



## *Vanadium deposits of the Placerville area, San Miguel County, Colorado*

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# VANADIUM DEPOSITS OF THE PLACERVILLE AREA, SAN MIGUEL COUNTY, COLORADO'

By

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## INTRODUCTION

The vanadium deposits of the Placerville area were discovered about 1900. Production totals about 240,000 tons of ore, which averaged a little more than 2 percent  $V_2O_5$ , and which probably yielded about 4,000 short tons of  $V_2O_5$  in concentrates, representing a little less than 5 percent of the total domestic production of vanadium. Most of this ore was mined between 1910 and 1920, but some of it was produced during World War II and some since that war. Most of the ore contains, in addition to vanadium, 1 to 2 pounds of  $U_3O_8$  per ton, and some of this has been recovered as a byproduct of the ore mined since about 1950.

The vanadium deposits and general geology of the Placerville area were described by Hess (1911) and by Fischer and others (1947), and the geology of three quadrangles covering most of the area has been studied in detail by Bush and others (1959, 1960, and 1961).

## GEOLOGY

Most of the Placerville area is underlain by nearly horizontal sedimentary beds 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 Late Jurassic age.

The Cutler Formation of Permian age is the oldest formation exposed in the Placerville area. About 1,000 feet of Cutler beds crop out along the lower slopes of the San Miguel River valley and tributaries near Placerville. The formation is composed dominantly of lenticular beds of arkosic sandstone and conglomerate and a small proportion of thin siltstone and limestone beds. Most of these beds are purplish red.

The Dolores Formation of Late Triassic age is separated from the Cutler by a disconformity of small relief. The Dolores consists of irregularly interbedded sandstone and siltstone, some conglomerate composed mainly of limestone pebbles, and a little mudstone and limestone. Brick red is the dominant color. The formation is nearly 600 feet thick.

The Entrada Sandstone of Late Jurassic age is 40 to 75 feet thick in the area. It is composed entirely of light-colored sandstone, which is uniformly fine grained except for a small proportion of coarse, well-rounded sand grains in the lower part of the formation. From a distance the outcrop of the Entrada suggests that it is a single thick stratum, but actually the upper 5 to 20 feet of the formation

is rather thinly and evenly bedded and tends to form a ledgy cliff whereas the lower part is massively crossbedded and forms a steep slope or rounded cliff. The Entrada lies on a disconformity of small relief, and in places its contact with the underlying Dolores Formation is sharp, but elsewhere it is inconspicuous due to reworked material.

The Wanakah Formation, also of Late Jurassic age, lies on the Entrada with a plane contact. It is composed of three members, of which the Pony Express Limestone Member is the lowest. This limestone is thin bedded, dark gray, fine grained, with a petroliferous odor from freshly broken surfaces. It is 10 to 15 feet thick several miles east of Placerville, but it thins to a depositional edge along a line that trends slightly west of north and crosses the San Miguel River valley at Placerville. The Pony Express is overlain by the Bilk Creek Sandstone Member, which averages about 30 feet thick and is composed of light-colored, fine-grained sandstone, similar to but slightly softer than the Entrada. The upper member of the Wanakah Formation is called the marl member and is composed of gray or red limy siltstone and a few thin beds of sandstone and silty limestone; the marl member averages about 50 feet thick in the Placerville area.

The Morrison Formation is also of Late Jurassic age and is conformable with the Wanakah Formation. The Morrison is about 700 feet thick and is divided into two units of about equal thickness. The lower unit, the Salt Wash Sandstone Member, consists of reddish mudstone and light-brownish sandstone, mainly interbedded in layers several tens of feet thick, whereas the upper unit, the Brushy Basin Shale Member, consists dominantly of varicolored mudstone with some thin sandstone beds and a few lenses of conglomeratic sandstone.

Beds of Cretaceous age in the Placerville area comprise three formations, the Burro Canyon Formation, the Dakota Sandstone, and the Mancos Shale in ascending order. The Burro Canyon consists of conglomeratic sandstone that occurs in thick channel-fill lenses, but these lenses are present in only a few places in the area. The Dakota Sandstone, on the other hand, was originally continuous over the area and caps the slopes of all the valleys in the area. The Dakota consists of beds of sandstone, in part conglomeratic, and shale. The Mancos is composed of dark-gray shale and sparse thin beds of limestone, and it occurs only as poorly exposed erosional remnants on the mesa tops in the area.

Several igneous dikes are conspicuous along the valley of the San Miguel River near Placerville and sills, laccoliths, and plugs are present nearby. These igneous rocks are varied in type, but they are dominantly intermediate

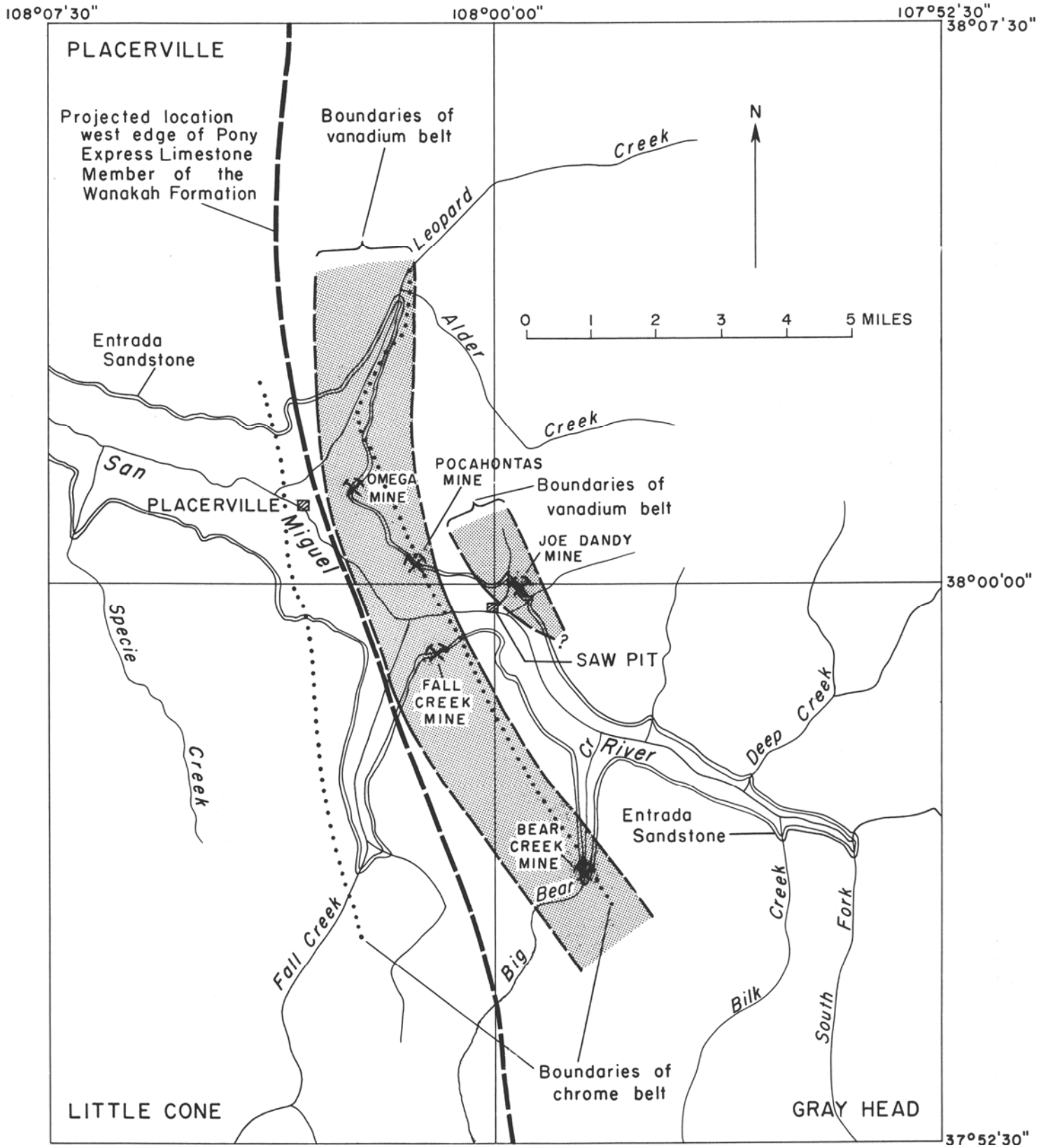


FIGURE A.

Map of the Placerville area, showing the approximate distribution of the Entrada Sandstone, the vanadium and chromium belts, and the west edge of the Pony Express Limestone Member of the Wanakah Formation (after Bush and others, 1960).

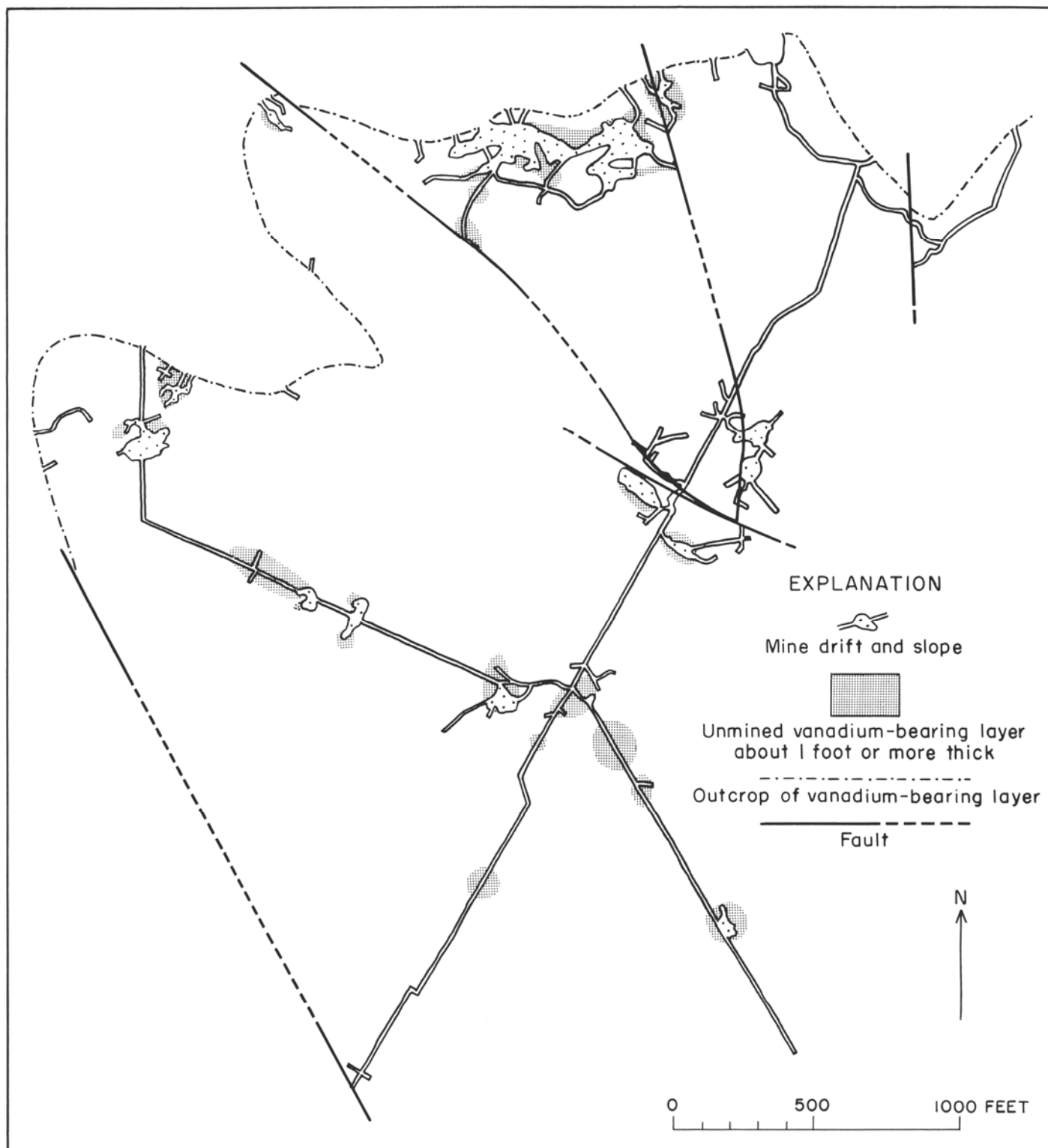


FIGURE B.  
Simplified geologic map of the Fall Creek vanadium mine (modified from Fischer and others, 1947).

in composition. They are probably related to the intrusive rocks in the San Juan Mountains and are of middle to late Tertiary age.

The sedimentary rocks in the Placerville area are nearly flat, but they are tilted by minor flexures and broken by numerous faults. All the faults are normal and dip steeply; displacements range from a few feet to as much as 700 feet. Most faults trend northward or northwestward. The faults and the igneous dikes are probably contemporaneous.

#### VANADIUM DEPOSITS

The vanadium deposits in the Placerville area occur in the upper part of the Entrada Sandstone and consist of sandstone impregnated with vanadium minerals. Roscoelite, the vanadium mica, is the principal ore mineral. It occurs as minute flakes that coat the sand grains and partly or completely fill the pore spaces between grains. Minor amounts of montroseite, a hydrous vanadium oxide, occur in high-grade ore. These minerals impart a greenish-gray color to the sandstone, and the color darkens as the vanadium content increases. Carnotite, the yellow hydrous uranium vanadate, is the only secondary mineral common in the deposits, and it occurs only sparsely at and near the surface where the ore is oxidized; no primary uranium mineral has been recognized.

The vanadium deposits in the area occur as a continuously mineralized layer in two apparently separate belts. One belt is about 11/2 miles wide and extends for at least 9 miles from the point where the Entrada outcrop crosses Leopard Creek southward to where the Entrada crosses Big Bear Creek (fig. A). It is not known how much farther this belt might extend to the north and south of these points, for the Entrada is not exposed for many miles in these directions. The second belt is exposed for only about 1 1/2 miles along the Entrada outcrop north and east of Sawpit (fig. A), and therefore, its limits are not well known.

In both belts the vanadium-bearing layer generally lies nearly parallel to the even bedding in the upper part of the Entrada Sandstone, but in detail the layer is wavy or undulant and crosses the bedding, ranging stratigraphically from the top of the Entrada to as much as 25 feet below the top. In most places the layer is only 3 to 6 inches thick, but it is clearly recognized by its greenish-gray color, although it is too thin and low grade to be mined. Locally, however, this layer thickens rather abruptly, forming lenticular or tabular masses that are minable. Individual ore bodies have a wide range in size. The small ones are only several feet across and a couple of feet thick and contain only a few tons of ore, whereas the large ones are a few hundred feet across and 2 to 20 feet thick and contain many thousand tons of ore. Ore bodies are diverse in plan

but dominantly are roughly circular or irregularly elliptic. The long axes of the elongate bodies tend to be about perpendicular to the long axis of the principal belt. The ore bodies seem to be irregularly scattered within this belt, and no geologic relations that seem to control the localization of these bodies have been recognized. Figure B shows the ore bodies that were found at the outcrop and by drifting in the Fall Creek mine; it is assumed that if these drifts had been driven along other lines they would have found other ore bodies and probably just about as much ore.

A thin, ill-defined layer of light-green sandstone, colored by a finely disseminated chromium-bearing mineral, lies a few feet below the vanadium-bearing layer in the Leopard Creek-Big Bear Creek belt and extends about a mile west of it (fig. A), forming a belt similar to the vanadium belt. Like the principal vanadium-ore mineral, the chromium-bearing mineral is micaceous and occupies the sandstone pores. This layer has no commercial value, for its average content is only a few hundredths percent  $Cr_2O_3$ , but it is a useful horizon marker.

Like the vanadium-uranium and uranium deposits in sandstone in other parts of the Colorado Plateau region, the origin of the vanadium deposits in the Placerville area is unknown. The ore minerals obviously were emplaced after the Entrada Sandstone was deposited, for the vanadium-bearing layer crosses the sandstone bedding. On the other hand, this layer is displaced by faults, and almost certainly it formed before regional deformation. In some respects the pattern of the layer resembles a slightly uneven water table, or the contact between two ground waters of different composition, so possibly mineralization occurred under ground-water conditions. In the Placerville area the western depositional edge of the Pony Express Limestone Member, which lies on the Entrada, coincides closely with the western edge of the Leopard Creek-Big Bear Creek belt (fig. A); possibly the geochemical environment along the edge of this limestone during its deposition or sometime afterward influenced the localization of the vanadium and associated metals.

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