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Strategic minerals investigations

GEOLOGY OF THE RIFLE CREEK VANADIUM AREA, GARFIELD COUNTY, COLORADO

Preliminary report

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Vanadium ore is being mined from two deposits in the Entrada sandstone, at the Rifle and Garfield mines, about 13 miles northeast of Rifle, Garfield County, Colo. The deposit at the Rifle mine has been the most productive of the vanadium-bearing sandstone type of deposit. It was mined from 1925 to 1932, and the current period of mining began in 1941. The Garfield mine was operated at intervals before 1942 and has been in continuous operation since that time. Small deposits of vanadium ore have also been mined from the Morrison formation in the area shown on the map and in the adjoining area to the east. The total production of vanadium ore from all of these deposits is about 500,000 tons.

The area was examined and mapped in June, July, and August 1944, in the course of the investigation of domestic vanadium resources by the Geological Survey, United States Department of the Interior. The accompanying maps show the structure and distribution of the ore-bearing formations and closely associated strata. The map base was compiled from aerial photographs, from which distortion was removed during compilation, but the primary horizontal and vertical control were established by plane-table triangulation. The topography is controlled by many points whose altitudes were established with the alidade, and the contours were sketched after stereoscopic study of the aerial photographs.

Geology.—The area lies on part of the Grand Hogback monocline, a fold which flanks the White River Plateau uplift to the north and east and exposes rocks ranging from pre-Cambrian to Tertiary in age. The map shows the Jurassic formations; part of the underlying Triassic and overlying Cretaceous formations, and also Quaternary (?) landslides. The significant lithologic features, topographic expression, and variations in thickness of these rocks are summarized below.

Quaternary(?) landslides:	Feet
Mostly Dakota(?) and Morrison rocks, in jumbled masses; from uneven topography. Map-pattern superimposed on patterns showing bedrock geology	0-250±

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	Feet
Upper Cretaceous:	
Mancos shale.--Shale, gray to dark gray, thin-bedded with sandy and limy beds; forms valleys and minor scarps. Only basal part mapped. Total thickness.....	5,000
Dakota(?) sandstone.--Sandstone, light brown and light gray, fine- to coarse-grained, partly conglomeratic, with brown to dark-gray, carbonaceous shale in middle; sandstone mostly weathers dark, forms cliffs and dip slopes.....	80
Upper Jurassic:	
Morrison formation.--Shale, predominantly green and gray but in part vari-colored, with thin lenticular sandstone, siltstone, and limestone beds.....	350
Sandstone and shale, gray, lenticular; sandstone is partly conglomeratic; vanadium-bearing just east of sec. 25, T. 4 S., R. 92 W.....	15-30
Shale, light red and purple, with thin, lenticular, bluish-gray partly recrystallized limestone in middle.....	40-50
Sandstone, lenticular, medium-grained and greenish-gray or fine-grained and red or gray, interbedded with red, green, or gray shale; sandstones near the top are vanadium-bearing in places.....	70-80
Entire formation is poorly exposed, but the thicker sandstones and limestones form cliffs or poorly defined scarps and dip slopes in places.	
Entrada sandstone.--Upper unit: Sandstone, white to light gray, predominantly fine-grained but with large, well-rounded grains scattered through it; cross-bedded with curved planes that are not inclined in a common direction, soft and friable, weathering to rounded cliffs or steep slopes; ore-bearing at the Garfield mine and at places at the Rifle mine.....	70-125
Lower unit: Sandstone, light brown, fine-grained, hard, with large-scale cross-bedding inclined southward; forms rough, nearly vertical cliff; contains the principal ore body in the Rifle mine.....	30-75
The total thickness of the Entrada is fairly constant locally but decreases gradually eastward from 175 to 140 feet. Each unit alone, however, has a greater local range in thickness than do the two units combined, for the upper unit was deposited on a partly uneven, eroded surface of the lower unit, so that a local thickening of one is accompanied by a compensating thinning of the other. Only the upper unit resembles the Entrada of western Colorado and eastern Utah.	
Triassic:	
"Red Beds".--Red, fine-grained sandstone and shale, forming steep slopes; in places a thin zone at the top is altered to a limy, light-colored rock that is in part vanadium-bearing.....	300±

The rocks in the area dip southward at moderately low angles, but this attitude is modified locally by faults and minor flexures. Some of the flexures probably are the surface expressions of underlying faults (see geologic structure map). Although some of the faults are steeply inclined, most are vertical, and all are projected vertically on the geologic structure map and the structure sections. Low-angle reverse faults, with displacements ranging from a small fraction of an inch to as much as a foot, are common in the massive sandstone beds, especially the Entrada. In the Rifle and Garfield mines, all of these faults dip southward, and for the most part follow the bedding planes or cut across the beds at small angles.

The competent sandstones are highly jointed. Most of the joints strike northeast, northwest, or east, and dip steeply to the north, but a few strike north. Few joints can be traced as much as a hundred feet along a single sandstone bed, and not many cross from one sandstone bed to another.

Below the zone of oxidation, some of the joints and a few of the high-angle faults contain thin, discontinuous veinlets of calcite and iron sulfide, probably marcasite, and where oxidized, these fractures are iron-stained. In the "Red Beds" some of the joints and the faults are bordered by a narrow band of alteration, similar in appearance to the zone of alteration that is locally present at the top of the "Red Beds".

Ore deposits.--The ore is sandstone impregnated with vanadium minerals, the most important of which is a fine-grained, micaceous mineral of uncertain composition, similar to or identical with the principal ore mineral in other vanadium-bearing sandstone deposits in western Colorado and the adjoining States. The ore is light to dark gray, and in general it becomes darker as the vanadium content increases. Most of the ore being mined contains from 1 to 3 percent V_2O_5. Much of the ore in the Morrison formation is closely associated with fossil plant remains, but no fossils have been observed in the Entrada sandstone.

The known vanadium deposits in the Entrada sandstone are in three layers, one in the lower unit and two in the upper unit, and they occur along a belt that extends northeastward through the Garfield and Rifle mines. The layers range in thickness from a feather edge to as much as 30 feet and average about 5 feet. Although the layers are irregular in detail, in general they nearly conform to the formation contacts and cut across the bedding where it is inclined to the contacts.

The ore layer in the lower unit of the Entrada forms an elongate deposit at the Rifle mine that has been followed and mined for nearly 5,000 feet in a northeasterly direction from its outcrop on the East Fork of Rifle Creek. The ore is thickest on the north side of the deposit, and the limit of minable ore to the north is determined by an

assay wall. On the south side, on the other hand, the layer thins gradually until it cannot be mined at a profit. In general the grade of the thin ore is higher than the average grade of the deposit. In a few places along the south edge of the deposit, the layer passes from the Entrada sandstone down into the altered zone at the top of the "Red Beds." This layer also extends into the altered zone at the top of the "Red Beds" on the west side of the East Fork of Rifle Creek.

The two ore layers in the upper part of the Entrada occur about 15 to 30 feet above the base of this unit. Both layers have been worked along the west side of the Garfield mine, where they come together, but only the lower one has been followed by the main workings. Both layers crop out east of these workings, where a small ore body along the upper layer has been mined. One ore body in the upper unit of the Entrada has been worked at the Rifle mine.

Mining and prospect drilling show the ore in the upper unit to be less continuous than the ore in the lower unit but to be closely related to it in position. The ore bodies of commercial grade and thickness in the upper unit appear to lie on the fringes of minable bodies in the lower unit; none have yet been found that directly overlies minable ore in the lower unit. The vanadium-bearing sandstone in one unit, however, is not known to be directly connected with that in the other.

Usually where the ore layers are no more than a few feet thick, they have well-defined upper and lower limits. Where such is true, one surface of each of the ore layers is bounded by a band of gray- or green-colored, weakly vanadiferous sandstone, in places with a half-inch band of barren sandstone between. The gray or green band is several inches to a foot wide, and is commonly bordered, on the side toward the ore, by a band that is rarely more than an eight of an inch wide and which contains finely disseminated galena. This mineral was identified by Charles Milton in the chemical laboratory of the Geological Survey, and confirmed by spectroscopic, x-ray, and microchemical tests. In the lower unit of the Entrada these bands lie above the ore layer, whereas in the upper unit similar bands lie beneath the lower ore layer and others above the upper ore layer. In most places where the ore is thick, the upper and lower limits are not well-defined, and these bands were not recognized.

The altered zone at the top of the "Red Beds" ranges from a feather-edge to about 8 feet in thickness, and the contact with the unaltered rock beneath is well defined but uneven and crosses the bedding. The rock comprising the zone is limy, and where fresh it is greenish gray in color and contains finely disseminated, cubic crystals of pyrite--the change in color from the original red rock, and the formation of pyrite, probably resulted from the reduction of iron oxide. Where weathered, the rock is buff-colored. The altered rock at the top of the "Red Beds" is present at several places, both in the area shown on the map and in the adjoining