Reconnaissance for Radioactivity in the Metal-Mining Districts of the San Juan Mountains Colorado

GEOLOGICAL SURVEY BULLETIN 1046-O

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By C. T. PIERSON, W. F. WEEKS, *and* F. J. KLEINHAMPL

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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CONTENTS

ILLUSTRATIONS

[Plates 43 and 44 are in pocket]

TABLES

RECONNAISSANCE FOR RADIOACTIVITY IN THE METAL-MINING DISTRICTS OF THE SAN JUAN MOUNTAINS, COLORADO

By C. T. Pierson, W. F. Weeks, and F. J. Kleinhampl

ABSTRACT

Thirty-four metal-mining districts in the San Juan Mountains, Colo., were investigated during 1951–53 in a reconnaissance for radioactive materials. No commercial uranium deposit was found during the reconnaissance, but one deposit has since been discovered and developed in the Cochetopa area by private interests. Except for the Cochetopa deposit, all the known occurrences of uranium minerals are small or of low grade. Additional prospecting, however, might result in the discovery of small ore deposits of uranium, or of ores of other metals that contain sufficient uranium to be produced as a byproduct.

Samples collected from the Bonanza, Upper Uncompahgre, La Plata, and Red Mountain districts contain 2.71, 0.53, 0.40, and 0.35 percent of uranium, respectively; and samples from the Telluride, Lower Uncompahgre, Rico, Engineer Mountain, Burrows Park (Whitecross), Carson Camp, and Creede districts contain smaller though significant amounts of uranium. Radioactivity caused by thorium is known in the Cebolla-Powderhorn district and in the Burrows Park (Whitecross) district. Radon was largely responsible for the radioactivity measured in the Mount Wilson district.

In the Bonanza district, pitchblende was found on the dump of the caved Whale adit, where it is associated with pyrite, galena, chalcopyrite, tetrahedrite, and enargite as fracture coatings in silicified andesite of Tertiary age. In the Upper Uncompahgre district, pitchblende was found in the Michael Breen mine in a narrow vein in the San Juan tuff of Tertiary age and near Bear Creek Falls south of Ouray in a shear zone in the slate of the Precambrian Uncompahgre formation. In the La Plata district, small amounts of uranium are contained in limonite in altered Tertiary diorite from a surface trench on the Tomahawk vein. In the Red Mountain district, pitchblende occurs in the pyritic silver-bearing galena-sphalerite-chalcopyrite-enargite ores from several chimney and vein deposits of Tertiary age. In the Telluride district a uranium-bearing hydrocarbon is found in pyritic and silicious galena-sphalerite ore from the footwall of the Montana vein in the San Juan tuff of Tertiary age. The small amounts of uranium in the other districts occur with base-metal sulfide ores from several geologic environments.

INTRODUCTION

A reconnaissance for radioactive minerals in the western part of the San Juan Mountains, Colo., (fig. 48) was started by W. S. Burbank and C. T. Pierson in 1951 and continued in 1952 by Pierson, W. F.

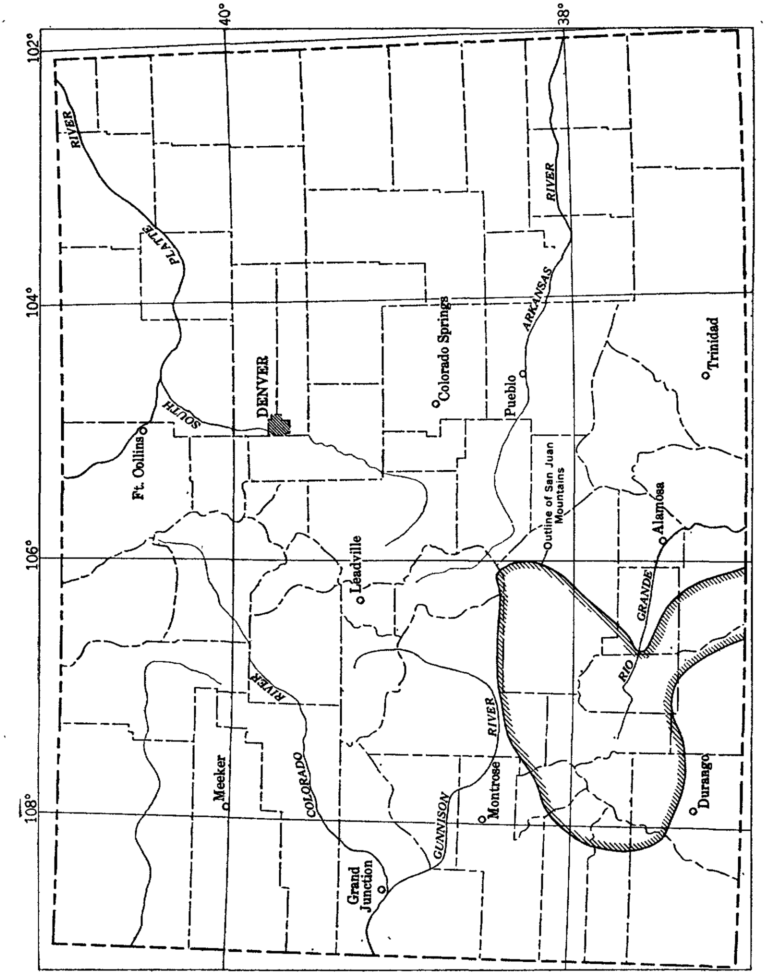

FIGURE 48.—Index map of Colorado showing location of the San Juan Mountains, Colo.

Weeks, and F. J. Kleinhampl and in 1953 by Pierson and J. W. Hawley. During 1953 a week was spent by Pierson and T. H. W. Loomis of the U. S. Atomic Energy Commission in the western part of the mountains in reconnaissance and in examination of a pitchblende occurrence found by Loomis. The work on which this paper is based was done by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

Thanks are due V. Robinson of Ouray who accompanied the writers on some of the underground work and to the many mine owners and operators who gave assistance during studies of their mines, as well as access to maps and other data. Theodore Botinelly of the Geological Survey provided much data during the microscopic study of the radioactive material.

GENERAL GEOLOGY

The following summary of the general geology and ore deposits of the San Juan Mountains has been taken from published reports by Burbank and others (1947, p. 396–446) and Cross and Larsen (1935). References for the more detailed descriptions of mining districts will be given later in this report in the individual sections. Plate 43, reproduced with some modifications from Burbank and others (1947, pl. 27), shows the general geology of the San Juan Mountains; the mining districts or areas examined are shown by numbered rectangles.

The rocks exposed in the area range from Precambrian to Recent and consist of the following rock types and units, not all of which are differentiated on plate 43. Precambrian rocks consisting of schist, gneiss, granite, quartzite, conglomerate, and slate are exposed in the deep valley of the Uncompahgre River south of Ouray, along the Lake Fork of the Gunnison River southwest of Lake City, in the Needle Mountains in the southwestern part of the San Juan Mountains, near the Gunnison River, and in the Sangre de Cristo Mountains on the north and northeast flanks of the San Juan Mountains. Sedimentary rocks of Paleozoic and Mesozoic age are exposed only on the flanks of the mountains and in the deeper canyons; locally along the margins of the mountains they underlie the volcanic rocks, but in the central part of the mountains they were largely removed before the volcanic rocks were erupted. Tertiary volcanic rocks, consisting for the most part of bedded lavas, tuffs, and breccias, underlie most of the higher parts of the San Juan Mountains. The volcanic rocks have been divided into the following main units, listed in order of decreasing age: The San Juan tuff of Miocene(?) age; the Silverton volcanic series of Miocene age; the Beidell latite-andesite and the Tracy Creek quartz latite of Miocene(?) age; the Potosi volcanic series, also of Miocene age; the Fisher quartz latite of Miocene age; and the Hinsdale formation of Pliocene(?) age. Early and late

Tertiary intrusive rocks, not differentiated on plate 43, consist of dikes, sills, stocks, and volcanic pipes. Only the larger areas of undifferentiated Tertiary and Quaternary sedimentary rocks and alluvium are shown.

The generalized structural features shown on plate 43 consist of high- and low-angle faults and monoclinal folds. Areas of cauldron subsidence, near the towns of Silverton and Lake City, are outlined by the concentric fault patterns shown on the map. Other structural features important in understanding the known uranium occurrences will be described in the sections on individual districts.

METHOD OF TESTING FOR RADIOACTIVITY

A scintillation counter was used in most of the districts to locate areas of abnormal radioactivity; individual radioactivity readings were taken mainly with portable survey meters equipped with 6-inch beta-gamma probes, though some readings were made with a scintillation counter. The readings taken at anomalously radioactive localities were measured in milliroentgens per hour (mr per hour) and are recorded in tables 1, 2, 3, and 4.

For most anomalously radioactive localities, both the maximum reading obtained on the most radioactive rock found and the range of background readings at that locality are listed in the tables. The maximum readings were obtained by repeated tests during which the probe was held directly against the rock being tested. All maximum readings were made on rocks of hand-specimen size unless the tables indicate that a spot reading was taken with the probe held directly against a rock exposure. The background readings were obtained by holding the probe at waist height for about 1 minute and recording the range of readings.

A locality is considered to be anomalously radioactive if the ratio of the maximum radioactivity reading to the maximum background reading is equal to or greater than an arbitrary figure. The figure used was 2.1 for all districts except the Upper Uncompahgre district, where a figure of 3.0 was chosen. This exception was made because most of the radioactivity readings taken in the Upper Uncompahgre district were spot readings, which ordinarily are higher than readings made on hand specimens from corresponding outcrops. The radioactivity readings taken in the other districts were made for the most part on samples of hand-specimen size.

RESULTS OF RECONNAISSANCE

Twenty-eight areas embracing about 34 mining districts in the San Juan Mountains (pl. 43) have been tested for radioactivity. A few of the smaller mining districts, the vanadium-uranium deposits in sedimentary rocks of Mesozoic age on the west and southwest borders of the mountains (Fisher, Haff, and Rominger, 1947; A. L. Bush and Leonid Bryner, written communication), and the uranium-bearing hydrocarbon deposits in the Placerville area west of Telluride (V. R. Wilmarth and R. C. Vickers, written communication) were not examined. Results of work in areas 1–7 (pl. 43) have been published (Burbank and Pierson, 1953) but are briefly summarized here to present a complete picture and to include additional data for areas 1, 3, 5, and 6.

Anomalous radioactivity was found in the Cochetopa, Cebolla, Upper Uncompahgre, Lower Uncompahgre, Red Mountain, Telluride, Sneffels, Mount Wilson, Rico, La Plata, Engineer Mountain, Burrows Park (Whitecross), Carson Camp, Creede, and Bonanza districts. Uranium is the chief cause of the radioactivity; thorium is important only in the Cebolla and Burrows Park (Whitecross) districts; and radon is largely responsible for the radioactivity measured in the Mount Wilson district. No anomalous radioactivity was found in the Silverton, Ophir, Eureka, Animas Forks, Mineral Point, Galena, Lake, Spar City, Embargo, Beidell, Summitville, Platoro districts, or in several other smaller districts.

Samples were collected that had amounts of uranium, listed in the tables, ranging from 0.001 to 2.71 percent; but none of the deposits at the sample localities can be classed as commercial at present because of their low grade, small size, or unknown characteristics where a sample came from a mine dump at an inaccessible working.

Pitchblende is the main uranium mineral in the Upper Uncompahgre, Red Mountain, and Bonanza districts and probably contains the uranium in most of the other districts where the radioactive material has not been identified because of fine grain sizes and small amounts.

AREAS OF ANOMALOUS RADIOACTIVITY

COCHETOPA AREA

The results of a brief reconnaissance in the Cochetopa area (pl. 43, area 1) in 1951 by Burbank have been published (Burbank and Pierson, 1953). Only one minor occurrence of radioactive jaspery vein matter was found near the southern limit of the Precambrian exposures along Cochetopa Creek. Since the 1951 reconnaissance, however, the Thornburg Mining Co., of Grand Junction, Colo., has developed a commercial uranium deposit on the Los Ochos claims in the Cochetopa area about 12 miles south of U. S. Highway 50 connecting Gunnison and Salida, Colo.

The geology of the Los Ochos deposit has been described by H. S. Stafford and R. C. Derzay (written communication) who found that the vein follows a major eastward-trending fault that cuts steeply across Precambrian granite, schist, and gneiss, as well as sedimentary rocks of the Morrison formation of Jurassic age. The ore consists of sooty uraninite and secondary uranium minerals which are localized where the main fault is intersected by northeastward-trending cross fractures. The Precambrian rock is the most favorable host rock for the ore.

CEBOLLA DISTRICT

The thorium-bearing quartz-carbonate-pyrite-sphalerite-galena veins in the Precambrian rocks of the Cebolla district (pl. 43, area 2) were studied briefly in 1951 by Burbank (Burbank and Pierson, 1953). Although local samples containing as much as 0.28 percent of thorium were obtained, none of the veins studied seemed to be of economic value. Olson and Wallace (written communication, 1956) later made a detailed study of the thorium and rare-earth minerals in the Powderhorn district south of the Cebolla district. Thorium-bearing veins and mineralized shear zones are found in or near alkalic igneous rocks. Although selected samples of high-grade material contain as much as 4 percent of ThO_2, the ThO_2 content of the veins is generally less than 1 percent and is only 0.05–0.1 percent in many of the veins. The age of the thorium deposits is not known more closely than pre-Jurassic.

UPPER UNCOMPAHGRE DISTRICT

General geology.—The generalized geology of the Upper Uncompahgre district (pl. 43, area 3), which lies south of the town of Ouray, is shown on plate 44. The geology shown on plate 44 and summarized below has been taken from published reports by Cross and Howe (1907), Burbank (1940), and Kelley (1946). The rocks exposed in the area, which includes most of the Upper Uncompahgre district, comprise steeply dipping quartzites and slates of the Precambrian Uncompahgre formation; moderately dipping limestones, shales and sandstones of Paleozoic age; and nearly horizontal Telluride conglomerate and San Juan tuff of Tertiary age. Quaternary deposits and pre-Tertiary and Tertiary dike rocks are not shown. The Uncompahgre formation and the San Juan tuff are of interest to this report because they are the host rocks of pitchblende-bearing veins.

The Uncompahgre formation consists of interbedded slate and quartzite units, ranging in thickness from 20 to several thousand feet, and aggregating about 9,000 feet in exposed thickness. Neither the top nor the bottom of the formation is exposed; in the northern part of the district the Ouray fault has thrown the Uncompahgre formation against the rocks of Paleozoic age, and in the southern part of the district the Uncompahgre formation passes beneath the

San Juan tuff. The Uncompahgre formation has been folded into a broad anticline trending N. 65° W., with the crest near the Dunmore vein. The limbs of the anticline dip between 55°–70°.

The rocks of Paleozoic age, not differentiated on plate 44, consist of the Elbert formation and the Ouray limestone of Late Devonian age, the Leadville limestone of Mississippian age, and the Molas and Hermosa formations of Pennsylvanian age.

The Telluride conglomerate of Oligocene (?) age is chiefly a coarse conglomerate containing pebbles and boulders of granite, schist, quartzite, porphyritic igneous rocks, and sedimentary rocks of Paleozoic and Mesozoic ages. The overlying San Juan tuff of Miocene(?) age, a bedded 1,800- to 3,000-foot thick gray to purplish-gray tuff breccia and conglomerate composed of coarse angular andesitic and latitic fragments in a tuffaceous matrix, forms the higher parts of the steep-walled Uncompahgre River gorge and constitutes an important part of the bedrock of the Upper Uncompahgre district.

The ore deposits of the district occur in the Uncompahgre formation, the rocks of Paleozoic age, and the San Juan tuff. The chief deposits in the Uncompahgre formation and in the San Juan tuff are fissure veins, which consist mainly of quartz with pyrite, sphalerite, galena, chalcopyrite, native gold, argentiferous tetrahedrite, rhodochrosite, and barite. A few veins have ore shoots with tungsten, usually huebnerite, and a few others contain sulfobismuthites of lead and silver, such as the mineral alaskaite. The ore deposits in the rocks of Paleozoic age are found mainly in the Mineral Farm area (pl. 44) as silver-lead replacement deposits in the upper part of the Leadville limestone.

Results of reconnaissance.—Rocks were tested for radioactivity along about 16 miles of linear traverse and one-fourth square mile of area traverse of the slate and quartzite bands of the Uncompahgre formation, and about 5 miles of linear traverse along the Ouray fault. Several mines in the Precambrian, Paleozoic, and Tertiary formations and about one-fifth square mile of area traverse of the Paleozoic formations in the vicinity of the Ouray hot spring deposit (pl. 44, loc. 1) were tested.

Although no uranium deposit of commercial size or grade was found in the district, anomalous radioactivity occurs at the hot spring deposit (pl. 44, loc. 1) near Ouray, at Bear Creek Falls (pl. 44, locs. 2 and 3), and at the Michael Breen mine (pl. 44, locs. 4 and 5). Table 1 gives data for samples from the anomalously radioactive localities.

Radioactive localities.—The radioactivity in calcareous tufa at the Ouray hot spring (Burbank and Pierson, 1953), which has been mined for manganese and tungsten, is caused mainly by radium and other daughter products of uranium. The deposit, just north of the Ouray

TABLE 1.—*Localities in the Upper Uncompahgre mining district having maximum radioactivity equal to or greater than 3.0 times maximum background* [1]

Map location	Sample	Radioactivity (mr per hr)[2]	Background (mr per hr)	Equivalent uranium (percent)	Uranium (percent)	Sample description	Spectrographic analysis of sample (percent)
[3] 1	K-43-1	1.0	0.05	0.11	[4] 0.001	Manganese-stained tufa and manganese ore from Ouray hot spring deposit.	>10 Mn 1.0 -10 Ba, Ca, Fe, Si, Sr, W .1 - 1.0 Al, As, Mg, Na .01 - .1 Be, Cu, Mo, Sb, Ti, Tl, V, Zn .001 - .01 Co, Pb, Zr .0001- .001 Cr
2	52-P-20	.70	0.02- .06	.15	[4] .099	Chip sample of highly radioactive slate from the shear zone near Bear Creek Falls; spot reading 1.30 mr per hr.	>10 Fe, Si 1.0 -10 Al, K, Mg .1 - 1.0 Mn, Ti, U .01 - .1 Ba, Cu, Mo, Na, Pb, Zn, Zr .001 - .01 B, Ca, Co, Cr, Ga, Ni, Sc, V, Y .0001- .001 Ag, Be, Sn, Sr
3	52-P-6	.35	.04- .07	.029	.019	A 2-ft channel sample across a quartz-pyrite-sphalerite-galena-rhodochrosite vein; from the north face of an 18-ft drift 140 ft from portal of adit.	>10 Si 1.0 -10 Al, Fe .1 - 1.0 Ca, K, Mg, Mn, Pb, Ti, Zn .01 - .1 Ba, Cu, Li, Na .001 - .01 Ag, Co, Cr, Ni, V, Y, Zr .0001- .001 Bi, Ga, Sr
4	53-P-22	20.	.02- .04	----------	69.53	Handpicked botryoidal arborescent pitchblende (identified by X-ray analysis) intermixed with about 15 percent megascopically visible galena, native bismuth, calcite, and quartz; from fracture filling in San Juan tuff, level 9 drift, Michael Breen mine, about 245 ft east of main haulage crosscut.	>10 U 1.0 -10 Bi, Ca, Pb .1 - 1.0 Cu, Mn, Sb, Sc, Si .01 - .1 Y .001 - .01 Ba, Sr .0001- .001 Mg, Ti (Usual sensitivities not attained because of high percentage of uranium.)
5	53-P-28	.40	.01- .03	.16	.14	Malachite-stained chalcopyrite-tetrahedrite(?)-quartz-barite vein material from outcrop above portal of Michael Breen mine.	>10 Si 1.0 -10 Al, Ba, Cu, Fe .1 - 1.0 Ca, K, Pb, Sb, U, Zn .01 - .1 Ag, Mg, Mn, Sr, Ti .001 - .01 Ga, Mo, Ni, V, Y, Zr .0001- .001 Co, Cr, Yb (> 1 percent Bi.)

[1] Chemical, X-ray, and spectrographic analyses by C. Angelo, G. W. Boyes, Jr., Rene Dufour, P. J. Dunton, S. Furman, R. G. Havens, A. G. King, W. Mountjoy, W. F. Outerbridge, J. N. Rosholt, P. Schuch, and J. Wahlberg, U. S. Geological Survey.

[2] All readings were made in milliroentgens per hour on samples of hand-specimen size.

[3] Data in part from Burbank and Pierson (1953, table 3).

[4] Disequilibrium caused by excess daughter products of uranium; no Th^{232} detected.

fault, rests on rocks of Paleozoic age and is overlain by glacial gravels of Pleistocene age. Most of the deposit was tested for radioactivity. A sample of tufa from the deposit contains 0.11 percent of equivalent uranium but only 0.001 percent of uranium. Spectrographic analysis shows relatively large amounts of manganese, silicon, iron, calcium, barium, strontium, and tungsten.

Small amounts of uranium, ranging from 0.003 to 0.099 percent, are found in the Precambrian rocks at Bear Creek Falls in the quartzite wall rock of a quartz-pyrite-sphalerite-galena-rhodochrosite vein, in the vein itself (pl. 44, loc. 3), and in a shear zone in slate (pl. 44, loc. 2). The uranium-bearing vein is the easternmost of the two veins shown on plate 44; no anomalous radioactivity was found along the other vein. The radioactivity of the easternmost vein is confined mainly to the pyritized quartzite of the footwall at the north face of an 18-foot drift 140 feet from the portal of the northernmost adit; however, moderate radioactivity was noted at several places along the outcrop of the vein about 50 feet above the adit level. A 2-foot channel sample containing 0.029 percent equivalent of uranium and 0.019 percent of uranium was taken from the north face of the drift; the sample included 8 inches of pyritized quartzite from the footwall, 4 inches of vein material, and 12 inches of quartzite from the hanging wall.

The uranium-bearing shear zone crops out near Bear Creek Falls (pl. 44, loc. 2). The shear zone is exposed for a length of about 70 feet, but the total length is at least 125 feet, and may be as much as 500 feet. The width of the zone ranges from 5 to 15 feet.

Although chip samples of radioactive slate from the zone contain as much as 0.099 percent of uranium, the percentages of uranium in 4 channel samples and 1 chip-channel sample across the strike of the zone are generally lower and range from 0.003 to 0.014.

The uranium mineral or minerals in the radioactive samples from the Bear Creek Falls area have not been identified. Attempts to concentrate the uranium minerals sufficiently for X-ray or other studies have not been successful, probably because the initial amounts and grain sizes of the uranium minerals have been too small. Examination of the most radioactive specimens of slate under ultraviolet light indicates that a mineral fluorescing yellow green, probably a secondary uranium mineral, is present on some of the radioactive surfaces. Some radioactive surfaces, however, do not contain any fluorescent mineral, and the uranium mineral may be pitchblende in these samples.

Sample 2 (table 1) was analyzed for Th^{232} and for radium and other daughter products of uranium. No Th^{232} was detected, and the analyses show that the difference between total radioactivity and uranium content is caused by radium and other daughter products of uranium. Leaching of uranium by supergene processes is the probable cause of this disequilibrium.

Pitchblende in veins cutting the San Juan tuff was discovered at the Michael Breen mine by T. H. W. Loomis and W. A. Hammond of the Atomic Energy Commission in 1953 and was studied by T. H. W. Loomis, C. T. Pierson, and W. A. Hammond (written communication, 1953). Two radioactive localities were found: one on level 9 of the mine (pl. 44, loc. 4), and the other at a hillside outcrop above the mine (pl. 44, loc. 5). At the underground locality, pitchblende is found in a narrow vein which strikes N. 15° to 20° W., and dips 85° SW. The pitchblende-bearing vein is offset about 4 feet where it crosses the main eastward-trending Michael Breen vein.

The pitchblende of locality 4 (pl. 44) is found as a ½- to ¾-inch wide seam in a 2- to 3-inch wide quartz-chalcopyrite-pyrite vein. The wall rock, in contrast to its usual dark gray, is pink or cream for widths up to one-half inch on either side of the vein. The pitchblende occurs both in arborescent and in botryoidal masses and is associated with chalcopyrite, pyrite, galena, native bismuth, hematite, malachite, and quartz. The pitchblende, at least in part, appears to be earlier than the pyrite; age relations to the other minerals are not known.

The uranium content of a 2-inch wide chip-channel sample along about 2 feet of dip length of the pitchblende-bearing vein was only 0.53 percent of uranium because of the spotty distribution of the pitchblende which pinches out upward in less than 20 feet and appears to occur in lenses along the strike of the vein. Several channel samples 2 feet in length that were taken across the fracture by T. H. W. Loomis (oral communication, 1953) each contain less than 0.02 percent of uranium.

The radioactivity noted at the hillside outcrop about 200 feet above level 9 of the Michael Breen mine (pl. 44, loc. 5) is in a narrow chalcopyrite-tetrahedrite(?)-quartz-barite vein in San Juan tuff. The vein strikes north and dips 80° E. A selected sample from the most radioactive part of the 2- to 4-inch wide vein contains 0.14 percent of uranium. The radioactive part of the vein has a strike length of about 15 feet and a dip length of about 7 feet. This radioactive vein is probably distinct from the pitchblende vein of locality 4 (pl. 44) but is generally parallel to it.

RED MOUNTAIN DISTRICT

Introductory statement and general geology.—In 1951 pitchblende(?) was found (Burbank and Pierson, 1953) in the Red Mountain district (pl. 43, area 5) near Red Mountain pass between Ouray and Silverton. Most mine dumps and accessible mines in the district were examined for radioactivity in 1952. The radioactivity readings and laboratory data are presented together with the previously published information (fig. 49, table 2) to give a more complete picture of the uranium

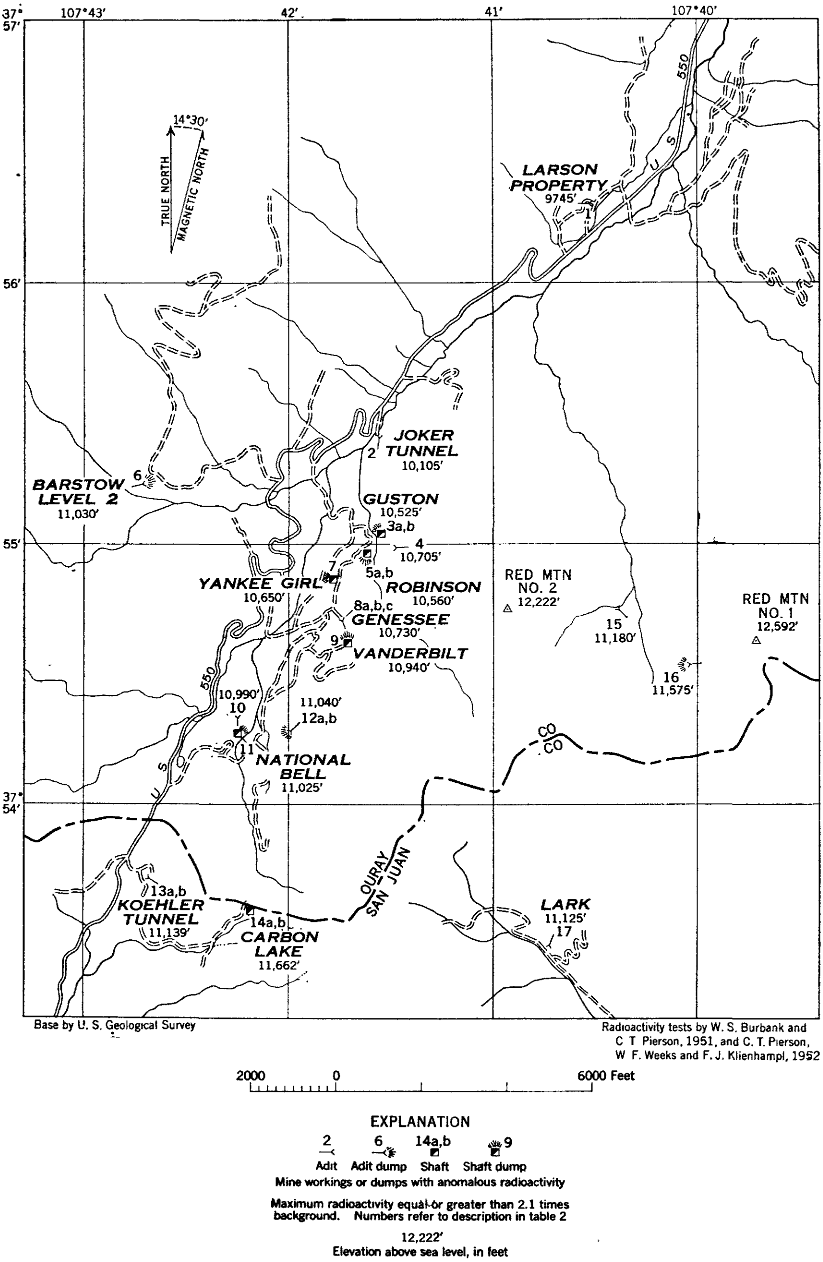

FIGURE 49.—Map showing mines tested for radioactivity, Red Mountain mining district and vicinity, Ouray and San Juan Counties.

TABLE 2.—*Mines or mine dumps in the Red Mountain mining district having maximum radioactivity equal to or greater than 2.1 times maximum background* [1]

Map location	Sample	Radioactivity (mr per hr) [2]	Background (mr per hr)	Equivalent uranium (percent)	Uranium (percent)	Sample description	Spectrographic analysis of sample (percent)
[3] 1	K-40-1	0.70 (spot reading)	0.03	0.044	0.034	Chip sample of pyritized, silicified latite with sooty pitchblende (?) at selvage of pyrite-chalcopyrite veinlet 5 mm wide; from crosscut about 750 ft from portal of tunnel, Larson property, Beaver claim (sample locality not reached in 1952 because of cave-in). General high background in drift (0.07-0.15) indicates dissemination of radioactive material in pyritize walls.	>10 Al, Fe, Si 1.0 -10 Zn .1 - 1.0 Ca, Cu, Mg, Pb, Ti .01 - .01 Ba, Bi, Mn, Na, Sr, Zr .001- .01 Ag, Co, Cr, Ga, Mo, Ni, Sc, Sn, V, Y
2	52-P-28	1.20	0.02- .05	.28	[4].070	Pyritic copper sulfide ore from dump of Joker tunnel. No anomalous radioactivity noted in traverse of crosscut to cave-in about 600 ft from portal.	>10 Fe 1.0 -10 Ba, Cu, Si .1 - 1.0 As, Sb, Zn .01 - .1 Ag, Bi, Pb, Sr, Ti, U .001- .01 Al, Ca, Ga, Ge, In, Mn, Ni, Sn, V, Zr .0001- .001 Cr, Sc Trace Mg
[3] 3a	K-36-1	.50	.02- .04	.11	.078	Pyrite in kaolinized material from dump of Guston shaft..	
[3] 3b	K-36-2	.17	.02- .04	.10	[4].023	Sample of rock from dump of Guston shaft; similar to 3a, but contains lenses of siliceous material.	>10 Al, Fe 1.0 -10 Si, Ti .1 - 1.0 Sr, Zr .01 - .1 Ag, Ba, Ca, Cu, Mg, Mn, Pb, V, Y, Zn .001- .01 B, Bi, Co, Cr, La, Mo, Nb, Sc, Sn
4	0-6-A	0.03- .15	----------	----------	----------	Radioactivity in adit east of Robinson shaft probably caused by radon because no wall-rock sample was appreciably more radioactive than background when tested outside the mine. No radioactivity greater than 1.7 times maximum background (0.06) noted in dump rock.	
[3] 5a	K-35-2	3.50	.02- .03	----------	----------	Lead-zinc-copper-silver ore from dump of Robinson shaft..	
[3] 5b	K-35-1	.60	.02- .03	.14	.061	Pyritic lead-zinc-copper-silver sulfide ore from dump of Robinson shaft.	>10 Ba, Fe, Pb, Zn 1.0 -10 As, Cu .1 - 1.0 Ag, Al, Si, Sr, Ti .01 - .1 Ca, Mg, Mn, Sb, U .001 - .01 B, Mo, Sn, V, Y, Zr .0001- .001 Bi, Cr, Sc
6	S-27-1	.14	.02- .05	----------	----------	Pyritized, kaolinized andesite(?) from dump of level 2, Barstow mine.	
[3] 7	K-37-1	.70	.02- .04	.22	.16	Pyrite-chalcopyrite-sphalerite-galena ore from ore pile in shaft house, Yankee Girl shaft.	

8a	52-P-5	.60	.02- .04	.052	[4].024	Lead-zinc sulfide ore from pillar about 600 ft from portal of Genessee tunnel. No anomalous radioactivity found in stopes above pillar or in other parts of mine tested.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Pb Al, Fe, Si, Zn As, Cu, Ti Ag, Ba, Sb, Sr, U Bi, Ca, Cd, Ga, In, Mn, Mo, Sn, V, Zr Co, Cr, Ni, Sc Mg
8b	52-P-29	.40	.02- .05	.22	[4].005	Pyritic copper-sulfide ore from dump of Genessee tunnel	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Cu, Fe Al, As, Si Ba, Bi, Pb, Ti, Zn Ca, Sb, Sr, Zr Ag, Ce, Cr, Ga, Ge, In, La, Mn, Ni, Sn, V Sc Mg
8c	52-P-31	.40	.02- .05	.16	.13	Pyritic zinc-sulfide ore from dump of Genessee tunnel	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001	Ba, Zn Al, Fe, Si As, Cu, Pb, Sr, Ti Ca, Cd, Ga, In Ag, Bi, Ce, Co, Cr, Ge, La, Mg, Mn, Mo, Ni, Sn, V, Zr Sc
9	52-P-13	.30	.02- .06	.023	[4].007	Pyritized silicified latite from dump of Vanderbilt shaft	>10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Fe, Si As, Cu, Ti Al, Pb, Sb, Zn, Zr Ag, Ba, Bi, Mn, Mo, Ni, Sn, Sr, V Co, Cr, Sc Ca, Ga, Mg
10	S-25-3	.18 (spot reading)	.03- .06	----------	----------	Limonite-stained lead-silver sulfide ore in stope above portal of adit, National Bell mine.		
[3]11	K-39-2	.18	.02- .06	.028	[4].002	Friable granular pyritic lead-sulfide ore from dump of shaft, National Bell mine.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01	Fe, Si Al, Pb, Ti As, Cu, Zn Ca, Co, Mg, Mn, Na, Sb, Sn, Ag, Ba, Bi, Cr, Ga, Mo, Nb, Ni, Sc, V
12a	52-P-9	.10	.02- .04	----------	----------	Pyritized silicified latite from dump of caved adit west of Copper King mine.		
12b	52-P-10	.14	.02- .04	.011	.007	Limonite from dump of caved adit west of Copper King mine.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 Trace	Fe Al, Si, Ti Pb, Zn Ba, Bi, Ca, Cu, Na, Sb, Sr, Zr Ag, Ce, Cr, Ga, La, Mn, Nb, Sc, Sn, V, Y Mg

See footnotes at end of table.

TABLE 2.—*Mines or mine dumps in the Red Mountain mining district having maximum radioactivity equal to or greater than 2.1 times maximum background* [1]—Continued

Map location	Sample	Radioactivity (mr per hr) [2]	Background (mr per hr)	Equivalent uranium (percent)	Uranium (percent)	Sample description	Spectrographic analysis of sample (percent)
13a	A-28-1	.11 (spot reading)	.03- .05	----------	----------	Brecciated quartz latite porphyry exposed by Koehler tunnel about 1,120 ft from portal. Radioactive area several square feet in extent; no structural features controlling radioactivity found. No anomalous radioactivity found in other parts of mine tested. Bad air about 1,935 ft from the portal prevented traversing the remaining 565 ft to the breast.	
[3] 13b	K-38	.20	.02- .06	----------	----------	Lead-zinc ore from dump of Koehler tunnel.	
14a	52-P-7	.50	.02- .05	.058	[4] .002	Pyritized silicified kaolinized latite(?) containing galena, sphalerite, and chalcopyrite from dump of Carbon Lake shaft. No anomalous radioactivity found on 50- or 125-ft levels entered through main shaft, nor on 50-ft level entered through small shaft just north of main shaft.	>10 Fe 1.0 -10 Al, Pb, Si .1 - 1.0 As, Cu, Ti, Zn .01 - .1 Ca, Na, Sb, Sn, Sr .001 - .01 Ag, Ba, Bi, Ce, Co, Cr, Ga, La, Mg, Mn, Ni, V, Zr .0001- .001 Sc
14b	52-P-8	.18	.02- .05	.026	.018	Pyritic lead-zinc-copper sulfide ore from dump of Carbon Lake shaft.	>10 Fe, Pb 1.0 -10 Al, Cu, Zn .1 - 1.0 As, Si, Ti .01 - .1 Ba, Ca, Cd, Sb, Sn, Sr .001 - .01 Ag, Bi, Ce, Co, Cr, Ga, In, La, Mg, Mn, Ni, V, Zr
15	52-P-3	.19	.07- .08	.025	.017	Pyritic lead-zinc-copper sulfide ore from dump of caved adit near Carbonate King mine.	>10 Fe, Pb 1.0 -10 Ba, Cu, Zn .1 - 1.0 Ag, Al, As, Sb, Si .01 - .1 Bi, Ca, Cd, In, Mn, Sr, Ti .001 - .01 Ga, Ge, Mg, Sn, V, Zr .0001- .001 Co, Cr, Ni
16	J-26-2	.13	.04- .06	----------	----------	Cherty limonite-stained brecciated rock from dump of caved adit in Corkscrew Gulch southeast of Carbonate King mine.	
17	52-P-30	.50 (spot reading)	.02- .04	.36	.35	Chip sample of pyritic siliceous galena-enargite(?) ore from drift 48 ft southwest from the Lark ore shoot, which is about 900 ft from the portal of the Lark tunnel.	>10 Al, Fe, Si 1.0 -10 Pb .1 - 1.0 As, Cu, Sr, Ti, U, Zn .01 - .1 Ag, Ba, Bi, Ca, Mg, Sb, V, Zr .001 - .01 Co, Cr, Ga, Mn, Ni, Sc .0001- .001 Mo, Sn, Y

[1] Chemical and spectrographic analyses by R. Dufour, P. J. Dunton, S. Furman, R. G. Havens, A. G. King, J. N. Rosholt, Jr., and J. Wahlberg, U. S. Geological Survey.

[2] All readings were made in milliroentgens per hour on samples of hand-specimen size unless noted that a spot reading, such as a reading taken with probe held directly against a rock exposure, was made.

[3] Data all or in part from Burbank and Pierson (1953, table 3).

[4] Disequilibrium caused by excess daughter products of uranium; no Th^{232} detected.

occurrences. The uranium occurrences are at the northwest border of the Silverton caldera (Burbank, 1941, p. 148) and are associated with chimneylike ore bodies in volcanic breccia pipes, veins, and adjacent wall rocks. Many of the deposits have been mined extensively for rich copper-lead-silver ore, and all except one are in the Silverton volcanic series of Miocene age. The exception, locality 1 (fig. 49), is in the underlying San Jaun tuff of Miocene(?) age.

Uranium occurrences.—No commercial deposit of uranium was found in the Red Mountain district, but specimens from 17 mine dumps are anomalously radioactive and locally contain as much as 0.35 percent of uranium. The sample containing 0.35 percent of uranium is pyritic siliceous galena-enargite(?) ore from a 2-foot wide shear zone at the border of a chimney deposit in the Lark mine (fig. 49, loc. 17). The length and thickness of the shear zone, which strikes N. 14° W. and dips 73° SW., are not known.

The ratios of percent uranium to percent of equivalent uranium for the 16 analyzed samples from the Red Mountain district range from 0.02 (table 2, loc. 8b) to 0.97 (table 2, loc. 17); the average value is 0.49. Samples 2, 3b, 8a, 8b, 9, 11, and 14a, all of which have ratios lower than the 0.49 average, were analyzed for Th^{232} and for radium and other daughter products of uranium. No Th^{232} was detected, and all the analyses show that the differences between the total radioactivity and the uranium content are caused by radium and other daughter products of uranium. As Phair and Levine (1953) have shown in their studies of the leaching of pitchblende, the most probable cause for these differences is the leaching of uranium by supergene processes.

In the Red Mountain district the radioactivity is usually associated with pyritic base-metal sulfide ore, such as at the Genessee mine (table 2, 8a, b, c) and the Carbon Lake mine (14b). In a few places, however, as at the Vanderbilt (9) and Carbon Lake (14a) mines, pyritized, silicified latite is radioactive.

Sooty pitchblende has been identified as the cause of radioactivity in some of the anomalously radioactive locations. In some of the other areas the uranium-bearing material has been concentrated somewhat in the laboratory, but none has been obtained in pure enough form to permit X-ray identification.

BONANZA DISTRICT

General geology and ore deposits.—The geology and ore deposits of the Bonanza district (pl. 43, area 27), which lies in the northeastern part of the San Juan Mountains, have been described by Burbank (1932, 1947a). The following general description of the district and the base map for figure 50 have been taken from these reports.

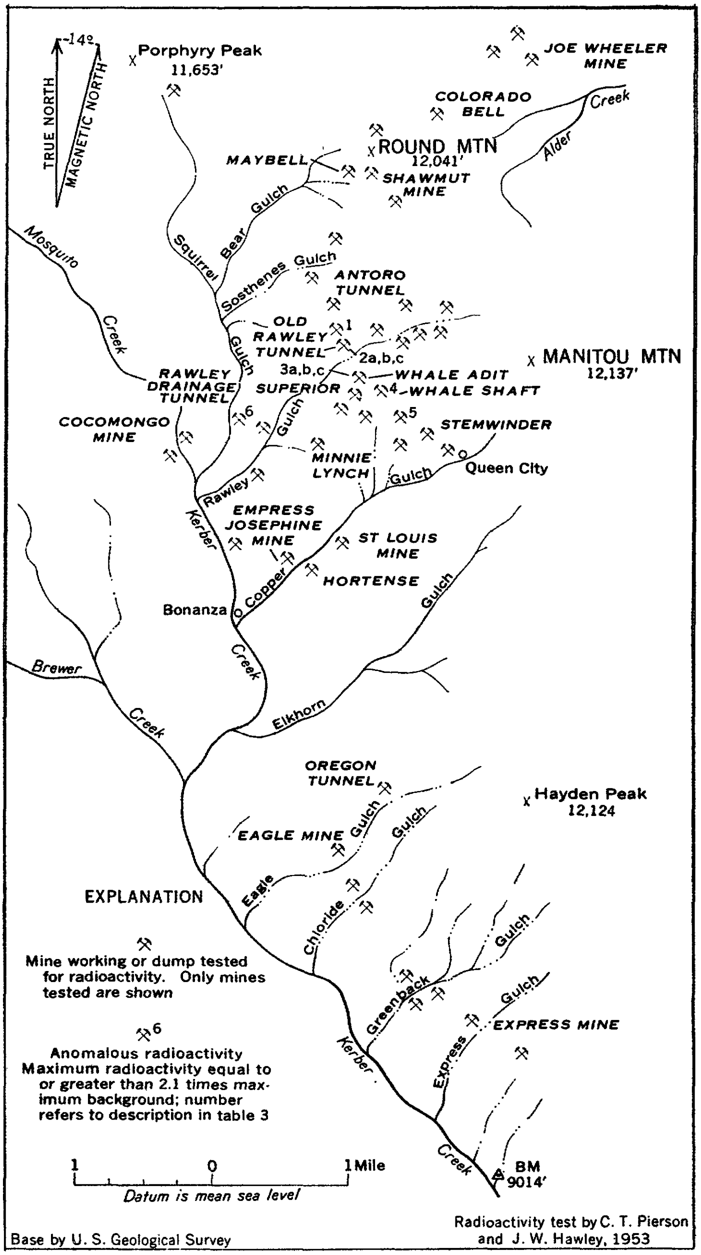

Figure 50.—Map showing mines tested for radioactivity, Bonanza mining district, Saguache County.

Tertiary volcanic rocks cover most of the district and lie on a basement of Precambrian granite, gneiss, and schist, and sedimentary rocks of Paleozoic age. The volcanic rocks are chiefly andesite, rhyolite, and latite flows and breccias intruded by many dikes and irregular masses of quartz latite and rhyolite. The volcanic rocks are intensely altered locally, and are silicified, pyritized, and altered to clay minerals, sericite, and carbonate minerals. Moderate doming of the crust may have accompanied the intrusive activity; subsequent collapse of the crust resulted in the formation of numerous small tilted fault blocks. In general, movements of the faults were downward in successive steps toward the central area of subsidence.

All the known metallic ore deposits are veins formed either along fault fissures bounding the blocks or in subsidiary tension fissures in the walls of large faults.

The ore deposits of the district are chiefly complex base-metal ores containing pyrite, sphalerite, galena, chalcopyrite, bornite, enargite, tennantite, and stromeyerite in a gangue of quartz, calcite, rhodochrosite, and barite. Some ores contain a little bismuth which occurs, in part, as the mineral cosalite. Quartz veins of relatively high sulfide content containing lead, zinc, copper, silver, and a little gold are found chiefly in the northern part of the district; whereas quartz-rhodochrosite-fluorite veins, with only minor quantities of sulfides valuable mainly for their silver content, are found in the southern part of the district.

Uranium occurrences.—About 60 percent of the mines or mine dumps in the Bonanza district were tested for radioactivity. Figure 50 shows mines or groups of mines that were investigated. The anomalously radioactive mines are designated in figure 50 by numbers which refer to the descriptions in table 3. All the anomalously radioactive localities are concentrated in the north-central part of the district in the vicinity of Rawley Gulch. No anomalous radioactivity was detected in the northern or southern parts of the district.

Samples from the radioactive localities have uranium contents ranging from 0.033 to 2.71 percent. The highest grade samples came from the dump of the caved Whale adit (fig. 50, loc. 3), but significant amounts of uranium were found in samples from the Old Rawley mine (fig. 50, locs. 1 and 2). Lesser though significant amounts of uranium were found in samples from the dump of a caved adit south of the Whale mine (fig. 50, loc. 5) and from the dump of the Rawley drainage tunnel (fig. 50, loc. 6). A few specimens from the dump of the caved Whale shaft (fig. 50, loc. 4) showed radioactivity of four times background.

The uranium in samples from the dump of the Whale adit is contained in hard lustrous noncolloform pitchblende which occurs as very

TABLE 3.—*Mines or mine dumps in the Bonanza mining district having maximum radioactivity equal to or greater than 2.1 times maximum background* [1]

Map location	Sample	Radioactivity (mr per hr)[2]	Background (mr per hr)	Equivalent uranium (percent)	Uranium (percent)	Sample description	Spectrographic analysis of sample (percent)	
1	53-P-20	0.40	0.05-0.09	0.27	0.24	Quartz-barite vein material impregnated and cut by veinlets of chalcopyrite, galena, and pyrite; from pillar about 730 ft from portal of 200-ft level, Old Rawley mine.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Ba, Cu, Fe; >1 percent Pb Al, As, Mn, Mo, U, W, Zn Ag, Bi, Ca, Sr Ni, Ti, V, Y, Zr Co, Cr, Yb Sb, Sc
2a	53-P-16	1.00	.05- .08	.75	[3].59	Siliceous chalcopyrite-tetrahedrite-enargite-wolframite(?)-sphalerite-pyrite-bearing ore from chute (to 400-ft level) about 150 ft south of breast of 500-ft level, Old Rawley mine.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si As, Cu, Fe; >1 percent Sb, W, Zn Ag, Al, Bi, Ca, Mn, Pb, U Ba, Cd, In, Mg, Mo, Ti Ni, Sc, Sr, V, Y, Yb, Zr Cr Be, Ga
2b	S-2-A	.10 (spot reading)	.02- .03	----------	----------	Area a few feet square, 35 ft north of main shaft, 500-ft level, Old Rawley mine.		
2c	53-P-17	2.00	.04- .07	.62	.61	Pyritized silicified andesite(?) from dump of Old Rawley mine; probably came from 300-ft level or above.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Ba, Cu, Fe Al, As, Pb, Sr, U, W, Zn Bi, Ca, Mn, Sb Ag, In, Mg, Mo, Ni, Sn, Ti, Y, Yb, Zr Cr, Sc, V Ga
3a	53-P-6	1.20	.04- .08	.064	.071	Sooty pitchblende in vugs in siliceous baritic vein material from dump of caved Whale adit.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Ba, Cu, Fe Al, As, Mn, Pb, Sb, Zn Ag, Bi, Ca, In, Sr, U, W Cd, Mg, Mo, Ni, Ti, Y, Yb, Zr Co, Cr, Sc, V Ga
3b	53-P-10	15.00	.04- .08	2.3	2.71	Galena, tetrahedrite, pyrite, chalcopyrite, anglesite, and pitchblende in fine-grained silicified andesite from dump of Whale adit. The pitchblende is mainly in vugs but also was observed in a veinlet cutting galena and at the selvage of a galena veinlet next to silicified andesite.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Pb As, Cu, Fe, Mn, Si, U; >1 percent Zn Al, Ba, Ca, K, Sb, Ti Ag, Bi, Dy, In, Mg, Sc, Sr, Y, Yb, Zr Ga, La, Mo, V Be, Cr, Ni Nb

3c	53-P-15	----------	----------	----------	44.62	Hard dark-colored lustrous noncolloform impure pitchblende handpicked from fracture coatings and vug fillings in altered andesite from dump of Whale adit. Megascopic impurities, totalling about 20 percent, were hematite, galena, chalcopyrite, pyrite, malachite, quartz, and barite. Pitchblende identified by X-ray analysis. Covellite, tetrahedrite, and tennantite were noted in polished section.[4]	>10	U
							1.0 -10	As, Ba, Ca, Cu, Pb, Sb, Si, Zn
							.1 -1.0	Fe, In, Mn, Sc, Y
							.01 - .1	Ag, Bi, Sr, Ti
							.001 - .01	Mg
							(Usual sensitivities not attained because of high percentage of uranium)	
4	A-28-A	.20	.02- .05	----------	----------	A few specimens from the dump of the caved Whale shaft showed minor radioactivity.		
5	53-P-19	.50	.02- .05	.22	[3].055	Siliceous vein material from dump of caved adit----------	>10	Si
							1.0 -10	Fe, Cu, Si; >1 percent Pb, Sb, Zn
							.1 -1.0	Ag, Al, As, Ba, Bi, Ca, Mo, U
							.01 - .1	Cd, In, Mg, Ti, Y
							.001 - .01	Co, Dy, Er, Gd, Ni, Sc, Sr, V, Yb, Zr
							.0001- .001	Cr
							Trace	Ga
6	53-P-5	.30	.03- .05	.048	.033	Pyrite-chalcopyrite-galena-barite vein material from dump of caved Rawley drainage tunnel.	>10	Fe
							1.0 -10	Ba, Cu, Si
							.1 -1.0	Ag, As, Sr
							.01 - .1	Al, Bi, Ca, Mn, Pb, Sb, Zn
							.001 - .01	In, Mo, Ni, Zr
							.0001- .001	Co, Cr, V, Y, Yb, Ti
							Trace	Ga, Ge, Mg, Nb

1 Chemical, X ray, and spectrographic analyses by C. Angelo, G. W. Boyes, Jr., N. M. Conklin, S. Furman, R. G. Havens, A. G. King, J. Meadows, W. Mountjoy, W. F. Outerbridge, J. N. Rosholt, Jr., P. Schuch, and J. Wahlberg, U. S. Geological Survey.

2 All readings were made in milliroentgens per hour made on samples of hand-specimen size unless noted that a spot reading, a reading taken with probe held directly against a rock exposure, was made.

3 Disequilibrium caused by excess daughter products of uranium; no Th^{232} detected.

4 Mineral identification by Theodore Botinelly, U. S. Geological Survey.

small discrete grains disseminated throughout sulfide vein material or as fracture coatings, vug fillings, and late-stage veinlets in limonite-stained siliceous vein material or silicified andesitic wall rock. Associated minerals are pyrite, galena, chalcopyrite, tetrahedrite, tennantite, enargite, covellite, quartz, chalcedony, barite, anglesite, hematite, and malachite, and small amounts of an unidentified secondary uranium mineral.

The uranium mineral from the other localities probably is also pitchblende but is not readily separable for identification.

OTHER DISTRICTS

Lower Uncompahgre (Ouray or Paquin) district.—The geology and ore deposits of the Lower Uncompahgre district (pl. 43, area 4), defined to include the mineral deposits of early Tertiary age that are chiefly near and north of Ouray in the sedimentary rocks of Paleozoic and Mesozoic age, has been described by Burbank (1940). The ores constitute base-metal and precious-metal veins and blanket bodies. The results of reconnaissance for radioactive minerals in the Lower Uncompahgre district described by Burbank and Pierson (1953) included tests of the Syracuse, Wedge, Bachelor, Sunbeam, J. V. Dexter, Calliope, El Mahdi, Pony Express, Slide and Newsboy, Senorita, and Black Girl mines or mine dumps.

Slight radioactivity was noted in Jurassic shale from the wall of the Pony Express vein in the Pony Express mine north of Ouray. The uranium content was only 0.010 percent. Small amounts of radon, ranging from 34 to 910 micromicrocuries per liter of air at mine temperature and pressure, were measured by H. Faul (written communication, 1952) of the Geological Survey in the Senorita, Black Girl, and Slide and Newsboy mines.

T. H. W. Loomis (oral communication, 1953) of the U. S. Atomic Energy Commission made tests in the Lower Uncompahgre district in 1953 but found no anomalous radioactivity.

Telluride district.—The geology of the Telluride district (pl. 43, southern part of area 9) has been described by Burbank (1941). Only one mine in the district, the Smuggler Union near the town of Telluride, was tested for radioactivity. About 20 percent of the accessible parts of this mine were checked, and one anomalously radioactive locality was found (table 4, loc. 1). At this locality a small area in the footwall of the Montana vein contains a viscous uranium-bearing hydrocarbon as disseminations and fracture fillings associated with galena and pyrite in silicified San Juan tuff. The radioactive zone is about 8 feet long and 2 feet wide; the thickness is not known.

Sneffels district.—The geology of the Sneffels district (pl. 43, northern part of area 9) has been described by Burbank (1941). Part of the Campbird mine and several mine dumps, including those of the Mountain Top and Keystone mines, were tested for radioactivity. Except for several slightly radioactive localities in the Campbird mine, no anomalous radioactivity was found. Only about 5 percent of the Campbird mine was tested for radioactivity, but 4 small occurrences were found at which the maximum radioactivity of "spot readings" was about twice maximum background. The radioactive zones, determined by the projection of the occurrences, appear to be about parallel to the ore shoots of the Campbird vein.

Mount Wilson district.—The geology of the Mount Wilson district (pl. 43, area 10) has been described by Varnes (1947a). The main mass of the mountains within the district is a stock of Tertiary age, which ranges in composition from diorite to monzonite. All the mines tested for radioactivity, except the Independence mine, are within the stock. The Independence mine is in the Telluride conglomerate of Oligocene(?) age. Most of the mines or mine dumps in Silver Pick, upper Bilk, and Navajo Basins were tested for radioactivity. Mines in lower Bilk, Elk, Magpie, and several unnamed basins were not tested. The maximum radioactivity at any of the 29 mines tested was only 1.7 times maximum background, except for a mine (table 4, loc. 2) in Navajo Basin, where radon was detected.

Rico district.—The geology and ore deposits of the Rico district (pl. 43, area 12) have been described by Cross and Ransome (1905) and by Varnes (1947b). The ore deposits consist of base-metal and precious-metal vein and blanket deposits; the main ore zone is the Hermosa formation of Pennsylvanian age.

The A. B. G. and C. V. G. mine dumps and the Silver Swan and Blaine tunnels were checked for radioactivity by the author and T. H. W. Loomis, of the U. S. Atomic Energy Commission. No anomalous radioactivity was noted at the C. V. G. or Silver Swan mine, but moderately strong radioactivity previously discovered by E. N. Harshman (oral communication, 1952) of the Geological Survey was noted at the A. B. G. mine, and anomalous radioactivity was found in the Blaine tunnel.

A sample of radioactive galena-sphalerite replacement ore in siliceous limestone (table 4, loc. 3) from the dump of the A. B. G. mine contained 0.013 percent of equivalent uranium and 0.010 percent of uranium.

The radioactivity in the Blaine tunnel (table 4, loc. 4) occurs in a 20-square-foot area along the Blackhawk vein about 1,750 feet from the portal. A sample of radioactive pyrite-quartz vein material submitted by T. H. W. Loomis (written communications, 1953) contains 0.017 percent equivalent of uranium and 0.009 percent of uranium.

TABLE 4.—*Mines or mine dumps in the Telluride, Mount Wilson, Rico, La Plata, Engineer Mountain, Burrows Park (Whitecross), Carson Camp, and Creede districts having maximum radioactivity equal to or greater than 2.1 times maximum background* [1]

Map location	Sample	Radioactivity (mr per hr)[2]	Background (mr per hr)	Equivalent uranium (percent)	Uranium (percent)	Sample description	Spectographic analysis of sample (percent)	
1	52-P-32	0.20	0.02-0.04	0.043	[3]0.035	Chip sample of uranium-bearing hydrocarbon in pyritic siliceous galena-sphalerite ore from footwall of Montana vein on 1,500-ft level about 50 ft north of manway 702, Smuggler Union mine, Telluride district.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001	Fe, Si Al, K, Pb, Zn Ca, Cu, Mg, Mn, Ti Ba, Cd, Mo, Sr, U Ag, Co, V, Y, Zr Cr, Ga, Ni, Sc
2	---------	1.0	----------	----------	----------	Radon(?), Wheel of Fortune mine, Navajo Basin, Mount Wilson district. No radioactive wall rock could be found despite high radioactivity.		
3	52-P-12	.30	.02- .06	.013	.010	Galena-sphalerite replacement ore in siliceous limestone from dump of A. B. G. mine, Rico district.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001	Si Ca, Fe, Mn, Pb Al, Cu, Zn Ag, Ba, Bi, Mg, Sr, Ti Cd, Cr, In, Mo, Ni, Sn, V, T, Zr Co, Ga
4	O-3-a	.40 (spot reading)	.02- .10	.017	.009	Pyrite-quartz vein material from north branch of Blackhawk vein, about 50 ft east of station V 42, about 1,750 ft from portal of Blaine tunnel, Rico district. Radiometric test and assay for chemical uranium made on sample submitted by Loomis of AEC.		
5	53-P-29	.40	.03- .05	.32	.40	Highly silicified limonite-stained kaolinized diorite from surface cut in Tomahawk vein, La Plata distrist. No uranium mineral identified; limonitic material, which occurs as crosscutting veinlets and as disseminations, contains small amounts of uranium.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001	Al, Si Fe, K Mg, Na, Ti, U Ba, Ca, Cu, Mn, Pb, Sr, V, Zr Cr, Ga, Mo, Sc, Y Ag, Be, Co, Ni, Yb
6	52-P-19	.45	.02- .06	.068	.051	Siliceous galena-pyrite-sphalerite ore from dump of caved Syracuse Pride adit, Engineer Mountain area.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001	Si, Zn Cu, Fe, Mn, Pb, Sb Al, As, Cd Ag, Ba, Bi, Ca, In, Mg, Mo, U Ga, Ni, Ti, V Co, Cr, Y
7	A-9-A	.18	.03- .04	.015	.010	Limonite-stained quartz-latite(?) from dump of caved shaft about 2 miles east of old town of Whitecross, Burrows Park district. Limonite stain may contain radioactive mineral.	>10 1.0 -10 .1 - 1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Al, Fe, K Ca, Mg Ba, Ce, La, Mn, Nd, Pb, Sr, Ti, Zn, Zr Cr, Cu, Mo, Nb, Ni, V, Y Ag, Yb Co, Ga, Na

8	A-9-B	.18	.04- .06	.061	.005	Vein material containing galena, sphalerite, quartz, and rhodochrosite from dump of water-filled shaft about three-fourths of a mile east of old town of Whitecross, Burrows Park district. The difference between percent equivalent uranium and percent uranium is probably caused by thorium.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Al, Fe, K, Mn; >1 percent Pb, Zn Ca, Th Cd, Ce, Cu, La, Mg, Nd, Sr, Ti Ag, Ba, Bi, Cr, Ge, Mo, Ni, Sn, V, Y, Zr Co, Ga, Yb P
9	53-P-3	.60	.03- .05	.032	.015	Limonite stained siliceous gouge (?) from dump of caved adit in volcanic rocks of the Silverton series, just north of Carson Pass in the southern part of the Carson Camp district.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Si Al, Fe, K Ca, Mg, Na, Pb, Ti, Zn Ag, Ba, Bi, Cu, Mn, Sr Cd, Cr, Ga, In, V, Zr Co, Mo, Ni, Sc, Y, Yb Ge, Nb
10	53-P-1	.18	.04- .05	.015	.020	Anglesite(?) in limonite-stained brecciated silicified rhyolite from a 6-square-ft area in the hanging wall of the Amethyst vein, about 815 ft from the portal of Commodore level 3, Creede district. Radioactive mineral not visible.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Pb, Si Al, As, Ba, Fe, K Ca, Na Ag, Cu, Mg, Mn, Sb, Sr, Ti, Zn Cr, Mo, Ni, V, Y, Zr Be, Co, Yb Ga, P
11	A-5-1	.17	.02- .05	----------	----------	Spot reading on small area Holy Moses vein, about 300 ft south of crosscut, level 2, Holy Moses mine, Creede district.		
12	A-5-3	.18	.02- .06	----------	----------	Spot reading on a 4-square-ft area in hanging wall of vein about 175 ft south of crosscut, Phoenix mine, Creede district.		
13	53-P-2	.17	.04- .07	.044	.055	Barite-quartz-anglesite(?) from vein near hanging wall, 90-ft level Phoenix mine, Creede district, about 40 ft south of shaft. Zone of radioactivity is parallel to the northward-trending vein and is 2 to 8 in. from the hanging wall; the approximate strike length of the zone, which is 3 to 10 in. wide, is 15 ft. The vertical extent is unknown. No uranium mineral visible.	>10 1.0 -10 .1 -1.0 .01 - .1 .001 - .01 .0001- .001 Trace	Pb, Si As, Ba, Fe, K Al, Na Ag, Ca, Cu, Mg, Sb, Sr, Ti, U Mn, Mo, V, Y, Zr Be, Bi, Cr, Ni, Yb Ga, Nb
14	A-4-A	.18	.01- .04	----------	----------	Spot reading on a 6-square-ft area in the footwall of the Amethyst vein, 150 ft southeast of crosscut, Amethyst level 5, Creede district.		

[1] Chemical and spectrographic analyses by N. M. Conklin, Rene Dufour, P. J. Dunton, S. Furman, R. G. Havens, A. G. King, J. Meadows, P. Schuch, D. Stockwell, and J. Wahlberg, U. S. Geological Survey.

[2] All readings were made in milliroentgens per hour on samples of hand-specimen size unless noted that a spot reading, a reading taken with probe held directly against a rock exposure, was made.

[3] Disequilibrium caused by excess daughter products of uranium; no Th^{232} detected.

La Plata district.—The La Plata district (Eckel, 1949), (pl. 43, area 13), is best known for its gold production, but it also has produced silver, lead, copper, and zinc. The chief ore minerals are native gold, gold and silver tellurides, galena, chalcopyrite, and sphalerite, which occur in quartz-pyrite veins and replacement deposits. Small amounts of palladium and platinum are associated with chalcopyrite in one deposit.

Only a brief investigation was made in 1953 in the La Plata district by the author and T. H. W. Loomis, of the U. S. Atomic Energy Commission. A chip sample of highly silicified limonite-stained kaolinized diorite was collected from the Tomahawk vein (table 4, loc. 5) and found to contain 0.32 percent of equivalent uranium and 0.40 percent of uranium. However, the highest uranium content of 7 channels taken across the vein by T. H. W. Loomis (written communication, 1953) was only 0.11 percent

Reconnaissance of part of the Tomahawk vein disclosed several localities where readings from 2 to 4 times background were obtained.

Engineer Mountain district.—The geology of the Engineer Mountain district (pl. 43, area 16) has been described by Kelley (1946). The dumps of two mines in this area, the Frank Hough and the Syracuse Pride, were tested for radioactivity. No anomalous radioactivity was found on the dump of the Frank Hough mine, but a sample of siliceous galena-pyrite-sphalerite ore containing 0.051 percent of uranium was obtained from the dump of the caved Syracuse Pride adit (table 4, loc. 6).

Burrows Park (Whitecross) district.—The geology of the Burrows Park district (pl. 43, area 19) is discussed in the section on the Lake City area (p 410).

The dumps of 3 mines in the Burrows Park district were tested, and anomalous radioactivity was found at 2 of them. Both radioactive localities are in the volcanic rocks of the Silverton series. The third, a nonradioactive locality, is a mine in Precambrian granite.

The radioactivity of 1 of the specimens (table 4, loc. 7) is caused by a small amount of uranium, but the radioactivity of the other specimen (table 4, loc. 8) is probably caused mainly by 0.1 percent or less of thorium shown by spectrographic analysis.

Carson Camp district.—The economic geology of the Carson Camp district (pl. 43, area 20), south of the Lake City area, has been discussed by Larsen (1911). The ore deposits occur mainly as veins and fracture fillings in altered zones in the lavas of the Silverton volcanic series near quartz diorite intrusive rocks of late Tertiary age. The vein minerals are barite, quartz, enargite, pyrite, marcasite, chalcopyrite, sphalerite, and galena. The chief minerals of economic value are silver and some gold and copper.

The dumps of nine mines or prospects, including the Batchelor mine, were tested for radioactivity. No anomalous radioactivity was found except for a small amount of siliceous limonite-stained gouge (?), containing 0.032 percent of equivalent uranium and 0.015 percent of uranium, from the dump of a caved adit (table 4, loc. 9) just north of Carson Pass in the southern part of the district.

Creede district.—The geology and ore deposits of the Creede district (fig. 2, area 22), in the central part of the San Juan Mountains, has been described by Emmons and Larsen (1923) and Larsen (1929).

The ore deposits of the district consist mainly of veins carrying sphalerite, galena, silver, gold, pyrite, chalcopyrite, amethystine quartz, barite, and fluorite. The veins occupy faults in rhyolite and quartz latite of the Potosi volcanic series of Miocene age. Secondary enrichment has been important in the district.

About 20 mines or mine dumps, including the Silver Horde, Magnusson, Alpha, Corsair, Solomon, Emperius, Amethyst, Commodore, Holy Moses, Outlet, Phoenix, Colewood, and Equity mines, were tested for radioactivity. The locations and descriptions of most of these mines are found in the above publications.

Anomalous radioactivity was noted at 5 places (table 4, loc's. 10–14) in the Commodore, Holy Moses, Amethyst, and Phoenix mines. However, the uranium contents of the 2 analyzed samples were only 0.055 and 0.020 percent. These were for vein material from the Phoenix mine (loc. 13) and altered wall rock of the Amethyst vein from the Commodore level 3 (loc. 10).

AREAS OF NO ANOMALOUS RADIOACTIVITY

SILVERTON AREA

The geology of the Silverton area and the nearby Arrastra Basin, Eureka, Animas Forks, and Mineral Point districts (pl. 43, areas 6, 7, and 15) has been described in reports by Cross, Howe, and Ransome (1905), Burbank (1933), Burbank (1951), Burbank and others (1947), and Kelley (1946). The ore deposits consist mainly of base- and precious-metal veins in Tertiary volcanic rocks.

The following mines or mine dumps, most of which are shown or described in the above references, were tested, but no anomalous radioactivity was detected: In the Silverton area and Arrastra Basin district (area 6), the Ione Extension claim, Blackhawk tunnel, American tunnel (Gold King), Empire tunnel, Ezra R. mine, A. S. and R. tunnel, and Highland Mary mine were investigated. In the Eureka, Animas Forks, and Mineral Point districts (area 15), the Columbus tunnel, Frisco tunnel, and the Lucky Jack, London, and Bill Young mines were tested. The Bandora mine (area 7), 8 miles westward from Silverton, showed no anomalous radioactivity.

SUMMITVILLE-PLATORO AREA

The geology and ore deposits of the Platoro, Summitville, Axell, Stunner, Gilmore, and Jasper mining districts (pl. 43, area 28) have been described by Patton (1917). Most of the mines mentioned below are referred to in his report. The districts have chiefly produced gold and silver from quartz-bearing veins in Tertiary volcanic rocks of the Conejos quartz latite and the Fisher quartz latite. Radioactivity tests were made in all districts except the Gilmore district, but no anomalous radioactivity was found.

In the Summitville district, in the northwestern part of the area, 15 mines or mine dumps, including the Aztec, Golconda, Bob Tail, Esmond, Highland Mary, Winchester, Chandler, Ida, French, Dexter, Science, Iowa, Copper Hill, Narrow Gauge, and Reynolds mines were tested for radioactivity. The Forest King and Mammoth mine dumps were tested in the Platoro district; Wilker's and Glacier mines were tested in the Axell district, just east of the Platoro district. The Pass-Me-By, Asiatic, Red Mountain No. 1, Louisa, Helper No. 10, Apex, and Victor mines were tested in the Stunner district; and the Sanger, Guadaloupe, and Miser mines were tested in the Jasper district.

LAKE CITY AREA

The geology and ore deposits of the Lake City area, including the Galena district along Henson Creek (pl. 43, area 17), the lake district along the Lake Fork of the Gunnison River (pl. 43, area 18), and the Burrows Park (Whitecross) district (pl. 43, area 19), have been described by Burbank (1947b). Irving and Bancroft (1911) described the geology and ore deposits of the Lake and Galena districts.

Most of the volcanic rocks of the Lake City area belong to the Silverton volcanic series. The ore deposits are concentrated near the border of an oval-shaped down-faulted block or caldera located between Henson Creek and the Lake Fork of the Gunnison River, and apparently are controlled by the marginal faults of the caldera. The ore deposits consist mainly of quartz-bearing base- and precious-metal veins. Silver is particularly important where the veins are enriched near the surface. Gold and silver tellurides occur locally. Precambrian granite is exposed along the south side of the caldera and on the west near the old town of Whitecross in Burrows Park. A few small ore deposits are found in the granite of the Burrows Park district.

The dumps of 11 mines or prospects, including the Ute and Ulay, Lucky Strike, and Golden Fleece mines, in the Galena, Lake, and Burrows Park districts, were tested for radioactivity. No anomalous radioactivity was noted in the Galena or Lake districts; the radioactive specimens from 2 of the 3 dumps tested in the Burrows Park district have been described previously.

OTHER DISTRICTS

Dunton district.—The gold and silver deposits of the Dunton district (pl. 43, area 11) are found mainly in Tertiary veins in Mesozoic sedimentary rocks. Dumps of the lower adit of the Modern Gold Mines Co., and of the main adit of the Free Coinage group were investigated and no anomalous radioactivity was found.

Ophir district.—The geology of the Ophir district (pl. 43, area 8) has been described by Varnes (1947c). Seven mines or mine dumps in the district, including the Carbonero, Attica, Badger, Silver Bell, and Butterfly, were tested, but no anomalous radioactivity was found.

Needle Mountains area.—The Precambrian slates and quartzites exposed along an old road east of U. S. Highway 550 in the Needle Mountains (pl. 43, area 14) were "spot checked" along a 2-mile length of the road, but no anomalous radioactivity was detected. However, radioactivity has been reported in the Needle Mountains district to the south, and additional testing is needed before any conclusions can be drawn.

Spar City district.—The Spar City district south of Creede (pl. 43, area 21) contains sparsely mineralized veins in Fisher quartz latite. One mine and two mine dumps were tested, but no anomalous radioactivity was found.

Wanamaker Creek district.—The ore deposits of the Wanamaker Creek district (pl. 43, area 23), probably mainly valuable for gold and silver, occur in pyrite-chalcopyrite-quartz veins in andesite of the Potosi volcanic series, near an intrusive body of Potosi age.

The dumps of eight mines or prospects in the district were checked, but no anomalous radioactivity was detected.

Embargo and Summer Coon districts.—The Embargo district (pl. 43, area 24), and possibly the Summer Coon district (pl. 43, area 25) in the east-central part of the San Juan Mountains, were small producers of gold, silver, lead, and copper. In the Embargo district the ore deposits occur in fissure veins which cut bedded andesites and quartz latite intrusive rocks of late Tertiary age. The vein minerals are galena, sphalerite, pyrite, and quartz. No ore minerals were observed in the Summer Coon district.

Checks of the dumps of 5 small mines or prospects in the Embargo district and of 6 prospects in the Summer Coon district did not disclose any anomalous radioactivity.

Beidell district.—The ore deposits of the Beidell district (pl. 43, area 26) consist of gold in limonite-cemented crudely bedded andesite breccia of pre-Potosi age; some open pits were dug in a zone of strong clay alteration. The dumps of 11 prospects, including a few of the cuts in the altered zone, and the face of a large opencut gold mine in the andesite breccia were tested, but no anomalous radioactivity was found.

The Crystal Hill district just south of the Beidell district was not examined.

CONCLUSIONS

A reconnaissance for radioactive minerals in 34 mining districts in the San Juan Mountains has disclosed significant though not commercial uranium occurrences in the Bonanza, Upper Uncompahgre, La Plata, Red Mountain, Telluride, Lower Uncompahgre, Rico, Engineer Mountain, Burrows Park (Whitecross), Carson Camp, and Creede districts. A commercial pitchblende deposit has been developed in the Cochetopa area since the reconnaissance. Additional prospecting in most of these districts and in the Needle Mountains district might disclose some small commercial uranium deposits, although the probability does not seem great for the Telluride, Lower Uncompahgre, Carson Camp, or Creede districts. Additional reconnaissance in the Sneffels, Mount Wilson, Silverton, Eureka, Animas Forks, Mineral Point, Poughkeepsie, Summitville, Platoro, Lake, Galena, Dunton, Ophir, Spar City, Wanamaker Creek, Embargo, Summer Coon, and Beidell districts probably would not be profitable because of the generally low level of radioactivity in these districts. Exploration in the Bonanza, Upper Uncompahgre, La Plata, and Red Mountain districts might result in finding small amounts of uranium ore, but the cost probably would be excessive.

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