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U. S. Atomic Energy Commission
P. O. Box 30, Ansonia Station
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Dear Phil:

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We are asking Mr. Hosted to approve our plan to publish this report as a Circular after revision, which may take considerable time.

Sincerely yours,

for W. H. Bradley
Chief Geologist

(200)
T67n

Geology and Mineralogy

This document consists of 21 pages,
plus 2 figures.
Series A

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RADIOACTIVITY RECONNAISSANCE OF PART OF NORTH-CENTRAL
CLEAR CREEK COUNTY, FRONT RANGE, COLORADO*

By

John D. Wells and Jack E. Harrison

July 1953

Trace Elements Investigations Report 305

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*This report concerns work done on behalf of the Division
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CONTENTS

	Page
Abstract	4
Introduction	4
Definition of terms	6
Background	6
Anomalous and abnormal radioactivity	7
Instruments	7
Method of reconnaissance	9
Surface reconnaissance	9
Underground reconnaissance	9
Reconnaissance data	10
General statement	10
Classification of abnormal radioactivity	16
Mineralogic data	17
Relation between mineralogy and radioactivity	18
Economic significance	20
Literature cited	20
Unpublished reports	20

ILLUSTRATIONS

- Figure 1. Index map of central Colorado showing area covered by reconnaissance 5
2. Map of north-central Clear Creek County, Colorado, showing radioactivity of localities examined In envelope
3. Map of part of north-central Clear Creek County, Colorado, showing distribution of vein types In envelope

TABLES

- Table 1. Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity 11
2. Relation of significant abnormal radioactivity and vein mineralogy 18
3. Relation of significant abnormal radioactivity to mineral zones 19

RADIOACTIVITY RECONNAISSANCE OF PART OF NORTH-CENTRAL
CLEAR CREEK COUNTY, FRONT RANGE, COLORADO

by John D. Wells and Jack E. Harrison

ABSTRACT

During the field seasons of 1951 and 1952, 334 localities in north-central Clear Creek County, Colo., were examined for abnormal radioactivity. Seven of the localities contain sufficient uranium to warrant some physical exploration.

Within the investigated region the highest proportion of occurrences of significant abnormal radioactivity is in veins that contain chalcopyrite. Also the highest grade samples are from chalcopyrite-bearing veins. Any locality or zone containing pyritic gold veins is unfavorable for finding a uranium deposit.

INTRODUCTION

A radioactivity reconnaissance of north-central Clear Creek County was made during 1951 and 1952 by the writers as a part of the U. S. Geological Survey's investigations of the uranium deposits in the Central City-Idaho Springs region (fig. 1). This work was done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission. Previous work in this region was done by Smith and Baker (1951, p. 5-10) of the U. S. Atomic Energy Commission. Because their report is a tabulation of radioactivity investigations in the area covered by figure 2, it includes the results of the earlier investigation. A summary of the results was given earlier (Sims, Harrison, and Moore, 1953).

The purpose of the reconnaissance was to determine the distribution and the economic importance of the radioactive occurrences of this region. The methods, as well as the results, of the investigation are given in this report, because the reconnaissance methods used during this investigation might be useful elsewhere.

Most of the new information presented in this report was gathered by Wells; Harrison is largely responsible for the information from the Freeland-Lamartine area. F. B. Moore gave the writers additional information on the Fall River area.

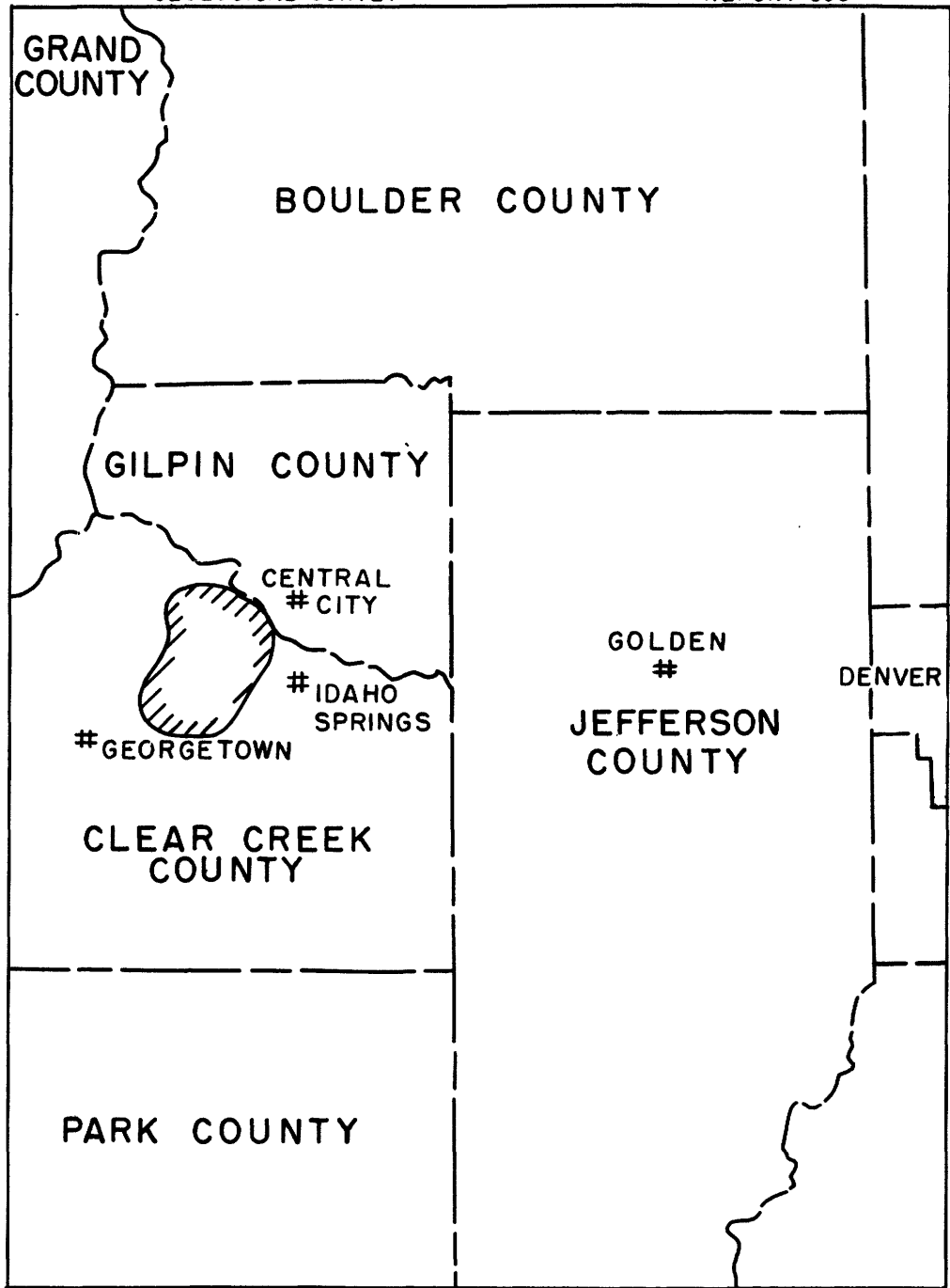


FIGURE 1.—INDEX MAP OF CENTRAL COLORADO,
SHOWING AREA COVERED BY
RECONNAISSANCE



DEFINITION OF TERMS

Background

Background as defined by Korff (1946, p. 23-24) is the instrument reading, at that particular time and place, caused by internal contamination of the counter, cosmic radiation, and the natural radioactivity of the surroundings. In precise laboratory determinations of radioactivity, the sum effect of these three factors is carefully determined. In the type of field reconnaissance done by the writers, the field measurements of radioactivity are used only to locate favorable areas to sample; therefore, the limits of error are much broader. For field measurements of radioactivity, the factor of variations in internal contamination can be ignored.

Cosmic radiation increases with altitude, therefore, the factor of variations of cosmic radiation was eliminated by establishing background at the approximate elevation of the area to be traversed. No attempt is made in this report to compare widely separated localities on the basis of field measurements of radioactivity.

The measurement of radioactivity at a given locality includes a geometric factor as well as a geologic factor. Other factors being equal, more radiation from a given rock type will be recorded in the bottom of a narrow canyon than from the same rock type on the top of a hill. The quantity of radiation reaching the instrument is increased through the proximity of a greater volume of radioactive material. The geometric factor can be ignored for all practical purposes of surface reconnaissance by recording background almost anywhere on the surface of the ground except at the bottom of a canyon. In the area of the Front Range covered by this report the radioactivity of the various rocks varies widely. In general, the radioactivity of the schistose rocks, mafic rocks, granite gneisses, and Boulder Creek granite is low relative to the intrusive rocks of Tertiary age and to the Silver Plume granite of pre-Cambrian age. From the analyses of several samples, Phair (1952) found that most of the Tertiary intrusive rocks have less than 0.02 percent equivalent uranium. Numerous scintillation counter readings on Silver Plume granite indicate that this granite has a nearly constant level of radioactivity over a wide area. A sample of this granite, considered to be representative, contained 0.006 percent

equivalent uranium. The radioactivity of vein material also is variable, for some veins contain no radioactive minerals and others contain pitchblende or other uranium minerals. In order to standardize the effect of the different rock types on the background, the background was established whenever possible over rocks known to be low in natural radioactivity. The rocks containing the lowest natural radioactivity were chosen as the standard because this reconnaissance was concerned with the measurement of the radioactivity of veins in a range below the natural radioactivity of the Tertiary dikes and Silver Plume granite. The term background is used in this report to mean the average radiation recorded at a given place and time over rock materials known to be low in natural radioactivity.

A n o m a l o u s a n d a b n o r m a l r a d i o a c t i v i t y

Any fluctuation from the general level of background is defined for this report as anomalous radioactivity. As an increase in radioactivity over the background can result from either radioactive vein material or unusually radioactive rocks, it is essential to distinguish the cause of the anomaly. The anomaly recorded from the highly radioactive country rocks has no relationship to possible uranium deposits in Tertiary veins.

Abnormal radioactivity is defined for this report as anomalous radioactivity caused by a concentration of radioactive material in Tertiary veins.

I N S T R U M E N T S

A portable scintillation detector and a portable survey meter with a 6-inch gamma-beta Geiger tube were used for the reconnaissance. Although both of these instruments measure radioactivity, the characteristics of each instrument are such that one supplements the other.

The portable scintillation detector measures gamma radiation only. Gamma radiation is more penetrating ("harder") than beta radiation; therefore, gamma radiation can be detected through greater thicknesses of rock materials and at greater distances from the source than beta radiation. In addition, a scintillation counter has a very high efficiency for the detection of gamma radiation; a Geiger counter has an efficiency of about 1 percent or less for the detection of gamma radiation (Brownell, 1950, p. 167),

but the scintillation counter has an efficiency of 20 to 25 percent for gamma rays. The larger number of impulses per unit time recorded by a scintillation counter combined with a mechanism to average the counts over several seconds results in a fairly stable dial reading. A change of 10 percent in the dial reading is readily noticed on the most sensitive scale. The instrument is sufficiently sensitive to detect large amounts of low-grade material as well as moderately small amounts of high-grade material. A scintillation detector is well adapted for field use when the purpose is to detect changes in the amount of gamma radiation dependent upon quantity or bulk of radioactive material regardless of grade. A scintillation counter was used in this reconnaissance to locate areas of anomalous radioactivity.

The portable survey meter with a 6-inch gamma-beta Geiger tube is not very sensitive to moderate amounts of radiation when the probe is held more than a foot or two away from the source. Only a small amount of radiation present in any particular area is recorded by the Geiger tube because of its low efficiency. Also the dial reading is inherently less stable than that of a scintillation counter. A 10-percent change in the reading on the most sensitive scale is very difficult to detect with confidence under field conditions. The survey meter supplements the scintillation detector because it is sensitive to a small source area. A survey meter was used in this reconnaissance to isolate the specific mineral or material causing abnormal radioactivity.

Both instruments will detect the presence of radon in a mine. Only very general statements can be made as to the quantity of gas present. In the presence of radon, both instruments will show a gradual increase in amount of radiation recorded even though the instrument is kept stationary. Even after the instrument is brought out of the mine, a higher-than-normal reading will continue for some time.

METHOD OF RECONNAISSANCE

Surface reconnaissance

In this reconnaissance the first procedure was to determine the local background for the instruments. The background for the scintillation counter was determined near the area to be examined so that local variations in cosmic radiation were eliminated. The background for a rate meter with a gamma-beta probe was determined by holding the probe several feet in the air to eliminate the effect of the rock material.

The area or dump to be examined was then traversed, using the scintillation counter. Traverses were made about 6 feet apart, holding the counter a few inches from the surface of the ground to obtain readings from a maximum depth. The traverses were made slowly to allow the instrument time to average the radioactive count for the material being traversed.

During this reconnaissance, abnormal radioactivity greater than twice background on the rate meter was considered significant, and the radioactive material was sampled. Abnormal radioactivity less than twice background on either instrument is reported in this paper but the rocks causing the radioactivity were not sampled.

Underground reconnaissance

A procedure similar to that for surface reconnaissance was followed for underground reconnaissance. Underground the background appears to be slightly higher than at the surface. Background was established underground by recording the instrument reading at least 50 feet from the portal or shaft.

Traverses were made by carrying the instrument at waist height. The scintillation counter used in this reconnaissance repeatedly recorded anomalies from small areas and thin fractures. Samples of material from these anomalous areas commonly assayed as low as 0.006 percent equivalent uranium.

Traversing of mines that contain radon is impractical because the instrument becomes contaminated. Henry Faul (oral communication), of the Geological Survey, has reported some success in combatting this contamination by placing the probe of the instrument in a plastic or rubber bag before entering a mine containing the gas.

RECONNAISSANCE DATA

General statement

A reconnaissance for radioactivity is useful in making a qualitative and broad quantitative estimate of the potentialities of a region for uranium production; that is, it can be used to determine the presence or absence of abnormal radioactivity. The grade of the material cannot be determined accurately, however, because the field measurements are made on non-homogeneous samples of different sizes. During this examination, any locality showing significant abnormal radioactivity was sampled, and these samples were sent to the laboratory for accurate determinations of equivalent uranium and uranium. To obtain dump samples that most nearly represent the highest-grade ore in the mine, only the material showing the highest radioactivity was sampled.

The results from more than forty assays show that most of the samples, particularly those collected from dumps, have radioactivity equivalent to more uranium than is actually present (table 1). Phair and Levine (1952, p. 14) have shown by a study of vein material from a dump that this condition of disequilibrium can be caused by acid solutions which leach uranium and leave a concentration of the radioactive disintegration products of uranium.

Equivalent uranium is used in this report as a basis for classification of the localities showing abnormal radioactivity. The assumption is made that the radioactive materials associated with Tertiary veins are in equilibrium. Because uranium is leached rapidly from material on dump surfaces (Phair and Levine, 1952), the radioactivity of a dump sample rather than the actual uranium content of that sample is probably more representative of the amount of uranium present in the fresh vein in the mine.

The apparent absence of radioactive material on a dump does not necessarily mean that no radioactive material occurs in the mine. Several dumps of inaccessible mines have been reported to show no abnormal radioactivity, but underground examinations following re-opening of the mine have revealed significant amounts of abnormal radioactivity.

Table 1. --Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity.

Locality 1/	Source of mineralogical data	Mineralogy 2/											Analyses				
		ga	sp	cp	py	qtz	lm	pbd	aut	ur	ba	cc	az	ma	cr	Equivalent uranium (percent)	Uranium (percent)
<u>High abnormal radioactivity</u>																	
Almaden (2)	Smith and Baker, 1951	x	x	x	x	x	x	x	x	x	x						2.04
Golconda (3)	Smith and Baker, 1951	x	x	x	x	x	x	x	x	x	x						0.57
Golden Calf (11)	Dump	x	x	x	x	x	x	x	x	x	x				0.20	.13	
Diamond Mountain (28) (Lanagan) 3/	Underground	x	x	x	x	x	x	x	x	x	x				.30	.35	
Martha E. (30)	Harrison, 1952, p. 4-5	x	x	x	x	x	x	x	x	x	x	x	x	x	.13	.12	
Orinoco (32) (Golden Glen) 3/	Dump and Spurr, et al. 1908, p. 377	x	x	x	x	x	x	x	x	x	x				.18	.22	
Baltic Tunnel (40)	Smith, 1952	x	x	x	x	x	x	x	x	x	x					.153	
<u>Moderate abnormal radioactivity</u>																	
Name unknown (5)	Dump	x	x	x	x	x	x	x	x	x	x				.036	.004	
Gold Chloride (8)	Underground examination														.029	.003	

1/ Number after locality refers to number on figure 2.

2/ Explanation of abbreviations: ga- galena; sp- sphalerite; cp- chalcopyrite; py- pyrite; qtz- quartz; lm- limonite; pbd- pitchblende;

to- torbernite; aut- autunite; ur-uranophane; ba- barite; cc- chalcocite; az- azurite; ma- malachite; cr- carbonate.

3/ Name in parentheses used in earlier U. S. Geol. Survey publications.

Table 1. --Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity. --Continued

Locality 1/ mineralogical data	Source of mineralogical data	Mineralogy 2/ to aut ur ba cc az ma cr												Analyses				
		ga	sp	cp	py	qtz	lm	pbd	to	aut	ur	ba	cc	az	ma	cr	Equivalent uranium (percent)	Uranium (percent)
<u>Moderate abnormal radioactivity--continued</u>																		
Sunnyside tunnel (16)	Underground	x	x	x	x	x	x	x									0.043	0.019
																	.092	.003
Middle tunnel, Little Johnie group (18)	Underground	x	x	x	x	x	x										.037	.033
Poor Man (20)	Dump																.028	.023
Brazil (21)	Dump	x	x	x	x	x	x										.040	.038
Crazy Girl (24)	Underground	x	x	x	x	x	x										.033	.026
Ariadne (25)	Dump																.039	.032
Belle Creole (27)	Underground	x	x	x	x	x	x										.037	.033
Gomer (29)	Dump	x	x	x	x	x	x										.068	.072
Silver Ring (33) (Silverine)	Dump and Spurr, et al, 1908, p. 375-376	x	x	x	x	x	x										.028	.028
Muscovite (35)	Dump and Spurr, et al, 1908, p. 375-376	x	x	x	x	x	x										.047	.046

Table 1. --Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity. --Continued

Locality 1/	Source of mineralogical data	Mineralogy 2/													Analyses				
		ga	sp	cp	py	qtz	lm	pb	to	aut	ur	ba	cc	az	ma	cr	Equivalent uranium (percent)	Uranium (percent)	
<u>Low abnormal radioactivity</u>																			
Gold Quartz (1)	Dump	x	x	x	x	x	x	x	x	x	x	x	x	x	x			(Not sampled)	
Standard (4)	Smith and Baker, 1951, p. 5-10 and Bastin and Hill, 1917, p. 312-313	x	x	x	x	x													
Pennsylvania (6)	Smith and Baker, 1951, p. 5-10 and Bastin and Hill, 1917, p. 312-313																	Goslarite	
Name unknown (7)	Dump																	0.011	0.006
Name unknown (9)	Dump	x																.010	.003
Albro (10)	Dump																		(Not sampled)
Major C and Little Colonial (12)	Dump																	.014	.001
Big Chief (13)	Dump	x	x															.018	.002
Old Settler tunnel (14)	Dump																	.009	.006
Old Settler shaft (15)	Dump																	.008	.008
Lower tunnel, Little Johnie group (17)	Underground	x	x	x	x	x	x	x	x	x	x	x	x	x	x			.017	.013

Table 1.--Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity.--Continued

Locality 1/	Source of mineralogical data	Mineralogy 2/													Analyses			
		ga	sp	cp	py	qtz	lm	pbd	to	aut	ur	ba	cc	az	ma	cr	Equivalent uranium (percent)	Uranium (percent)
<u>Low abnormal radioactivity--continued</u>																		
Lone Tree (19)	Dump	x	x	x	x	x	x										0.006	0.005
Bell of the West (22)	Underground	x	x	x	x	x	x										(Not sampled)	
Harrisburg (23)	Dump	x	x	x	x	x	x					x					.015	.013
Miller (26)	Underground	x	x	x	x	x	x										.006	.003
Name unknown (31)	Dump																.009	.007
Eclipse (34)	Dump	x	x		x	x	x										.006	.003
Alpine (36)	Dump and Spurr, et al, 1908, p. 333	x	x	x	x	x	x										.008	.002
Name unknown (37)	Dump																.011	.005
Argo (38)	Dump	x	x			x	x										.014	.006
Tolland County tunnel (39)	Dump	x	x	x	x	x	x										.012	.008
Humbolt (41)	Dump and Spurr, et al, 1908, p. 370-371	x	x	x	x	x	x										.010	.008
Dixie (42)	Dump																.012	.009

Table 1. --Radioactivity and mineralogic data for localities of high, moderate, or low abnormal radioactivity. --Continued

Locality 1/	Source of mineralogical data	Mineralogy 2/													Analyses			
		ga	sp	cp	py	qtz	lm	pbd	to	aur	ur	ba	cc	az	ma	cr	Equivalent uranium (percent)	Uranium (percent)
<u>Low abnormal radioactivity--continued</u>																		
Ella McKinney (43)	Dump and Spurr, et al, 1908, p. 374			x		x											0.007	0.002
Kitty Emmet (44)	Dump										x						.006	.002
Name unknown (45)	Dump																.018	.004
Two Brothers tunnel (46)	Dump	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	.009	<.001

Classification of abnormal radioactivity

For the purpose of this report, the intensity of the abnormal radioactivity is classified as follows:

- 1) slight abnormal radioactivity is radioactivity greater than background but less than twice background,
- 2) low abnormal radioactivity is in the range between 0.005 percent and 0.020 percent equivalent uranium,
- 3) moderate abnormal radioactivity is in the range between 0.021 percent and 0.099 percent equivalent uranium, and
- 4) high abnormal radioactivity is 0.10 percent or more equivalent uranium. Localities where abnormal radioactivity was noted are shown on figure 2.

The classification is based upon field instrument readings and laboratory determinations of equivalent uranium. This is necessary because samples were not collected from localities with abnormal radioactivity less than twice background. Twice background, as determined by the authors, is approximately 0.005 percent equivalent uranium. The category of slight abnormal radioactivity used in this report can be inferred to mean radioactivity that is generally less than 0.005 percent equivalent uranium. As this amount of radioactivity cannot be evaluated as yet, information on localities containing slight abnormal radioactivity is not given in table 1.

As has been stated, the lower limit of the low abnormal radioactivity is approximately equal to the equivalent uranium content of a sample showing twice background. The upper limit was placed at 0.020 percent equivalent uranium because all of the pre-Cambrian rocks and most of the Tertiary intrusive rocks contain less than 0.020 percent equivalent uranium. This range of abnormal radioactivity overlaps the range of anomalous radioactivity of some of the country rocks. The moderate abnormal radioactivity class has more equivalent uranium than the country rocks, but less equivalent uranium than present ore-grade material which is in equilibrium. The high abnormal radioactivity class has equivalent uranium equal to or greater than that of present ore-grade material which is in equilibrium.

Mineralogic data

The mineral suites identified at the localities included in this report have previously been recognized by Spurr, Garrey, and Ball (1908) and by Bastin and Hill (1917). Bastin and Hill (p. 105) have shown that these mineral suites are characteristic of three vein types, and this classification is used in this report. The vein types are: 1) pyritic, predominantly pyrite and quartz with minor amounts of chalcopyrite, 2) galena-sphalerite, predominantly galena, sphalerite, pyrite, and quartz with a subordinate amount of chalcopyrite, and 3) composite veins in which type 2 crosscuts type 1.

As much of the data in this report were obtained from dumps, the detailed relationships between vein types necessary to identify the composite type of vein are unknown. The composite type of vein, therefore, cannot be discussed and is not shown on figure 3.

Leonard (1952) suggests that in the Central City area appreciable quantities of chalcopyrite may occur in the intermediate zone between areas of predominantly pyritic type veins and areas of predominantly galena-sphalerite type veins. Leonard notes that pitchblende appears to occur principally in this intermediate zone.

The vein type occurring at each locality examined during this study is shown on figure 3. The area where veins of the pyritic type predominate has been outlined on figure 3. The southwestern part in the vicinity of Ute Creek on figure 3 is an area where veins of the galena-sphalerite type predominate and which do not contain chalcopyrite. An approximate boundary has been drawn between the area around Freeland, in which veins of the galena-sphalerite type with chalcopyrite predominate, and the area to the southwest in which chalcopyrite is absent in the galena-sphalerite type of veins. In the northern part of the area shown on figure 3 the information is inadequate to distinguish major areas similar to those shown on the southwest part of the map area.

Relation between mineralogy and radioactivity

In the area covered by this report, 334 localities have been checked for abnormal radioactivity, and eighty of these have abnormal radioactivity--7 have high, 12 have moderate, 27 have low, and 34 have slight abnormal radioactivity (fig. 2). The mineralogy of all localities having significant abnormal radioactivity is shown in table 1.

To relate the distribution of radioactive localities to vein mineralogy, two tables were prepared _/. In table 2, abnormal radioactivity is related to the mineralogy of each locality examined. In table 3 radioactivity is related to hypogene mineral zones.

From the data presented in table 2 three observations can be made:

1. The localities where pyrite was the sole ore mineral identified have a small percentage of significant abnormal radioactivity.
2. The localities where chalcopyrite has been identified have the greatest percentage of significant abnormal radioactivity.
3. Approximately the same percentage of localities where chalcopyrite plus pyrite were identified and where galena-sphalerite plus chalcopyrite were identified have significant abnormal radioactivity.

Table 2. --Relation of significant abnormal radioactivity and vein mineralogy.

Vein type	Percentage of localities with significant abnormal radioactivity
Pyritic	3.4
Galena-sphalerite	15.5
Chalcopyrite with both pyrite and galena-sphalerite	24.0
Chalcopyrite with pyrite	21.0
Chalcopyrite with galena-sphalerite	24.7

_/. For purposes of calculations for these tables, the assumption was made that localities showing only limonite belonged to the vein type of the geographic area in which they occur.

Table 3. --Relation of significant abnormal radioactivity to mineral zones.

Type of mineral zone	Percentage of localities within zone with significant abnormal radioactivity
Pyritic type veins	6.3
Galena-sphalerite veins	22.9
Chalcopyrite with galena-sphalerite veins	22.1
Area of galena-sphalerite type veins with or without chalcopyrite (zones not delimited)	10.1

The data in table 3 are based upon the zones as outlined in figure 3 without regard for the mineralogy at any particular locality. The percentage of the localities with significant abnormal radioactivity in the pyritic zone is lower than that for the remainder of the area studied. Of the 8 localities within the pyritic zone showing significant abnormal radioactivity, 3 have chalcopyrite with the pyrite. The lack of significant abnormal radioactivity in the central part of the pyritic zone is further emphasized by the observation that 6 of these 8 localities are near the margin and no localities with high and only one with moderate abnormal radioactivity occur within this zone.

When the data are considered from either of the two viewpoints (the localities individually or the distribution in mineral zones), similar conclusions are reached. Localities that have the pyritic type of vein without chalcopyrite are poor prospects for radioactive materials. Only the margin of the pyritic zone is favorable for localities showing significant abnormal radioactivity. The localities containing chalcopyrite have the highest grade as well as the highest percent of occurrence of significant abnormal radioactivity. Five of the seven localities with high abnormal radioactivity contain chalcopyrite. The other two localities have galena-sphalerite type veins. No locality with a pyritic type vein has high or moderate abnormal radioactivity. If the presence of chalcopyrite defines the intermediate zone between the pyritic and galena-sphalerite types of veins, then the intermediate zone, as suggested by Leonard (1952), appears to be the most favorable area for pitchblende prospecting in this part of the Front Range.

Economic significance

In the region covered by this report only the 7 localities showing high abnormal radioactivity contain uranium of ore grade at present prices. These 7 localities are considered to contain possible ore deposits and, therefore, are worthy of at least some exploration. As of March 1953, the Golconda and Martha E mines were being explored, but no uranium ore had yet been shipped. The owners of the Almaden, Golden Calf, and Diamond Mountain mines are considering exploration. No information is available as to the possibilities of exploration in the Orinoco mine and the Baltic tunnel.

A more objective evaluation of the potentialities of uranium production from this region awaits the results of detailed studies of the uranium occurrences. Additional information from producing mines is necessary to determine what economic significance can be attached to various amounts of abnormal radioactivity and to the pattern of its distribution.

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