Vanadium Deposits Near Placerville, San Miguel County, Colorado

Treasury Tunnel and Black Bear Mine

by

R. P. FISCHER, J. C. HAFF, AND J. F. ROMINGER

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By

R. P. FISCHER[2], J. C. HAFF[3], AND J. F. ROMINGER[4]

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[1]Published by permission of the Director of the Geological Survey, United States Department of the Interior, in cooperation with the State of Colorado through the Colorado State Geological Survey Board and the Colorado Metal Mining Fund.

[2], [3], [4]U. S. Geological Survey.

Illustrations

Abstract

Vanadium deposits were discovered near Placerville, Colorado, about 1900. Between 1910 and 1920 they were intensively mined and produced about 200,000 tons of ore, which yielded nearly 4,000,000 pounds of vanadium. After 1920 the mines were mostly inactive until 1940, when operations were resumed.

The geologic formations in the area are nearly horizontal sedimentary rocks, of Permian to Cretaceous age, which have been intruded by Tertiary igneous rocks and cut by numerous faults. The vanadium deposits occur in the Entrada sandstone, of Upper Jurassic age. The deposits seem to be older than the intrusive rocks and the faults and thus not genetically related to them.

The ore is sandstone impregnated with vanadium minerals. Most of the ore being mined contains 1½ to 3 percent V_2O_5 and ranges from 1½ to five feet in thickness. Small quartzitic nodules and lenses are commonly enclosed in the ore, especially in that of good grade.

The vanadium-bearing rock forms a wavy layer within the upper 25 feet of the Entrada sandstone and occurs in two belts. One of these, which contains the largest mines, extends northwestward from the Bear Creek mine about 10 miles to Leopard Creek; the other, recognized for two miles, is exposed north and east of Sawpit. In both belts the vanadium-bearing layer is nearly continuous and lies nearly parallel to the bedding, though without following it in detail. The layer averages a few inches in thickness, but locally it forms minable ore bodies one foot to 20 feet thick. The smaller individual ore bodies are only a few feet long and contain a few tons of ore each; the larger are several hundred feet long and contain many thousand tons. The ore bodies seem to be irregularly distributed and are either elongate or roughly circular in plan. Most of the elongate bodies, which are lens-shaped in cross section, occur where the vanadium-bearing layer cuts rather sharply across the

bedding to form what the miner calls "rolls." They are of various forms, but ordinarily have well-defined boundaries and pinch down abruptly at the sides. Most of the ore bodies not associated with large rolls are tabular and roughly circular in plan. They have poorly defined boundaries, and their thickness in cross section diminishes gradually from a maximum of about three feet to less than a foot.

The mineralization is believed to have taken place at a water table that existed prior to igneous activity and deformation. The genetic and structural conditions that controlled the localization of the ore bodies have not been definitely determined, and the exact locations of ore bodies cannot be predicted. Prospecting should be restricted, however, to the mineralized belts within the upper part of the Entrada sandstone. Since many ore bodies seem to be clustered in poorly defined areas 1,000 to 2,000 feet across, ground adjacent to closely spaced known ore bodies is favorable for prospecting. Rolls or unusual concentrations of quartzitic nodules and lenses in the vanadium-bearing layer, even where the layer is not workable, may indicate a nearby ore body. Systematic prospecting might be done by making a series of widely spaced parallel drifts, 30 to 40 feet below the ore-bearing zone, from which vertical and inclined diamond-drill holes could be driven upward into that zone.

Introduction

The Placerville area comprises parts of Tps. 43 and 44 N., Rs. 10 and 11 W., in San Miguel County, Colorado. Field work in the area was done during June, July, and August 1942, in cooperation with the State of Colorado and the Colorado Metal Mining Fund, as part of the program of investigation by the Geological Survey, United States Department of the Interior, of the vanadium deposits in Colorado, Utah, Arizona, and New Mexico. The work was greatly facilitated by the generous aid of the staffs of the Vanadium Corporation of America and the U. S. Vanadium Corporation.

The geology and vanadium deposits of the Placerville area were described by Hess[1] in 1911, and in general papers by Hess[2] and by Fischer[3] on the vanadium-uranium deposits of Colorado and Utah.

The area is in the eastern part of the Colorado Plateau physiographic province and is rugged and much dissected. Altitudes range from 7,300 feet at Placerville to about 9,000 feet on the plateau surface adjacent to the San Miguel River valley. In general, the south-facing slopes afford better rock exposures and carry less vegetation than the north-facing slopes, which bear pine and aspen suitable for mine timbers.

State highways and the narrow-gauge Rio Grande Southern Railroad follow the San Miguel River and Leopard Creek in the area. The railroad connects with the standard-gauge Denver and Rio Grande Western Railroad at Montrose, Colorado.

The map of the Placerville area (pl. 1) was compiled from plane-table maps, controlled by a triangulation net established from survey points on the coordinate system of the Vanadium Corporation of America. Vertical control was taken from U. S. Coast and Geodetic Survey bench marks along the railroad.

Production

The vanadium deposits of the Placerville area were discovered about 1900. A few years later the U. S. Vanadium Company purchased many of the original claims and built a small mill at Vanadium (then called Newmire). In 1909 the Rare Metals Mining & Milling Company was organized and purchased claims from independent claim holders. At about the same time the Primos Chemical Company pur-

[1]Hess, F. L., Notes on the vanadium deposits near Placerville, Colo.: U.S. Geol. Survey Bull. 530, pp. 142-156, 1911.

[2]Hess, F. L., in Ore deposits of the Western States (Lindgren volume): pp. 455-480, Am. Inst. Min. Met. Eng., 1933.

[3]Fischer, R. P., Sedimentary deposits of copper, vanadium-uranium, and silver in Southwestern U. S.: Econ. Geol., vol. 32, pp. 906-951, 1937. Vanadium deposits of Colorado and Utah, a preliminary report: U.S. Geol. Survey Bull. 936-P. 1942.

chased the interests of the U. S. Vanadium Company and built a 100-ton mill at Vanadium. This mill was destroyed by fire in February 1919, and was rebuilt with a 50-ton capacity. The properties of the Primos Chemical Company were sold on January 1, 1920, to the Vanadium Corporation of America, which operated the mines until December 1920. The Colorado Vanadium Corporation leased and mined the claims of the Rare Metals Mining & Milling Company during 1919 and 1920, and during 1920 it operated a small mill at Sawpit. There was little mining activity in the area between 1921 and 1940. The ore mined from 1940 to 1943 has been treated by the Vanadium Corporation of America mill at Naturita, Colorado, and the Metals Reserve Company mill at Durango, Colorado.

TABLE 1

Tons of vanadium ore milled, percent V_2O_5 contained, and pounds of vanadium (V) recovered by the Primos Chemical Company (1910-1919, inclusive) and the Vanadium Corporation of America (1920).[4]

	Ore milled (tons)	V_2O_5 contained (percent)	Vanadium (V) recovered (pounds)
1910	4,677	2.68	54,304
1911	6,903	3.07	153,335
1912	13,200	3.34	300,129
1913	23,299	2.84	448,180
1914	18,436	2.89	396,470
1915	28,728	2.93	667,600
1916	28,164	2.55	543,919
1917	29,632	2.38	499,739
1918	15,151	2.30	245,636
1919	8,213	2.34	123,070
1920	18,093	2.20	261,470
Total	194,496		3,693,852

[4]Published by permission of the Primos Chemical Co. and the Vanadium Corp. of America.

Table 1 shows the tons of ore milled, the percentage of V_2O_5, and the number of pounds of vanadium (V) recovered by the Primos Chemical Company and the Vanadium Corporation of America between 1910 and 1920. Before 1917 most of the ore milled came from the Bear Creek mine. Most of the ore treated after 1917 came from the Fall Creek and Omega mines, but the figures presented include about 2,000 tons of ore purchased from the Colorado Vanadium Corporation, and probably a similar amount purchased from other ore producers. Production data for the Colorado Vanadium Corporation mill in 1920 and for the U. S. Vanadium Company mill before 1910 are not available, but the production is known to have been small.

GEOLOGY

Most of the Placerville area is underlain by nearly horizontal sedimentary rocks of Permian to Cretaceous age, which have been intruded by Tertiary igneous rocks and cut by numerous faults. The vanadium deposits occur in the Entrada sandstone[5] of Upper Jurassic age, which is 35 to 70 feet thick.

The Entrada is a white to buff, rather fine-grained sandstone, through which are scattered large, well-rounded quartz grains. Its outcrop appears to be a single thick stratum, but actually its upper part consists of rather thin even beds and its lower part is massive and cross-bedded. Although the sandstone is soft and friable, it is well-exposed in the area and forms rounded cliffs or steep, bare slopes. It is easily distinguished from the underlying thick, reddish series of sandstone, sandy shale, and conglomerate, and its upper limit is clearly defined where overlain by the Pony Express limestone member of the Wanakah formation.[6] This limestone is dark gray to black, fine-grained, and thinly and

[5]In the Placerville area, as in the adjacent San Juan Mountain region, the Entrada sandstone was formerly called "lower La Plata sandstone" by the Geological survey, a term still used by some people.

[6]The Pony Express limestone was called the "La Plata limestone" in early Geological Survey reports on the San Juan Mountain region.

108°02'30" 108°00' 107°57'30"

38° 02' 30"

38° 00'

37° 57' 30"

EXPLANATION

SEDIMENTARY ROCKS

Jk — Post-Entrada formations — JURASSIC-CRETACEOUS

Je — Entrada sandstone — JURASSIC

PR — Pre-Entrada formations — PERMIAN-TRIASSIC

IGNEOUS ROCKS

Dike

Stock

Area probably underlain by vanadium-bearing sandstone

Fault, showing downthrown side

Important vanadium mine (see Plate 2)

Vanadium prospects and mines that have yielded less than 500 tons of ore

Outcrop of vanadium-bearing sandstone *(Dashed where covered)*

Outcrop of chromium-bearing sandstone *(Dots closely spaced where outcrop is exposed, widely spaced where it is covered)*

Limit of vanadium-bearing belt *(Shown by long dashes where it is relatively well located, by short dashes where only roughly located)*

1000 0 5000 Feet

N

TO MONTROSE

BM 7745

Alder Creek

STATE HIGHWAY NO. 62

Leopard Creek

Jk

8550

Je

PR

BM 7378

TO NORWOOD

8346

OMEGA MINE

7300

8110

STATE HIGHWAY NO. 145

San Miguel River

BM 7394

8681

POCAHONTAS MINE

8403

8474

6558

Fall Creek

Sawpit

BM 7527

8285

FALL CREEK MINE

8272

FRAZIER MINE

Vanadium

7740

TO TELLURIDE

Big Bear Creek

8102

CARPENTER MINE

BEAR CREEK MINE

8537

A

A'

R. 6 S.

109° 108° 107°

39° 38° 37°

Rifle

Grand Junction

Uravan

Montrose

Naturita

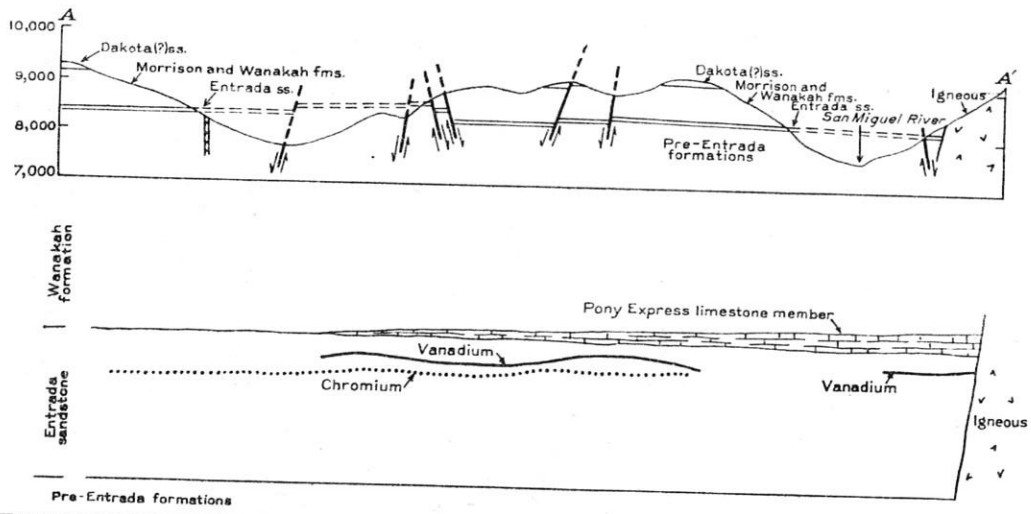
Placerville

Monticello

Durango

UTAH COLORADO ARIZ. NEW MEXICO

10 0 10 50 Miles



Upper section A-A' shows structural relations; lower section is diagrammatic and shows stratigraphic position and horizontal distribution of the vanadium- and chromium-bearing layers (vertical scale much exaggerated)

Geology by J.C. Haff, J.F. Rominger, and R.P. Fischer 1942

PLATE I.—MAP OF THE PLACERVILLE AREA, SAN MIGUEL COUNTY, COLORADO, SHOWING CROSS SECTION AND GEOLOGIC FEATURES RELATED TO THE VANADIUM DEPOSITS

Prepared by the United States Department of the Interior, Geological Survey, in cooperation with the State of Colorado and the Colorado Metal Mining Fund

irregularly bedded. It is as much as 15 feet thick in the eastern part of the area mapped but thins westward and is absent in the western and southwestern part of the area. Its western limit coincides approximately with that of the vanadium-bearing sandstone. The limestone is overlain by the Bilk Creek sandstone and marl members of the Wanakah formation, about 40 to 60 feet in total thickness.

The Morrison formation, which overlies the Wanakah formation, consists of about 650 feet of light-colored sandstone, interbedded with shale. Above the Morrison is the Dakota (?) sandstone, 150 to 200 feet thick, which caps the plateau adjacent to the San Miguel River and its tributaries.

The igneous rocks in the area are a dioritic or monzonitic stock east of Sawpit,[7] several basic dikes one foot to 10 feet thick, and some intrusive bodies of undetermined form that crop out of the north rim of the San Miguel River valley opposite the mouth of Fall Creek.

All faults in the area are normal, with dips of 55° to 85°. The displacement on most of them is less than 100 feet, but on a few it is several hundred feet. As the igneous rocks and the faults have no apparent genetic relation to the vanadium deposits, they are not accurately located on the map (pl. 1), except near mines and outcrops of Entrada sandstone.

Ore Deposits

The ore is sandstone impregnated with vanadium minerals. Most of the ore being mined contains 1½ to 3 percent V_2O_5 and is 1½ to five feet thick. The ore forms lens-shaped masses which lie nearly parallel to the bedding but do not conform to it in detail. These masses are in the upper 25 feet of the Entrada sandstone and occur in two belts, through which the ore bodies appear to be widely scattered.

Composition.—The principal ore mineral is micaceous, forming aggregates of minute flakes that coat sand grains

[7]Cross, Whitman, and Larsen, E. S., A brief review of the geology of the San Juan region of Southwestern Colorado: U.S. Geol. Survey Bull. 843. Plate 1, 1935.

and partly or completely fill the spaces between them. As the texture is extremely fine, no satisfactory optical identification of this mineral has been possible. Two chemical analyses show, however, that its composition is close to that of roscoelite, as was first suggested by Hillebrand.[8] A recent analysis of reasonably pure material separated from the Placerville ore is given in table 2, with an earlier analysis by Hillebrand of similar material from Placerville and two analyses of roscoelite from other localities.

1. Vanadiferous mica from vanadium ore collected near Placerville, Colorado. Concentrated by C. S. Ross. V. North, analyst.

2. Vanadiferous silicate, collected near Placerville, Colorado. Calculated by W. F. Hillebrand from analysis of vanadium-bearing sandstone. W. F. Hillebrand, analyst.[9]

3. Roscoelite, near Placerville, California, W. F. Hillebrand, analyst.[9]

4. Roscoelite from El Dorado County, California. F. A. Genth, analyst.[10]

The color of the ore ranges from dull greenish-gray to dark gray, and in general it becomes darker as the vanadium content increases, so that an experienced miner can estimate the grade of the ore within one-half percent from the color. Small, irregularly shaped, quartizitic nodules and lenses are commonly enclosed in the ore, especially in ore of relatively high grade.

Distribution.—The apparent geographic distribution of the vanadium-bearing sandstone is shown in plate 1. One mineralized belt, at least nine miles long and about 1½ miles wide, extends from the Bear Creek mine northwestward to the Omega mine and northward along Leopard Creek. As

[8]Hillebrand, W. F., and Ransome, F. L., On carnotite and associated vanadiferous minerals in Western Colorado: U.S. Geol. Survey Bull. 262, pp. 18-21, 1905.

[9]Hillebrand, W. F., and Ransome, F. L., op. cit., pp. 18-21.

[10]Genth, F. A., On some tellurium and vanadium minerals: Am. Phil. Soc. Proc., vol. 17, pp. 119-121, 1877.

TABLE 2

Analyses of vanadiferous mica from the Placerville area, Colorado, and of roscoelite from other localities:

	1	2	3	4
SiO_2	44.81	46.06	45.17	47.69
Al_2O_3	18.42	22.55	11.54	14.10
FeO	1.58		1.60	1.67
Fe_2O_3		.73		
V_2O_3	20.41	12.84	24.01	20.56
MgO	.83	.92	1.64	2.00
CaO	.20	.44		
BaO		1.35		
K_2O	8.28	8.84	10.37	7.59
Na_2O	.07	.22	.06	.19
H_2O at 105°	.53	1.98	.40	
H_2O at 105°-300°	3.87	.51	.17	4.96
H_2O above 300°		3.56	4.12	
TiO_2	.56		.78	
Cr_2O_3	.02			
MnO	.01			
LiO_2	none			tr.
F	.15			
P_2O_5	.01			
	99.73	100.00	99.86	98.76
Less O=F	.06			
	99.67			

the Entrada sandstone is not exposed for many miles southeast of the Bear Creek mine or north of the junction of Leopard and Alder Creeks, the southeastern and northern limits of this belt are not known. What appears to be a second belt is exposed north and east of Sawpit. It ends about a mile southeast of Sawpit and is bounded on the east by an igneous intrusion; its northern limits are not known,

but it may extend northwestward to the vanadium-bearing outcrops on Leopard Creek. The mineralized sandstone in these belts forms a nearly continuous, wavy layer within the upper 25 feet of the Entrada sandstone. Its thickness ranges from a small fraction of an inch to as much as 20 feet, but averages a few inches. This layer lies, in general, nearly parallel to the bedding, but does not conform to it in detail.

A thin layer of light-green sandstone, colored by a finely disseminated chromium mineral, lies a few feet below the vanadium-bearing layer of the Bear Creek mine-Leopard Creek belt and extends for a mile or more farther southwest (pl. 1). It has no commercial importance but is a useful horizon marker.

Ore bodies.—The individual vanadium ore bodies have a wide range in size. The small ones are only a few feet across and from one to five feet thick and contain only a few tons of ore; the large ones are several hundred feet across and from two to 20 feet thick and contain many thousand tons of ore. In plan, some of the ore bodies are roughly circular and others are elongate; some of the latter being curved. Plate 2 shows the size, plan, and special relations of the known ore bodies in the larger mines. These bodies appear to be distributed irregularly, though they may be clustered in poorly defined areas 1,000 to 2,000 feet across.

Most of the elongate ore bodies occur where the vanadium-bearing layer cuts rather sharply across the beds, forming what the miners call a "roll." Such bodies take several forms. A single roll is formed where the vanadium-bearing layer cuts down across the beds from a higher stratigraphic position on one side of the body to a lower position on the other (fig. 1, A). Many ore bodies in the Omega mine are of this type. Other ore bodies are convex upward. Some of these have nearly flat bottoms (fig. 1, B), but in many large deposits the bottom is more decidedly convex upward in the center than the top, so that the ore is thickest near the margins (fig. 1, C). In some examples of

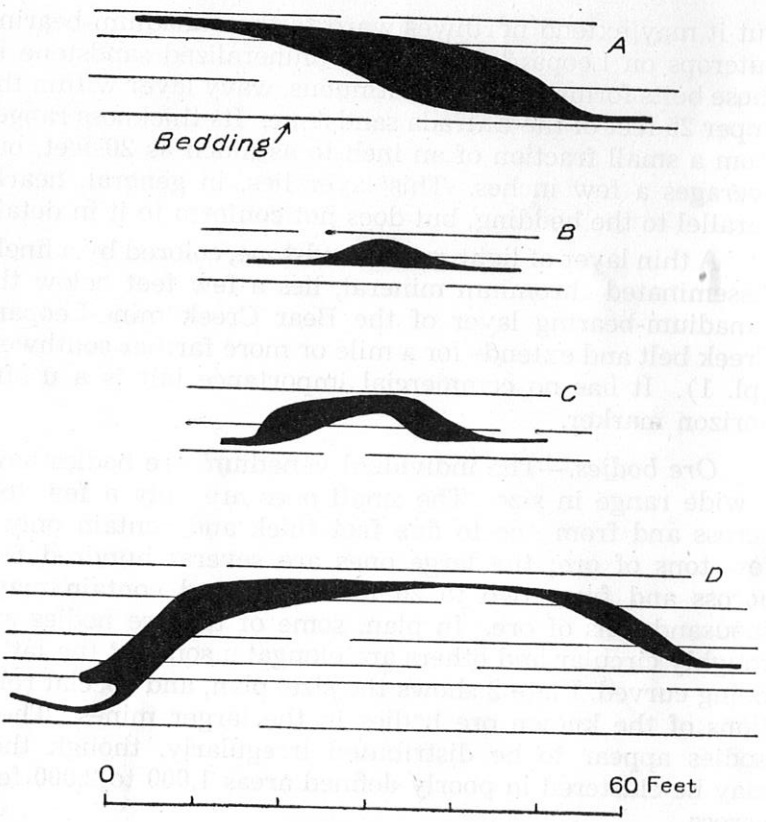


Figure 1.—Vertical sections across elongate ore bodies, perpendicular to the long axes of the rolls, showing different forms of the rolls. *A* section across an ore body in Omega mine; *B* section across an ore body in the Pocahontas mine; *C* section across an ore body in the Pocahontas mine; *D* section across an ore body in the Fall Creek mine. *(Horizontal scale in section D is foreshortened one half, vertical scale as shown by the bar scale.)*

this type (fig. 1, D) the vanadium-bearing layer is too thin near the center to be mined; bodies of this form are found in the north end of the Fall Creek mine. An ore body having the form of a single roll (fig. 1, A) closely resembles one-half of a convex body whose center is too thin to mine (fig. 1, D), and the ground adjoining the stratigraphically high side of a

single roll should therefore be prospected in the hope that a roll dipping in the opposite direction may be found. Some of the bodies are convex downward rather than upward. In most elongate bodies the thickness of the ore near the edges diminishes laterally within a few feet from more than two feet to less than a foot, so that the boundaries of such bodies are sharply defined.

In many ore bodies that are roughly circular in plan the vanadium-bearing layer lies nearly parallel to the bedding and no large rolls are present. As these bodies thin gradually from a maximum thickness of about three feet to less than a foot, their boundaries are very indefinite. The ore is typically dark gray and quartzitic and contains more than 2 percent V_2O_5. Some ore containing 3 percent or more of V_2O_5 has been mined where its thickness is slightly less than a foot, but when so thin a layer is blasted the ore becomes diluted with rock waste.

Geologic controls.—No satisfactory explanation can yet be offered for the origin of these deposits, and no geologic controls are known that make it possible to predict the exact locations of ore bodies. The ore is displaced by faults and cut by dikes, but neither the distribution of the ore bodies nor variations in the grade of the ore suggest any genetic relationship between the ore and either the faults or the dikes. This lack of apparent relationship is especially striking along the fault that extends from the Bear Creek mine to the vicinity of the Omega mine, passing as it does almost through the center of the mineralized belt.

As the layer of impregnated sandstone in places cuts across the bedding, the minerals in their present form must have been deposited from solutions after the sands had accumulated. The fact that the vanadium-bearing layer lies wholly within a relatively permeable stratum and is not conformable with the bedding at many places, both within and between the ore bodies, suggests that mineralization occurred at a slightly uneven water table, or at the contact between ground waters of two types. Under such conditions

the ore bodies might have been localized at places where groundwater circulation was relatively active, particularly where the water table, or the contact between the two kinds of ground water, cut across the beds.

It may be significant that in the Placerville area the southwestern limit of the sandstone impregnated with vanadium-bearing minerals corresponds closely to that of the immediately overlying Pony Express limestone. As the present southwestern limit of the limestone appears to mark its original extent in that direction, there may be a geologic relationship, involving ground water conditions, between the vanadium-bearing belt and the edge of the limestone or between the vanadium-bearing belt and the border of the basin in which the limestone was deposited. Although this relationship may not aid in predicting the exact location of ore bodies in the Placerville area, it may be a useful guide in finding other vanadium-bearing areas in the San Juan Mountains.

The chromium-bearing layer is similar in its occurrence to the vanadium-bearing layer and probably similar in origin.

Prospecting and Mining

Prospecting in the Placerville area has consisted mostly of searching for outcrops of ore, in driving adits through soil and talus where bedrock is covered, and in drifting from stopes. Some drifts are placed at the general level of the vanadium-bearing layer, but, as this layer is wavy, it may rise above or dip below the level of a drift so placed. Many drifts have been driven below the vanadium-bearing layer —as much as 25 feet below it in places—and raises have been put up from these drifts at intervals. As the Entrada sandstone is exposed along steep-walled canyons and overlain by 800 to 1,000 feet of strata, prospecting with drifts is regarded as more economical than diamond drilling from the surface.

In mining the ore, modifications of the room-and-pillar methods are commonly employed. In small deposits the ore

is followed and is mined as it is opened. Large bodies, particularly those that are nearly flat-lying and of uniform thickness, are developed by one or more haulage drifts, from which side drifts are driven at intervals of about 25 feet, and the ore is mined from these drifts. Layers of ore as thin as 1½ feet can be sliced from the area between side drifts, with the removal of little or none of the enclosing barren sandstone and with little dilution of the ore by waste. Pillars are left as local conditions require, and vertical stulls are used in places. Ore pillars are robbed on final retreat from the mine.

Suggestions for Prospecting

Regardless of any general theory of origin for these deposits, certain geologic features of the known ore bodies (see pp. 123-128) may be used to a limited extent in prospecting for ore. They can, at least, give some guidance in restricting search to the mineralized belts and in selecting sites for prospect drifts a short distance in advance of known mineralized ground.

Subsurface prospecting should be restricted to the known vanadium-bearing belts, and to the upper part of the Entrada sandstone within these belts. Both the Pony Express limestone member of the Wanakah formation, immediately overlying the Entrada, and the chromium-bearing layer—where present—below the vanadium-bearing layer are easily recognized and useful stratigraphic guides.

As the known ore bodies appear to be irregularly clustered in poorly defined areas about 1,000 to 2,000 feet across, the ground adjacent to closely spaced bodies is favorable for prospecting.

Many ore bodies occur as rolls, and where the vanadium-bearing layer, either at the outcrop or in a drift, cuts rather sharply across the bedding it may be part of a roll. Even though the part of the layer exposed at such a place is not of workable thickness, ground along the trend of the roll should be prospected for a workable ore body. The area

between two exposures 50 to 100 feet apart, at one of which the vanadium-bearing layer is stratigraphically lower than at the other, also should be prospected, for this shift in position of the mineralized layer may lie along the trend line of a well mineralized roll. In short, a roll encountered in prospecting or mining should be followed, and if this seems to be a single roll (fig. 1) the ground adjacent to its stratigraphically higher side should be prospected for a roll dipping in the opposite direction, the two forming a double roll.

Quartzitic nodules and lenses are common in the ore, and in places they are abundant in the vanadium-bearing layer adjacent to an ore body. An unusual concentration, therefore, of these nodules and lenses in the vanadium-bearing layer at the outcrop or in drifts might indicate the proximity of an ore body.

Prospecting drifts may be placed below the ore-bearing zone, so that they can be used advantageously for haulage if ore is found. The vanadium-bearing layer cannot, however, be thoroughly prospected by drifts and raises alone unless these are so closely spaced as to be very costly. For systematic prospecting on a large scale, vertical and inclined diamond drilling from widely spaced drifts driven below the ore-bearing zone could probably be employed to advantage and at less expense. It is suggested, as a general plan, that parallel drifts be run at 300-foot intervals about 30 or 40 feet below the ore-bearing zone, and that from these drifts, at stations 100 feet apart, one vertical and two inclined holes be drilled. The inclined holes should be so directed as to intersect the vanadium-bearing layer at a horizontal distance of about 75 feet on either side of the drift. In detail, however, the plan would have to be adapted to local geologic features, such as faulting, inclination of beds, the average size of the ore bodies that seem likely to be found, and to mining conditions.

Descriptions of Mines and Prospects

Fall Creek mine.—The Fall Creek mine is on the south

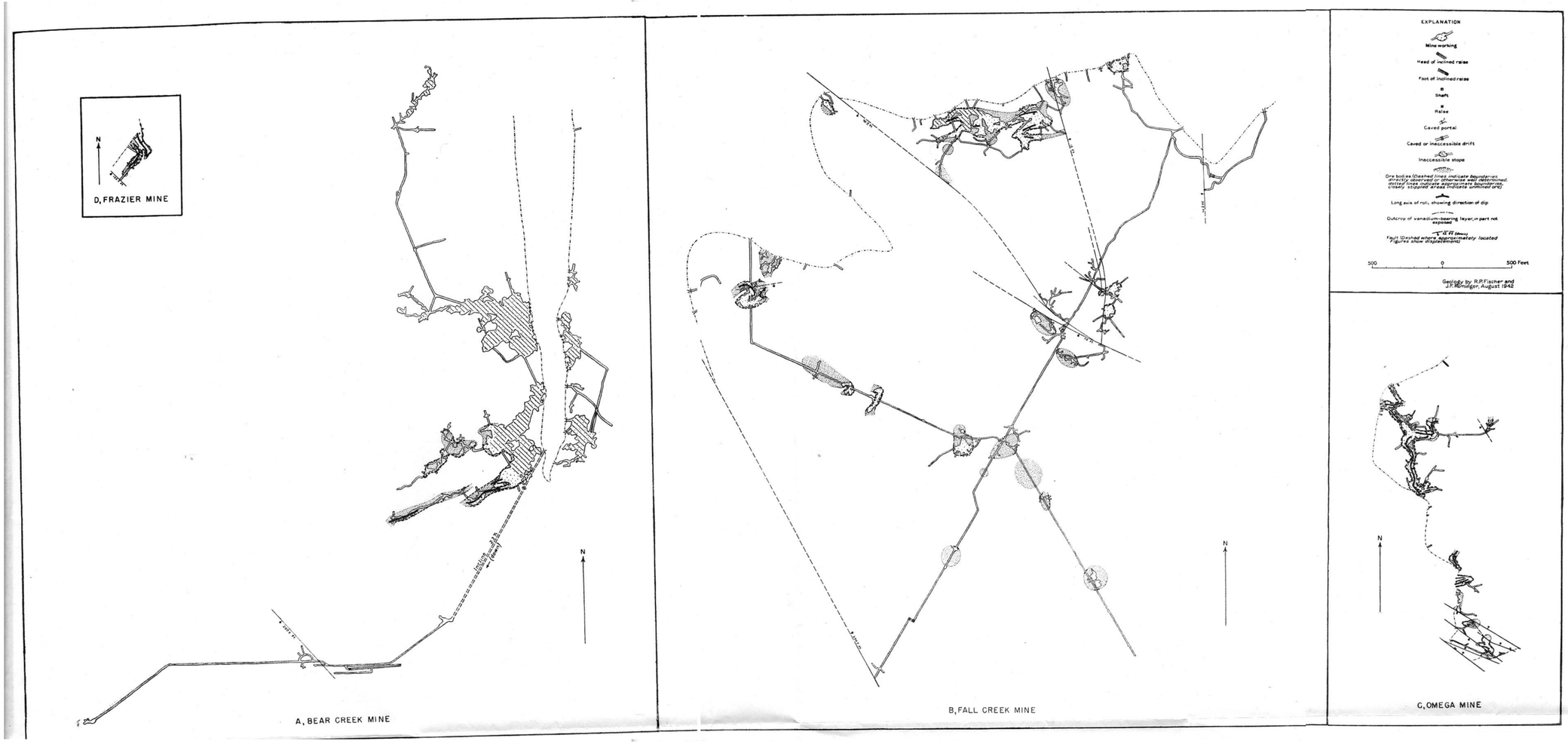


PLATE 2:-MAPS SHOWING THE GEOLOGY AND ORE BODIES OF FOUR VANADIUM MINES NEAR PLACERVILLE, COLORADO
A, BEAR CREEK MINE; B, FALL CREEK MINE; C, OMEGA MINE; D, FRAZIER MINE
Prepared by the United States Department of the Interior, Geological Survey, in cooperation with the State of Colorado and the Colorado Metal Mining Fund

side of the San Miguel River and about 3 miles southeast of Placerville. The mine is at an altitude of about 8,300 feet, approximately 800 feet above the highway that borders the river. A gravity-operated jig-back cable tram is used to lower the ore from the mine to a receiving bin beside the highway, from which the ore is shipped 44 miles by truck to the Naturita mill. Development consists of about 3 miles of drifts and many stopes (pl. 2). Ore is trammed by hand from the working faces to the main haulage tracks, and then pulled by mules to the ore bin at the upper end of the cable tram. Some of the waste rock is trammed to waste dumps at the mine portals, and some is used to back-fill worked-out stopes.

The mine was operated by the Primos Chemical Company for several years prior to 1920, and by the Vanadium Corporation of America in 1920, and it is estimated that in those years yielded about 20,000 tons of ore that averaged about 2 percent V_2O_5. After 1920 the mine lay idle until November, 1940.

Mine workings and known ore bodies are shown in plate 2. Most of these ore bodies contained 1,000 to 2,000 tons of ore, but some contained less than 100 tons and one contained about 30,000 tons. They include both circular and elongate bodies.

Ground south and west of the main stoped area at the north end of the mine and ground in the western and central parts of the mine is favorable for prospecting, because there the vanadium-bearing layer in many exposures is well defined, contains many quartzitic nodules, and is wavy, and because the known ore bodies are rather close together.

Omega mine.—The Omega mine is on the north side of the San Miguel River, northeast of Placerville. A gravity-operated jig-back cable tram lowers the ore nearly 1,000 feet to a receiving bin beside the highway along Leopard Creek, from which it is trucked 41 miles to the mill at Naturita. Mine development consists mostly of stoping

on ore bodies that were discovered at the outcrop (pl. 2). Ore is trammed by mules to the bin at the upper end of the cable tram, and waste rock is trammed by hand to waste dumps at the portals.

The mine was operated by the Primos Chemical Company prior to 1920, and by the Vanadium Corporation of America in 1920. Its production to the end of 1920 is estimated at 15,000 tons of ore containing about 2 percent V_2O_5. Operation by the Vanadium Corporation was resumed in 1941.

Most of the ore bodies contain about 1,000 tons of ore and are elongate, each being a roll; but one mined-out body, consisting of several rolls, contained about 15,000 tons. No intensive program of exploration has been undertaken in the Omega mine, but ground adjacent to the known ore bodies is favorable for prospecting.

Frazier mine.—The Frazier mine is on the east side of Fall Creek, about 1½ miles south of the San Miguel River. It is at an altitude of about 8,400 feet, approximately 700 feet above the county road that follows Fall Creek; and it is connected with this road by a truck trail.

In operations prior to 1920, the mine produced about 1,000 tons of ore. Since 1942 the mine has been operated by the U. S. Vanadium Corporation. The ore averages about 2½ percent V_2O_5. The ore body shown in plate 2 was exposed at the outcrop and consists of two rolls. Although other ore bodies will probably be found by drifting, lack of other exposures and of much development make it impossible to predict their position and size.

Bear Creek mine.—The Bear Creek mine is on Big Bear Creek, about 2½ miles south of the San Miguel River. The portals of the mine, which are on a level with the ore in the main workings, are at an altitude of about 8,500 feet, 20 to 50 feet above the road that follows Big Bear Creek. Development consists of several large stopes on each side of Big Bear Creek, and about 2,000 feet of prospect drifts adjacent to these stopes. A 24-percent incline, about 1,200

feet long and bottomed at an altitude of about 8,200 feet, was driven southwest of the main workings to test the vanadium-bearing layer on the downthrown side of the Big Bear Creek fault. About 2,700 feet of drifts extend westward from the bottom of the incline (pl. 2). The large stoped areas are now caved and mostly inaccessible, and water stands at an altitude of about 8,460 feet in the incline.

Between 1910 and 1918 the mine was operated by the Primos Chemical Company and produced about 130,000 tons of ore. Mining was resumed by the Vanadium Corporation of America in 1943.

As the large stopes and most of the portals in the Bear Creek mine are caved, only a small part of the mine was accessible to study. Outcrops of ore and accessible exposures underground indicate that the ore bodies are typical. Two of the largest ore bodies in the Placerville area were worked in this mine; each of which yielded about 50,000 tons of ore, allegedly averaging 2½ to 3 percent V_2O_5. Geological evidence indicates that the ground west and south of the large stoped areas in the mine is favorable for prospecting.

Carpenter mine.—The Carpenter mine is on Big Bear Creek, about 2 miles south of the San Miguel River. It is at an altitude of about 8,475 feet, approximately 175 feet above the road along Big Bear Creek. Development consists of about 4,000 feet of drifts, with some stopes.

The mine was operated under lease by the Colorado Vanadium Corporation during 1919 and 1920. Production data are not available, but it is estimated that the mine yielded about 2,000 tons of ore that averaged about 3 percent V_2O_5. Prospecting in this mine was undertaken by the Metals Reserve Company in 1943-44.

Except for a small stope at the north portal, all stoping has been confined to several ore bodies that are alined in a northwesterly direction. As the ore varies abruptly in thickness and grade, the ore bodies are poorly defined and

irregular in plan, and the ore mined was from 8 inches to 5 feet thick.

Pocahontas mine and prospects to the west.—The Pocahontas mine is on the north side of the San Miguel River, opposite the mouth of Fall Creek. It lies at an altitude of about 8,500 feet, and is accessible by an old mule trail. Development consists of stoping on an ore body that was exposed at the surface. The mine was operated, under lease, by the Colorado Vanadium Corporation during 1919 and 1920 and produced about 1,500 tons of ore, which probably contained about 2½ percent V_2O_5.

An area extending for half a mile west of the Pocahontas mine contains outcrops of several ore bodies. Although these ore bodies are largely undeveloped and production from them probably has not exceeded 500 tons, this appears to be an area favorable for prospecting.

Other prospects.—Throughout the Placerville area, promising exposures of the vanadium-bearing layer in the Entrada sandstone have been prospected by making benches along the outcrop or by driving short adits, and in places they have been mined on a small scale. The total production from such exposures has not exceeded 1,000 tons of ore, and much of this has come from three small workings—one on the east side of Leopard Creek about 1½ miles north of the Omega mine, a second about ½ mile south of the Frazier mine, and a third northeast of Sawpit. Except for a few favorably located prospects, the difficulty and high cost of packing ore to the roads along the canyon bottoms has discouraged intensive exploration, and none of the prospects has shown sufficient promise to justify the expense of a road or tram.