the favorability of ground with information obtained from moderately wide-spaced drilling alone. Further drilling around the holes that cut weakly mineralized rock in the Calamity group area, as shown on figures 2 and 3, should result in the finding of additional ore bodies. Offset drilling by the claim operators is recommended to be done on about 50-foot centers around the margins of the deposits found by Geological Survey drilling to test for extensions of the deposits, particularly along the local trend of the logs and rolls.

Much of the ground in the area can be tested more economically by use of jackhammers or wagon drills.

GEOLOGICAL SURVEY EXPLORATION

The Geological Survey started exploration of the Maverick and Calamity groups of claims on Calamity Mesa in June 1948 _/. The first

_/ As a result of conflict of plans for exploration on Calamity Mesa, an informal agreement on areas of exploration was made between the Geological Survey and the Atomic Energy Commission, New York Raw Materials Operations, Colorado Exploration Branch. It was agreed that the Geological Survey would explore only that part of the ground west of Indian Creek that lies in the Maverick and Calamity groups of claims. Other ground on Calamity Mesa was explored in 1949-50 by the Commission. For a description of the Commission drilling see: Waulters, Ervin E., Diamond drill exploration for uranium-vanadium deposits in the Morrison formation-Salt Wash member of Calamity Mesa, Colorado., U. S. Atomic Energy Commission, Grand Junction, Colo., January 1951.

10 holes were drilled on the Maverick group, to fulfill assessment work requirements for that group of claims. After these 10 holes were drilled, operations were moved to the Calamity group and drilling continued until mid-January 1949.

From June 17, 1948 to January 10, 1949, the Geological Survey drilled 622 holes, totaling 41,296 feet, in the Calamity group area. Four of these holes were drilled in the fraction of public land between the Calamity Nos. 5, 21, and 27 claims (fig. 3). Of the 622 holes drilled, 225 cut uranium- or vanadium-bearing rock.

At the start of the drilling, much of the ground was considered favorable, on the basis of rim exposures and mine workings. Drilling was planned on about 200-foot centers, except that, in areas where unfavorable ground was encountered, the spacing was increased to 300 feet. Where ore deposits were cut, offset holes were drilled on about 50-foot centers to partly define the deposits. Holes ranged in depth from 30 to 130 feet and averaged about 65 feet. About one-half of the total number of holes and footage were used to appraise the ground. The remaining holes and footage were used in offset drilling to delimit the ore deposits found.

On January 10, 1949, drilling operations were moved to the Maverick group area, and on January 19, 1949, to Outlaw Mesa, because of difficult access to the Calamity-Maverick area. Additional drilling was planned for the Calamity group area during the summer of 1949, but these plans were abandoned when the Atomic Energy Commission leased the Government claims to the U. S. Vanadium Co. in June 1949.

RESERVES

The terms "indicated" and "inferred" reserves are applied to the uranium- and 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. Figures expressing the calculated tonnage and grade of the indicated and inferred reserves for each reserve block, and for each grade cut-off, are given in table 5. The ground containing the reserve blocks and several geologic sections showing the position of the mineralized rock in the ground are shown on figures 2, 3, and 4.

In addition to the known deposits, there probably are other deposits which have not yet been found. These deposits are predicted solely on interpretation of geologic evidence, for there is no physical proof of their existence. The term "potential" reserves is applied to the material in these deposits. Potential reserves are described on page 29.

Although reserves are not classified in this report according to their availability for mining, consideration was given to the 1950 mining and milling practices in selecting the higher grade and thickness cut-offs. This was done to obtain figures for one category of reserves that would express as nearly as possible the tonnage and grade of the material that might actually be mined from these deposits under 1950 conditions. A summary of indicated and inferred reserves in this category, and in an additional lower-grade category, is given in table 1. A more detailed breakdown, by grade and thickness cut-offs, and by unit or block number, is given in table 5.

Indicated and inferred reserves

Definitions

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 within a small limit of error, and thus can be classed as "measured", is so small as to be nearly negligible. Therefore, reserves that might be classed as measured are included with indicated reserves.

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, gamma-ray logs, 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, if any, samples or measurements.

Because of the variations in thickness and grade of ore and the scarcity of sample data, the indicated reserves in any single reserve block might actually amount to as much as twice the calculated tonnage or as little as one-half the calculated tonnage. The limit of error of the total tonnage for several blocks, however, is apt to be considerably lower, perhaps not more than 25 percent of the calculated tonnage. 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.

Thickness cut-off

Although mining practices vary from place to place in the region as well as with individual operators, under 1950-51 mining conditions most ore bodies of average grade are being mined to where they pinch to a layer about 1 foot thick. Reserves, therefore, are calculated with a thickness cut-off of 1 foot. Layers of material less than 1 foot thick are mined in places if the grade is high. As only a few drill holes in the Calamity group area, however, are in high-grade layers of material less than 1 foot thick, the tonnage of minable material less than 1 foot thick is so small as to be negligible, and for that reason no reserves less than 1 foot thick are calculated.

Grade cut-offs

The deposits contain two metals of value, uranium and vanadium. The oxides of these metals, U_3O_8 and V_2O_5, occur in an average ratio of about 1:4.5 as estimated from the assays of the Geological Survey drill core from the Calamity group area. Within the deposits, however, the two 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 the material near the point sampled. Knowing this by experience, the miner will drive to a drill hole that shows a good value in vanadium, even though the uranium content of the sample might be negligible. Thus the material in the vicinity of this sample must be classed as a reserve, even though the sample shows a value for only one metal. Furthermore, with the 1951 price schedules _/ for ore, the vanadium content of ore containing the normal metal ratio constitutes about one-fourth of the market value of the ore. Thus both metals must be considered in reserve appraisals and in selecting grade cut-offs.

_/ Domestic Uranium Program Circular 5 Revised, Part 60 -- Domestic Uranium Program, Atomic Energy Commission, Washington, D. C., February 26, 1951.

Reserves 1 foot or more thick are classified by two grade cut-offs. The higher 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 also are 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 demand or permit the mills to accept lower-grade ore.

Calculation of tonnage

The ground near the known deposits in the Calamity group area was drilled by the Geological Survey-Bureau of Mines exploration project in 1943. The tonnage and grade of indicated reserves found by that drilling _/ are included in the figures shown on table 5, although

_/ Fischer, R. P., Duncan, D. C., Stokes, W. L., and Rominger, J. F., Federal exploration for vanadium in southeastern Utah and southwestern Colorado: U. S. Geol. Survey manuscript report, table 2, 1944.

they are modified slightly to adjust for difference in grade cut-offs.

The method used for calculating the volume, and hence the tonnage, of a reserve unit 1 foot or more thick is based upon the premise that the reserve unit is a tabular mass. The average thickness of the drill-hole samples that can be combined within the specified grade class is assumed to be the average thickness of the reserve unit.

By definition, the tonnage of indicated reserves "........ is computed by projection for a reasonable distance on geologic evidence." In most places in the Calamity group area, indicated reserves are projected between drill holes and other sample points that are not more than 50 feet apart. On the other hand, 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.

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

Calculation of grade

The average grade of the indicated reserves is calculated by weighting the assay values of all samples that qualify as reserves within the grade and thickness limits. As strict grade cut-offs are used, it is generally expected that the average grade assigned to the reserve blocks will be somewhat higher than the average grade of the ore that will be eventually mined from them, owing to the unavoidable dilution of the ore with waste and low-grade material during mining. On the other hand, the tonnage assigned to these blocks should be somewhat lower than the tonnage mined from them, owing to the increment of waste and low-grade material. It should be noted, however, that the 8,100 tons of ore mined in 1949-50 (table 3), has a weighted average grade of 0.36 percent U_3O_8 and 1.66 percent V_2O_5, which is slightly higher than the calculated average grade of the reserves -- 0.34 percent U_3O_8 and 1.53 percent V_2O_5. This close correspondence of grade, between production and reserves, is believed to be due largely to careful mining practices, including hand-sorting and screening of much of the low-grade material.

The grade assigned to the inferred reserves is nearly the same as that calculated for the indicated reserves in the same block, except for the unit designated as block 20 (fig. 2 and table 5). The grade of the indicated reserves for block 20 was based on the assays for three "ore-bearing" holes, two of which (CA 163 and CA 171) showed an abnormally high uranium content. The grade of the inferred reserves for block 20 was therefore decreased to about the same average grade and metal ratio as that of the other deposits in the area.

Wherever a discrepancy was found between a uranium assay for a sampled interval and the percentage of equivalent uranium, as shown on the gamma-ray log, an attempt was made to adjust this difference by using the average grade of the deposit, as based on other drill-core assays and/or production figures.

Reserve blocks

Masses or units of mineralized rock that constitute an indicated or inferred reserve, as defined by the thickness and grade cut-offs, are called reserve blocks. The geometric limits of reserve blocks are determined by the rules used in calculating reserves (see above). The exact positions of the blocks are not shown on figures 2 and 3, though the carnotite-bearing ground that contains the blocks is designated by block numbers. 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 weighted average grade, is shown on table 5.

Potential reserves

Potential reserves include the material in deposits that have not yet been found, but which are predicted solely on geologic evidence. For the Calamity group area about 15,000 tons of potential reserves, in material 1 foot or more thick and containing 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5, are predicted. These reserves have an estimated average grade of about 0.30 percent U_3O_8 and 1.5 percent V_2O_5, and are estimated to contain about 90,000 pounds of U_3O_8 and 450,000 pounds of V_2O_5. About 10,000 tons of these reserves are predicted to be in the large area of favorable ground in the central part of the Calamity group area. In this part of the area the known deposits normally average about 2,000 tons of minable material each. It seems reasonable to predict that in the vicinity of the many holes that are in favorable or mineralized ground in this area (see figures 2 and 3), there are at least five deposits of average size to be found. Deposits in the northern and southern parts of the Calamity group area are generally sparser and smaller in size. It is predicted that there are about 5,000 tons of potential reserves to be found in these parts of the area.

PLANS AND RECOMMENDATIONS

No additional diamond drilling by the Geological Survey is planned for the Calamity group area, as the Government claims have been leased for mining.

The ground near block 17 (fig. 3) and in the vicinity of blocks 19, 28, and 30 (fig. 2) should be tested by the claim operators. Each of these blocks contains a single drill hole, and each hole cut material 1 foot or more thick and above the higher grade cut-off. Offset holes should be drilled to prove the extensions of these deposits and plan possible development. Offset holes should also be drilled around holes that cut weakly mineralized rock, on the chance that ore bodies might be found. Extensions of known ore bodies should be defined by additional close- and moderate-spaced drilling along the local trend of the known logs and rolls.

Except in the area covered by shales and mudstones of the Brushy Basin member, further exploratory and development drilling can be done economically with wagon drills.