# Iron-Ore Deposits of the Iron Mountain District, Washington County, Idaho

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A CONTRIBUTION TO ECONOMIC GEOLOGY

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*A description of the iron-ore reserves of the district*

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# CONTENTS



# ILLUSTRATIONS

[Plates 13-18 in pocket]

# A CONTRIBUTION TO ECONOMIC GEOLOGY

## IRON-ORE DEPOSITS OF THE IRON MOUNTAIN DISTRICT WASHINGTON COUNTY, IDAHO

By J. Hoover Mackin

### ABSTRACT

The oldest rocks of the Iron Mountain district are a group of greenstones, with interbedded marble, probably correlative with the Permian Clover Creek greenstone. These metamorphic rocks are cut by granodiorite and associated granite rocks that are probably outlying parts of the Late Jurassic(?) Idaho batholith. An intensely sheared conglomerate, preserved only in the northwestern part of the district, is interpreted as part of a mass of detritus spread out by streams at the front of a thrust plate and overidden and sheared by continued movement of the plate. The date of the "thrust conglomerate" relative to the time of emplacement of the granitic rocks cannot be determined in the district; regional relations suggest that the thrusting may have occurred during the late Cretaceous and early Eocene Laramide revolution.

These rocks, which comprise the basement complex of the district, are beveled by an erosion surface of low relief that is tentatively regarded as early Tertiary in age. The Tertiary history includes: (1) burial of the early Tertiary erosion surface by andesite porphyry flows; (2) faulting, accompanied by a westward tilting of individual fault blocks; (3) erosion; (4) spreading of basalt flows that are probably correlative with the mid-Tertiary Columbia River basalt; and (5) uplift and deep dissection that produced the present relief.

The iron-ore deposits of the district are magnetite and specularite replacements in the marble unit of the Permian metamorphic rocks. The iron ores are associated with tactite and sulfide deposits in a typical pyrometasomatic suite around the borders of the granitic rocks. Sharply contrasting in origin with these primary ores are deposits of earthy red hematite underlain by secondary copper deposits formed by weathering processes where the early Tertiary erosion surface happened to bevel pods of primary sulfide. The red-hematite ores are exposed where the old erosion surface, covered by andesite porphyry flows, is intersected by the present surface.

Reserves available for open-pit mining are 150,000 to 200,000 tons, of which only about 20,000 tons are measured ore.

### INTRODUCTION

#### SCOPE OF THIS REPORT

The Iron Mountain district as here defined includes a number of small iron-ore deposits occurring as replacements in Permian marble on the divide between the Snake and Weiser Rivers in southwestern Idaho. The study on which this report is based was a part of the Strategic Minerals program of the Geological Survey during World War II; the field work occupied 6 weeks during July and August 1943. The specific purpose of the investigation was to determine the iron-ore reserves of the district, and the field work was therefore confined very largely to the immediate vicinity of deposits. The general geologic map was prepared merely to bring out the mutual relationships of the several widely scattered occurrences of ore, and to serve as a basis for evaluating the possibility of the existence of blind-ore bodies between the known deposits. Little attention was given to structural and stratigraphic relationships other than those directly associated with the iron deposits, and any contributions that this report may make to the general geology of the region are incidental byproducts of the economic work.

## ACKNOWLEDGMENTS

The writer was ably assisted in the field by Earl F. Cook and Joseph R. Fribrock. James Gilluly, Charles F. Park, and P. J. Shenon, of the U. S. Geological Survey, visited the party in the field and made many helpful suggestions. The petrographic descriptions set in small type were written from notes by Harry Smedes, of the University of Washington.

## GEOGRAPHY

The Iron Mountain district is located in southwestern Idaho, 6 miles east of the Snake River and 20 miles north of Weiser, Idaho. (See fig. 31.) The district is approximately 2½ miles in north-south dimension, with an average width of 1 mile. It includes parts of secs. 11, 12, 13, 14, and 23, T. 14 N., R. 6 W. (Boise meridian).

The altitude of the iron deposits ranges from 5,400 feet to 6,500 feet; the general topographic relations are indicated on the U. S. Geological Survey topographic map of the Pine quadrangle, Oregon-Idaho. South-facing slopes are mantled chiefly by sage and grass; the remainder is forested, commonly with a heavy growth of underbrush. Springs and small perennial streams provide an adequate water supply in all parts of the district.

The deposits are about 33 miles from the Union Pacific Railroad at Weiser, of which 13 miles is paved highway and 20 miles is graded dirt road. The greater part of the dirt road is impassable in wet weather, and it includes local grades exceeding 10 percent. The deposits are about 6 miles from Still, Oreg., on a branch of the Union Pacific Railroad on the west side of the Snake River. A dirt road, with very steep grades, extends from the Iron Mountain district to the Snake River

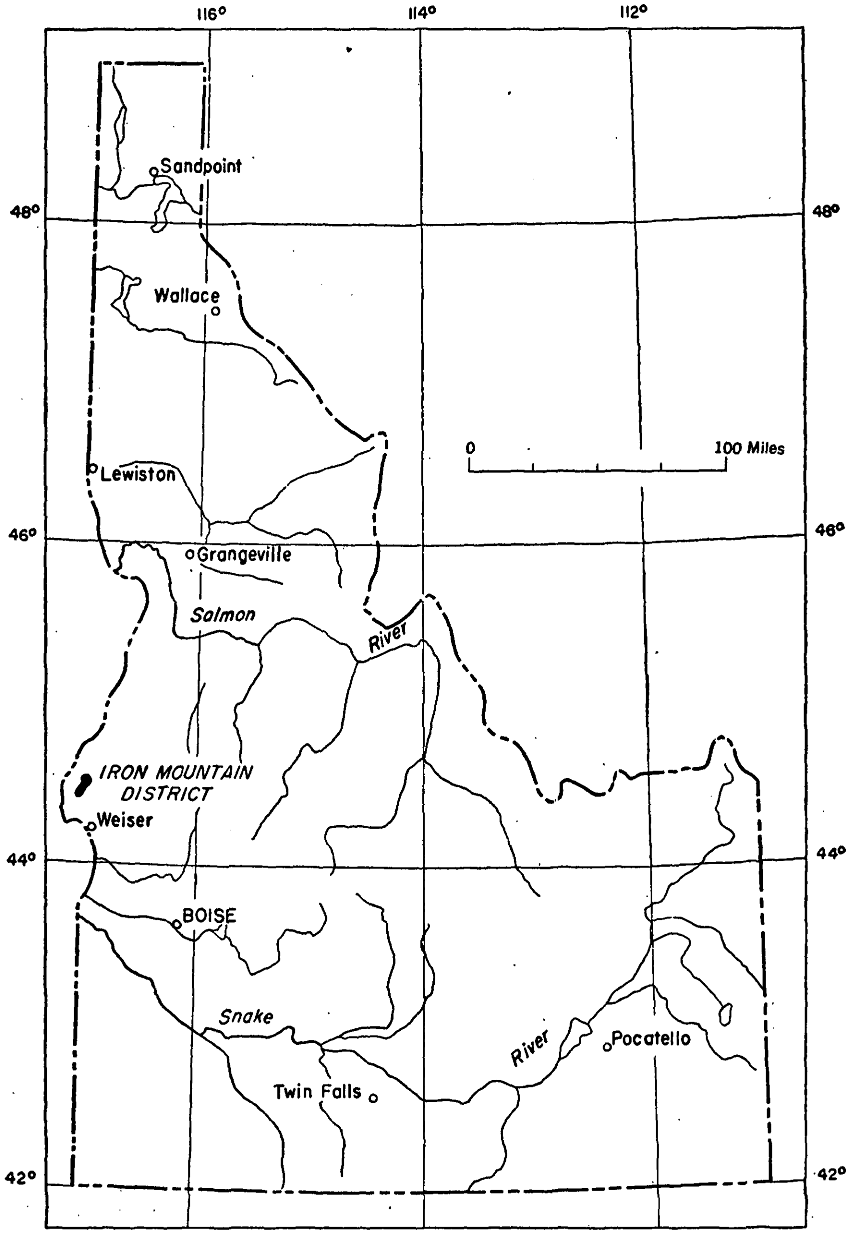


FIGURE 31.—Index map of Idaho showing the location of the Iron Mountain district, Washington County, Idaho.

via the valley of Dennett Creek. Movement of the iron ores to Still by way of the Dennett Creek road would require construction of a tram or other means of conveyance across the Snake River.

## ROCK UNITS

The rocks of the district consist of a pre-Tertiary basement complex of greenstone and marble cut by granodiorite and associated granitic rocks, overlain unconformably by andesite and basalt flows of Tertiary age. A conglomerate that is preserved only in one part of the district is interpreted as a remnant of a mass of detritus spread out by streams at the front of an overthrust plate during the Laramide revolution.

Tentative correlations with formations that have been named in adjacent areas will be suggested, but these correlations are not well enough established to permit use of the same formational names for the Iron Mountain units. For this reason, and because too little is known about the units to justify a new set of stratigraphic terms, they are given lithologic names.

In general, treatment of each of the units includes a statement of distribution, lithology, origin, age, and, where necessary, structural relations. A summary of the structural history of the district correlates the structural relations of the different units.

### METAMORPHIC ROCKS

The metamorphic rocks consist of two greenstone units separated by a bed of marble; the greenstone units cannot be distinguished lithologically and are therefore shown by the same symbol on the geologic maps.

The sequence is seen to best advantage in the south-central part of the district, where a north-trending belt of marble about a mile long is flanked on the east and west by greenstone. The same sequence is probably represented in the northeastern part of the area, where a downward-tapering wedge of marble, transected by the valley of Fourth of July Creek, is underlain by greenstone on the east and is in fault contact with greenstone on the west. A smaller body of marble is completely surrounded by granitic rock on the Mortimer property in the southwestern part of the district, and there are small pods of marble in greenstone (not shown on plate 13) on the Montana property in the north-central part of the district. The fact that these occurrences of marble are identical in lithology and are alined in an almost continuous belt with an over-all trend of about N. 15° E. suggests that they are parts of the same stratigraphic unit. Isolated bodies of marble west of this belt, on the Abundance property on Fourth of July Creek and on the Standard property on Iron Mountain, are similar in lithology and may be parts of the same unit repeated by folding or faulting.

### GREENSTONE

The greenstone is light to dark gray-green, dense, and generally massive. Varieties, not separately mapped, include porphyries and fine-grained laminated rocks that were probably intermediate or basic tuffs or sediments derived from volcanic rocks. Foliation is weakly developed.

In the southern and eastern parts of the district there is a transition zone between greenstone and the adjacent granitic rock that ranges in width from a few hundred to a thousand feet or more. Different ledges within the transition zone show all variations, with an increase in developemnt of porphyroblasts, from the normal dense greenstone to a coarsely crystalline granitic rock, but because exposures are very poor, and especially because the greenstone is essentially structureless, it is impossible to evaluate the alternative hypotheses that the mixed zone is (1) a protoclastic border in which shattered greenstone is intimately laced by intrusive apophyses and much altered, or (2) a recrystallization-replacement border through which the greenstone actually grades into the granitic rock.

A typical specimen from the greenstone unit shows euhedral phenocrysts of andesine ($An_{36}$) as much as 4 millimeters long in a matrix of diopside and green hornblende. The phenocrysts are rimmed with a more sodic plagioclase and are so thoroughly sericitized that albite twin lamellae are almost completely masked. The groundmass consists of small anhedra and clusters of diopside, prisms of green hornblende, magnetite, chlorite, and small amounts of quartz. Three generations of hornblende can be recognized: large phenocrysts of original brown hornblende, rarely seen because they are largely replaced by diopside; the small green prisms of the groundmass; and late veinlets and large subhedral clusters of green hornblende. Sulfides and a small amount of late fresh plagioclase are present, and there are patches and veinlets of retrograde chlorite and hematite. Cataclasis was mild. The rock is mineralogically and texturally identical with the Clover Creek greenstone of the Wallowa Mountains, which was described by Smedes in an unpublished report.

Another specimen is a metavolcanic rock consisting of actinolite, chlorite, zoisite, epidote, and calcite in a very fine-grained groundmass of quartz and feldspar. Relict shapes of plagioclase phenocrysts are discernible, but the feldspars are completely altered and blend into the groundmass. Accessory minerals are sphene, garnet, and sulfides.

### MARBLE

The marble is white to light gray, coarsely crystalline, and generally massive. Foliation in some micaceous phases tends to parallel the greenstone contacts and probably represents the original sedimentary bedding.

In the vicinity of granitic rocks the marble is replaced by tactite, a complex in which (a) brown garnet and other lime and iron silicates, and (b) iron oxides and sulfides are present in all proportions from nearly zero to nearly 100 percent.

In thin section a specimen of epidosite from the contact zone consists of epidote and chlorite with small amounts of quartz and iron ore. The epidote occurs as shattered grains engulfed in pale-green prochlorite; some of the larger crystals are intact but are cut by cracks filled with limonite. Quartz occurs in a few irregular patches and large masses of magnetite rimmed with hematite are present.

Another specimen is a garnet-chlorite rock with epidote and veins of anhedral quartz, magnetite, sulfides, calcite, and comb quartz. The magnetite is partly replaced by hematite, and the garnet is cut by smaller veinlets and patches of quartz, magnetite, sulfides, and calcite. Both epidote and garnet have been extensively chloritized.

Bedding and foliation in the metamorphic rocks strike north to north-northeast in conformity with the general trend of the marble outcrop. Dip ranges from 30° east or west to vertical, but very few reliable attitudes could be obtained. For this reason, and because it is impossible to distinguish between top and bottom of beds, little is known as to structural detail. On the basis of an average dip of 60°, the thickness of the main marble unit is about 500 feet. The thickness of the metamorphic rocks as a whole (greenstone plus marble) is at least several thousand feet, with neither base nor top exposed.

A southward extension of the metamorphic rocks is assigned by Kirkham (1931, fig. 1, p. 565) to the Permian. This view has some support in the lithologic similarity between the greenstone of the Iron Mountain district and the Permian Clover Creek greenstone of the Wallowa Mountains, noted above in the petrographic description from Smedes.

## GRANITIC ROCKS

The granitic rocks crop out in two belts trending north on the east and west sides of the strike ridge of the metamorphic rocks that makes the principle drainage divide in the central and southern parts of the district. Granitic rocks are not exposed in the valley of Fourth of July Creek in the northern part of the district, but their presence at moderate depth is suggested by the occurrence, on the Abundance property, of mineral deposits of types closely associated with granitic rocks elsewhere in the district.

The dominant rock type is a quartz-plagioclase-biotite-hornblende rock that might be classified in the field as a coarse-grained granite or quartz diorite. No attempt was made in the course of the mapping to distinguish between this rock and subordinate types and migmatitic phases in the border zones; it is doubtful whether even the most detailed work would permit a good delineation of the boundaries between the several types because the granitic rock crumbles readily to a granite sand that forms soil-covered slopes with rare ledge exposures.

Specimens range from granodiorite to tonalite in composition. Under the microscope the granodioritic types consist of quartz, plagioclase, orthoclase, biotite, muscovite, hornblende, chlorite, and magnetite. The rock contains as much as one-third quartz. The quartz anhedra are clear but are cut by lines of minute vacuole and mineral inclusions which may extend across several grain boundaries. The plagioclase varies from calcic oligoclase to calcic andesine, the most abundant being a sodic andesine about $An_{33}$. It is usually zoned, having slightly more sodic rims. Orthoclase and biotite make up at least 10 percent of the rock. Hornblende is rare in most specimens but is common in the tonalitic types. Magnetite is abundant. The quartz grains are very irregular in form, filling in around and irregularly replacing subhedral feldspar. Rims of both quartz and feldspar are minutely crenulated and show fine crystalloblastic extensions into neighboring grains and sericitic patches of the groundmass. Chlorite, relict hornblende, and shreds of muscovite are intergranular and have ragged outlines. The texture is seriate and hypidiomorphic granular. The effects of cataclastic action are minor.

The original shape of the granitic mass can be inferred rather generally from the pattern of its contacts with respect to the present topography. A hypothetical section through the divide in the south-central part of the district might show the rib of metamorphic rocks as a shallow-keeled erosion remnant on a generally smooth-topped granitic mass, or as a deep-keeled septum between two steep-sided granitic masses possibly connected at depth. The fact that the contact of granitic and metamorphic rocks differs markedly in level within short distances elsewhere in the district, as on the south slopes of Iron Mountain and in Barton Gulch, favors the second interpretation and suggests that the two belts of outcrop correspond with high-crested cupolas elongate in the strike direction of the metamorphic rocks.

Uncertainty as to the origin of the transitional zone between the granitic rocks and the greenstone has been noted above. The same uncertainty applies to the granitic rock itself—absence of foliation or other directional structures in it and poor exposures make it impossible to apply the field criteria for determining whether it was formed by solidification of an intrusive melt, or by recrystallization-replacement of the country rock without mass movement.

Kirkham (1931, p. 569) suggests that the granitic rock of the Iron Mountain district is a part of the Idaho batholith, of probable Late Jurassic age.

### SHEARED CONGLOMERATE

The sheared conglomerate unit is confined to the northwestern part of the district and is best seen in scattered exposures in the headwater parts of the valley of Fourth of July Creek and on the Fourth of

July Creek-Dennett Creek divide north of the saddle utilized by the road to Mineral.

The lower part of the unit, in the valley of Fourth of July Creek just west of the Abundance property, consists of conglomerate—made up chiefly of marble, quartzite, argillite, and greenstone pebbles—interbedded with sandstone and siltstone. The degree of shearing varies widely; outcrops of undeformed conglomerate, which might be mistaken for parts of a recent valley fill, alternate with ledges in which moderately elongated and fractured pebbles lie in a phyllitic matrix. The bedding and foliation dip westward 15° to 30°, and the elongated pebbles define a lineation that plunges westward down the dip.

Upward in the section, on the steep headwater slopes of the valley of Fourth of July Creek, the conglomerate lenses increase in coarseness until, at the divide, the dominant lithology is a fanglomerate-breccia with individual blocks of marble 10 feet and more in diameter. The over-all degree of shearing also increases upward. Along the divide the ledges have the aspect of an augen gneiss, with marble pebbles and boulders drawn out into long twisted laths, and argillite, greenstone, and quartzite pebbles rolled out or stretched in the same sense by development of gash fractures filled with secondary minerals. Some of the larger marble blocks are boudinage pods simulating depositional lenses. Schistosity and lineation dip and plunge westward and northwestward 15° to 45°; the once-gaping fractures in the quartzite pebbles are about normal to the lineation.

Insofar as lithology of the pebble types is concerned, the sheared conglomerate unit could be merely a conglomeratic phase of the metamorphic rocks. But the low-grade thermal metamorphism that pervades every part of the metamorphic rocks suggests a condition of stress wholly different from that indicated by the range from moderate induration to intense low-angle shearing that characterizes the sheared-conglomerate unit. This difference, and especially the outstanding fact that the shearing definitely increases in intensity upward in the section, suggests the operation of a stress couple in which the upper part, presumably a thrust plate, was the active component. According to this interpretation the conglomerate-fanglomerate was shed from the advancing front of the plate and was overridden and sheared by its continued movement—it is, in other words, a thrust conglomerate.

Reconnaissance observations in the Mineral district, in the Dennett Creek valley on the west side of the divide, and therefore in the hypothetical thrust plate, indicate that the rock sequence there is distinctly different from that in the Iron Mountain district and includes quartzite, argillite, and a fine-textured marble similar to the pebbles and blocks in the conglomerate. The ore at Mineral is a tetrahedritetennantite-chalcopyrite-pyrite-galena-sphalerite suite altogether different from the magnetite-specularite-pyrite-chalcopyrite ore of the Iron Mountain district, but this has little bearing on the thrust hypothesis because, while the contrast might suggest that the Mineral suite was formed elsewhere and carried forward in a thrust plate to the vicinity of the Iron Mountain deposits, it might equally well be that the Mineral ore is simply the mesothermal part of the same vein system that is represented by pyrometasomatic deposits in the Iron Mountain district. The deeper underground workings at Mineral were not accessible, and there is, unfortunately, nothing in the published descriptions of the district to suggest whether or not the workings penetrated to the thrust conglomerate(?) that may extend down dip from the divide under the Mineral camp.

Livingston (1932) has outlined evidence indicating the presence of a major low-angle fault, the Bayhorse thrust, in the Mineral district and at a number of other localities in a belt trending north-northeast, with an over-all length of at least 50 miles. He describes a "schistose conglomerate" at several points but interprets it, probably rightly, as an agglomerate in the Permian(?) volcanic sequence, sheared by movement in the fault zone. At Mineral, the Bayhorse thrust is said to bring Triassic or Permian rocks of the thrust plate over a contrasted lithologic sequence that includes shales with Late Jurassic marine fossils; the "schistose conglomerate" on the Bayhorse fault and the overlying and underlying strata dip northwesterly. If Livingston's interpretation is correct, the sheared conglomerate unit of the Iron Mountain district, which also dips northwestward, may be a thrust conglomerate at the base of an overriding mass consisting of two or more individual plates, the lower of which has brought Jurassic rocks over the Permian(?) metamorphic rocks of the Iron Mountain district (younger over older), while the next higher Bayhorse thrust plate has brought Permian or Triassic rocks over Jurassic rocks (older over younger).

This hypothesis has no direct bearing on the iron-ore deposits, all of which are beneath the base of the hypothetical thrust complex; therefore, except for the brief visit to Mineral, no attempt was made to test it further. The following discussion of age relationships is little more than a balancing of uncertainties, but it is needed to distinguish between what is known and not known as to the date of the sheared conglomerate unit relative to the other rock units in the Iron Mountain succession.

The Late Jurassic fossils reported at Mineral indicate that the thrusting is Late Jurassic or later. It is definitely older than the mid-Tertiary basalt, because the basalt lies unconformably on the sheared conglomerate on the Fourth of July Creek-Dennett Creek divide.

There is, in the Iron Mountain district, no direct evidence bearing on the date of the thrust within this long interval.

The pattern of the contact between the sheared conglomerate unit and the andesite in the valley of Fourth of July Creek permits the interpretation that the andesite passes northwestward beneath the conglomerate in essential conformity with it. (See pl. 13.) If the andesite is early Tertiary, this would make the thrusting early Tertiary or later. An alternative view is that the andesite is younger than the sheared conglomerate and is downfaulted against it in Fourth of July Creek area. This interpretation is supported, on the negative side, by the absence of low-angle shearing in the andesite, and, on the positive side, by the pattern on the map in the vicinity of the Montana property, where the andesite appears to rest on an erosion surface that bevels both the greenstone and the sheared conglomerate. Finally, it is in harmony with the general theory that large-scale low-angle thrusting in this region occurred during Late Cretaceous and early Tertiary. For these reasons faults are inferred along the contact of the conglomerate and andesite in the Fourth of July Creek valley. The point to be emphasized is that the pattern of the contacts on the map is based on float in soil and that the interpretation of the nature of the contacts is based largely on a general theory that the thrusting should have been pre-andesite, rather than on field evidence indicating that it was actually pre-andesite.

The date of thrusting relative to emplacement of the granitic rock is important in any consideration of regional tectonic history, and it may be significant in a practical way in any future deep exploration at Mineral. If mineralization is prethrusting the mineral deposits will bottom at the fault plane. The thrust conglomerate is nowhere in contact with the granitic rock or with the associated mineral deposits in the Iron Mountain district, and therefore the date of thrusting relative to the emplacement of the granitic rocks must be left open to question insofar as local evidence is concerned. The tentative dating discussed above makes the thrusting later than the granitic rock.

## ANDESITE

Andesite forms a discontinuous belt trending N. 20°–30° E. from the southwestern to the northwestern parts of the district. Flattened vesicles and a flow layering strike generally parallel with the trend of the belt and are inclined 20°–30° westward in each of the larger remnants. Westward tilting of the andesite and its preservation along the north-northeasterly trending belt are probably related to movement on a set of high-angle faults that parallel the belt.

The andesite is a dense, medium- to dark-gray porphyry; bleaching to light gray and yellow, observed in most large exposures, is probably due to deuteric alteration. Most ledge outcrops show a poorly developed columnar jointing and, normal to the long axes of the columns, a platy parting that corresponds with the flow layering. These original structures and the general absence of greenish color help to distinguish the andesite flows from the older meta-andesites of the greenstone complex.

Because boundaries of flow units are very rarely discernible, the number and thickness of individual flows are not known.

Specimens from all the larger outcrop areas of andesite are closely similar in texture and alteration effects, and all lie within the andesite-dacite range of composition. The groundmass is composed of completely turbid plagioclase recrystallized into a hazy mosaic texture, with only an occasional grain or patch of clear quartz or hazy albite twin lamellae showing through. Plagioclase phenocrysts range in composition, in different specimens, from a very calcic oligoclase ($An_{29}$) to a slightly calcic andesine ($An_{43}$). Most of the plagioclase phenocrysts have growth rims of more sodic plagioclase, and many are almost completely replaced by sodic plagioclase. The feldspars are variously altered to kaolin and sericite but always less so than the groundmass. Hornblende is almost completely replaced by chlorite, calcite, and magnetite. Microcline and orthoclase are present but not abundant. Magnetite is common and is generally segregated in clusters. Quartz is rare. Apatite, biotite, and muscovite are consistently present as accessories.

The degree of turbidity of groundmass and feldspars is correlated in the hand specimen with darkness of color, the darker being the more turbid. The darkest specimen has a groundmass of kaolinized devitrified glass and still shows delicate flow banding around phenocrysts. Andesite of the flow sequence and meta-andesite of the greenstone unit, collected from adjoining ledges at the east end of Chinamans Hat, have an altogether different appearance under the microscope. The andesite shows original flow structures and its alteration is confined to deuteric effects, while in the meta-andesite the original minerals and structural features have been almost completely destroyed.

The map pattern of the contact, especially in the Fourth of July Creek area, indicates that the andesite rests on an erosion surface of low relief, which bevels the metamorphic rocks. Locally, where the unconformity truncates sulfide replacement deposits in the metamorphic rocks, the ancient erosion surface beneath the andesite has a residual blanket of red hematite formed by thorough weathering of the sulfides. This indicates that the ancient erosion surface and the overlying barren andesite postdate the period of mineralization, and, hence, the emplacement of the granitic rocks. Direct evidence bearing on the age of the andesite relative to the granitic rocks is seen in the southwestern part of the district, where the granitic rocks are cut by a swarm of andesite dikes, and, in Chinamans Hat, overlain unconformably by andesite flows.

Neither Livingston (1925) nor Kirkham (1931), in reconnaissance mapping south and west of the Iron Mountain district, recognized an andesite unit that postdates the major period of intrusion; if the andesite of the Iron Mountain district occurs in the areas studied by them, it was apparently regarded as part of the older group of Permian(?) metavolcanic rocks. As indicated above, the andesite unit of the Iron Mountain district rests unconformably on granitic rocks, and on a greenstone which is probably equivalent in part to Permian(?) metamorphic rocks. It is similar to a unit of flow-banded andesite described by Gilluly (1937) in the Baker quadrangle, 40 miles to the west, in that both lie on an erosion surface that truncates all the older metamorphic and granitic rocks and are overlain in turn by Columbia River basalt. Gilluly tentatively assigns the andesite of the Baker quadrangle to the Miocene; the evidence at hand justifies only the statement that the andesite of the Iron Mountain district predates the Columbia River basalt and is probably early to middle-Tertiary in age.

### BASALT

Three bodies of basalt on the main divide between streams flowing westward to the Snake River and eastward to the Weiser River are interpreted, on the basis of position and outcrop pattern, as erosion remnants of a sequence of flows. Jointing habit ranges from coarse columnar to blocky in different ledges but, in the absence of exposures showing definite interflow boundaries, nothing is known as to number or thickness of individual flow units.

Basalt dikes, only a few of which are shown on the geologic map, occur in all parts of the area.

A specimen of basalt from a flow on the divide between Dennett Creek and Fourth of July Creek consists of labradorite, augite, olivine, and magnetite, with secondary calcite, chlorophaeite, and chlorite. The labradorite ($An_{54}$) laths of the groundmass are 0.20 to 0.75 millimeters long and are partly enclosed by pale purplish-brown augite and clear olivine. Calcic labradorite ($An_{63}$) phenocrysts as much as 20 millimeters long are common, and there are relatively rare phenocrysts of olivine as much as 5 millimeters long. Magnetite is abundant, occurring as skeletal forms and subhedral masses that fill in around plagioclase and olivine but are enclosed within the augite, which crystallized later. Most of the olivine has been deuterically altered to an orange and yellowish-brown chlorophaeite and a pale-green mass of fine chloritic fibers and magnetite dust in irregular patches, cracks, and cavity fillings. A few small patches of calcite occupy cracks in the feldspar and are associated with the chloritic masses.

Specimens from two basalt dikes show the same subophitic to intergranular texture as the flow rock, but differ from it in the following respects: smaller grain size and absence of phenocrysts, smaller proportion of olivine, almost complete absence of the chlorophaeite-chlorite material, and slightly more sodic plagioclase (andesine-labradorite).

Differences in mineralogy between the flow basalt and the dike basalt have little meaning because, from the three specimens examined under the microscope, nothing whatever is known about the range in mineralogic differences in the flows as a group or in the dikes as a group; all the differences noted might well occur within either group. But random observations in the course of the mapping indicate that the flow rock is generally porphyritic, while the dike rock is not, and this suggests that the dikes may not have been (as might otherwise be assumed) the feeders for the flows. A difference in age between the dikes and flows would not be in any way extraordinary, because there is a record in adjacent areas of recurrent basaltic volcanism through much of the Cenozoic.

Their positions on the divide indicate that the occurrences of flow basalt are remnants of sheets that were spread over the district previous to the development of the present rugged topography. Kirkham (1931, p. 565) has assigned olivine-basalt that caps divides just south of the Iron Mountain district to the Miocene Columbia River basalt.

## SUMMARY OF STRUCTURAL GEOLOGY

An area the size of the Iron Mountain district can, at best, provide only a decidedly incomplete record of the deformational history of the region of which it is a part, and interpretations based on the local record are therefore certain to involve oversimplification of the actual history. This fact needs to be stated, but it is not cause for concern in the present report, which deals specifically with the local geology only as a setting for the iron deposits.

For purposes of this limited objective, it is useful to emphasize the division of the structures of the district into two major groups, formed during periods of sharply contrasted deformational habit. The deformational periods were separated by a period of crustal stability long enough to permit reduction of the district to low relief by erosional processes.

The principal events of the earlier period were:

(1) Folding of a geosynclinal sequence of sedimentary and associated intermediate and basic volcanic rocks, represented by the greenstone and marble. The fold axes trend north to north-northeast.

(2) Invasion by acidic magma or by emanations from depth that transformed the metamorphic rocks into granitic rocks. The two outcrop areas of granitic rocks in the district are in general alinement with the fold structures, but cut across the units of the metamorphic rocks in detail.

(3) Deposition of a thick sequence of detritus shed from the front of a thrust plate that advanced from the west or northwest. Intense low-angle shearing in this thrust conglomerate indicates that the plate formerly extended across the northwestern part of the district; it has been stripped back by erosion and is now preserved only in the adjoining Mineral district.

These events cannot be definitely dated on the basis of direct evidence in the district. Indirect local evidence and dates established (?) elsewhere in the region suggest that the metamorphic rocks are Permian in age, that the folding was Jurassic or older, that the granitic rocks are Jurassic, and that the low-angle thrusting occurred during Cretaceous or early Eocene time. For present purposes the significant point is that the primary mineral deposits are replacements in the metamorphic rocks around the granitic bodies, and that residual and secondary enrichment deposits were formed by weathering of primary sulfides on an erosion surface that bevels all the rocks of the basement complex.

The principal events of the second period were:

(1) Spreading of andesite flows over the erosion surface, at least in part from feeder dikes in the district. The andesite flows are probably early to mid-Tertiary in age.

(2) High-angle faulting, accompanied by westward tilting of the fault blocks. A few post-andesite faults trend northwest, but most of them trend north to north-northeast in general conformity with the structural grain of the basement complex. The andesite is now preserved only where it was tilted down or inset by westward rotational movements on these faults.

(3) Injection of dikes of nonporphyritic basalt and, perhaps somewhat later in the mid-Tertiary, the spreading of flows of porphyritic basalt. The post-andesite erosion surface that was covered by the basalt may have had moderate to high local relief; there is no evidence that the porphyritic flows covered the top of Iron Mountain.

(4) Uplift and dissection to produce the present relief. While no post-basalt faults have been recognized in the district, it is likely, on the basis of relationships elsewhere, that the regional uplift was accompanied by differential movements.

The significant point, for present purposes, is that the Tertiary volcanic rocks cover the mineralized basement complex in about 20 percent of the district and may therefore conceal other ore bodies of the types now exposed.

## IRON DEPOSITS

### HISTORY AND DEVELOPMENT

The greater part of the prospecting and development around Iron Mountain took place toward the end of the last century, being encouraged in part by the discovery of silver in the Mineral district, which adjoins the Iron Mountain district on the west. Nearly all the adits in the district were driven in search for copper or gold- and silver-bearing sulfides on the basis of a long-standing local theory to the effect that the iron deposits grade into massive sulfide ores at a shallow depth.

A small amount of iron ore, probably less than 1,000 tons, has been shipped for use in cement manufacture at Lime, Oreg., and as smelter flux at Mineral and Cuprum, Idaho. The ore was taken chiefly from open-cuts on the crest and north slope of Iron Mountain. No shipments have been made in recent years.

Ownership of the iron-ore prospects in 1943 was as follows: the Abundance red-hematite, the Standard specularite, and the Montana red-hematite and magnetite deposits by John Siegwein, of Weiser, Idaho; the Mortimer magnetite deposit by Frank Mortimer and associates (the Iron Mountain Mining Co.), of Weiser; and the Campbell magnetite deposit by J. W. Campbell and Clifton Barton, of Weiser.

Few claim corners were found in the course of the mapping, and, for the most part, all identifying markings had been effaced by weathering. A claim map of the district is included in the Hodge (1938, pl. 3) report.

## PREVIOUS GEOLOGIC STUDIES

The iron deposits on Iron Mountain are described briefly by Bell (1918, p. 98) as consisting of crystalline hematite carrying from 50 to 60 percent metallic iron, with estimated reserves of several million tons.

A report by Hodge (1938) includes a very generalized geologic map, claim maps, and a number of analyses. Hodge does not mention occurrences of magnetite in the district but follows Bell (1919, p. 108) in describing the Campbell magnetite of the present report as belonging to the hematite vein type of ore (Hodge, 1938, p. 41). He concludes that reserves of low sulfur (leached) ore probably total less than 100,000 tons (Hodge, 1938, pp. 38–39).

The area was visited briefly by John R. Cooper, of the U. S. Geological Survey in November 1942, when snow cover made detailed study of the deposits impossible. Cooper's unpublished report includes several analyses, a generalized map of part of the area, and a recommendation that the district be given further study.

## GENERAL DESCRIPTION OF THE DEPOSITS

The three principal types of ore bodies in the district are primary deposits consisting chiefly of magnetite or specularite, primary deposits consisting chiefly of sulfides, and secondary deposits of earthy red hematite. Generalizations as to the relationships between these types are outlined briefly here; details of occurrence of the iron ores are treated in the descriptions of individual properties.

### MAGNETITE AND SPECULARITE DEPOSITS

The magnetite and specularite deposits are irregularly shaped bodies in the marble unit of the metamorphic rocks at or near contacts with granitic rocks. The magnetite is massive, very rarely showing small crystal faces; the specularite is finely to coarsely crystalline. Common mineral associates are quartz and brown garnet, and (with the specularite) red jasper. It is noteworthy that in a given deposit the primary iron oxide is exclusively magnetite (Campbell and Mortimer properties) or specularite (Standard property); these minerals have not been observed together in the same deposit.

The deposits can be examined only in natural exposures and shallow pits. Both the magnetite and, to a lesser extent, the specularite contain cavities occupied in part by cellular limonite formed by leaching of soluble minerals, probably chiefly sulfides. The cavities make up less than 5 percent by volume of the deposits classed as iron ores in this report. The relations indicate that the magnetite and specularite ores are primary replacement deposits—the sulfur content may be expected to increase somewhat below the zone of leaching, but ores of this type will not normally grade downward into massive sulfides.

### SULFIDE DEPOSITS

Veins and podlike bodies made up chiefly of pyrite, commonly with some magnetite and chalcopyrite, occur at a number of points in the district. These deposits are not discussed as such in the present report, but they are closely related to the magnetite and specularite deposits in that both were probably formed by solutions from a common source at the time of emplacement of the granitic rocks. The proportion of sulfides relative to oxides has a tendency to increase with distance from granitic masses, this change presumably reflecting a decrease in temperature of the solutions outward from the source. If this factor had been the dominant control of the oxide-sulfide ratio in the deposits there should be every gradation between high-oxide and high-sulfide types of ores—but this is definitely not the case. There is, on the contrary, a well-defined group of deposits high in oxides that are replacements in marble, and another group of deposits high in sulfide that are replacements in greenstone. It is likely, therefore, that the character of a given replacement deposit was determined dominantly by the nature of the host rock; marble appears to have favored precipitation of the oxide ores, and greenstone, the sulfide ores.

### RED-HEMATITE DEPOSITS

The red-hematite ore is compact earthy material that locally approaches the theoretical iron content of pure hematite; in general, though, the grade is lower because of the presence of quartz and carbonate veinlets and jasper. The idea that the red hematite, and the magnetite and specularite deposits as well, should pass downward from the present surface into sulfide ore seems to be based on the fact that, on the Abundance property, red hematite does grade downward into massive sulfides. But, as pointed out in the preceding paragraph, the magnetite and specularite deposits are primary ores, wholly different in origin and in significance as to what lies beneath, from the red hematite. The red hematite that overlies sulfides at the Abundance prospect is different in all respects from the cellular limonitic gossans now in process of formation by leaching of the same types of sulfides elsewhere in the district. Field relations indicate that the red-hematite type of residual blanket was formed, not with respect to the present surface, but by leaching of the sulfides on an ancient erosion surface that bevels the metamorphic rocks, probably under conditions of climate and relief altogether different from those of the present time. (See p. 147.) According to this theory, the compactness of the red hematite is the result of static pressure and contact-metamorphic effects associated with the spreading of andesite flows over the ancient erosion surface, and regional deformation subsequent to its burial by the andesites.

The implications of this pre-andesite theory of origin of the red hematite differ markedly from those of the theory that it was formed by leaching at the present surface, both with regard to the extent of the red hematite as an iron ore and in connection with its use as a guide to secondary copper deposits.

## ORIGIN OF THE ORE

As in most districts of this type, the theory that the ore deposits are related genetically to the granitic rock is based primarily on geographic proximity—the ore bodies occur at or near the borders of the granitic rock or, in the case of the Abundance deposit, under conditions that make it reasonable to postulate the existence of granitic rock at a shallow depth. An alternative hypothesis might hold that the ore deposits were formed long before emplacement of the granitic rock and were crosscut by it, the present spatial relationships being wholly a matter of chance. A second alternative view might hold that the deposits long postdate the granitic rock and are grouped about its borders because upward movement of mineralizing emanations was favored by shattering around the contact. The fact that the ores are a typical pyrometasomatic suite and especially the fact that the deposits show a rude silicate-oxide-sulfide zoning outward from the contact count heavily against these views and favor the idea that "the granite was the ore-bringer."

This tentative conclusion is, of course, only a first step toward a theory of origin of the ore. The district provides no evidence that would help to determine whether the ores were evolved directly from the adjoining granitic rock, or whether both were derived from a common source at depth. Neither is there any evidence to solve the practical problem of why the ores are sharply localized at a few points in a contact zone that is otherwise barren; this localization implies a collecting of the mineralizing emanations and their passage outward through trunk conduits, but no mineralized breccia zones or other possible ore-body feeders have been observed in the granitic rocks. Even if evidence bearing on these and associated problems were present in the rocks of the district, a considerable proportion of bare-rock exposure would be needed to make it understandable; there is actually less than 1 percent of ledge outcrop in the granitic areas.

The undeveloped state of the district, which limits observation mostly to weathered outcrops, and especially the fact that the ores have not been examined microscopically leave many uncertainties as to details of paragenesis and mineralogy. The evidence at hand suggests that the formation of silicates preceded metallization, and that the metal-bearing emanations selectively replaced marble beyond the slightly earlier tactite near the contact. However, a simple silicate-oxide-sulfide zonal arrangement is rarely developed because difference in permeability caused by premineral fracturing made the depositional wave fronts highly irregular in form, and because of the influence of wall-rock composition on the nature of the deposits. As a result, individual exposures may consist of iron oxides, sulfides, tactite, and (or) marble, with any one of these constituents making up nearly 100 percent of the bulk of any one exposure.

## RESERVES

Reserves available for open-pit mining in the district are 150,000 to 200,000 tons, of which only about 20,000 tons can be regarded as measured ore. These totals include certain concentrations of ore boulders on slopes below ore in place, and represent three different deposits, two of magnetite and one of specularite. The bodies of red hematite are small in size and could be mined only by underground methods.

Analyses of the several ore bodies indicate an average composition of 62 percent iron, 0.05 phosphorous, and a trace of sulfur. These figures apply to the total reserves, all of which are in the zone of weathering. It is to be expected that the sulfur content of the ore will increase markedly below the water table.

## DESCRIPTION OF INDIVIDUAL DEPOSITS

### CAMPBELL MAGNETITE DEPOSIT

#### GEOLOGY

The Campbell deposit is in a block of marble on a spur between Fourth of July Creek and a tributary of Barton Creek. (See pls. 13 and 14.) The marble is underlain by greenstone on the east and is in fault contact with the same rock on the west. The magnetite occurs as pods at the base of the marble on the north and south slopes of the spur; the remainder of the marble is traversed by stringers and irregular masses of brown garnet and other lime silicate minerals.

Three hundred feet south of the south ore body and 200 feet vertically below it on the south slope of the spur is a caved adit that was probably driven to pass beneath the magnetite croppings. On the dump are sulfides but no massive magnetite. The adit follows the trend of a set of quartz-pyrite-magnetite veins that strike about N. 30° E.; individual veins cannot be mapped on the soil-covered hill slopes, but the trend of the set is indicated on the general map (pl. 13) by a grouping of prospect adits in a zone from the Montana prospect to the north edge of the map. The space relations suggest (1) that the mineralizing solutions were associated with granitic rocks that crop out in Barton Gulch, and (2) that these solutions formed veins with predominant sulfides in their passage through the greenstone but produced irregularly ramifying magnetite bodies, low in sulfides, where they entered the overlying marble on the Campbell spur.

#### DESCRIPTION OF ORE OCCURRENCES

The south ore body crops out in a mass of magnetite boulders that form a mantle over an area of about 10,000 square feet. (See pl. 14.) Only the higher portion of the boulder mass is in place; a single exposure of the base of the ore body shows massive magnetite underlain by an intergrowth of magnetite and garnet, with a large proportion of limonite-filled cavities formed by leaching of sulfides. This basal contact, a poorly developed sheeted structure in the magnetite, and the foliation of the overlying marble dip westward about 20°. The south ore body is therefore believed to be a westward-dipping pod at the base of the marble; its thickness, exclusive of the subjacent magnetite-garnet material, is 20 to 30 feet.

The north ore body is exposed in a short adit and an adjoining pit on the north slope of the Campbell spur. The caved portal of the adit shows an 11-foot face of magnetite underlain by a thin magnetite-garnet layer that grades downward into greenstone. The magnetite is overlain by marble, the general relations suggesting a westward-dipping tabular body 11 to 15 feet in thickness. Magnetite float can be traced from the adit northwestward diagonally down the hill slope about 150 feet, and southeastward part way around the nose of the spur to a small caved pit with magnetite in place; the over-all length of the float band is about 400 feet. Insofar as can be determined from the exposures, the north ore body could be a continuous tabular sheet or a series of small pods along the contact of the marble and greenstone.

A train of boulders composed in part of magnetite mantles the south slope of the Campbell spur near the west margin of the marble. The boulder material is so heavily contaminated with garnet and has so high a proportion of leached cavities that it is not considered to be an iron ore.

The north and south ore bodies are not connected at the surface trace of the contact of the marble and greenstone around the east end of the spur, but their relations suggest that they may be parts of a single body, continuous through the spur. The magnetic contour map of the Campbell deposit (pl. 14) provides rather definite answers for this and other uncertainties. It indicates (1) that the north and south ore bodies are separate units not connected through the spur, (2) that the north ore body is a single continuous sheet passing westward under marble, and (3) that the south ore body extends westward under a thin cover of marble for at least 100 feet beyond the western margin of the ore outcrop.

The surface exposures and dip-needle data provide a basis for preliminary estimates of tonnage available for open-cut mining on the Campbell property. The first steps in exploration of the deposit should include trenching or bulldozing across the float band to determine the actual thickness of the north ore body at several points, and perhaps drilling of one or more holes to determine the down-dip extent of the ore and its sulfur content at depth. (See pl. 14, section *A–A′*.)

### GRADE

The following analyses are representative of the grade of the leached ore. The material sampled is massive magnetite with small quartz and garnet veinlets, and limonite-filled cavities suggesting that sulfides constitute 1 to 3 percent of the material below the zone of weathering.

*Analyses of Campbell magnetite*

| | 1 | 2 | | 1 | 2 |
|---|---|---|---|---|---|
| $SiO_2$ | 6.88 | 7.97 | MnO | 0.12 | ------- |
| $Al_2O_3$ | 2.98 | 1.08 | Mn | ------ | .06 |
| $Fe_2O_3$ | 88.92 | ------- | $H_2O$ | .80 | ------- |
| $TiO_2$ | .70 | .01 | | | |
| $P_2O_5$ | .12 | ------- | Total | 100.52 | ------- |
| P | ------ | .056 | | | |
| Total Fe | | | | 62.15 | 63.25 |

1. Sample collected by E. T. Hodge. ". . . 39 pounds chipped from boulders (and perhaps ore in place) across 40 feet on the east line of the Last Chance claim." (Hodge, 1938, p. 43.)
2. Sample collected by J. H. Mackin. 22 pounds chipped from boulders for distance of 70 feet along trail around base of south ore body.

## THE MORTIMER MAGNETITE DEPOSIT

### GEOLOGY

The Mortimer deposit lies in a pendant of marble surrounded by granitic rock (pl. 15). Except on the north, where a postintrusion fault is inferred, the marble in the contact zone around the pendant is strongly impregnated with garnet and other lime silicate minerals. The position of the ore body inside of this zone is reminiscent of the rule that, in deposits of this type, the ore is on the limestone side of the skarn rock.

### DESCRIPTION OF ORE OCCURRENCES

The ore is best exposed in a caved shaft at *B* and two pits at *C* (pl. 15). The shaft is approximately 15 feet in diameter and 15 feet deep to a floor of caved material; the north, south, and west sides are in magnetite. The larger of the pits at *A* shows a curving face 12 feet in length and 9 feet high at the deepest point, all in magnetite. The surface between the shaft and the pits is covered by magnetite float except along the outcrop of a 30-foot dike of basalt that passes between them.

A belt of abundant float and scattered outcrops of ore extends north-northeastward from the caved shaft for about 300 feet. An average width of about 60 feet of ore in place is distinguished on the map from a veneer of blocks of ore lower on the slope on the basis of numerous dip-needle traverses.

The portal of the adit at *D* is caved; the dump is made up largely of granitic rock, tactite, and basalt. It is reported that the adit, or a crosscut from it, penetrated to a point directly below the caved shaft at *B*; that a raise was extended to the surface at this point; and that a winze was sunk to a depth of 40 to 50 feet, the raise and winze together forming a vertical shaft about 100 feet deep. The tunnel is said to have been in "soft rock," definitely not ore, for the greater part of its length; the winze and raise are said to have been in "very heavy black material," possibly magnetite. (It should be noted, in this connection, that the exploratory work was done, not to develop the iron ore as such, but in search of sulfides that were supposed to underlie the iron ore "gossan"). But there is little magnetite on the dump and it is possible that the black material may have been (dike) basalt. It will be noted on plate 15, section *A–A′*, that the possible lower limit of the ore, drawn on the basis of this very doubtful hearsay evidence, extends much deeper than a line connecting the intrusive contacts on the two sides of the Mortimer spur. The ore in the section is, of course, entirely hypothetical; nothing is known as to its actual extent in depth.

Any further exploration should include (1) clearing of the caved portal at *D* to determine whether the underground workings are accessible for examination, (2) trenching across the float band at several points to permit accurate measurement of the width of outcrop and grade of the ore, and (3) drilling of a hole on the slope a short distance east of the caved shaft (see pl. 15, section *A–A′*), with an inclination of 45°, and a westerly bearing in the plane of the section.

### GRADE

The solid magnetite in the several openings mentioned above shows an estimated 3 percent of cavities resulting from leaching of soluble materials, probably sulfides. Copper stain is common in some of the leached material. The ore in the openings, and especially in some parts of the float band, includes a considerable admixture of garnet and other lime silicate minerals and may require benefication. The quality of the leached material is suggested by the accompanying analysis.

*Analysis of Mortimer magnetite*

| | | | |
|---|---|---|---|
| $SiO_2$ | 4.77 | Mn | 0.61 |
| $Al_2O_3$ | 2.10 | P | .035 |
| Fe | 61.34 | $TiO_2$ | .02 |

Sample collected by J. H. Mackin. 23 pounds of chips from horizontal cut across faces of ore exposed in openings *B* and *C* (pl. 15).

## THE STANDARD SPECULARITE DEPOSIT

### GEOLOGY

The geologic relations of the Standard ore body can be described in terms of the succession of rock types encountered in a traverse westward across the three peaks and the two intervening saddles that form the crest of Iron Mountain. (See pl. 16.)

The east peak is made up of flows of andesite that rest unconformably upon, or are in fault contact with, greenstone and tactite to the west. The rocks of the eastern saddle and middle peak are subdivided into numbered zones for convenience in description; the map symbol for greenstone and tactite includes minor pods of marble and iron ore both in the numbered zones along the crest and on the talus and soil covered north and south slopes.

The east saddle (zone 1) shows mixed float including spheroidally weathered boulders of basalt, probably from a small dike; dense reddish marble with seams of red hematite, red jasper, and garnet; and aplitic dike rock, probably representing one or more small offshoots from the main body of granitic rock to the west. (See pl. 16, section *A–A′*.)

The eastern slope of the middle peak (zone 2) is made up largely of dense red marble, heavily impregnated by garnet and with minor hematite veinlets. Bedding or foliation in the marble strikes N. 20° E. and is essentially vertical.

The eastern part of the middle peak (zone 3) consists of a 4- to 7-foot rib of massive quartz containing pods or lenses of coarsely crystalline hematite, with individual warped folia as much as three-fourths of an inch in breadth. The hematite surrounds euhedral quartz crystals and penetrates cracks in massive quartz. The larger pods of hematite are as much as 3 feet in width and a few tens of feet in length, the elongation of the tabular bodies paralleling the structure of the adjacent marble. The western half of the rib consists of massive and coarsely crystalline brown garnet containing masses of crystalline calcite and some small veinlets of specularite.

The surface that slopes westward from the quartz-garnet rib to the contact of the quartz diorite in the western saddle (zone 4) is largely reddish marble and jasper, generally poorly exposed. In relief above this surface are two ledges of massive hematite, trending parallel with the bedding or foliation of the marble wall rock. The relations of the two bodies are indicated on plate 16; whether they represent separate lenses or are parts of a single lens displaced by a minor fault cannot be determined from present exposures. As seen in a 34-foot horizontal face prepared for sampling across the north body, the ore is in sharp contact with red jasper at both ends. The body contains some small quartz veinlets and very small portions of jasper but is composed principally of finely crystalline specularite traversed by vertical bands (paralleling the walls) of coarsely crystalline specularite. Cavities caused by leaching probably amount to less than 1 percent by volume; a small copper-green stain appears at one point. The south ore body is much smaller in size and appears to be inferior in grade.

A number of dip-needle traverses across the exposures indicate that the ore is nonmagnetic. The dip needle is therefore of little use in defining the limits of ore in place under float cover.

The limits of the several rock types and ore can be determined with reasonable accuracy only along the crest line of Iron Mountain; the steep slopes descending northward and southward from the crest are mantled by talus and creep material which makes it impossible to trace out zones noted along the crest. Data on the geology of the slopes, which bears directly on the probable subsurface extension of the north and south ore bodies, are as follows:

Granitic rock crops out at *B* on the south slope of the ridge, and the intrusive contact probably continues southward and southeastward under a cover of andesite talus in the vicinity of *A*. The draw at *B* contains a train of hematite boulders. Some are larger in size (as much as 6 feet in diameter) than any hematite pods now exposed in the quartz-garnet-hematite rib at the head of the draw (zone 3).

Some of the hematite boulders may have been derived from lenses of hematite in the tactite at and southeast of *A*, now covered by andesite talus.

Small caved adits at *C* are in granitic rock, and the contact as drawn between *B* and *D* is based on float and scattered outcrops.

The caved adit at *E* trends in the direction of the north ore body and was evidently intended to cut it 50 to 60 feet below the outcrop. The size of the dump suggests that the adit was extended 75 to 100 feet beyond the caved portion, that is, it was driven close to or beneath the downward projection of the ore. The dump is composed of a greenstone type of contact rock believed to be unfavorable for replacement by iron oxide ores; there is no evidence that ore was encountered in the adit.

A train of hematite boulders extends down the north slope of the mountain from the ledge croppings of the north ore body to and beyond a caved open cut near *F*. (See pl. 16.) The intrusive contact is traceable by float from *D* to the west side of the boulder train and is exposed farther down the slope on the east side. Dumps from adits at *F* and *G*, in the boulder train area, show only granitic rock; there is no evidence of ore in place.

There is a local belief that boulders of ore at *F*, some exceeding 10 feet in diameter, are essentially in place and that they indicate a hematite ore body probably continuous with the north ore body at the crest of the mountain. If this were the case, that is, if the boulder train were taken to be outcrop of ore in place, a horizontal length of 700 feet and a difference in level of 400 feet between the two ends of the body would provide a basis for large tonnage estimates; earlier estimates of several million tons were probably based on this theory. But as the hematite replacement ores occur only in marble and do not occur in granitic rock so far as known, the geologic relations described above indicate that the boulder masses at *F* are part of an ore talus from farther up the slope, probably from the north ore body.

The contact shown on plate 16, section *A–A′*, by closely spaced dashes is based on connecting a number of points along the surface trace of the contact on the north and south slopes of the ridge by straight lines passing through the plane of the section. An alternative (deeper) position of the contact is shown by widely spaced dashes to emphasize the uncertainty which attaches to its position. The position of adit *E* in the section is entirely hypothetical, being based on the assumption that the adit continues far enough in a straight line to intersect the plane of the section.

## DESCRIPTION OF ORE OCCURRENCES

The north ore body is almost continuously exposed for 140 feet, the width decreasing from about 30 feet near the south end to 13 feet near the north end; the difference in level between the two ends is 50 feet. Two pits in the rib of ore show a depth of at least 10 feet.

The south ore body is exposed in a blasted face 12 feet high, is at least 20 feet in length in a north-south direction, and at least 10 feet in width. There may be ore in place beneath a stock pile and bouldery masses extending 25 feet downslope to the west from the ledges.

If conditions not foreseeable at the present time call for exploration of the deposit, a drill hole entering at 1 (see pl. 16, section *A–A′*), with an inclination from the horizontal of 40°, and a westerly bearing in the line of section *A–A′*, will yield a maximum of data at small cost. The hole should stop at an incline depth of 90 feet if it is in quartz diorite or greenstone at that depth, but should be continued beyond the 90-foot point, as long as it remains in carbonate rocks, to 150 feet. If ore is encountered in minable thickness in hole 1, a second hole entering at 2, with the same inclination, bearing, and qualifications as 1, but with a minimum slant depth of 200 feet, will provide data regarding zones 3 and 4 in addition to the extension of the ore encountered in hole 1. The advantages of this program, which combines the core data in a single vertical plane, more than offset the disadvantage resulting from the divergence of section *A–A′* from a direction normal to the strike of the north ore body.

The almost continuous showings of hematite and hematite-quartz-jasper boulders extend down the north slope to the 6,170 contour. The width of the hematite boulder train is 50 to 100 feet and sparsely distributed blocks of hematite appear east of the boulder train for an additional 100 feet. Outcrops are relatively poor from the 6,170 to the 6,050 contour, but the open cut at *F*, in this area, exposes large hematite boulders intermixed with soil and other rock types in a face at least 12 feet in height, along the full length of the cut (70 feet). Examination of this face and other pits suggests that hematite boulders make up about one-half of the blanket.

Preliminary estimates of grade and tonnage of boulder ore could be determined by bulldozer cuts to bedrock across the boulder train, at least one of which should be in the area of scant exposures between 6,050 and 6,170 feet.

## GRADE

The quality of the ore is indicated by the accompanying analyses. Number 1 was probably taken from the south ore body of the present report. Numbers 2 and 4 are representative of the north ore body. Number 5 indicates the grade of ore boulders on the north slope. Number 3 is a grab sample of low-grade ore probably taken across zone 3 and the portion of zone 4 east of the north ore body.

*Analyses of Standard hematite ores*

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 33.92 | | | 12.30 | 16.92 |
| $Al_2O_3$ | 2.59 | | | 1.24 | 4.26 |
| $Fe_2O_3$ | 54.19 | 79.7 | 57.00 | | 77.78 |
| MgO | .40 | | | | |
| CaO | 3.23 | | | | |
| $Na_2O$ | .40 | | | | |
| $TiO_2$ | .92 | | | .02 | .48 |
| $P_2O_5$ | .13 | | | | .06 |
| P | | .008 | | .039 | |
| $SO_3$ | .02 | | | | .06 |
| MnO | .11 | | | | .02 |
| Mn | | | | .09 | |
| $H_2O$ | 3.91 | | | | .64 |
| Insoluble | | 20.4 | 42.1 | | |
| Total | 99.82 | | | | 100.22 |
| Total Fe | 37.90 | 58.8 | 39.9 | 58.36 | 54.37 |

1. Sample collected by E. T. Hodge. ". . . 31 pounds taken on a 16-foot horizontal cut along an old pit, the westernmost opening on Iron Mountain . . ." (Hodge, 1938, p. 42).
2. Sample collected by J. R. Cooper. "Half a dozen chips taken at random across 40 feet of high grade ore lying immediately west of the low-grade ore . . ."
3. Sample collected by J. R. Cooper. "A grab sample of low-grade specularite ore which is about 100 feet wide. Since the specularite is not uniformly distributed throughout the 100 feet, the analysis is only suggestive of the average grade."
4. Sample collected by J. H. Mackin. 32-pound chip sample across 34-foot face of north ore body, north edge of middle peak of Iron Mountain.
5. Sample collected by E. T. Hodge. ". . . 49 pounds of chips from a large number of boulders of ore float on the north slope of Iron Mountain just above the blacksmith shop on the Standard claim." (Hodge, 1938, p. 42.)

## THE ABUNDANCE RED-HEMATITE DEPOSIT

### GEOLOGY

The principal rock types of the Abundance claim area are (1) andesite flows resting uncomformably on (2) greenstone and marble. Measurements of attitude in the andesite indicate that the flows strike N. 40°–60° E. and dip 20° to 30° NW. The outcrop pattern suggests that the unconformity between the flows and the older metamorphic rock is a rather regular plane having the same attitude as the layering in the flows; it is, in other words, an erosion surface of low relief, covered by outpourings of andesite porphyry and later tilted northwestward.

Red hematite is seen at *A* (pl. 17) on the dump of a short caved adit; at *B* in a small pit, possibly in float; at *C* and *D* as fragments in surficial soil; at exposures above and below the road at *E;* in a small pit at *F;* and in stock piles adjacent to short caved adits at *G*, *H*, and *J*. All these occurrences lie at or near the uncomformable contact between the metamorphic rocks and the overlying andesite flows. The only other known deposit of the red-hematite type of ore in the Iron Mountain district (on the Montana claim) lies at the same geologic horizon.

The base of the red hematite is exposed in the first right-hand crosscut in the main Abundance tunnel (portal at *K*—see pl. 17, section *A–A′*) where it is underlain by massive sulfides, with secondary copper enrichment in the sulfides just below the contact; a specimen from this point contains 24 percent copper. A long caved adit at *L* passes beneath the hematite exposures at *G*, *H*, and *J* and is said to have encountered sulfides.

For these reasons and because of the characteristic features of the hematite ore noted in an earlier section, which serve to distinguish it from the primary specularite ores on the one hand and from the limonitic gossans now being formed by weathering of sulfides on the other, the red hematite is believed to be an ancient gossan, formed by leaching of sulfide bodies in the metamorphic rocks on a pre-andesite erosion surface and subsequently buried by the andesite flows.

The red hematite formed by weathering of sulfides on the pre-andesite surface may have been entirely residual, or it may have been in part transported and deposited previous to the spreading of the andesite flows. If it was entirely residual it would now be strictly coextensive with sulfide bodies truncated by the pre-andesite surface and should therefore serve as a reliable guide to the location of secondary copper deposits; whether these are of such size and grade as to be minable is another matter. If it was reworked it may have been spread widely as a depositional blanket over barren greenstone or marble and would serve only as a general clue to the presence of subjacent sulfides. Thus, even if there is a continuous blanket of red hematite at the base of the andesite along the segment of the contact southwest of the Abundance mine, it does not necessarily follow that that blanket is underlain by secondary copper ore.

### DESCRIPTION OF ORE OCCURRENCES

The specularite ores and the magnetite ores commonly form ledge outcrops and heavy trains of float. In sharp contrast, the red hematite does not crop out and it yields little float; the artificial excavation at *E*, for example, exposes a face 11 by 12 feet in solid red hematite, but there are no fragments in the soil on adjacent natural slopes to suggest the presence of the ore. For this reason there is little basis even for preliminary estimates of the available tonnage.

Even if the red hematite does form a continuous thin blanket at the base of the andesite, its geologic relations are such that it could be mined only by underground methods, at costs that would probably exceed its value as an iron ore. The red hematite is significant economically chiefly as a guide to the possible presence of secondary enrichment in sulfides wherever, in this or neighboring districts, the pre-andesite surface is transected by the present surface.

### GRADE

The quality of the ore is suggested by the accompanying analyses:

*Analyses of Abundance hematite*

| | 1 | 2 | | 1 | 2 |
|---|---|---|---|---|---|
| $SiO_2$ | ------ | 27. 87 | P | ------ | 0. 116 |
| $Al_2O_3$ | ------ | 1. 56 | $TiO_2$ | ------ | . 01 |
| $Fe_2O_3$ | 89. 8 | ------- | Insoluble | 9. 7 | ------- |
| Mn | ------ | . 14 | Total Fe | 62. 9 | 46. 25 |

1. Sample collected by J. R. Cooper. ". . . compact earthy hematite exposed at the end of the caved ground over the Abundance tunnel . . . From a uniform-looking vertical outcrop 10 feet high by 12 feet broad. The grade indicated is probably close to the average exposed, but this ore is known to pass over into massive iron sulfides at depths between 10 and perhaps 25 feet."

2. Sample collected by J. H. Mackin. 14-pound grab sample from stock piles adjacent to pits *G*, *H*, and *J*. The grade is obviously lower than that of the red hematite exposed over the Abundance tunnel. (See pl. 17.)

## THE MONTANA MAGNETITE AND RED-HEMATITE DEPOSITS

### GEOLOGY

The principal rock types on the Montana property include the marble and greenstone units of the metamorphic rocks, overlain unconformably by andesite flows on the west. (See pl. 18.) While the attitude is not determinable locally, the flows and the unconformity at their base probably dip westward at a low angle. The greenstone includes marble and granular quartzitic phases probably representing recrystallized felsites or quartzose sedimentary rocks. Aplite occurs as float at several points, and aplite dikes cut the greenstone in the underground workings. Basalt float suggests the presence of one or more late basalt dikes, not separately mapped.

Three types of mineral deposits occur on the property: red hematite, magnetite, and sulfides.

### DESCRIPTION OF ORE OCCURRENCES

The red hematite is exposed in a vertical face 15 feet high by 14 feet wide in a caved shaft at *A*. Adjoining ledges of red hematite and jasperoid material indicate a north-south dimension of 40 feet, and an outcrop width of 20 feet.

The Montana adit, about 400 feet in length, was driven from the portal at *B* to a point directly beneath the caved shaft at *A*. The adit is principally in greenstone, which contains disseminated sulfides and some small pyritic stringers. According to the owner, John Siegwein, the shaft at *A* was sunk to a depth of 50 to 55 feet, and a crosscut was extended from the base in a westerly direction for 45 feet. (See pl. 18, section *A*–*A′*.) The shaft and crosscut were said to have been chiefly in marble, but it is reported that 5 feet of red hematite was encountered at or near the end of the crosscut. Later a raise was driven through greenstone from the adit to connect with the shaft. This part of the workings is inaccessible.

Like the Abundance red hematite, the Montana hematite deposit is believed to be a lens or a tabular body dipping westward along the unconformity at the base of the andesite flows. Section *A–A′* indicates that this possibility has not been tested by exploratory work to date.

A short adit at *C* penetrates a body of coarsely crystalline pyrite containing some magnetite and a small percentage of chalcopyrite. The wall rock is a quartzose phase of the greenstone complex and contains disseminated sulfides. The occurrence is worthy of mention in this report because the caved portal shows a complete gradation from the massive sulfides into a cellular limonitic gossan, evidently due to leaching of the sulfides under existing conditions of relief and climate. This typical modern gossan is wholly unlike the primary specular hematite and magnetite ores, and does not resemble in any way the compact red hematite regarded here as an ancient residual blanket, formed under conditions different from those of the present time.

The Montana magnetite deposit is exposed in a bouldery mass at *D*, adjacent to the sulfide body. Brown garnet and small fragments of marble on the dump of a caved adit at the south end of the exposure suggest that the magnetite body may be a replacement of a pod of marble, not exposed at the surface. The relationship is thought to be analogous to that at the Campbell deposit; that is, selective replacement of marble by the iron oxide molecule, and of greenstone by the sulfide molecule.

The length of the exposure is 50 feet measured along the contour and the boulders mantle the surface for 30 to 40 feet below the highest outcrops. Dip-needle traverses indicate that the ore in place is confined to the very small area of outcrop. Cavities caused by leaching of sulfides make up 5 to 7 percent of the magnetite boulder masses, suggesting that excessive amounts of sulfur may be present below the leached material.

As nearly as can be determined at the surface, the iron deposits on the Montana property are insignificant in size and add nothing to the reserves of the district. The occurrences are of special interest because they include, in close juxtaposition, red hematite on the pre-andesite erosion surface, massive sulfides grading into a cellular limonitic gossan at the present surface, and selective replacement of marble and greenstone by magnetite and sulfides, respectively.

### GRADE

The grade of the Montana ores is indicated by the following analyses:

*Analyses of Montana hematite and magnetite*

| | 1 | 2 | 3 |
|---|---|---|---|
| $SiO_2$ | 27.16 | 20.27 | 3.51 |
| $Al_2O_3$ | 2.46 | 1.20 | .31 |
| $Fe_2O_3$ | 70.40 | | |
| $TiO_2$ | .40 | .19 | .01 |
| $P_2O_5$ | .05 | | |
| P | | .044 | .031 |
| MnO | .06 | | |
| Mn | | .03 | .09 |
| Total | 100.53 | | |
| Total Fe | 49.20 | 53.67 | 66.95 |

1. Hematite sample collected by E. T. Hodge. ". . . 25 pounds cut across the 20-foot face of a shaft on the Montana claim." (Hodge, 1938, p. 42.)
2. Hematite sample collected by J. H. Mackin. Composite of 10-pound chip sample across 14 feet of ore in south face of caved shaft at *A*, and 10-pound chip sample of hematite and jasperoid material south of the shaft. The siliceous character of the surface ledges may be a weathering effect; if so, the sample may have an iron content somewhat lower than the average grade of the body. (See pl. 18.)
3. Magnetite sample by J. H. Mackin. 15 pounds of chips from 40-foot bouldery outcrop at *C*. Cavities formed by leaching of sulfides make up about 5 percent, by volume, of the material sampled.

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# INDEX