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PRE-BELTIAN GEOLOGY OF THE CHERRY CREEK AND RUBY MOUNTAINS AREAS, SOUTHWESTERN MONTANA

PART 1—GEOLOGY OF THE CHERRY CREEK AREA
by E. Wm. Heinrich and John C. Rabbitt

PART 2—GEOLOGY OF THE RUBY MOUNTAINS
by E. Wm. Heinrich

MONTANA BUREAU
of
MINES AND GEOLOGY

Butte, Montana

STATE OF MONTANA

BUREAU OF MINES AND GEOLOGY

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MONTANA SCHOOL OF MINES

BUTTE, MONTANA

1960

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PRE-BELTIAN GEOLOGY OF THE CHERRY CREEK AND RUBY MOUNTAINS AREAS, SOUTHWESTERN MONTANA

PART ONE

GEOLOGY OF THE CHERRY CREEK AREA GRAVELLY RANGE, MADISON COUNTY, MONTANA*

By

E. Wm. Heinrich and John C. Rabbitt**

INTRODUCTION

The Cherry Creek area is a north-south strip, 26 miles long, about a mile wide at its northern end, and about 7 miles wide at its southern end, which forms the foothills of the eastern slope of the Gravelly Range on the west side of the Madison Valley in south-central Madison County (See fig. 1). It is bounded on the north by Wigwam Creek and on the south by Elk River, a northern tributary of the West Fork of the Madison River. The pre-Beltian rocks are estimated to underlie an area of about 95 square miles. Of this area, only the northern end, a strip about 15 miles long, has been mapped in detail (pl. 1, in pocket).

The area is one of low relief, characterized by rounded hills flanking the higher parts of the range to the west, which is outlined by the prominent cliffs of Paleozoic sediments (pl. 3, A). From north to south the major drainages, which trend generally northeastward, are: Wigwam Creek, Morgan Gulch, Sunrise Gulch, Cherry Creek, Johnny Gulch, Ruby Creek, and Wall Creek. Of these only Ruby Creek flows in a pronounced canyon throughout its length.

The area was named after Cherry Creek, for it was here, along its northern side, that Peale (1896) established the type section of the Cherry Creek group. The area also was described briefly by Douglass (1905). Peale's work was reviewed by Van Hise and Leith (1909), by Keyes (1926), and by Tansley, Schafer, and Hart (1933). Sahinen (1939) made a reconnaissance of the Cherry Creek type section. Runner and Thomas (1928) published an abstract on the geology of the area. As part of his doctoral dissertation at Harvard University, Rabbitt mapped the area during 1940 and 1941 (Rabbitt, 1946) but was somewhat handicapped owing to a lack of base maps and aerial photographs. Heinrich examined the region in 1947 and 1948 and mapped it in 1949 (pl. 1); short visits were made in 1951, 1954, and 1956. Some of the marbles have been described by Heinrich (1947) and by Levinson (1949). The mineralogy of several anthophyllite rocks from the area have been described in detail by Rabbitt (1948). Nordstrom (1947) and Heinrich (1948B) have described the kyanite and sillimanite deposits. Stoll (1945, 1950) and Heinrich (1949A, 1949B) have published descriptions of the more important pegmatites. Manganese deposits of the area have been investigated by Pardee (1918), and the occurrence of hollandite in one of them has been noted by Frondel.† Perry (1948) has presented information on the talc deposits, and Jobin (1949) has reported on an occurrence of detrital minerals.

GENERAL GEOLOGY

The area is underlain chiefly by a folded complex of metamorphic rocks belonging to the Cherry Creek group, which westward pass unconformably beneath the Cambrian Flathead quartzite and younger Paleozoic formations. The southern-most part of the area mapped, south of Wall Creek is underlain by granite gneiss. On the east the pre-

*Contribution No. 231 from the Department of Mineralogy, The University of Michigan

**Dr. John C. Rabbitt, miner, student, and painstaking investigator of Montana geology and minerals, died suddenly June 10, 1957. He was one of the first geologists to recognize the need for and the value of a detailed study of the Precambrian of Montana. It was mainly because of his enthusiastic exponence of Montana geology that the senior writer, his ling-time friend, first came to Montana.

† Personal Communication

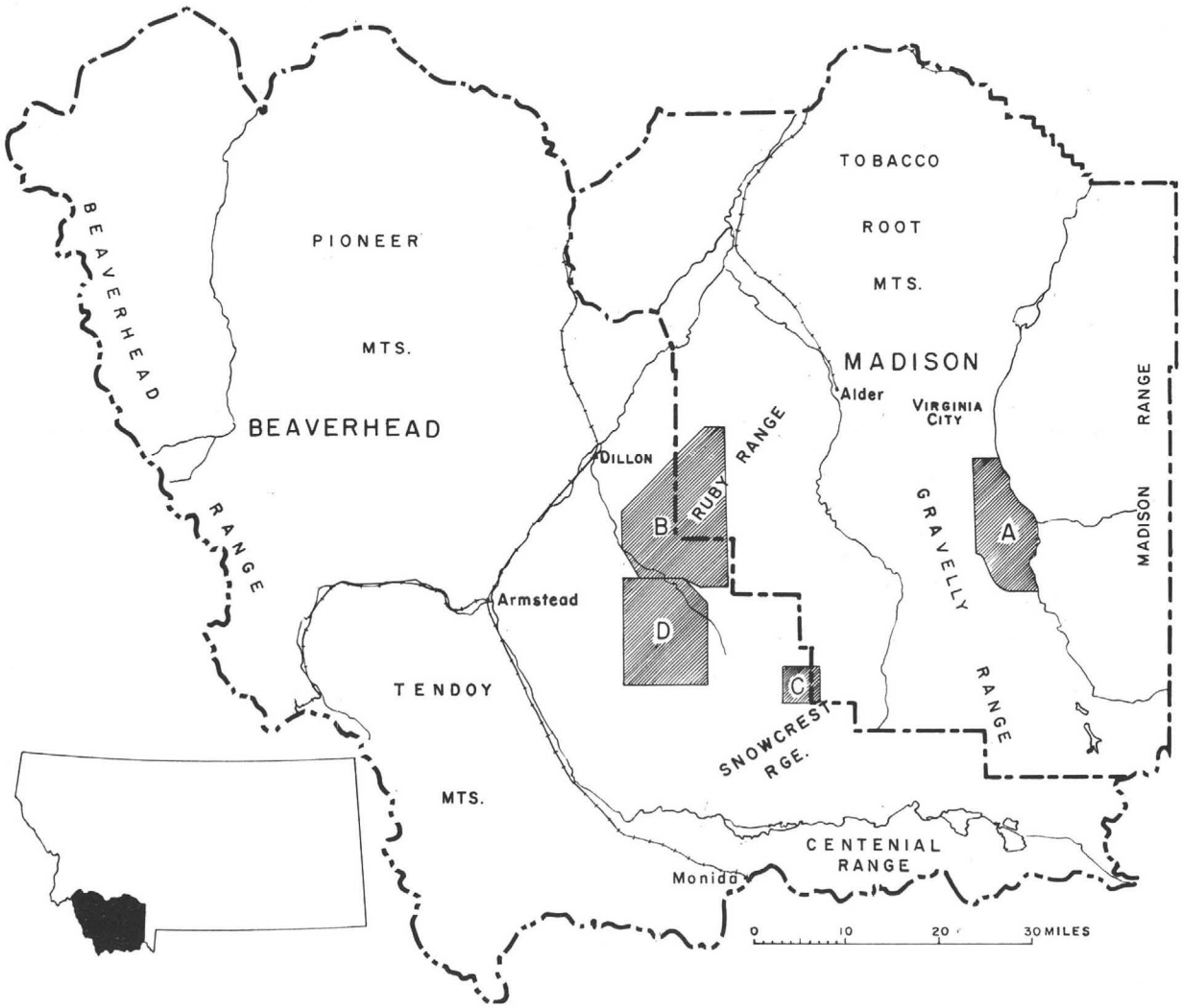


FIGURE 1.—Index map showing location of areas described. A, Chery Creek; B, Ruby Range; C, Snowcrest Range; D, Jake Creek

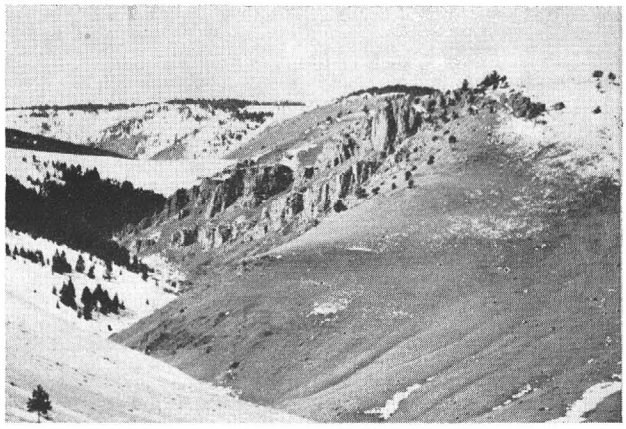
Beltian rocks are overlapped by a series of prominent river terraces of alluvium, out of which small knobs of metamorphic rocks protrude in a few places. Locally the pre-Beltian rocks are capped by remnants of lava flows (chiefly rhyolitic) and by thin sheets of travertine.

The Cherry Creek rocks were intruded by sills of granite, later metamorphosed to granite gneiss, and by sills and dikes of pegmatite, of which there are both foliated and non-foliated representatives. Quartz veins also are abundant, particularly south of Ruby Creek.

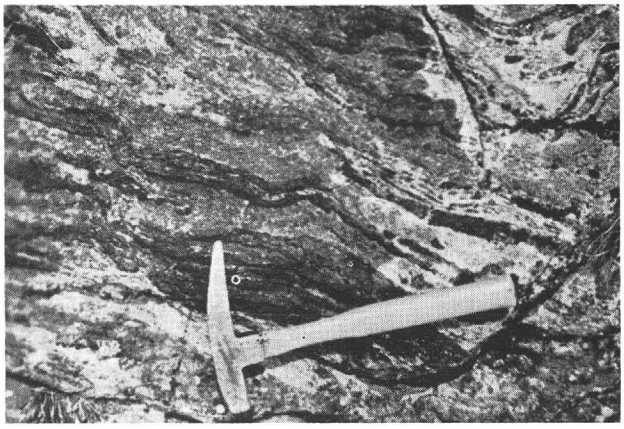
The Cherry Creek was defined by Peale (1896) as consisting of " . . . a series of marbles . . . and interlaminated mica schists, quartzites, and gneisses . . . not less than several thousand feet (thick)." A partial section as measured by Sahinen (1939, p. 10) is given as follows:

4. Pinkish-gray gneiss—"several thousand feet"
3. Chlorite schist and quartzite gneiss containing bands of amphibole schist.....560 feet
2. Light brown-weathering gray marble interbedded with thin beds of quartzite.....830 feet
1. Fine-grained greenish gray slaty mica schist .....1,000 feet

As can be seen by comparison with plate 1, the detailed rock sequence is much more complex and will differ considerably, depending upon the exact place of measurement, for there is a marked variation in petrology along the strike of some units at this locality. A layer of quartzite and an overlying thicker band of marble become thinner and pass northeastward into phyllite, and there are other similar graduations of a minor nature. These changes reflect original sedimentary differences, i.e., facies changes.



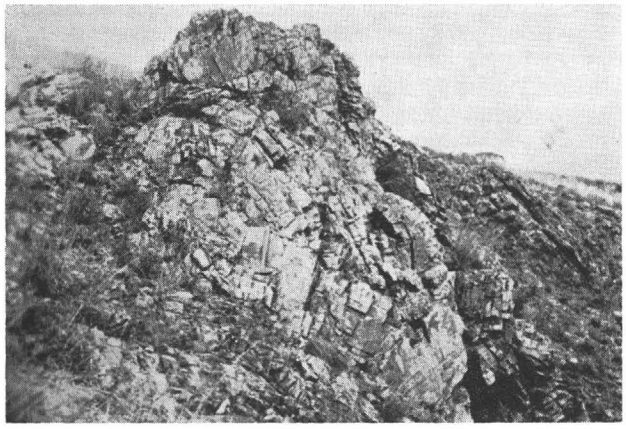
A. VIEW OF CHERRY CREEK AREA



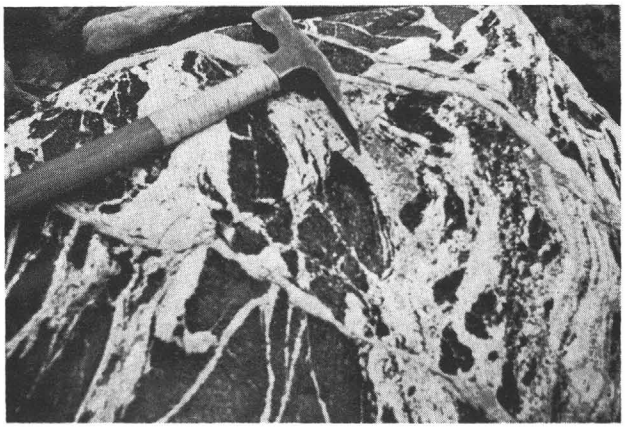
B. CONTORTED MARBLE

C. OUTCROP OF BLACK PHYLLITE

D. OUTCROP OF QUARTZ FELDSPAR GNEISS



E. RECRYSTALLIZED MARBLE



F. GNEISS INJECTED BY GRANITE

Another peculiarity of the type section is the close association of phyllite with such higher grade rocks as kyanite schist. In general the grade of metamorphism increases slightly northward. Between Wall and Ruby Creeks, shales have been metamorphosed chiefly to phyllites; along Cherry Creek phyllites, mica schists, and kyanite schists occur together; but north of Sunrise Gulch phyllites are totally absent, and sillimanite first appears about a mile north of Morgan Gulch. Although these phyllites commonly contain biotite (seen only under the microscope), they are nevertheless still very fine-grained rocks. Garnets also become much more abundant and coarser northward. Garnets appear first in phyllite near the emergence of Cherry Creek and are conspicuous from Morgan Gulch northward. Near Gulches 1, 2, and 3 (pl. 1) some rocks contain three- to six-inch porphyroblasts of this mineral.

STRUCTURE

The Cherry Creek layers have been deformed into a large complex fold whose axial plane, in the general vicinity of Sunrise Gulch, strikes N. 20°-40° E. The southern limb, exposed from Johnny Gulch to above Cherry Creek, dips in general to the southeast. The northern limb, south of Wigwam Creek, appears to be generally vertical. The eastern part of the fold is not exposed, being covered by the alluvial terrace gravels.

From the general attitude of the limbs the structure appears to be that of an asymmetrical anticline whose axis probably plunges north-northeast. However, minor folds in granite gneiss in the central part of sec. 29, T. 8 S., R. 1 W. plunges to the west, and in sec. 30 a syncline outlined by hornblende gneiss also plunges to the southwest at 35°.

The central part of this fold is occupied by a thick body of granitic and micaecous gneisses, whereas the flanks consist mainly of marbles, schists, and quartzites. In detail the major fold is exceedingly complex with numerous minor folds along the flanks, particularly on the northern limb. One such fold, a syncline plunging 45° WSW., occurs in the central part of sec. 5, T. 8 S., R. 1 W. and involves marble and kyanite schist layers. A syncline in marble extends through secs. 30 and 31, T. 7 S., R. 1 W. Other minor folds also occur nearby.

The foliation and former sedimentary layering are generally conformable; however in many of the marbles, particularly in the thinner layers, such as in the NW¼ sec. 21, T. 8 S., R. 1 W., the foliation is markedly contorted and is not parallel with the contacts between layers. Flow structures resulting from plastic deformation are most conspicuously developed in the marble bands. Phyllites, the more fissile schists, and the "iron formations" also display marked crumpling locally. Lineation, which is conspicuous in many of the rocks, in general is parallel with fold axes, and in layers that strike northeast and dip northerly, the lineation plunges most commonly to the northwest at moderate to steep angles. Where the foliation dips southerly, the lineation plunges southwestward at moderate angles. Locally small gash veins of quartz are parallel with the lineation in quartzite.

No major faults occur in the area, but small slips with minor displacement occur within several of the units.

Jointing is locally conspicuous in some of the more massive rocks, such as amphibole gneisses. In Gulch No. 1, two joint sets in actinolite gneiss form a rhombohedral pattern, with one set striking N. 5° E., the other N. 70° E.

DESCRIPTION OF ROCK TYPES

The rocks of the Cherry Creek group in this area are highly varied in petrology but in general may be grouped into the following major classes:

1. Marble, calc-schists, and lime-silicate gneisses
2. Quartzite and quartz schist
3. Phyllite
4. Mica schists
5. Kyanite schist and kyanite-staurolite schist
6. Sillimanite schist and gneiss
7. Magnetite schist and related rocks ("iron formation")
8. Amphibole gneiss, schist, and amphibolites
9. Quartz-feldspar gneiss, granitic gneiss, biotite, and injection gneiss

MARBLES AND RELATED ROCKS

Marbles form the thickest and most persistent layers in the area. The Black Point* dolomitic marble between Johnny Gulch and Cherry Creek (Rabbitt, 1946; Heinrich, 1947) is nearly 6,000 feet thick. South of this unit only a very few short lenses of marble occur in the group. Several marble layers ranging in thickness from a few feet to as much as 1,500 feet occur in the type sections on both sides of Cherry Creek. The northernmost marble band of this group becomes highly contorted to the northeast and has been carved into a conspicuous ridge, Sunrise Point. These marbles are again exposed north of Gulch B in the northern limb of the major fold, and at the area the Black Point marble also crops out again on this flank, and here it is about 7,900 feet thick.

The rocks mapped as marbles include not only the relatively pure carbonate marbles but also a few calc-schists and minor lime-silicate gneisses. The marbles usually weather to light-brown rounded outcrops. Some are thick layered; many have layers only a few inches thick, differing

* The name, Black Point, was first used in the field by E. S. Perry, and its usage was continued by Rabbitt (1946).

in grain size and color (pl. 3, B). Most of the marbles are dolomitic, with any minor calcite that may be present either in small interstitial grains, in secondary veinlets, or in thin and very fine-grained layers along the foliation planes. Most also contain as much as 15 percent of accessory constituents, chiefly quartz, phlogopite, talc, minor tremolite, albite, and secondary chalcedony, manganese oxides, and limonite. Grain size and fabric differ greatly. Many dolomitic marbles are an oriented mosaic of subhedral to euhedral rhombs. Others are anhedral, even-grained; in still others the grain size varies markedly. Much of the dolomite includes numerous minute specks, blebs, and veinlets of manganese oxide, locally so abundant that much of the carbonate appears "dirty" microscopically. In some varieties twinning is common; in others it is nearly absent. Wavy extinction may be marked. The quartz may be disseminated or in granular aggregates. Phlogopite, essentially colorless to light brown, commonly forms oriented scattered flakes.

Locally parts of the marble layers have been intensively replaced by fine-grained white quartz, by talc, and by manganese oxides (see section on Economic Geology). Runner and Thomas (1928) noted that some "quartzites" were merely silicified marbles. Vein-like masses of brown chert also are common.

Tremolite marbles of limited extent occur in a few places; a notable example is associated with the talc lens in sec. 5. T. 8 S., R. 1 W., where blades of the white amphibole, as long as four inches, form rosettes. Tremolite also occurs as rosettes and parallel aggregates in the marble of Sunrise Point, which also contains flaser and brecciated structures. Near the emergence of Gulch No. 1 from the Precambrian terrain, a carbonate gneiss transected by quartz veins contains diopside, actinolite, forsterite, clinozoisite, chlorite, and sphene.

Along the north side of Cherry Creek, in Gulch B as well as at several other localities, tremolite or actinolite marbles occur along contacts with hornblende gneiss. In these rocks the abundant green amphibole is relatively fine grained and occurs with carbonate, chlorite, quartz, and sphene.

In Gulch No. 1 both diopside and tremolite marbles form selvages along hornblende gneiss layers. The diopside marble contains abundant calcite and much phlogopite, scapolite, sphene, quartz, hematite, graphite, and pale-green actinolite which replaces the pyroxene. In several places actinolite also has been formed in marble along contacts with pegmatite dikes and sills.

Calc-schists, which occur in a few widely distributed localities, usually contain biotite, hornblende, quartz, and calcite as essential minerals. Others also contain garnet or plagioclase poikiloblasts as well as different combinations of accessory actinolite, diopside, epidote, sphene, muscovite, chlorite, and magnetite. One variety from Gulch No. 4 contains a peculiar garnet-microcline symplectite.

QUARTZITE AND QUARTZ SCHIST

Quartzites, which are in general neither abundant nor thick, are best developed in the section along Cherry Creek, where two principal bands occur. One of these is as thick as 550 feet. In the same section there is the only major occurrence of quartz schist in the area. Quarztites are represented to only a very minor extent on the northern limb of the fold, a not surprising absence in view of the marked facies graduations in some of the other meta-clastic rocks within much shorter distances.

The quartzites are usually white to gray; many are fine grained, porcellanoid; others are coarser and glassy. Bright-green quartzites occur in short lenses in the vicinity of the Ruby Creek mine and also in the southwest corner of sec. 2, T. 9 S., R. 1 W., where some parts of the outcrops are strikingly coated by "desert varnish", a thin coating of manganese and iron oxides. The pronounced green color results from the presence of clusters and sinous streaks of minute flakes of green muscovite. Most of the flakes lie along quartz grain boundaries, but a few are enclosed in quartz grains. Sphenes, zircon, and magnetite are rare accessories.

Numerous thin lenses of quartzite, few of which are thicker than six feet, are interlayered with the thick series of phyllites north of Wall Creek. Some of these quartzites are stained by limonite, owing to the presence of thin fine-grained magnetite-quartz bands in thicker coarse quartzite layers. Others of these lenses contain considerable muscovite or dark-green or brown biotite.

The quartz schist along Cherry Creek is a highly schistose quartz-rich rock with sericite films along foliation planes.

PHYLLITE

Phyllite, a uniformly thin layered greenish-gray to black very fine-grained rock (pl. 3, C) is the main rock type between Johnny Gulch and Wall Creek, forming a belt nearly three miles thick, with only thin interbedded magnetite schist, hornblende gneiss and quartzite. Several much thinner bands crop out on both sides of Cherry Creek but none occur north of this drainage.

Intense crumplings on both large and very minute scales is typical. Under the microscope the rock can be seen to be very minutely banded with muscovite layers, quartz layers, biotite layers, and biotite-magnetite layers alternating. At the Tracy Ranch on Cherry Creek a phyllite layer 1 by 50 feet in plan, contains garnet porphyroblasts as much as an inch across wherever the bank lies in contact with a lens of hornblende gneiss. This

rock contains very fine-grained biotite, muscovite, quartz, abundant minute crystals of olive-brown tourmaline, graphite, and garnet porphyroblasts; the latter partly altered to chlorite.

MICA SCHISTS

Mica schists are not common south of Sunrise Gulch, although kyanitic micaceous schists occur in the Cherry Creek section. The best development of mica schists occurs in the complex sequence between Gulch A and Gulch No. 1. Here too, many of the layers may change to kyanite-bearing locally. The rocks are generally fine-grained and dark, containing biotite (usually without muscovite), quartz, some oligoclase, tourmaline, and magnetite. In Gulch No. 1 local phases of these layers crop out as coarse silvery muscovite schists wherever they have been injected by numerous pegmatite stringers.

KYANITE SCHIST AND RELATED ROCKS

Kyanite schists are widely distributed from Cherry Creek northward. In the Cherry Creek section alone, there are three major occurrences; another is near the head of Sunrise Gulch in sec. 19, T. 8 S., R. 1 W.; and there are some dozen occurrences in the area between Gulch A and Gulch No. 3 (Nordstrom, 1947; Heinrich 1948B). Kyanitic rocks are chiefly of the following types:

1. Kyanite schist — quartz, biotite, kyanite, ± garnet
2. Kyanite gneiss — quartz, feldspar, biotite, kyanite, ± garnet
3. Kyanite-staurolite gneiss—quartz, feldspar, biotite, kyanite, staurolite
4. Kyanite-bearing pegmatites
5. Kyanite or kyanite-staurolite quartz veins

The mineral composition and texture of the kyanitic schists and gneisses change markedly within short distances, and in many places these rocks grade along the strike into biotite schists or gneisses, biotite-garnet schists or gneisses, or even, as in the Cherry Creek section, into phyllites. In many places the appearance of kyanite or staurolite in a micaceous schist layer is accompanied by a spectacular increase in the amount of the intruded pegmatitic material or in the number of quartz veins. In the area near the junction of Gulches No. 1 and 2, much of the biotitic gneiss contains little or no kyanite except in aureoles 10 to 25 feet wide, surrounding numerous pegmatites which themselves may contain scattered kyanite crystals. At the head of Gulch B, increases in both the amount and size of the kyanite can be correlated with increasing numbers of pegmatites (fig. 2). Weathering of these rocks generally produces very poor outcrops, but residual blue kyanite blades or cobbles are concentrated at the surface.

The kyanite schists and gneisses, which intergrade, contain a wide variety of accessories including staurolite, sillimanite, andalusite (rare), muscovite, tourmaline, zircon, rutile, magnetite, graphite, and apatite. Alteration minerals are chlorite, sericite, and hematite. The kyanite occurs as blue to gray blades usually an inch or less in length. Much of it is subhedral and may be somewhat poikiloblastic, including quartz grains. Garnet, if present, also typically forms large poikiloblasts containing quartz, staurolite, biotite, muscovite, magnetite, and rutile inclusions, which may show greater degree of orientation and abundance in the garnet cores than in the rims. The feldspar is mainly sodic plagioclase (Ab_{68} - Ab_{74}), but some orthoclase also may be present. Muscovite usually is developed at the expense of biotite, some of which shows inclusion zoning. Tourmaline, locally abundant, appears as light olive-green to dark olive-green stubby crystals, generally not parallel with the foliation. Rutile, almost invariably present, varies in shape from rounded grains to euhedral crystals and knee-shaped twins. Graphite, which is abundant in some sections, lies as tabular crystals along grain contacts between quartz, garnet and kyanite. Sharply-defined graphite veinlets also transect garnet and quartz in some examples. Modes of the three rocks of this group are given in Table 1.

TABLE 1.—Modes of kyanite and kyanite-staurolite rocks, Cherry Creek area.

	M-13*	M-9*	M-10*
Quartz	41%	63%	44%
Plagioclase	18	—	—
Biotite	16	27	32
Kyanite	10	3	6
Garnet	6	2	8
Staurolite	4	—	9
Muscovite	—	2	—
Tourmaline	—	2	—
Graphite	1	1	1
Sillimanite	1	—	—
Magnetite	—	tr.	—
Rutile	3	tr.	tr.
	100%	100%	100%

*M-13, Gulch No. 2 *M-9, Gulch A *M-10, Forks of Cherry Creek; also minor pyrite and chalcopyrite

Sillimanite, which was not found in significant amounts south of Gulch A, becomes locally conspicuous in kyanite rocks. The sillimanite fibers replace biotite and garnet, but also vein, corrode, and replace kyanite. Many sillimanite-bearing kyanite rocks show slight cataclastic effects. In Gulch No. 2, near its junction with Gulch No. 1, an unusual sillimanite-garnet rock is conspicuous. The very abundant red garnets, which average a quarter of an inch in diameter and reach a diameter of four inches, are set in a matrix of fibrous gray sillimanite which "wraps around" the porphyroblasts. Quartz, minor kyanite, graphite, magnetite, and rutile are microscopically visible. Nearby in the same gulch, several pods 2 by 3 by 6 inches, of quartz, oligoclase, and fibrous sillimanite occur in biotite-garnet schist.

Staurolite, which is present only as an accessory in the Gulch A-Gulch No. 3 area, is very abundant along the north side of Cherry Creek. Locally it forms spectacular rocks in which the individual prisms are as much as 2½ inches long and ¾ inch wide. In the same rock there appear kyanite blades as long as half an inch. The staurolite poikiloblasts, which may be twinned, enclose garnet, quartz, and biotite and are veined by fine-grained quartz. The fine-grained matrix consists of quartz, oligoclase with included blebs of quartz, biotite, and kyanite. Accessories are muscovite, chlorite, graphite, magnetite, rutile, and garnet.

Kyanitic pegmatites are especially abundant in sec. 6, T. 8 S., R. 1 W. The kyanite, in bright-blue blades commonly as long as six inches, occurs both in quartz cores or in feldspathic wall zones, either disseminated or as border selvages (Heinrich, 1948B). Sillimanite also may be present, usually as bundles of gray fibers replacing kyanite, but in one locality a two-inch vein of quartz and cross-fiber sillimanite bisects a pegmatite (Heinrich, 1948B, p. 8, fig. 3). Kyanite also is replaced by silvery flakes of muscovite and by olive-yellow cryptocrystalline sericite. Except for the kyanite and sillimanite and a few flakes of graphite, the pegmatites are structurally and mineralogically similar to other pegmatites of the area, containing quartz, microcline, oligoclase, biotite, muscovite, schorl, apatite, and garnet. Most are zoned, and they are neither foliated nor cataclastically disturbed.

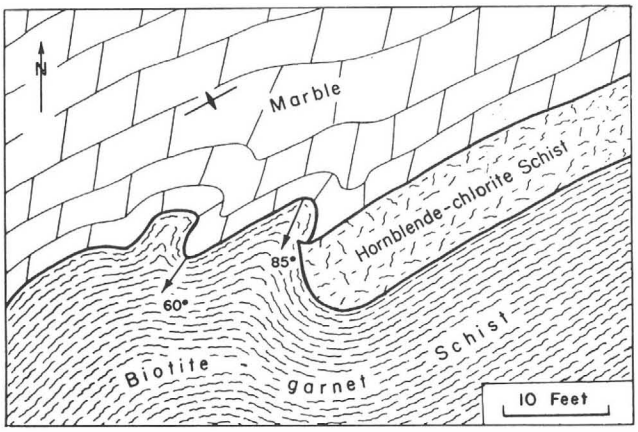


FIGURE 3.—Sketch showing termination of tabular hornblende-chlorite schist representing a metamorphosed sill, probably originaly diabasic in composition. Gulch No. 1, Cherry Creek area, Montana.

Along the north side of Cherry Creek, quartz veins containing kyanite or kyanite and staurolite locally are abundant, especially in rock layers that also contain these minerals. From one such vein, a mass of interlaced kyanite blades, 2½ feet in diameter, was collected. Minor constituents are muscovite and feldspar. Veins with comb-structure kyanite, eight inches long, also were noted near the head of Sunrise Gulch.

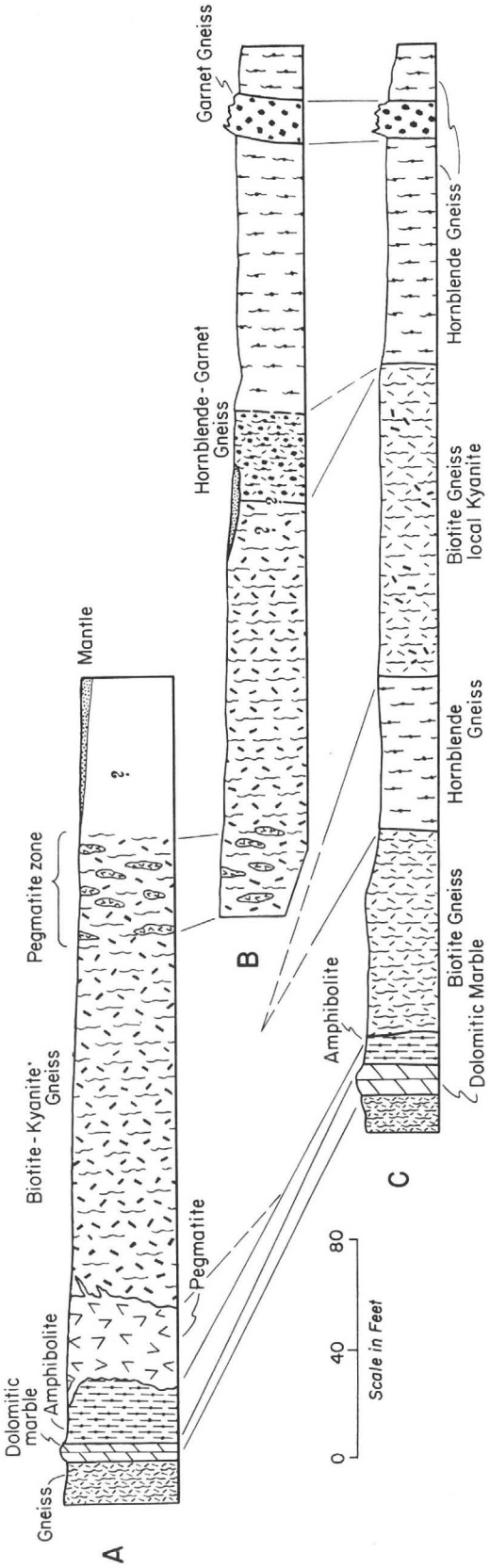


FIGURE 2.—Representative sections of Cherry Creek rocks showing occurrence of kyanite gneisses injected by pegmatites. Also shows the difficulty in correlating such units, even within short distances; sections A and C are about 1,800 feet apart. Near the head of Gulch B, Cherry Creek area, Montana.

MAGNETITE SCHIST AND RELATED ROCKS

Magnetite schists and other similar magnetite-rich rocks ("iron formation") form very thin layers at the head of Gulch B, in the upper part of Gulch A, above Johnny Gulch, and northeast of the Ruby Creek mine, where the longest and the thickest bands occur. Here some of the iron schist bands are as wide as 125 feet. Magnetite schists occur principally in phyllites, to a lesser extent in banded hornblende-quartz schist, and as very thin uncommon seams in marble. In outcrop the rocks are dense, minutely banded in ¼- to ½-inch quartzose versus iron-rich bands, which are usually contorted. The rocks are strongly magnetic. Microscopically, in the commonest variety, coarser-grained quartz layers can be seen in alternation with finer-grained magnetite-quartz layers. In some, grunerite is an essential constituent, occurring in the coarse quartz bands or along the contact between the two different layers. Much of the grunerite is altered to a fine-grained chlorite-hematite mixture. In others the amphibole contains numerous central quartz inclusions. Blades and rosettes of hematite also may be present.

Apatite-rich layers occur in a few specimens; the phosphate usually forms needles in quartz. In polished section the subhedral to euhedral magnetite shows marked peripheral alteration to hematite; in some cases entire bands are so transformed. Secondary veinlets of hematite cut across the layering. There also is considerable alteration of the hematite to goethite and much redistribution of the latter through the rock, along with abundant chalcedony.

AMPHIBOLE GNEISS AND RELATED ROCKS

Dark-colored amphibole gneisses are much less common in the Cherry Creek area than some other pre-Beltian areas, as for example, in the Ruby Mountains. Thick bands occur along Johnny Gulch, Cherry Creek, the head of Sunrise Gulch, Gulch A, and Gulch No. 2. Thinner layers also were noted in Gulch No. 4, and interlayered with phyllite north of Wall Creek. Outcrops differ considerably in appearance; felted rock varieties are generally tough, forming resistant outcrops. Some of the lenses are discontinuous or end in abrupt noses (fig. 3).

Four amphiboles occur in the mafic gneisses of the area. In order of abundance they are hornblende, anthophyllite, actinolite and cummingtonite.

The hornblende rocks include:

1. Hornblende gneiss—hornblende, intermediate plagioclase, quartz, accessory apatite, magnetite, rutile, chlorite.
2. Garnetiferous hornblende gneiss — hornblende, plagioclase, garnet, quartz, accessory sphene.
3. Hornblende schist—hornblende, quartz, and accessory biotite, plagioclase.
4. Garnetiferous hornblende schist — hornblende, quartz, garnet, and accessory magnetite, plagioclase, cummingtonite, rutile.
5. Hornblende amphibolite—hornblende, plagioclase, and accessory sphene, quartz, magnetite, biotite, chlorite.
6. Garnetiferous hornblende amphibolite — hornblende, plagioclase, garnet.

Type 1 is the most abundant. Both banded and non-banded varieties occur. Usually the hornblende is subhedral, well oriented; some is porphyroblastic in a finer-grained matrix also containing hornblende. Ragged hornblende poikiloblasts characterize some of the gneisses. Some amphibolites show a decussate fabric and little foliation. The hornblende commonly is green and may show darker green margins. The garnet typically forms large porphyroblasts, either euhedral or of ragged outline; many include quartz and a few enclose magnetite.

One unusual hornblende schist on Cherry Creek is characterized by clusters and semi-radial sheaves of hornblende needles flattened along the separation planes. A few hornblende gneisses also contain abundant epidote locally.

At the head of Gulch B an eight-foot band of garnetiferous hornblende gneiss occurs in marble. The marginal part of the gneiss band contains pale olive-green hornblende quartz, labradorite, sphene, magnetite, apatite, secondary biotite, and pennine replacing amphibole, and much calcite and scapolite. Other hornblende gneisses, where in contact with marbles, may contain abundant coarse garnet, actinolite, or anthophyllite. One such hybrid rock in Gulch No. 1 contains hornblende-quartz layers, epidote-graphite layers, actinolite, diopside, phlogopite, garnet, and sphene. This grades into an actinolite schist containing quartz and rutile. Another, south of Morgan Gulch, is an actinolite-calcite rock also containing anthophyllite, forsterite, chlorite, and magnetite.

Anthophyllite rocks are widely distributed but commonly form only local phases in hornblende gneiss and amphibolite. One of these occurrences is in Gulch No. 1, where a pod of coarse brown anthophyllite forms along a hornblende gneiss-marble contact (fig. 4). Another is in Gulch No. 4 where anthophyllite-garnet rock forms a part of a thin garnetiferous amphibolite band between granite gneiss and lime-silicate gneiss. This is Rabbitt's analyzed anthophyllite specimen CC352C (Table 2). Specimen CC206F comes from the north side of Gulch No. 2 in sec. 6, T. 8 S., R. 1 W., where pegmatites with rose qartz veins cut a thick amphibolite layer. Analyzed specimen CC298 comes from a thin hornblende gneiss within granite

gneiss near the head of Sunrise Gulch, in the southwest part of sec. 20, T. 8 S., R. 1 W. Specimen CC200A is from a group of boulders of very coarse randomly oriented gray anthophyllite rock found in the river terrace gravels at McAtee's Bridge. This last anthophyllite, which is in blades as much as several inches long, is intergrown with chlorite and is likely of replacement origin in an altered peridotite, judging from its low iron and alumina and high magnesia contents and also from its coarse unoriented texture. Significantly it is highest in both chromium and nickel. It may well be derived from a Precambrian area north of the Cherry Creek area.

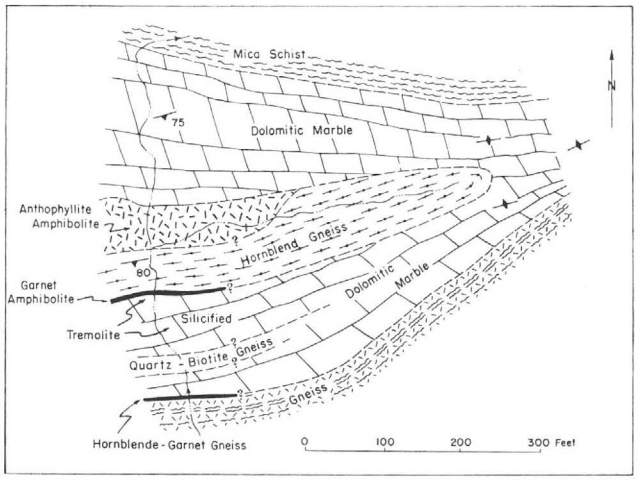


FIGURE 4.—Sketch of anthophillite occurrence. The horneblende gneiss represents a metadionite intruded into limestone with resulting endomorphic and exomorphic effects prior to general regional metamorphism. Gulch. No. 1, Cherry Creek area, Montana.

Most of the anthophyllite rocks are characterized by a dark-brown to a golden-brown color Some are schistose; in others the blades are unoriented. Microscopically some show a well-oriented arrangement of anthophyllite blades; others have a felted texture. Mineralogically they fall into the types:

1. Anthophyllite schist — anthophyllite, quartz with accessory plagioclase, magnetite, apatite, tremolite, rutile, chlorite, and talc.
2. Garnetiferous anthophyllite schist — anthophyllite, quartz, garnet, accessory rutile, chlorite.
3. Anthophyllite gneiss—anthophyllite, quartz, plagioclase (An_{40}), accessory rutile.
4. Garnetiferous anthophyllite gneiss — anthophyllite, quartz, plagioclase (An_{40}), garnet, accessory phlogopite, cummingtonite, staurolite, rutile, magnetite, chlorite.
5. Garnetiferous anthophyllite amphibolite — anthophyllite, plagoclase, garnet, accessory rutile, magnetite, chlorite, talc.
6. Anthophyllite - actinolite rocks. Scattered slender laths of euhedral anthophyllite in a finer-grained decussate actinolite matrix. Found on the north side of Cherry Creek and in Gulch No. 4. Apatite, rutile, and phlogopite are accessories. The Cherry Creek rock, although mapped as part of the hornblende gneisses, is apparently an altered peridotite.

TABLE 2.—Composition of anthophyllites from Cherry Creek area (Rabbitt, 1948, p. 210, 288, 291).

	1 (CC206F)	8 (CC298)	17 (CC352C)	29 (CC200A)
SiO_2	42.80%	45.41%	50.36%	57.02%
TiO_2	.49	.44	.43	—
Al_2O_3	17.78	15.84	8.06	1.40
Fe_2O_3	1.03	2.94	2.18	—
FeO	18.32	15.32	18.36	8.71
MnO	.14	.07	—	.09
MgO	15.54	17.60	17.57	28.81
CaO	—	.14	.74	1.48
Na_2O	.03	—	—	—
F	.31	—	—	—
H_2O+	1.94	1.84	1.69	1.59
Ag	.004%	.002%	.003%	.002%
Co	.003	.007	.008	.007
Cr	—	.03	.002	.2
Cu	.004	.005	.02	.008
Li	.03	.03	.04	.005
Ni	.002	.01	.006	.1
Sn	—	—	—	.002
V	.001	.04	.05	.01
Zr	—	.001	.001	.002

Optical properties (sodium light) of the samples listed in table 2 are:

1. (CC206F), $a = 1.6566$, pale tan; $B = 1.6670$, pale tan; $r = 1.6781$, tan; (+); $2V = 89°$.
8. (CC298), $a = 1.6553$, pale tan; $B = 1.6630$, pale tan; $r = 1.6718$, tan; (+); $2V = 89°$.
17. (CC352C), $a = 1.6540$, pale tan; $B = 1.6595$, pale tan; $r = 1.6671$, tan; (+); $2V = 81°$.
29. (CC200A), $a = 1.6180$, pale tan; $B = 1.6270$, colorless; $r = 1.6354$, colorless; (—); $2V = 88°$.

In nearly all of these rocks anthophyllite shows a strong tendency toward euhedralism. Rutile is an almost invariable associate.

Cummingtonite-rich rocks are uncommon, but the mineral occurs with anthophyllite and hornblende in a few localities. Rabbitt (1948) has had one cummingtonite analyzed, from the same locality and rock as anthophyllite CC352C (Table 3). Other minerals in these rocks are garnet, quartz and plagioclase. Cummingtonite may replace anthophyllite; in one variety hornblende forms rims around cummingtonite.

TABLE 3.—Composition of cummingtonite from Gulch No. 4, Cherry Creek area (Rabbitt, 1948, pp. 285, 288).

SiO_2	50.32%	Ag	.003%
TiO_2	—	Co	.003
Al_2O_3	.86	Cr	.005
Fe_2O_3	1.75	Cu	.01
FeO	35.36	Li	.002
MnO	.02	Mo	.001
MgO	8.61	Ni	.01
CaO	.88	Pb	.001
Na_2O	.13	Sn	.002
K_2O	—	V	.002
H_2O	1.89	Zr	.005
F	—		

QUARTZ-FELDSPAR GNEISS AND RELATED ROCKS

Under the label granite gneiss are grouped on the map (Pl. 1) a number of gneissic rocks including:

1. Light-colored quartz-feldspar gneiss
2. Red granite gneiss, faintly foliated
3. Gray fine-grained biotite gneiss
4. Banded biotite gneiss
5. Injection gneiss
6. Coarse - grained crumpled garnet - biotite gneiss

The commonest type is light colored, thinly layered (pl. 3, D), containing quartz, microcline, plagioclase, and biotite. A few types contain subordinate garnet; others have hornblende in place of biotite. In most, microcline is greatly in excess of plagioclase, although in a few places microcline is subordinate. Rarely orthoclase is present in place of microcline. Most of the plagioclase is oligoclase and shows no zoning. The biotite normally is brown, exceptionally green. Accessories include muscovite, tourmaline, augite, epidote, apatite, sphene, rutile, zircon, magnetite, altered allanite (?), altered cordierite (?), chlorite, and secondary serpentine. The quartz may be granular or in elongated spindles. Biotite is either disseminated or aligned in thin layers. Some microcline forms porphyroblasts. Micropegmatite was noted in a few specimens. The estimated percentage composition of this type is quartz 35, microcline 30, plagioclase 20, biotite 10, accessories 5.

The red granite gneiss, which is subordinate, resembles the Dillon granite gneiss of the Ruby Mountains and elsewhere (Heinrich, 1953), and may perhaps be correlated with it. It intrudes the other strongly foliated gneisses as well as the schists, marbles, and quartzite locally.

A peculiar honrblende granite occurs along the margin of the gneiss body at the northern end of the area, just south of Wigwam Creek. It contains a deep greenish-blue alkali amphibole, perhaps hastingsite, as well as quartz, albite, microcline, abundant altered zircon, rare rutile, and epidote.

The major bodies of gneiss occur: (1) in the core of the major fold from Gulch A south to the north wall of Cherry Creek, and (2) south of Wall Creek at least to English George Creek. This latter area was mapped by Peale (1896) as Archean, and Perry (1948, p. 7) regarded these rocks as belonging to the Pony group. The contact between these gneisses and the phyllite is imperfectly exposed, and the exact relations between these two units are not known. That this contact swings sharply northeastward north of Wall Creek can be determined from the presence of the isolated granite knobs in secs. 12 and 13, T. 9 S., R. 1 W.

The gneiss body in the central part of the major fold is in general conformable with the surrounding marbles, and other rocks. Unless the Cherry Creek section is overturned, these gneisses lie at the base of the section and form the oldest unit. The gneiss-marble contact above Cherry Creek is rather irregular in detail. On the north limb of the fold the gneiss-marble and gneiss-hornblende contacts are much disturbed by local folding, but it is possible that an unconformity exists between the gneiss and the meta-sedimentary units of the outer parts of the fold. If this is the case, the gneissic core may be pre-Cherry Creek in age.

PEGMATITES AND QUARTZ VEINS

Pegmatites of the area have been described by Stoll (1945, 1950) and by Heinrich (1949A, 1949B). Both zoned and undifferentiated pegmatites occur in nearly all of the rock units. The zoned types, usually crosscutting, contain cores of quartz, rarely rose quartz, with marginal microcline and tourmaline crystals. In thinner dikes comb-structure mica or tourmaline occur. Other constituents are oligoclase, muscovite, biotite, garnet, and apatite. The kyanite- and sillimanite-bearing pegmatites have already been described. A few of the apatite crystals are shell-like in structure, with cores of fine-grained quartz. Few of the pegmatites are metamorphosed, except that several show a slight mortar structure along grain contacts.

Thick quartz veins are conspicuous northwest of the Tracy Ranch on Cherry Creek and particularly abundant in the phyllites on both sides of Ruby Creek.

DIABASE DIKES

Several thin diabase dikes occur in the southern part and south of the area mapped, in the pre-Cherry Creek gneiss area. One, which strikes N. 75° E. and is 40 feet thick, crops out between Hyde and Nickerson Creeks, about half a mile northwest of the Wall Creek Ranger Station. The diabases are unmetamorphosed and of post Cherry Creek age.

PRE-BELTIAN GEOLOGIC HISTORY

The pre-Beltian geologic history of the Cherry Creek area may be summarized as follows:

1. Marine sedimentation, with deposition of
   (a) A series of impure clastic, dominantly quartzose beds, at least 3,500 feet thick.
   (b) A sequence of rapidly alternating shales and pure limestones with minor pure sandstone and impure limestone, about 5,000 feet thick
   (c) Limestone, about 7,500 feet thick
   (d) Shale and interlayered iron formation with minor quartzite about 5,500 feet thick
   (e) Shale, perhaps as much as 10,000 feet thick

Thus the total minimum thickness of the Cherry Creek group in its type area is estimated to be about 30,000 feet. The nature and sequence of the parent sediments indicate that they were laid down as continental shelf deposits in a relatively stable tectonic framework. At first the depositional change was from impure sandy clastics to clayey and calcareous material to pure limestones, probably reflecting a generally uninterrupted period of erosion and reduction of the adjacent source land mass. Possibly the reappearance of the upper thick shale unit (e) marked a renewed, gentle but continuing uplift of the source area. It is possible, of course, that the units were not all deposited as part of a single depositional sequence. However, any unconformities that might have been present must have been erosional unconformities and, if present, must have been obliterated during metamorphism.

The change along the strike of some of the units on the flanks of Cherry Creek from limestone (marble) to shale (phyllite) from west to east indicates that the source area for the sediments probably lay to the east.

2. Extensive dolomitization accomplished and perhaps followed consolidation of the limestones.

3. Intrusion of diabasic and gabbroic sills with some attendant contact metamorphism of the wall rocks. Some sills were several hundred feet thick.

4. Regional metamorphism and folding. Transformation of quartz-feldspar-clay sediments to quartzose gneisses, of sandstones to quartzites, of shales to phyllites and micaceous schists, of limestones to marbles, of hematite-chalcedony sediments to magnetite-grunerite-quartz rocks, and of diabases to amphibolites. The intensity of the metamorphism was greatest at the northern end of the area (staurolite-kyanite subfacies of the amphibolite facies), decreasing slightly southward.

Regional metamorphism of some of the contact metamorphic rocks previously produced along diabase-limestone contacts resulted in the formation of anthophyllite rocks, garnetiferous amphibolites, and tremolite and actinolite schists.

5. Intrusion of granite, followed by the intrusion of bodies of pegmatite. The granite emplacement appears to have been largely discordant, clearly transecting the main folded structures and locally disrupting some metamorphic layers completely. Migmatite formation was minor, and contact effects were minimal. Around many of the pegmatites, however, aureoles of recrystallization were developed.

6. Formation of quartz veins, largely barren of other minerals.

7. Intrusion of diabase dikes.

8. Hydrothermal mineralization, generally of low-intensity character to form manganese vein and replacement deposits, talc replacement deposits, and minor copper deposits.

ECONOMIC GEOLOGY

TALC

The only mineral that has been produced commercially from the area is talc. Relatively large bodies of talc occur at two places: 1) the Johnny Gulch (Yellowstone) talc mine is the south-central part of sec. 4, T. 9 S., R. 1 W., and 2) in the NE¼ SE¼ sec. 5, T. 8 S., R. 1 W. (pl. 1). Several other very much smaller occurrences also were noted. The talc, which has been formed by the replacement of marble, occurs in lenses, generally elongated parallel with the metamorphic foliation. The deposit in Johnny Gulch (Perry, 1948) consists of an aggregation of lenses, the larger ones of which are 30 to 50 feet wide and as much as 150 feet long. Most of the talc is crypotcrystalline; some is in concretionary masses of radiating plates within massive talc; a small amount shows an indistinct relict banding. The color varies from white or gray to generally pale green or blue. One subordinate variety is distinguished by intergrown dendrites of manganese oxides.

The mineralized area, elongated northeast-southwest, is about 2,000 feet long and 800 feet across. About half a dozen major lenses have been worked chiefly by means of open cuts. The deposit was of some importance during World War II because of its yield of the strategic material "block talc" or "lava talc". This is a pure cryptocrystalline variety of talc, structureless in the mass, whose cohesiveness is such that from it shaped bodies can be machined. In addition to yielding over 100 tons of block talc, ceramic and cosmetic grade talc have also been produced. The deposit and its early history have been described in some detail by Perry (1948). In 1951 the deposit was taken over by Sierra Talc and Clay Company of Los Angeles.

The second, much smaller deposit, which has been prospected, is on a low hill overlooking the Madison Valley, just north of Gulch B, at the

north end of a bed of travertine that caps the truncated Cherry Creek beds (pl. 1). The deposit is apparently a small lens of impure talc, at the most not more than several tens of feet long associated with a body of coarse tremolite formed in marble.

MANGANESE

Replacement masses of earthy, vuggy manganese minerals in marble are widely distributed in the area, especially north of Gulch A and on the northwest side of Black Point. The main minerals are manganite, psilomelane, and wad, but Frondel* also has identified hollandite. Dr. M. Fleischer,** who analysed the hollandite-bearing material, states that its composition is about half way between hollandite and cryptomelane, indicating that this type of ore is a mixture of hydrated Mn^3-Mn^4 oxides with barium, potassium, and sodium. Associated with the manganese oxide minerals are calcite in veins and crusts, quartz, and limonite. Around some of the deposits the marble has been extensively recrystallized, over areas as large as 20 by 30 feet, to rhombs of carbonate as much as one foot on edge (pl. 3, E). Pardee (1918) regarded the manganese as being of supergene origin and probably Tertiary age, but this seems unlikely because of the intensity of the recrystallized wall rocks. Moreover, manganese is absent in the overlaying Paleozoic limestones, and very likely the deposits are of Precambrian age. Some bands of marble are so completely impregnated by microscopic manganese minerals, secondary carbonates, chalcedony, and iron oxide minerals that they have been converted to chocolate-brown crumbly porous aggregates.

The deposits fall mainly into two groups: 1) those in the northern part of the area in Gulch No. 1 and Gulch No. 4, and 2) those in the central part of the area on the northern side of the Black Point dolomite. Those of the former are principally irregular replacement deposits, whereas the latter are more commonly tabular and vein-like in structure.

Spectroscopic analyses of the impure ores show the following:

Manganese	0.5% - 50%
Barium	tr. - 1%
Strontium	tr. - 1%
Bismuth, Lithium, Molybdenum, Nickel, Tungsten, Rubidium	0.00001 - 0.001%

IRON

Iron deposits occur in two parts of the area: 1) in secs. 3, 9, 10, 16, and 17 (last two unsurveyed), T. 9 S., R. 1 W., between Johnny Gulch and Ruby Creek and 2) in secs. 5 and 6, T. 8 S., R. 1 W., chiefly in Gulches B and A (pl. 1). All of the deposits are in the "iron formation", a characteristic metamorphic unit of the Cherry Creek group. In the Cherry Creek area the "iron formation" consists chiefly of finely banded magnetite-quartz rocks in which bands rich in relatively coarse-grained quartz alternate with somewhat finer-grained magnetite-quartz layers. Grunerite is present in some specimens, and apatite is locally abundant. Supergene alteration has resulted in the formation of hematite, limonite, and chalcedony.

The deposits in the northern part of the area (Guches B and A) are of very minor significance for here the layers are thin and discontinuous. However, between Ruby Creek and Johnny Gulch some of the bands are over 100 feet thick, and the zone contains at least five major "iron formation" bands over a width of about ¾ mile. The most persistent band, the central, can be traced northeast for slightly over two miles. It is near the southwestern end of this band that the Ruby Creek mine was developed (pl. 1). The deposits were explored during summer 1958 by the U.S. Steel Corporation.

GOLD

The Ruby Creek mine, although located on the main band of the "iron formation", was developed by the Montana Coal and Iron Company of Red Lodge, Montana, in what was hoped to be a gold deposit. The "iron formation" contains numerous veins of massive white ("bull") quartz, most of which are parallel with the foliation. They range in thickness from less than a foot to over six feet. The small mill at the mine was used in an attempt to recover gold from one of these veins. Sampling of the "iron formation" with its included quartz veins indicates that the gold content is very low, ranging from $0.35 to $.70 per ton. The only other mineral reported in the veins is arsenopyrite in very minor amounts.

COPPER

A small copper prospect occurs in the fork of Cherry Creek just above the junction, chiefly in a band of marble. The copper minerals are chalcopyrite and its supergene alteration products, chiefly copper carbonates. Most of the copper mineralization is associated with talc, forming an irregular replacement in a tremolite marble. Some secondary copper minerals also were noted in a coarse staurolite-kyanite gneiss.

KYANITE AND SILLIMANITE

Deposits of kyanite and minor sillimanite are widespread in the area. They consist of the following types:

1. Bands of kyanite-bearing schists and gneisses
2. Kyanite (± sillimanite)-bearing pegmatites

*Personal Communication

**Personal Communication

3. Kyanite (± staurolite)-bearing quartz veins
4. Sillimanite-schist and sillimanite-quartz pods in micaceous schist

These deposits have been described in detail in Montana Bureau of Mines and Geology, Miscellaneous Contribution No. 10 (Heinrich, 1948B). The kyanite pegmatites and veins are capable of yielding fine mineralogical specimens of kyanite, but only the layers of kyanite gneisses and schists are of any potential economic significance. The thickest and most uniform kyanite layers occur in the northern part of the area, between Gulch A and Gulch No. 3 (pl. 1), where five major kyanite-bearing zones were mapped. Several other generally thinner kyanite-staurolite bands occur in the type section, especially on the north side of Cherry Creek.

MICA

Mica-bearing pegmatites have been prospected in the northern part of the area, north of Morgan Gulch. These include the Rim Rock and Vetter pegmatites, which have been described by Stoll (1945, 1950) and by Heinrich (1949A, 1949B). Other mica-bearing pegmatites have been found throughout the area, but none appear to be capable of yielding more than very limited amounts of scrap grade mica.

COMPARISON WITH NEARBY PRE-BELTIAN AREAS

MADISON RANGE-CENTENNIAL VALLEY AREA

The pre-Beltian area that occupies the southern end of the Madison Range and extends southward across the Montana-Idaho line into the Centennial Valley area is one of the larger imperfectly known pre-Beltian areas of Montana, covering an estimated 190 square miles. It lies mainly in Madison County but extends southward into Gallatin County and southwestward into Beaverhead County. The northern end, in the vicinity of Indian Creek, was mapped by Peale (1896), and examined by Runner and Thomas (1928) and the writers. The Cliff Lake section has been mapped by Freeman, Sweet, and Tillman (1950) and also has been studied by the senior writer. Bowles (1937) and Perry (1948) have described the Cliff Lake asbestos deposit. Rocks north of Henrys Lake first were studied by Peale (Hayden, 1873). The geology of the Centennial region has been studied by Honkala (1949A, 1949B), by Vaughn (1948), by Lemish (1948), and by Kennedy (1949), who reportedly has mapped the major part of the Lyon Quadrangle and some of adjacent Henrys Lake Quadrangle.

The rocks at the northern end of the area were divided by Peale (1896) into the Cherry Creek group (Algonkian) and an older Archean group of gneiss and schist. This division appears unwarranted, for no rocks assignable to the Cherry Creek group were noted in this part of the area. The rocks here appear to belong to two major groups: 1) a highly contorted and injected group of gneisses, mainly of meta-igneous origin, and 2) an intrusive granite gneiss. The first is thought to be pre-Cherry Creek in age; the latter may be assignable to the Dillon granite gneiss (Heinrich, 1948A.)

The older unit in the vicinity of Indian Creek include the following varieties:

1. Fine-grained hornblende gneiss
2. Banded hornblende gneiss
3. Hornblende-bearing quartz-feldspar gneiss
4. Pyroxene-bearing quartz-feldspar gneiss
5. Garnetiferous biotite-quartz-feldspar gneiss
6. Biotite-rich gneiss
7. Hornblende-biotite-quartz-feldspar gneiss
8. Quartz-feldspar and aplitic gneisses

Many of these rocks are strikingly injected by granitic material (pl. 3, F). The foliation varies considerably in attitude, striking from N. 85° E. to N. 52° W., with prevailing strikes to the northeast. Dips also vary greatly.

The granite gneisses north of Indian Creek are reddish in color, poor in dark minerals and range from markedly banded types to varieties characterized by quartz lenticles. Microscopically these gneisses show many of the typical Dillon granite gneiss characteristics. The rocks are biotite-poor, have elongated quartz spindles, zoned plagioclase with blebby myrmekite, microcline, and magnetite. A few small bodies of altered peridotite also occur north of Indian Creek.

In the Cliff Lake area rocks typical of the Cherry Creek group are found: marbles, phyllites, quartzites, hornblende gneiss, and biotite gneiss. In general, however, these rocks appear to be of slightly lower metamorphic grade than most of the Cherry Creek rocks in other areas, except possibly those at the southern end of the Cherry Creek area in the Gravelly range. The marbles are relatively fine grained, rarely coarse grained, weathering brown, pink to light red, or white. The quartzites similarly are fine grained and also display marked color variations, with gray, blue gray, red, pale lilac, or white predominating. Most of the quartzites have a sub-vitreous luster; a few have a saccharoidal texture, and still fewer display a conchoidal fracture. Thin seams of calcite occur in some. Others contain minor feldspar and veinlets of hematite. Foliation is rarely pronounced. In thin section the quartzites show mortar structure and Bohm striations as well as accessory muscovite and hematite along grain contacts.

The phyllites are black to gray-green, fine-grained rocks, very well foliated with no megascopically identifiable constituents save for a few

chlorite flakes and thin veinlets of calcite. A light-colored sericite phyllite also was observed.

The hornblende gneisses are massive dark rocks showing only parallel hornblende needles in hand specimens and hornblende, quartz, and plagioclase in thin section. The feldspar gneisses range from biotite-rich to biotite-poor. Some contain both red microcline and white plagioclase; others have little or no potash feldspar. In a few, small euhedral brown garnet crystals are abundant. These usually contain poikiloblastic cores with quartz and inclusion-free rims.

In sec. 25, T. 12 S., R. 2 E., a deposit of asbestos was discovered about 1890 along the northeast side of a steep gulch tributary to Mile Creek. It was mined first about 1900 and again around 1930. Here Cherry Creek marbles are intruded by a diabase dike that strikes nearly north-south and dips gently eastward. The metamorphic layering strikes generally N. 20°-25° E. and dips 70°-80° NW. but locally departs to N. 80° W., 35° SW. Along the diabase contacts, particularly along the hanging wall side, the marbles have been extensively recrystallized and altered to tremolite, serpentine, talc, fine-grained white quartz, and magnetite. Some of the serpentine is green and cryptocrystalline, but much has formed as white to yellow cross-fiber veinlets, few of which are wider than one inch. Tremolite forms silky white fibers, as long as six inches, which may be severely crumpled. The fibers are either parallel with the layering or in comb structure at right angles to it. Purple stichtite is reported to have been found (Freeman and others, 1950). Microscopically much of the marginal diabase shows pyroxene altered to pale-green amphibole. Patches of serpentine and epidote also are abundant in it.

Garnetiferous kyanite-staurolite schist and green sericite schist occur across the line in Idaho near the headwaters of Targhee Creek. The sieve-like staurolite poikiloblasts, which include quartz, rounded garnet, and biotite, are set unoriented in a fine-grained matrix of quartz, biotite, kyanite, and garnet.

In the Centennial area Kennedy (1949) reports " . . . greenstone schists, gneisses, and highly contorted marbles. . . ." Near the Landon Ranger Station on the West Fork of the Madison River, Honkala (1948A, 1948B), Vaughn (1948), and Lemish (1948) have mapped part of a pre-Beltian area underlain by quartzites, marbles, and schists, probably also of Cherry Creek age.

HEBGEN LAKE-MONUMENT MOUNTAIN AREA

The Hebgen Lake-Monument Mountain area consists of several exposures of pre-Beltian rocks near the northwest corner of Yellowstone Park in the southwestern part of Gallatin County.

The pre-Beltian rocks near Hebgen Lake have been described briefly by LeVan and McLean (1951), who report that a narrow, north-trending strip about half a mile long is exposed on the east side of the mouth of Red Canyon, along the west side of sec. 1, T. 12 S., R. 4 E., about half mile north of Montana Highway No. 1. The rocks which are overlain unconformably by the Cambrian Flathead formation consist of gray quartzite, grayish-white and green mica schist, some of which is garnetiferous, and granite gneiss.

Another narrow belt, about 1¼ miles long in a general east-west direction, also crops out below the Flathead formation along the north side of Montana Highway No. 1, in the central part of sec. 10, T. 12 S., R. 4 E. The rocks here are mainly sillimanite schists and gneisses. One type, a dark-colored, medium-grained schist, is rich in biotite and also contains quartz feldspar, and sillimanite. A lighter-colored slabby variety, which occurs as one- to two-foot layers, consists of quartz, white feldspar, and minute bundles of white sillimanite fibers. The foliation of these rocks strikes north to east of north and dips at moderate angles to the west.

Exposures of metamorphic rocks south of Monument Mountain in the upper valley of Bacon Rind Creek (southwest part of T. 10 S., R. 5 E., and the northwest part of T. 11 S., R. 5 E.) have been described by May (1950) as consisting of tremolite schist and marble. The former consists of fine to coarse needles of white silky tremolite, some parallel, some radial, with calcite and minor phlogopite. This rock grades into a well-foliated marble with tightly crenulated quartz bands, locally exhibiting boudinage.

Another area shown on the geological map of Montana (Andrews, and others, 1944) but not studied, is in the central part of T. 11 S., R. 5 E. and continues eastward into Wyoming and Yellowstone Park.

The rocks of the Hebgen Lake-Monument Mountains area also can be referred to the Cherry Creek group.

PART TWO

GEOLOGY OF THE RUBY MOUNTAINS AND NEARBY AREAS IN SOUTHWESTERN MONTANA

By

E. Wm. Heinrich

INTRODUCTION

The Ruby Mountains form a blocky, northeast-southwest trending range that lies across the Madison-Beaverhead county line, mainly in southwestern Madison County. The range is bounded on the south and southwest by the Blacktail Deer Creek drainage system, on the west and north west by the valley of the Beaverhead River, and on the north, northeast, east, and southeast by the Ruby River and its tributaries (fig. 1). At its southwest end the relief is low, and the mountains are rounded. Much of the southeastern corner is capped by a broad, gently rolling, plateau-like upland. Toward the northeast the relief increases; the uplifted early Tertiary erosion surface becomes inconspicuous and sharp peaks appear. The major drainages trend generally at right angles to the range axis. On the northwest flank from northeast to southwest are aligned Trout Creek, Spring Creek, Stone Creek, Carter Creek, and Axes Creek. The major drainage on the southeast slope is Sweetwater Basin, which is bounded on its southwest side by a conspicuous fault line scarp. At the southern end of the range major southwestward-trending drainages are, from northwest to southeast, Proffitt Gulch, Timber Gulch, Elk Creek, and Moose Creek.

Pre-Beltian rocks, which underlie about 220 square miles, constitute all of the range except its northeastern quarter, where two wedge-shaped blocks of Paleozoic sediments terminate it. The smaller southern block, consisting of Cambrian, Devonian, and Carboniferous sediments, overlies the metamorphic rocks unconformably on the south, and is separated from the larger and stratigraphically similar northern block by a wedge of pre-Beltian rocks bounded on both sides by major faults.

The pre-Beltian area is not entirely isolated, but at Ruby Dam extends in a narrow prong across the Ruby Valley to continue in the Greenhorn Mountains south of Virginia City.

The earliest recorded observations on Precambrian rocks in this area are those of Hayden (1872), who noted quartzite, gneiss, and mica schist on Blacktail Deer Creek. Douglass (1905) recognized an Archean group of rocks and a younger Algonkian group, which he correlated with the Cherry Creek group of Peale (1896). Some scattered notes on the general geology of the Dillon district were made by Winchell (1914), but most of his contributions to the geologic knowledge of the area deal with the graphite deposits (Winchell, 1919, 1911). Bastin (1912), Hum (1943), Armstrong and Full (1946, 1950), and Ford (1954) also have described and discussed the graphite deposits. Klepper (1950) in his geologic reconnaissance of a larger area in southwestern Montana, describes the general distribution and structure of the pre-Beltian rocks. Various deposits in the area have been investigated by Perry (1948). Others who have contributed to geological understanding on the area include: Sinkler (1942) and Lindberg (1946) on the Wolf Creek ultramafic intrusive; Rabbitt (1946, 1948) on anthophyllite; Bracken (1949) on sillimanite deposits; Graham and Robertson (1951) on dumortierite; Levinson (1949) on marbles; and Jobin (1949) on detrital minerals. Descriptions of mineral deposits and occurrences have been presented by the writer (Heinrich, 1947, 1948A, 1948B, 1949A, 1949B, 1950A, 1930B). The general geology of much of that part of Montana that lies south and southwest of the Ruby Range has been described by Scholten and others (1955).

ACKNOWLEDGMENTS

The writer began a systematic study of the pre-Beltian geology of the Ruby Mountains in the summer of 1947. Detailed mapping continued throughout the summers of 1948 and 1949. Brief examinations of various mineral deposits were made in 1950, 1951, 1954, and 1958. To the late Dr. John C. Rabbitt the writer is greatly indebted for first arousing his interest in the metamorphic rocks of the state and for subsequent discussions of many of the geologic problems. Dr. E. S. Perry assisted greatly by putting at the writer's disposal both in the field and laboratory a considerable body of knowledge on the geology and mineral

occurrences of the area and its environs. Most of the field work was carried on with the encouragement and support of the late Dr. Francis A. Thomson, former director of the Montana Bureau of Mines. Mr. E. O. Bracken and Dr. J. E. Bever served as field assistants in 1948 and 1949 respectively. Assistance and information in the field also have been given by Drs. M. R. Klepper, W. R. Lowell, C. A. Mortiz, W. O. Kupsch, Robert Scholten, K. A. Keenmon, L. L. Sloss, and A. J. Eardley. Laboratory studies of some of the rocks of the area were completed by Drs. A. A. Levinson (marbles) and M. E. Hilmy (peridotites.) Detailed studies of the rocks and minerals were completed in the Mineralogical Laboratory of the University of Michigan, which also paid for many of the thin sections. Completion of the field and laboratory work was materially advanced by a grant from the Geological Society of America (No. 564-51).

GENERAL GEOLOGY

The area mapped (pl. 2, in pocket) is underlain by three main units, which in general strike parallel with the range axis, i.e., northeast-southwest. The southeasternmost unit consists of an isoclinally folder group of gneisses and subordinate schists, which, based on stratigraphic position and lithology, represent a distinct pre-Cherry Creek group of rocks. The northwestern belt consists mainly of Cherry Creek group rocks, and these two units are separated by a thick intrusive mass of granite gneiss, named the Dillon granite gneiss*, by the writer.

These units have been intruded by usually small, irregular, and widely scattered pods and tabular bodies of peridotite, the largest of which is Wolf Creek pluton (Sinkler, 1942; Heinrich, 1959). Transecting all units including the peridotites is a group of diabase dikes that strike generally northwestward across the metamorphic layers. Small remnants of formerly much more extensive Tertiary lava flows cap the pre-Beltian rocks.

The sequence of pre-Beltian units is:

6. Diabase dikes
5. Peridotite intrusives
4. Aplites, pegmatites, quartz veins
3. Dillon granite gneiss
2. Cherry Creek group
1. Pre Cherry Creek rocks

The pre-Cherry Creek rocks have an exposed outcrop width of about five miles, but its true thickness is difficult to estimate accurately owing to considerable isoclinal folding and lack of distinctive units. The belt of Cherry Creek rocks has a maximum thickness of about four miles, but this includes about 10 percent of intruded Dillon granite gneiss. The maximum width of the Dillon granite gneiss wedge is nearly five miles.

*This granite gneiss was originally called the Blacktail granite gneiss by the writer (1948A, 1950A), but owing to the possibility of its confusion with the Blacktail Deer formation of Tertiary age and the Blacktail formation of Beltian age, it was withdrawn and the substitution Dillon proposed. This has been accepted by the Committee on Geologic Names of the U.S. Geological Survey (communication of October 10, 1949).

STRUCTURE

In general the trend of the three main units, the strikes of the different layers within them, as well as the strike of the metamorphic foliation, all are northeastward, and the dip is mainly to the northwest (pl. 2, in pocket). There are several conspicuous large-scale exceptions to this relatively uniform structural pattern, as for example, near the emergence of Carter Creek, where several folds trend to the northwest. In addition there are very numerous small-scale folds and a few minor faults which profoundly affect the local structural attitudes. Cutting at nearly right angles across the layering and foliation is a series of generally parallel, vertical, northwest-striking faults (pl. 2).

Rocks of the pre-Cherry Creek group show the greatest degree of structural variation, being highly crumpled over large areas and ptygmatically folded locally. Large isoclinal folds are probably much more abundant than can be determined, for outcrops are generally poor on the rolling upland of the southeastern corner of the area, and the lack of distinctive petrologic units makes deciphering of the detailed structure still more difficult. However, southeast of the Wolf Creek ultramafic intrusive, in secs. 6 and 7, T. 9 S., R. 6 W., several tight, steeply plunging isoclinal folds are conspicuous (pl. 2).

In rocks of the Cherry Creek, the metamorphic foliation and the original bedding generally are parallel; except in some parts of marble layers, in which plastic flow has resulted in marked distortion of the bedding. The foliation strikes, in general, between N. 80° E. and N. 10° E., averaging near N. 40° E. Dips are usually at moderate angles to the northwest, ranging, however, from about 20° to vertical. Some rocks of this group display lineation, as well as foliation, but usually it is inconspicuous. The plunge of the lineation, which is best developed in quartzites, ranges from 24°, N. 8° E., to 20°, N. 25° W.

Where Carter Creek emerges from the range it follows the axis of a large northwest-trending isoclinal syncline in marble, which has been overturned to the southwest, with limbs dipping 30°-50° NE (pl. 2). The axial plane strikes N. 45° W., and the axis plunges at a steep angle to the north. Southeast of this fold the beds pass through the vertical and resume their normal northwestward dip, with the strike swinging from northwest through north and back to northeast. About one-half mile south of the keel of this fold, on the southwest side of Carter Creek and the Sweet-

water fault, is a smaller syncline in marble with its axis trending N. 10° E. Adjoining it on the west is a syncline, mainly in hornblende gneiss and lime-silicate gneiss, with its axis trending just north of west.

In secs. 24, 25, and 36, T. 7 S., R. 7 W., the layering in the Cherry Creek group has been profoundly disrupted, and detailed structural features are obscure, owing to incomplete exposures. In sec. 13 to the north the bands trend nearly east-west. In the vicinity of Stone Creek the layers strike nearly north, but toward Spring Creek the layers again swing northwestward.

The Cherry Creek and older groups are not in contact in the area, but are separated by the generally tabular pluton of Dillon granite gneiss, which was intruded mainly along the contact between the two units. The contacts of the Dillon with both older rock groups are extremely irregular in detail, and numerous large sills of Dillon granite gneiss are interlayered with the Cherry Creek rocks. Within the Cherry Creek strip, some other biotitic gneisses, injection gneisses, and quartz-feldspar gneisses have been grouped with the Dillon granite gneiss. In the area underlain by pre-Cherry Creek rocks, sills of Dillon granite gneiss are not separately shown, except in the extreme southeastern part of the area (pl. 2), where they are large and well exposed. Within the Dillon pluton large tabular roof pendants of Cherry Creek rocks are common, especially of marble and hornblende gneiss.

The Dillon granite gneiss is metamorphosed to different degrees, usually to a lesser degree than the Cherry Creek rocks. Most of the pegmatites associated with it are only slightly metamorphosed, commonly only cataclastically, whereas others are essentially unmetamorphosed and are thus difficult to distinguish from pegmatites of possible Laramide age. Most of the pegmatites, aplites, and quartz veins are parallel to the metamorphic foliation.

The peridotites are not deformed and are altered only metasomatically. Most of them have been intruded along the foliation, but the larger bodies have produced considerable crumpling of the metamorphic structures along their margin.

The most prominent post-metamorphic structural feature is a series of generally parallel, vertical faults that strike on the average between N. 30°-50° W., nearly at right angles to the prevailing strike of metamorphic structures. Two prominent faults just northeast of Stone Creek have broken the Cherry Creek belt into three slices (pl. 2). These faults coalesce southeastward, and the single fault is marked by resistant outcrops of a silicified zone, 50 to 100 feet wide consisting of brecciated Dillon granite gneiss cemented by quartz and stained by iron oxide. The largest fault is the Sweetwater fault, which has been traced from near the emergence of Carter Creek southeastward for ten miles. On the northwest side of the range the trace of the fault is occupied by the valley of Carter Creek; across the Sweetwater Divide the fault swings to due south for about two miles, thence back southeastward before splitting into the southeastward-trending branches. On this (southeast) side of the range the prominent fault line scarp forms the southwest margin of the Sweetwater Basin. Several springs emerge from the fault on this side of the valley.

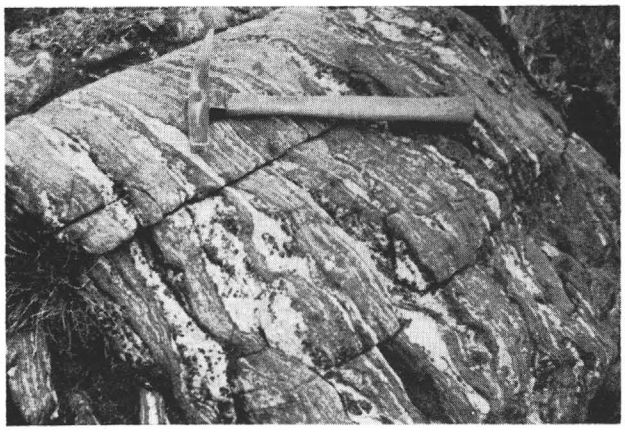
Four faults, one nearly three miles long, occur in the west-central part of T. 8 S., R. 7 W. The second largest of these, the Elk Creek fault, which begins above the headwaters of Timber Gulch and continues to the southeast for nearly eight miles, is occupied by Elk Creek for two miles. This fault cuts off the southwestern end of the Wolf Creek ultramafic pluton, just as the northeastern end is truncated by the Sweetwater fault (pl 2). The Elk Creek fault displaces the Dillon granite gneiss-pre-Cherry Creek contact a horizontal distance of about two miles. South of the Wolf Creek pluton, this fault is occupied by a diabase dike nearly three miles long. Another fault, also followed by a diabase dike, extends from the Camp Creek-Axes Creek junction for three miles southwestward past the Crystal graphite mine.

The faults are younger than the peridotite intrusives and appear to be nearly contemporaneous with the intrusion of the diabases. Most of the major diabase dikes have the same general strike as the faults and at least two dikes have been intruded along faults. However, the northeastern of the two Stone Creek faults truncates a small diabase dike. Thus it appears that most of the diabases were intruded after faulting had been completed, but that faulting and intrusion overlapped to some extent.

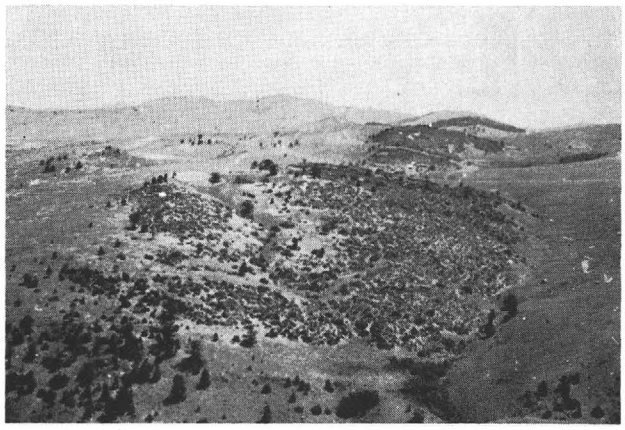
In secs. 16, 17, and 18, T. 9 S., R. 6 W., two prominent sets of vertical joints transect pre-Cherry Creek rocks, sills of Dillon granite gneiss, and diabase dikes (pl. 2). One set strikes N. 20° E., and the other, at 50° to 60° to the first, strikes about N. 75° E.

PRE-CHERRY CREEK ROCKS

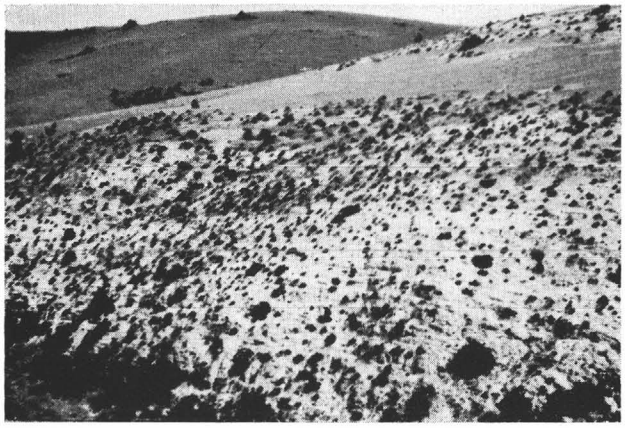
Most of the rocks of the pre-Cherry Creek group are gneissic, banded, and coarse-grained. Although they are petrologically variable, the individual layers continue for only relatively short distances along the strike, and distinctive, persistent units are largely absent. Most of the rocks are strongly injected lit-par-lit by thin granitic layers, stringers, and pods of material originating from the Dillon pluton to the northwest (pl. 4, A). Larger sills of Dillon granite gneiss, some as much as 1,500 feet thick, also intrude these rocks, and pegmatites and quartz veins are common. Locally the foliation is highly crumpled and contorted, particularly around the Wolf Creek peridotite body.



A. INJECTED BIOTITE-GARNET GNEISS

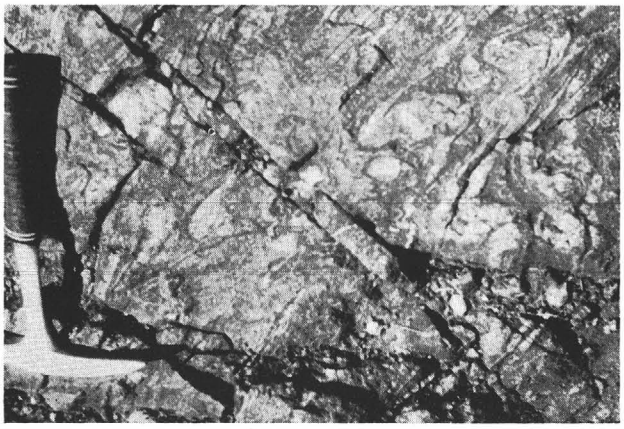


B. BRUSH-COVERED MARBLE BAND

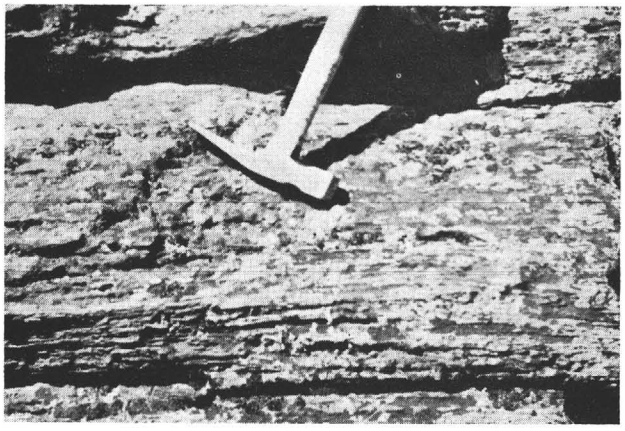


C. CHERRY CREEK MARBLE

D. DISCOIDAL SILLIMANITE



E. IRON FORMATION



F. BIOTITE-AUGITE GNEISS

The main rock types in the group are:

1. Biotite-garnet gneiss, coarse-grained, banded, with layers of quartz-feldspar-brown garnet alternating with quartz-feldspar-biotite bands.
2. Gray fine-grained biotite granite gneiss, not banded.
3. Buff-colored coarse-grained quartz-feldspar gneiss, with minor garnet.
4. Poorly foliated quartz-feldspar gneiss with very abundant garnet porphyroblasts.
5. Dark-colored biotite-rich gneiss, some with large metacrysts of feldspar.
6. Light-colored hornblende - quartz - feldspar gneiss, usually banded.
7. Dark-colored hornblende gneiss and amphibolite, usually banded in dark and light layers.
8. Dark-colored hornblende gneiss with pods and lenses of quartz-garnet rock (Sinkler, 1942, p. 146).
9. Light-colored banded epidote gneisses.

Minor varieties include biotite schist and sillimanite garnet gneiss. Sillimanite as well as considerable anthophyllite and actinolite occur locally along the margins of the Wolf Creek peridotite, and here also occurs a fine-grained green diopside-garnet gneiss containing sericitized plagioclase and abundant sphene.

THE CHERRY CREEK GROUP

The Cherry Creek group contains numerous distinctive units of contrasting petrology which can be mapped separately as aids in deciphering the structural pattern. The types are:

1. Marble and calcium-manganesius-silicate gneiss
2. Quartzite and conglomeratic quartzite
3. Muscovite and biotite schists, some garnetiferous
4. Biotite gneisses, some with variable amounts of garnet
5. Sillimanite schists and gneisses, some garnetiferous
6. Hypersthene-magnetite schist
7. Pyroxene schist and gneiss
8. Chlorite schist
9. Corundum schist
10. Hornblende gneisses, amphibolites, and schists
11. Anthophyllite gneisses and schists

The map (pl. 2) shows large sill-like masses of Dillon granite gneiss intruding the Cherry Creek group. In some places this designation includes, in part, older quartz-feldspar gneisses that are properly part of the Cherry Creek group itself as well as feldspathic migmatites of combined Cherry Creek-Dillon derivation.

MARBLES AND CALCIUM-MAGNESIUM SILICATE GNEISSES

The marbles and closely related calcium-magnesium-sillicate gneisses are among the most conspicuous and structurally useful rocks in the group. They crop out well, are easily recognized from a considerable distance, and the layers generally are considerably more uniform and continuous than most of the other meta-sedimentary units. The marbles are relatively resistant to weathering and usually form continuous outcrop bands, not uncommonly outlined exactly by strips of larger vegetation, particularly greasewood bushes (pl. 4, B and C). At higher altitudes even sharp ledges are characteristic. Much of the outcrop typically is coated by a bright orange lichen.

The weathered outcrops range in color from chalky white through buff to chocolate and even black depending on the manganese content of the rock. The darker weathering types are so only superficially, usually showing tan or light-buff interior colors; and those that weather tan normally are white on fresh surfaces. Surfaces commonly are rounded, nodular or cuspoid, and typically are veneered by a loose sand of coarse, subangular calcite grains as well as angular multicolored chert fragments of varying size. In a few cases because of small-scale mineralogical or textural variations, spongy surfaces are developed.

Along Axes Canyon seven different major marble layers crop out, but six others are too thin for map representation. They range in thickness from 5 feet to 1,600 feet, but locally may be even thicker owing to plastic flow. Along Carter Creek six major layers occur, and near Stone Creek the number ranges from four to six. Several of the thicker bands are continuous for 4.5 to 5 miles, but may vary markedly in thickness within a few hundred or a thousand feet. Other marble units are lenses or pods. This may be due in small part to the original shape of the limestone bed, but more commonly has resulted from either plastic flow during metamorphism or deformation during intrusion of younger igneous material. Toward the southeast all of the meta-sedimentary units become less continuous or more lens-like in shape, owing to incorporation in the Dillon pluton. Thus many of the marble units toward the base of the Cherry Creek group are represented only by large xenoliths or roof pendants in granite gneiss. Some of the marbles have been injected to a considerable extent by granitic and pegmatitic bodies and stringers.

The marbles are all layered, ranging from thin bedded, slabby types, with bands as thin as an inch, to massive varieties in which the layers are six feet or more thick. The layering in most cases results from both the foliation and the original bedding, which generally are parallel, although locally numerous exceptions appear, particularly near the crests and the troughs of major folds or wherever the marbles are markedly contorted

and distorted in thickness. Some marble layers are color-banded in shades of white, buff, and brown. Others contain nodular masses of contrasting color and grain size, which apparently are meta-concretions.

Parts of the marbles have been intensely silicified, the silicification taking various forms. In a few places entire layers or major parts of marble lenses, 30 feet or less in width, have been almost completely replaced by snowwhite, fine-grained quartz, so that the resulting rock resembles a banded, very pure quartzite, but relict patches and lenses of marble remain. Porcelanoid chert nodules, masses, and stringers are very widely distributed, including black, red, brown, buff, brownish-green, green, and mottled black-buff types. Black and buff varieties are most common. Some of the cherty nodules, upon thin-section examination, are seen to contain, in addition to the greatly predominant very fine-grained quartz, considerable fine-grained orthoclase, and some muscovite, magnatite, and streaks of slightly coarser-grained quartz, epidote, and magnetite. Possibly these nodules are primary in origin representing meta-concretions of clayey material. In several localities near the Keystone talc mine, chips and broken artifacts of this material are locally concentrated where Indians collected and worked it.

Manganese oxide minerals are disseminated widely as layers, lenses, pods, and grain coatings and stains. The larger manganese masses, which rarely exceed several feet in width, may be accompanied by marginal zones of very coarse-grained recrystallized calcite. The manganese minerals are earthy, pulverulent, and intergrown with drusy chalcedonic quartz.

Some marbles are locally veined and replaced by bright-yellow serpentine, either a cryptocrystalline structureless variety or a cross-fiber type. The replacements form irregular blebs and pods or sharply defined parallel vein sets usually along the foliation. Some serpentine formation is related to minor faults; some occurs along contacts with sills of Dillon granite gneiss or adjacent to layers of hornblende gneiss. In a few places serpentinization and the white "quartzite" type of silicification occur together. In other places minor serpentinization appears to have followed nearby emplacement of diabase dikes. Thus probably several ages of serpentine are present.

In numerous places talc occurs as a replacement mineral in the marbles, much of it as finely disseminated flakes and small parallel blebs. Less commonly, stringers and pods generally conformable with the foliation attain a thickness of three to six inches and several feet of length. Rarely the masses may be in the order of many tens of feet thick and as much as several hundred feet long and become of commercial significance (see section on Mineral Deposits).

The marbles display considerable petrological variation, grading into rocks consisting predominantly of calcium-magnesium silicates, such as diopside, tremolite, or actinolite, but normally such types are subordinate or marginal phases that cannot be given separate map representation. However, between Carter and Hoffman Creeks, near the alluvium contact, a large lensoid mass of tremolite-carbonate gneiss could be mapped as a distinct unit (pl. 2).

The petrography of the marbles has been studied by the writer (Heinrich, 1947) and by Levinson (1949), who determined the textural relations of calcite and dolomite by means of staining with Lemberg solution or copper nitrate. Of the pure marbles studied by this technique dolomitic marbles are twice as abundant as calcite types, but those marbles in which calcium-magnesium or magnesium silicates, such as tremolite, actinolite, diopside, or phlogopite, occur abundantly are dominnantly calcitic due to breakdown of dolomite during dedolomitization.

The main petrologic varieties included under the map designation, marble and calcium-magnesium silicate gneiss, are:

1. Calcitic marbles
2. Dolomitic marbles
3. Tremolite (rarely actinolite) marbles
4. Diopside marbles
5. Tremolite schists
6. Diopside schists and gneisses
7. Scapolite marbles
8. Thulite marbles
9. Clinozoisite and epidote rocks

Calcitic marbles show considerable variation in grain size and texture. Some are essentially equigranular; others display a marked variation in grain size. Grain sizes range from 0.075 mm. to 2.0 mm. In some coarse-grained types the average size is 1.2 mm, whereas in some fine-grained varieties the size averages about 0.15 mm. In many relatively pure calcitic marbles the grains are slightly elongate and are interlocking in a simple fabric or, less commonly, complexly sutured.

The dolomitic marbles generally are somewhat coarser grained, ranging in grain size from 0.6 to 2.5 mm. The grains may be irregular and interlocking, elongate, and subparallel, or equidimensional in mosaic arrangement. A few marbles are dominately dolomitic with subordinate interstitual calcite, some of which may be secondary.

Many of the marbles, particularly the calcitic ones, contain different amounts of other minerals, especially tremolite (rarely actinolite), diopside, quartz, microcline, phlogopite, chlorite, sphene, talc, serpentine, and graphite. Less common accessories include sodic plagioclase, epidote, clinozoisite, thulite, hornblende, garnet, scapolite, and

apatite. Also noted rarely were muscovite, ilemnite, pyrite, pyrrhotite, orthoclase, biotite, zircon, and tourmaline. In general, in rocks in which tremolite, diopside, or sphene are essential constituents, the carbonate is mainly calcite. Dolomitic marbles have phlogopite, talc, and quartz as the principal silicates.

With an increase in tremolite or diopside the marbles grade into tremolite or diopside schists, or lime-silicate gneisses. Although in a few places such rocks appear to have resulted directly from regional metamorphism of sandy or argillaceous dolomite beds, in most places, rocks of these types are local phases in relatively pure marbles. They have been formed chiefly along contacts with layers of lenses of hornblende gneiss, to a lesser extent along marble-granite gneiss or marble-pegmatite contacts. Irregular lenses and bands of tremolite marble also occur enclosed within hornblende gneiss layers (fig. 5), and usually are surrounded by a reaction zone of actinolite or anthophyllite rock. In sec. 10 T. 8 S., R. 7 W., abundant actinolite, chlorite, and one-foot euhedra of calcite have been formed in marble against a hornblende-gneiss layer.

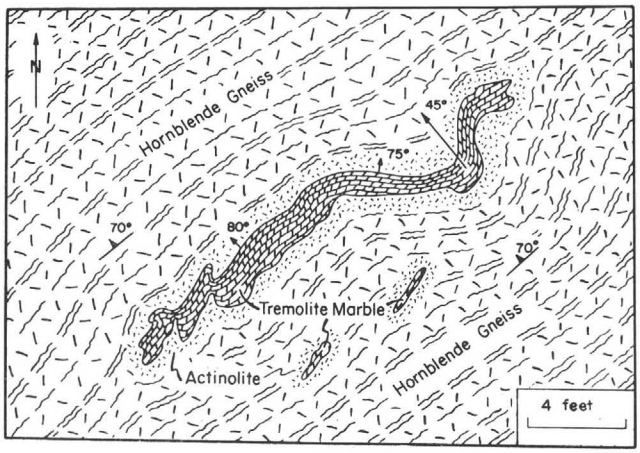


FIGURE 5.—Crumpled tabular xenolith of tremolite marble in horneblende gneiss showing reaction zones of actinolite rocks. Cherry Creek group, northeast of Blacktail Deer Creek valley between Timber and Proffitt Gulches, Ruby Mountains, Montana.

The white tremolite schists consist mainly of parallel needles or blades of tremolite, a quarter of an inch to six inches long. Calcite, quartz, diopside, and phlogopite usually are present in variable, but subordinate amounts. Tremolite, which may replace diopside, may in turn be replaced by talc or marginally by serpentine. At the Keystone feldspar pegmatite (Heinrich, 1949B) coarse phlogopite, pale-green tremolite partly replaced by talc, and abundant chalcedony have been formed in the marble adjacent to the pegmatite.

Diopside gneisses and schists are light gray, fine grained, and commonly banded. In some, diopside-quartz-phlogopite bands alternate with layers of carbonate. Other types that contain much more diopside and little or no carbonate are mosaic in texture without distinct foliation. Such rocks also commonly contain abundant quartz and tremolite and may have variable amounts of phlogopite, sphene, forsterite, epidote, chlorite, and talc. Some talc replaces diopside. A few quartz-microcline-diopside rocks with considerable sphene, magnetite, graphite, and sodic plagioclase represent hybrids between impure marbles and granitic material. Rare hornblende-diopside rocks with minor calcite, phlogopite, talc, and sphene are marble-hornblende gneiss hybrids.

Scapolite marble occurs east-northeast of the Crystal graphite mine in secs. 29 and 31, T. 8 S., R. 7 W. The scapolite commonly occurs as columnar aggregates in bands with zoisite. The gneissic rock also contains bands of quartz and phlogopite, and of diopside and tremolite. Feldspar occurs in one variety together with a few minute crystals of blue tourmaline.

Thulite marbles and thulite-bearing gneisses were observed at three localities: (1) in the southwestern part of sec. 26, T. 7 S., R. 7 W.; (2) in the southwestern part of sec. 10, T. 8 S., R. 7 W.; and (3) at the Camp Creek corundum deposit, in the northeast corner of sec. 36, T. 8 S., R. 8 W. (Heinrich, 1950B). At the first locality light-pink thulite occurs in the marginal parts of a small marble xenolith in hornblende gneiss. In hand specimens the thulite is minutely felted; microscopically it can be seen in twinned elongate crystals, some in radical groups intergrown with patches of very fine-grained sericite. At the second occurrence thulite is found near the top of a thin marble layer between two hornblende gneiss layers. Calcite euhedra as large as three inches are intergrown with fibers of pale-green tremolite and irregular patches of finely fibrous thulite. Thin veins of cross-fiber thulite cut the rock.

The occurrence at the Camp Creek corundum deposit has been described (Heinrich, 1950B, pp. 11-12). Here the principal silicate minerals in the impure marble are diopside, tremolite, phlogopite, thulite, and chlorite. The proportions of these minerals differ widely. Some varieties of the rock consist almost entirely of large blades of very pale-green tremolite, some of which attain a length of six inches. In other outcrops the rock consists almost exclusively of brownish-weathering, granular diopside. Locally thulite becomes an important and conspicuous constituent. It ranges in color from very pale pink to deep rose and occurs as irregular grains, small needles and rarely as conspicuous radial aggregates that may be as much as two to three inches across.

In addition to the thulite, the rock also contains much calcic bytownite, scattered large anhedral grains of sphene, and monomineralic layers and lenses of diopside. The diopside lenses may show banding, with alteration of coarser and

finer grained layers. Scattered small crystals of zircon appear throughout the thulite-plagioclase phase, and where included in the thulite, have produced pleochroic haloes in that mineral. A few nests of biotite flakes also occur locally. Replacing the thulite-plagioclase-diopside aggregate in wholesale fashion is a generally very fine-grained mixture that contains sericite, chlorite, and locally some calcite and granules of magnetite. Most of the plagioclase is at least partly replaced by sericite, and many of the thulite blades are corroded by chlorite, which also replaces diopside to a limited extent.

Rocks consisting mainly of clinozoisite in combination with other calcium or magnesium silicates are rare. One such at the Crystal graphite mine (Heinrich, 1939A, p. 33) is a coarse pink and green mottled rock without foliation containing irregular blades of clinozoisite and minor phlogopite, chlorite, pale hornblende, graphite, and quartz. Another occurrence, across the valley southwest of the graphite deposit, consists of a three foot pod of subvitreous structureless red and gray rock enclosed in hornblende gneiss intruded by pegmatite. Under the microscope the rock is seen to consist of uniformly very fine-grained garnet and clinozoisite with accessory sphene.

In the southeast corner of sec. 20, T. 8 S., R. 7 W., a rounded non-foliated inclusion 8 by 50 feet in plan, consists of a fine-grained mosaic of pink garnet, clinozoisite, and sphene, transected by thin veinlets of epidote.

A distinctive lens of epidote gneiss occurs in the southwestern part of sec. 25, T. 7 S., R. 7 W. (pl. 2). It is a dark-green rock injected irregular by red microcline-rich stringers and pods. The thick coarse-grained epidote bands also contain much actinolite, quartz, sericitized plagioclase, apatite, and sphene. The thinner red layers contain mainly fine-grained microcline, sericitized plagioclase, chlorite, sphene, magnetite, and minor epidote.

Massive fine-grained epidote rock also occurs in marble at the Christensen sillimanite deposit, in sec. 34, T. 7 S., R. 7 W. It is cut by pink veinlets of manganiferous calcite.

QUARTZITE AND CONGLOMERATIC QUARTZITE

Quartzites form relatively thin bands or short lenses and are much less common than marbles. The most continuous band is 2½ miles long, and the thickest layer measures about 1,200 feet across, but most are less than 300 feet thick. The bands, in general, maintain a very uniform thickness and show very few of pinch-and-swell features so characteristic of the marbles. In general, quartzites are more common in the upper part of the Cherry Creek group, toward the northwest side of the range. Two well-exposed quartzite layers crop out in Axes Canyon just southeast of the Smith-Dillon talc mine. A number of lenses occur between Axes and Hoffman gulches. The quartzites are most extensively developed southwest and south of Stone Creek where six major layers were mapped. Well exposed slabby outcrops are typical.

The rocks are generally massive, with imperfect foliation and little or no banding. What layering is present usually results from concentrations of fine-grained muscovite in thin bands. The texture ranges from coarse-grained glassy to fine-grained sugary, and the color ranges from white to dark gray. A subordinate type is pale to bright chrome-green. These green quartzites owe their unusual color to variable quantities of slightly chromiferous green muscovite. In some places entire pods, as large as 10 by 200 feet, are green, whereas elsewhere the green variety is a local phase of a white or gray quartzite and contacts between the two are gradational. Six occurrences of green quartzite were noted in the area.

The layering is parallel with the original bedding, and contorted foliation is uncommon. Lineation may be present and normally is better developed than in the other rock types.

Most of the quartzites are at least slightly micaceous, containing either colorless or very pale-green muscovite. Normally the mica is present in minute parallel scales, either disseminated or in thin bands. Other common constituents are feldspar, usually sericitized, and minute grains of magnetite. Some varieties, relatively rich in feldspar, represent meta-arkoses.

Conglomeratic quartzite occurs southeast of Stone Creek, where stretched pebbles of white quartz as much as an eighth of an inch thick and two inches long are set parallel in a fine-grained quartz-rich matrix containing some muscovite and feldspar. At the east end of the Christensen sillimanite deposit (Heinrich, 1950A, p. 33) elongate pods of a brown banded quartzite in sillimanite gneiss contain augen of coarse clear quartz, 2½ inches or less in length and ⅜ inch thick, that appear to be deformed pebbles. The coarse-grained matrix contains much white feldspar.

MICA SCHISTS

Both biotite and muscovite schists are moderately abundant, but generally these rocks have been so thoroughly injected by granitic material that they can only be mapped as injection gneisses. Such rocks have been grouped with Dillon granite gneiss in the northwestern part of the area. The amount of granitic, aplitic, pegmatitic, and quartz vein material in the micaceous schists is usually conspicuously greater than that in other associated rock types, probably because the thinly-foliated structure of these rocks permitted much easier injection.

Layers of micaceous schists generally are thin and tend to be discontinuous or to grade along the strike into sillimanite schist, garnet schist, or injection gneiss. Outcrops are very poor. One rel-

atively thick band, 2,000 feet in width, has served to localize the upper drainage of Axes Canyon. Other major layers occur near the headwaters of Camp Creek, in the upper reaches of Hoffman Gulch, and along one of the southern tributaries of Stone Creek. Xenolithic pods of biotite schist and gneiss also are included in Dillon gneiss and hornblende gneiss.

Biotite schists are more common than muscovite schists. Coarse-grained muscovite schist occurs near the base of the marble at the Keystone talc mine on the Sweetwater road. Predominant muscovite flakes, as large as a quarter of an inch, are oriented parallel in a highly subordinate quartz-feldspar matrix.

The dark-colored biotite schists show considerable textural, mineralogical, and grain-size variations. A crinkly foliation is common. Many are garnetiferous, usually with euhedra of dark-red almandite, half an inch or less in diameter. Some have metacrysts of potash feldspar as much as an inch long, some of which have their long axes to the schistosity. The chief minerals are biotite, quartz, garnet, orthoclase, oligoclase or andesine, and muscovite. Common accessories are magnetite, sillimanite, graphite, tourmaline, and zircon. Certain types, transitional toward impure marbles, contain diopside, epidote, sphene, and calcite. Invariably much of the biotite is altered to chlorite-dusty magnetite aggregates and the feldspars to sericite. In Timber Gulch a very fine-grained garnetiferous biotite schist contains parallel augen of coarse quartz set at 60 degrees to the schistosity; these may represent recrystallized pebbles.

BIOTITE GNEISS

Most of the gneissic biotite-rich rocks have been formed by the injection of granitic stringers along the foliation planes of biotite schist. However, in a few places, gneissic to banded biotite-rich rocks have resulted from the metamorphism of pelitic sediments. Such fine- to coarse-grained rocks usually contain garnet with quartz inclusions, microcline, minor magnetite, muscovite, tourmaline, graphite, and rarely diopside and calcite.

GARNET GNEISS

In a few places there occur small bodies of coarse-grained gneiss, sufficiently rich in garnet to receive the separate designation, garnet gneiss. Some bodies are large enough for map representation, e.g., southwestern corner sec. 1, T. 9 S., R. 8 W.; southeastern part sec. 23, T. 8 S., R. 8 W.; and northwestern part sec. 15, T. 8 S., R. 7 W. At the last locality a lens of garnet gneiss, with individual garnet subhedra as large as three inches in diameter, forms a hood along the keel of a tightly folded syncline in marble plunging 20° NNE.

Pods of garnet-quartz rock, coarse grained and several tens of feet long, occur in other gneisses. Some biotite and feldspar normally also are present. The almandite anhedra may be as much as 2½ inches across, and biotite flakes are as large as a quarter of an inch. In some types, finer-grained garnet also occurs in the matrix. Plagioclase and tourmaline are accessory constituents.

SILLIMANITE SCHISTS AND GNEISSES

The common sillimanite-bearing rocks are biotitic schists that may contain variable amounts of garnet, but a few are garnet free. Invariably the rocks are strongly injected lit-par-lit and also across the foliation by innumerable thin pegmatitic and granitic stringers and lenses. This association of abundant sillimanite with unusually abundant igneous material is sufficiently constant so that the conspicuous outcrops of injection gneiss can be used as guides for locating sillimanite-bearing rock. Generally the more abundant and coarser the intruded material, the more abundant the sillimanite will be. Sillimanite rocks grade along or across the strike into biotite schists or gneisses. The foliation of the sillimanite schists typically is irregular and crinkly.

Major sillimanite schist and gneiss layers occur in Proffitt and adjoining gulches to the southeast; just northwest of the Crystal graphite mine; at the Christensen deposit on Carter Creek; near the Keystone talc mine on the Sweetwater road; across Carter Creek from the talc mine; and along and south of Stone Creek (Heinrich, 1950A). The bands are normally thin, not over 1,500 feet thick, and the most continuous has been traced for about 1½ miles.

The chief minerals are biotite, quartz, and sillimanite. Muscovite is an accessory in a few cases, but rarely is abundant. Feldspar, except in the granitic stringers, is subordinate; andesine, or less commonly oligoclase, exceeds orthoclase (rarely microcline). Garnet, varying in size and abundance, occurs in some types as widely scattered, spongy anhedra, in others as rounded grains of uniform size and regular distribution, as large as several inches in diameter. Accessory constituents in approximate decreasing order of abundance are zircon, magnetite, graphite, tourmaline, and uncommon apatite. Microscopic stubby, unoriented tourmaline crystals are abundant locally. Graphite forms subhedral aggregates of minute plates.

Sillimanite is invariably one of the youngest minerals. It commonly replaces biotite, and to a lesser extent appears to replace quartz. "Trains" of sillimanite fibers extend into ragged biotite shreds; the biotite flakes become crowded with minute sillimanite needles; and ragged relicts of the mica remain isolated in clumps of fibrous sillimanite. Microscopically, sillimanite appears as minute scattered needles, as elongate fibrous composite "trains", as radial fibrous aggregates, and as small euhedral crystals. Characteristic of some of the sillimanite rocks are discoidal quartz-silliman-

ite pods (pl. 4, D) arranged parallel with the foliation. The discs weather out and collect in drainages. Many measure as large as 3 by 1½ by 1 inch. Other types contain thin, stubby "pencils" of sillimanite and quartz, 2 by ½ by 1/10 inch, which impart a distinct lineation to the rock (see Heinrich, 1950A, pl. 2, A).

In a few places a coarse-grained garnet-sillimanite gneiss forms a striking rock, with abundant uniformly distributed garnets half an inch in diameter crowded into a swirly matrix of mainly fibrous sillimanite and very minor biotite and quartz. Such rocks occur as blocks several feet across included in hornblende gneiss layers along their contacts with biotite-garnet gneiss.

An unusual sillimanite rock crops out on the mine road, a quarter of a mile north of the Crystal graphite mill, lying between the base of a hornblende gneiss and the top of a 200-foot marble bed. It is a dark blue-gray fine-grained rock with very abundant pods, several inches long, that consist of coarse orthoclase, minor quartz and sodic plagioclase set in a finely felted matrix of biotite, quartz, garnet, sillimanite, muscovite, and zircon. Sillimanite wraps around the pods as abundant and coarse sinuous fibers.

MASSIVE SILLIMANITE ROCK

Rocks consisting almost entirely of finely felted sillimanite were found in about a dozen places in the Ruby Mountains. Near the head of Proffitt Gulch lie residual blocks as large as 14 by 15 by 30 inches estimated to weigh about 600 pounds. However, most of the dornicks (boulders) are less than a foot long (Heinrich, 1950A, pl. 1, A). Similar blocks occur near the Keystone talc mine. The pods are closely associated with large pegmatites, commonly lying directly along the pegmatite contacts. The dornicks have a smooth waxy surface and, because of the finely felted texture, are exceedingly tough. The color varies from gray white to mottled purple, but many are very pale green. The fibrous sillimanite is most commonly in a sub-parallel fabric, but radiating "sunbursts" of sillimanite as much as 1½ inches across are also common (Heinrich, 1950A, pl. 1, E). One type contains randomly oriented, coarse euhedral blades of sillimanite in a finely fibrous sillimanite matrix (Heinrich, 1950A, pl. 3, D). Other very subordinate constituents are biotite, quartz, black tourmaline in crystals half an inch or less long, corroded grains of garnet, and scales of graphite.

HYPERSTHENE-MAGNETITE SCHIST

In the Ruby Mountains representatives of the "iron formation" are finely banded hypersthene-magnetite schists, occurring chiefly across Carter Creek and the Sweetwater fault from the Keystone talc mine, in secs. 3, 10, and 9, T. 8 S., R. 7 W. Two minor occurrences are near the Christensen sillimanite deposit and in south-central sec. 25, T. 7 S., R. 7 W. These iron-rich rocks occur in close association with a banded quartz-hornblende gneiss.

The schist is a dark, heavy rock, fine grained and banded, with ¼-inch to ½-inch dark bands rich in the iron minerals alternating with 1/16-inch to ¼-inch bands of brown quartz, slightly coarser grained. The bands are invariably highly crumpled in small-scale patterns, a feature characteristic of similar rocks in many other areas of the world (pl. 4, E.)

The microscope reveals that most specimens have fine-grained bands containing hypersthene, magnetite, and quartz, interlayered with coarser bands of quartz and hypersthene. Apatite is a rare accessory. Near the western end of the principal unit, layers of coarse-grained quartz alternate with bands of fine-grained quartz, magnetite, and minor grunerite, which is markedly twinned and is overgrown along margins and terminations by blue riebeckite.

Near the Christensen sillimanite deposit the iron rock contains bands of quartz; of quartz and hypersthene; of fine-grained quartz, hypersthene, and magnetite; and rare bands of quartz, magnetite, and abundant apatite.

Locally the rocks show considerable alteration, with the bulk of the magnetite altered to hematite and limonite, the hypersthene replaced by a brown, fine-grained fibrous or platy mineral, possibly an iron-rich chlorite, and much quartz replaced by fine-grained chalcedonic quartz. Numerous veinlets of the secondary quartz and limonite transect the altered rock.

PYROXENE SCHISTS AND GNEISSES

Small lenses of biotite-augite schist occur in a horizon above the Christensen sillimanite deposit; on the northwest side of Timber Gulch in secs. 31 and 32, T. 8 S., R. 7 W.; in the nothern part of sec. 36, T. 7 S., R. 7 W.; in the central part of sec. 23, T. 7 S., R 7. W.; and in the northwestern part of sec. 30, T. 7 S., R. 6 W. The fine-grained rock forms dark-colored, resistant outcrops characterized by an unusual, fluted weathered surface (pl. 4, F). Under the microscope the rock is seen to contain chiefly diopsidic augite (as much as 75 percent), biotite, and quartz. Much of the augite is poikiloblastic, in anhedral grains arranged in a mosaic pattern. Most of the quartz is interstitial. Tourmaline occurs as an abundant accessory in small euhedral crystals with cores of pale-buff color and borders of olive green. Other accessories are blue-green hornblende, which replaces the pyroxene, chlorite replacing biotite, orthoclase, interstitial calcite, apatite, zircon, and graphite. In some varieties tremolite is present instead of hornblende.

Near the mouth of Carter Creek, above the east limb of the overturned syncline, occurs a thin layer of fine-grained augite schist containing quartz and augite as essential constituents and accessory orthoclase, tremolite, and sphene.

On the north side of Timber Gulch a dark fine-grained dense rock forms a thin layer about three-quarters of a mile long enclosed in Dillon granite gneiss. It contains chiefly enstatite in skeletal anhedra, plagioclase, and biotite. Accessories are quartz, pale-brown hornblende, and rutile.

South of Stone Creek in sec. 19, T. 7 S., R. 6 W., is a minor occurrence of an unusual rock consisting of lenticles of fine-grained mosaic diopside and lenticles of quartz. Other minerals are sphene, magnetite, chlorite, and tremolite. The rock appears to have been a conglomeratic sandstone with a dolomitic cement.

In the southwest corner of sec. 19, T. 7 S., R. 6 W., along the margins of a quartzite, is a selvage of quartz-diopside schist with minor biotite and talc. The diopside contains very fine exsolution lamellae of orthopyroxene. The original rock apparently was a quartzose dolomite.

CHLORITE SCHIST

Chlorite schist is a very minor rock type in the Cherry Creek group, and the units are too thin for map representation. Occurrences were noted in Axes Canyon about a mile southeast of Smith-Dillon talc mine; between the Keystone talc mine and the Christensen sillimanite lens on the northeast side of Carter Creek; and along the line between secs. 3 and 10, T. 8 S., R. 7 W. The rocks are dark thinly foliated and fine grained. Chlorite and quartz are the essential constituents.

CORUNDUM SCHISTS

Corundum schist was found at only one locality, at the Camp Creek corundum deposit, in the NE¼ sec. 36, T. 8 S., R. 8 W. (Heinrich, 1950B). Within a lens of marble, near its upper contact with biotite schist are three pods of corundum schist, 20 to 130 feet long and 4 to 20 feet thick. Considerable disseminated corundum also occurs in biotite schist near the pods.

The gray corundum rock consists mainly of elongate corundum crystals scattered abundantly throughout an exceedingly fine-grained matrix. The rock is very resistant to weathering and persists as boulders and good outcrops. Other minerals that can be identified megascopically are margarite in pearly-gray flakes interstitial to corundum and partly replacing it, scattered crystals and needles of black tourmaline, irregular aggregates of pale-blue apatite grains, needles and radial groups of pink thulite, and clusters of biotite flakes. Locally diopside becomes an important constituent. Most of the corundum crystals are concentrated in rudely defined layers as much as several inches thick and parallel with the foliation. The mineral occurs in well-formed crystals that may be as large as an inch in diameter but average about a quarter of an inch in diameter. They are blue gray in color, show a tapering barrel-shaped habit, and stand out in relief on weathered surfaces (Heinrich, 1950B, pl. 1, D). In addition to these euhedral crystals, some of the corundum occurs in narrow vein-like masses of small anhedral grains and also to a lesser extent in large irregular clusters of coarse anhedral grains. The percentage of corundum is estimated to range from 5 to 35 percent.

The corundum is strongly zoned, a feature that can be observed both megascopically and microscopically. In one type of zoning a narrow zone of the crystal is dull blue gray, whereas the center is a brilliant, deep, gemmy sapphire. In other crystals the zoning is formed by alternating colorless and dark-brown bands rich in minute inclusions (Heinrich, 1950B, pl. 1, G).

Under the microscope the rock can be seen to consist of individual grains and crystals of corundum, usually zoned, set in a generally fine-grained matrix that consists of sericite, chlorite, margarite, calcite, and rare magnetite granules. In addition to the corundum crystals, corroded blades of thulite, elongate crystals of epidote, patches of biotite, irregular bands of calcic plagioclase, and grains of rutile and zircon appear in the matrix. The corundum shows both zoning and twinning. Some crystals are veined by chlorite and others are strongly embayed by chlorite, margarite, and the fine-grained matrix. A few pseudomorphs of chlorite after corundum were noted. In one case, although the entire corundum crystal had been replaced, the zonal structure was preserved in the chlorite aggregate. The rutile grains are usually closely grouped around the corundum, and a few are included. The plagioclase is sericitized and corroded by the fine-grained matrix. Biotite is in part altered to chlorite.

HORNEBLENDE GNEISSES, AMPHIBOLITES, AND SCHISTS

Among the most abundant types in the Cherry Creek group are generally similar, dark-colored hornblende-rich rocks that are common in nearly all parts of the northwestern section of the area (pl. 2). Bands of these rocks reach a thickness of a mile and a length of five miles. Some are exceedingly irregular in shape and extend into other units in digitate patterns. They enclose small to large blocks of marble and various schists, and are themselves intruded by sills and lenses of Dillon granite gneiss and its related pegmatites and aplites. In many places the hornblende rocks are strongly injected lit-par-lit on a small uniform scale. In a few places there is clearcut evidence that some of the gneisses were originally of intrusive igneous origin, as, for example, on the east limb of the overturned syncline at the emergence of Carter Creek, where a 10-foot con-

formable layer of the gneiss swings abruptly across the layering of a banded marble (fig. 6).

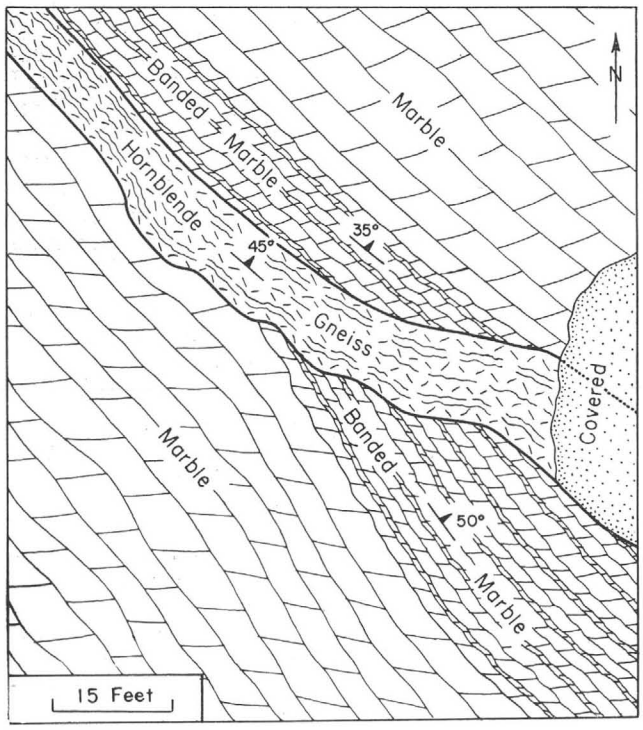


FIGURE 6.—Sketch of hornblende gneiss band discordant to marble layers, east limb of major syncline near emergence of Carter Creek, Ruby Mountains. Horneblende gneiss is a matamorphosed gabbroic or diabasic dike.

A similar relationship is exposed in the north-central part of sec. 15, T. 8 S., R. 7 W. In numerous places lenses and pods of hornblende gneiss, isolate in plan, occur in marble and transect the structure of the marble in detail (fig. 7). Many of the hornblende gneiss bodies vary greatly in thickness over short distances, e.g., swelling from 6 to 100 feet in width within a few hundred feet. Many thicker hornblende gneiss bands contain altered renoliths of metasedimentary rocks.

Further evidence for the igneous derivation of much of the hornblende gneiss is afforded by the endomorphic and exomorphic changes that have taken place in the margins of the hornblende gneiss layers and in contiguous parts of adjacent metamorphic bands as well as around and within inclusions of other rock types. These changes are most noticeable along hornblende gneiss-marble contacts and to a lesser extent along hornblende gneiss-mica schist contacts. In the marbles the common change is the formation of tremolite; in the mica schists garnet and sillimanite have been formed; in the adjoining hornblende rock actinolite, anthophyllite, or garnet have been produced.

The hornblende rocks vary considerably in texture and composition, and it is certain that the different varieties were not all derived from the same type of parental material. The most common variety is a medium-grained dark rock in which perponderant thick hornblende bands are separated by thin discontinuous light-colored feldspathic layers. Another widely distributed type consists mainly of very coarse hornblende needles in a decussate texture. Other types are well-foliated gneisses, fine to medium grained, without banding; minor varities are schistose and fissile. Garnet porphyroblasts, as large as 4½ inches in diameter, occur in several places, but generally the garnets are smaller. In a garnetiferous variety at Stone Creek, each garnet is enclosed in a narrow light-colored hornblende-free halo of quartz and feldspar. With the exception of the very coarse decussate type and those with exceptionally large garnets, most rocks of this category have a good foliation, and locally lineation also has been well developed.

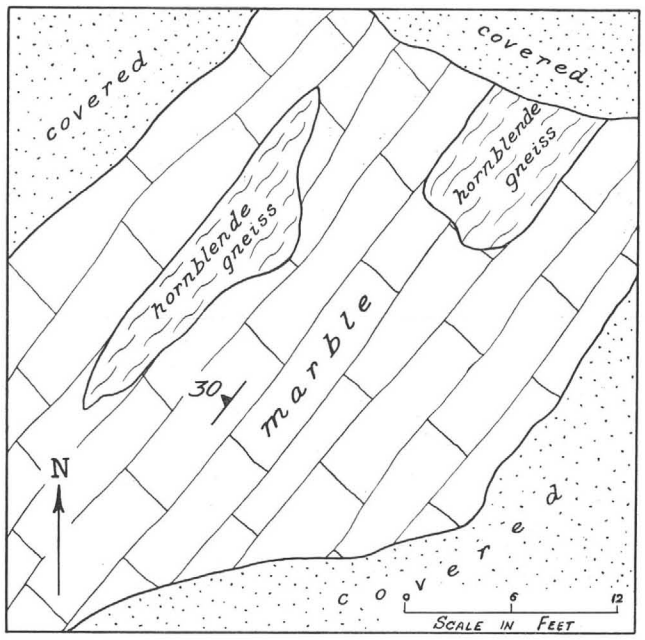


FIGURE 7.—Sketch of hornblende gneiss lenses in marble near head of Axes Canyon, Ruby Mountains, Montana.

The major types grouped in this unit on the map (pl. 2) are:

1. Medium-grained hornblende gneiss and amphibolite, commonly banded
2. Hornblende schists (uncommon)
3. Garnet-hornblende gneiss and amphibolite
4. Feather-amphibolites (Hornblende-garbenschiefer)
5. Biotite-hornblende gneiss (rare)
6. Pyroxene-hornblende gneiss
7. Actinolite schist
8. Cummingtonite schist (rare)
9. Anthophyllite schist and related rocks

Another type, a finely banded quartz-hornblende rock, has been mapped with the "iron formation" with which it is intimately associated.

Normally hornblende is the chief mineral, commonly olive brown or olive green, although pale-green, green, bright-green, and pale-brown types also occur. Usually in a single specimen the color and pleochroism of the amphibole are relatively uniform, but in a few cases, the mineral is zoned (e.g., with pale-green centers and bright-green margins), or, if both porphyroblastic and finer-grained matrix hornblende occur together, slight color differences may characterize the two types. The hornblende varies in shape from euhedral prisms, through subhedral and anhedral blades to ragged poikiloblasts.

Most of the rocks contain some quartz locally as much as 20 to 25 percent; however, some are quartz-free. Plagioclase, usually andesine, is second in abundance; it is commonly strongly sericitized. Minor augite forms relict grains in the replacing amphibole. Magnetite in rounded grains or skeletal crystals is the most common and widespread accessory. Others are apatite (locally abundant to 10 percent), garnet, biotite, ilemnite, and sphene. Hornblende may be altered to chlorite, some of which displays a pale bluish-green pleochroism, or to chlorite plus biotite. Secondary calcite is abundant in some specimens.

In a few types hornblende decreases to 20 percent, and plagioclase is the most abundant constituent. One such variety, in the northwestern corner of sec. 3, T. 8 S., R. 7 W., has minute hornblende needles segregated in lenticles about a quarter of an inch long, set in a fine-grained plagioclase-rich matrix. Schistose rocks in which quartz exceeds plagioclase are rare.

These varieties grade into garnet-hornblende gneisses. Garnet occurs in subhedral to skeletal grains. Not unusual are segregations of garnet and quartz, as much as 1 by 3 inches in section.

Strikingly-textures "feather-amphibolites" were found in sec. 19, T. 7 S., R. 6 W. as lenses in a layer of hornblende gneiss between two quartzite bands. The rocks are gray, coarse grained, banded to massive, and contain randomly oriented, plumose blades of greenish-gray hornblende, an inch or less long, in a fine-grained matrix of plagioclase and quartz. In the thinly-layered types, the amphibole forms flattened, swirly aggregated along the foliation planes. Minor garnet and chlorite are accessories.

A peculiar rock, probably a hornblende gneiss-granite gneiss hybrid, occurs as a small lens in the headwaters of Spring Creek, north of the map area. Coarse-grained and non-foliated, it consists of large mesh-like poikiloblasts of golden-brown biotite in a matrix of hornblende and actinolite. The biotite plates may be three-fourths of an inch in diameter.

Pyroxene-hornblende rocks likewise are rare. A fine-grained hypersthene-hornblende amphibolite (a meta-norite) is exposed near the emergence of Hoffman Creek. Hornblende-augite gneiss was observed near the Crystal graphite mine. A xenolith of augite-hornblende gneiss, enclosed in Dillon granite gneiss in the western part of sec. 35, T. 8 S., R. 7 W. consists of about 60 percent brown hornblende in a mosaic matrix of plagioclase and magnetite, in which small parallel lenses of fine-grained granular augite and a few large rounded augite porphyroblasts, peripherally replaced by hornblende, are set.

The hornblende rocks contain, in addition to lenses and stringers of Dillon granite, aplite, and pegmatite; veins of quartz; of quartz and epidote; coarse pegmatitic pods of plagioclase, quartz, hornblende, epidote, and pale-blue apatite; veinlets of quartz, white feldspar, and dark-brown hypersthene crystals as large as ½ by ⅜ inch.

ACTINOLITE SCHISTS

Actinolite schists occur in hornblende gneiss principally along contacts with layers of inclusions of marble. The rocks typically are bright grass-green in color and coarse grained, consisting of parallel blades of actinolite as long as 2 inches, and interstitial quartz and calcite. Some types are banded with alternating fine-grained actinolite - minor diopside layers between brown layers of coarse-grained quartz. A few varieties have one-inch bands of fine-grained, reddish garnet alternating with thinner green actinolite bands, the aggregate cut by veinlets of dark-green actinolite and epidote. Unusual actinolite rocks are those in which the amphibole occurs in rosettes of coarse blades in a quartzose matrix.

A noteworthy occurrence of actinolite is in a small copper prospect pit in the northwestern corner of sec. 36, T. 7 S., R. 7 W. Disseminated grains of chalcopyrite and supergene crusts of malachite occur in a hybrid marble-hornblende gneiss rock, cut by several veins of gray-green cross-fiber actinolite asbestos in needles 3 inches or less long.

In a few places actinolite has been formed in hornblende gneiss along pegmatite contacts. Elsewhere the intrusion of pegmatitic material has resulted in the formation of a sheath of biotite or biotite plus hornblende around the intrusive.

CUMMINGTONITE AND ANTHOPHYLLITE ROCKS

Cummingtonite occurs as a major constituent of a hornblende gneiss layer about one mile south of the Crystal graphite mine. Other minerals are garnet and plagioclase. The cummingtonite, which occurs wherever the dark gneiss has been injected lit-par-lit by granitic stringers, is complexly twinned and replaces hornblende. A thin lens of cummingtonite schist also was discovered as an inclusion in Dillon granite gneiss in the northeastern part of the Sweetwater Basin, just beyond the eastern edge of the mapped area. This dark-colored fine-grained rock also contains quartz, minor plagioclase, and accessory rutile.

About 50 widely distributed occurrences of anthophyllite have been recorded, all but a few of which are in or closely associated with hornblende gneiss. The anthophyllite rocks occur as pods either in hornblende gneiss along a tremolite marble contact or in hornblende gneiss where that rock has been invaded by granitic sills and stringers, pegmatites, and quartz veins. Between Hoffman and Carter Creeks, for example, near the alluvium contact a pod of massive milky quartz, 50 by 200 feet in plan, in hornblende gneiss is selvaged by a zone of anthophyllite as much as 25 feet wide. Several gulches south of Proffitt Gulch, anthophyllite, in half-inch blades, has been developed around quartz-tourmaline veins. Nearby, two 4-foot pegmatite pods, 5 feet apart, have converted the intervening hornblende gneiss to anthophyllite rock.

The maximum thickness of anthophyllite layers is about 100 feet. The anthophyllite may be pseudomorphous after hornblende, but commonly it has been recrystallized to either very coarse parallel blades or to bladed aggregates in random or radial groups. Some varieties are fibrous.

Nearly all the anthophyllite rocks are light- to medium-brown in color and form very resistant outcrops compared to the neighboring hornblende gneiss. Although the rocks are megascopically rather similar, mineralogical differences appear microscopically. The varieties include:

1. Anthophyllite gneiss with plagioclase, quartz, and accessory rutile and biotite. In one variety, inch-long rounded porphyroblasts of anthophyllite are surrounded by a coarsely gneissic matrix of quartz, feldspar, anthophyllite, and biotite.

2. Garnet-anthophyllite gneiss consisting of coarse anhedral anthophyllite enclosing ragged augite relicts, biotite flakes replacing anthophyllite, irregular coarse garnets, fine-grained quartz and plagioclase, and accessory rutile and magnetite. Locally garnet crystals attain a diameter of two inches.

3. Anthophyllite schist, containing chiefly quartz and anthophyllite and accessory magnetite and rutile. Some schists also are garnetiferous, containing elongated skeletal poikiloblasts of garnet enclosing quartz, rutile, and biotite. The last occurs solely as inclusions in the garnet. Anthophyllite in the schists may contain a core rich in dusty magnetite inclusions surrounded by a clear margin.

It is noteworthy that nearly all the anthophyllite rocks contain rutile, but that magnetite, common in hornblende gneisses, is subordinate. There are a few rocks containing both abundant hornblende and anthophyllite. In some granitized hornblende gneisses, anthophyllite blades occur both in and adjacent to the stringers.

DILLON GRANITE GNEISS

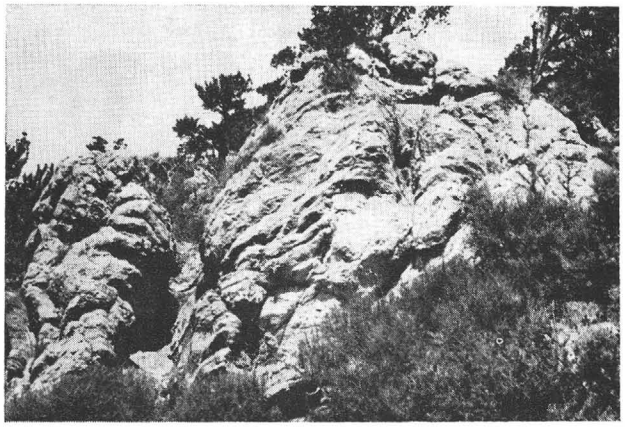
Dillon Granite gneiss (Heinrich, 1953) is widespread in all parts of the Ruby Mountains, with a thick sheet-like mass laying between the Cherry Creek group to the northwest and the pre-Cherry Creek group to the southeast and numerous sills and lenses and lit-par-lit stringers in both of these units (pl. 2). The "pegmatite and aplite" noted by Sinkler (1942, p. 142-8) forms the southeastern margin of the sheet-like pluton. Oriented xenoliths and roof pendants, especially of hornblende gneiss, are common in the pluton, and irregularly distributed bands richer in mafic minerals probably attest to considerable resorption of wall rocks. The granitoid rock appears as generally resistant rounded to angular outcrops, gray to reddish brown in color (pl. 5, A and B). These are particularly conspicuous in the high upland underlain mainly by pre-Cherry Creek gneisses. The rock shows varying degrees of development of the metamorphic structure, ranging from nearly massive types with a foliation that is inconspicuous megascopically to gneissic varieties strongly layered and even lineated. Accompanying the pluton are numerous conformable bodies of aplite and pegmatite as well as many quartz veins.

Most of the rock contains quartz, microcline, plagioclase, and minor biotite. The quartz commonly forms stringers or elongate pods of relatively coarse grains. The microcline, which contains bleb and string perthite, may be bordered by very thin quartz rims. The plagioclase is usually zoned, with thin, more sodic rims. Accessories are zircon in stubby euhedral crystals, allanite, magnetite, and local garnet. Some types contain hornblende as well as biotite. The biotite is commonly altered to chlorite, the plagioclase to sericite. Near the head of Spring Creek, north of the map area, a hypersthene-bearing variety contains quartz, microcline, characterized by very fine-grained bleb perthite and rims of albite, minor plagioclase and biotite, and accessory zircon and allanite. Both the zircon and the allanite are zoned, the latter with broad brown centers and green rims. The abundant coarse hypersthene contains exsolution lamellae of clinopyroxene.

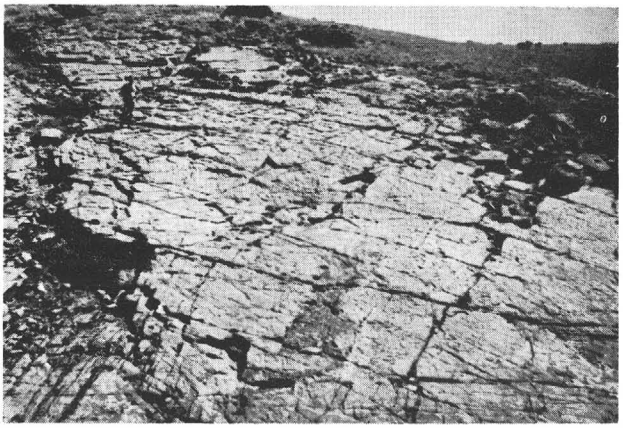
The aplites are in thin sills of uniform thickness that form sharply defined linear outcrops. The color ranges from white to buff, red, and olive gray. The rocks are fine grained, usually gneissic, and poor in mafic minerals. Some contain minor biotite, others reddish garnet and magnetite. Thin epidote veinlets transect the foliation.

Two types of pegmatite are common in the Ruby Mountains (Heinrich, 1949A, 1949B). They are contrasted in Table 4.

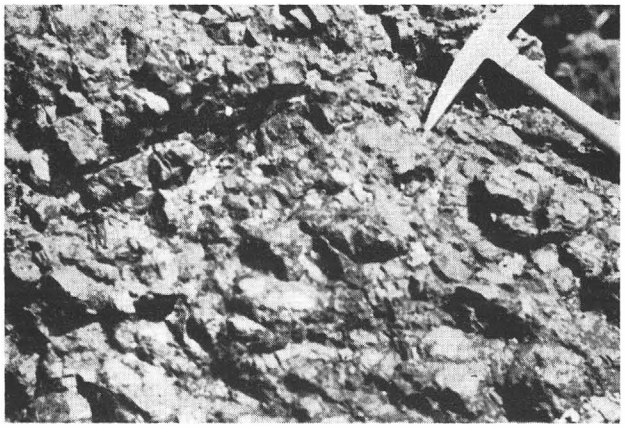
The texture of the older pegmatites is usually markedly gneissic with attenuated quartz spindles as long as 4 inches.



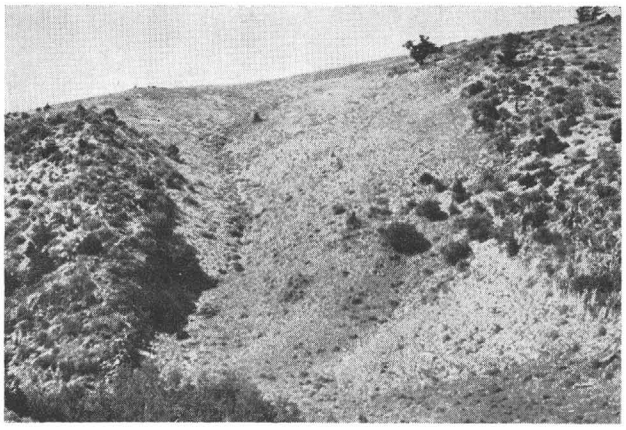
A. DILLON GRANITE GNEISS



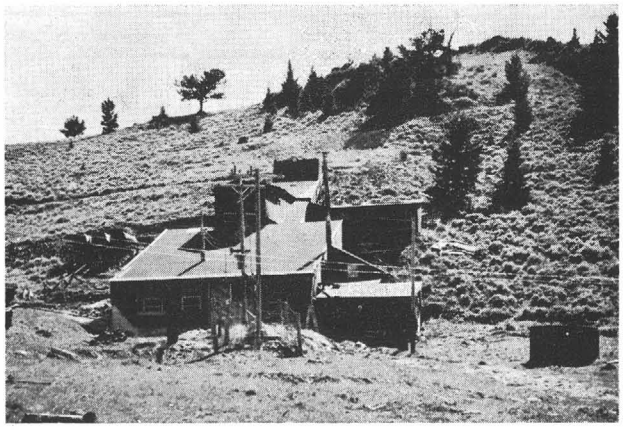
B. JOINTED DILLON GRANITE GNEISS



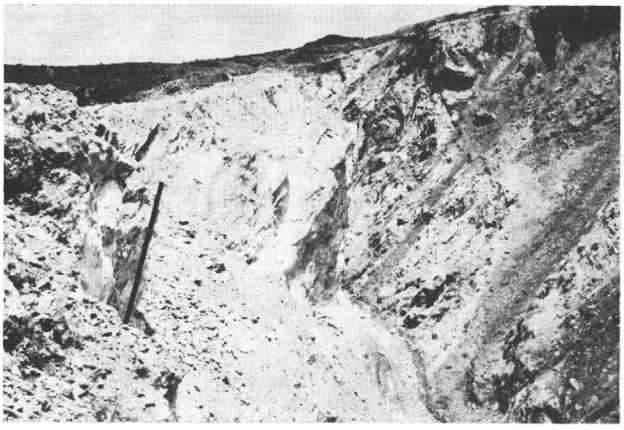
C. OUTCROP OF HARZBURGITE



D. GULLY IN DIABASE



E. CRYSTAL GRAPHITE MINE



F. SMITH-DILLON TALC MINE

TABLE 4.—Characteristics of Pegmatites in the Ruby Mountains.

Older	Younger
1. Very abundant	1. Less common
2. Generally concordant, as sheets, lenses, and stringers	2. Generally discordant, as dikes, pods, and irregular bodies
3. Normally unzoned	3. Commonly zoned, may have rose quartz cores
4. Metamorphosed, with a cataclastic to gneissic structure; may even show lineation	4. Unmetamorphosed
5. Mainly quartz and microcline	5. Mainly quartz, microcline, and plagioclase (usually olive colored)
6. Accessory white oligoclase, garnet, sillimanite, muscovite, biotite, magnetite, apatite, zircon, and graphite. Tourmaline is rare; dumortierite in one deposit	6. Accessory tourmaline, biotite, muscovite, garnet, chlorite, epidote, actinolite, and graphite; also graphic intergrowths of tourmaline - quartz, garnet - quartz and tourmaline rosettes

Some have granulated zones; others have a marked cataclastic structure throughout. The foliation is accentuated by parallel biotite-rich stringers, by thin felted seams of fibrous sillimanite (Heinrich, 1950A), or by the arrangement of garnets in layers.

Dumortierite occurs in a foliated pegmatite near the head of Spring Creek, north of the map area (Graham and Robertson, 1951). The sill contains microcline with bleb perthite, quartz, oligoclase, muscovite, tourmaline, and acicular to columnar deep-blue dumortierite. The dumortierite forms lenses and streaks as much as a quarter of an inch thick, generally parallel with the marked gneissic arrangement of quartz and feldspar. Here and there, however, rosettes of fibrous dumortierite transect the foliation.

The non-foliated pegmatites, which commonly are zoned, usually transgress the regional structure, particularly the larger ones. In general they are less abundant and smaller than the foliated ones. Because of their distinct structural and mineralogical characteristics, it is possible that they may not be consanguinous with the Dillon granite gneiss, but may actually be much younger, perhaps even of Laramide age and related to the Boulder batholith and its related intrusives, such as the Tobacco Root batholith. However, major intrusive bodies of undoubted Laramide age have not been found in the Ruby Mountains. These unmetamorphosed pegmatites were not found in contact with the unmetamorphosed diabase dikes. Nor were they found intruding the overlying Paleozoic sediments north of Spring Creek. However, a few small pegmatites (of this type?) intrude the northwestern part of the Wolf Creek peridotite pluton and have introduced fine-grained silica along their margins. Thus their age is indeterminate, but probably post-Dillon and perhaps post-ultramafics.

Quartz veins and pods also are abundant in the area, although less common than pegmatites. Some contain black tourmaline; others have muscovite and tourmaline or muscovite alone; a few contain epidote. Near Timber Gulch, two veins, consisting entirely of rose quartz, are 2 feet thick and 25 feet long.

ULTRAMAFIC INTRUSIVES

Bodies of peridotite and related rocks, varying greatly in size and shape, intrude the Cherry Creek and pre-Cherry Creek rocks and the Dillon granite gneiss. These intrusives are unmetamorphosed and are themselves cut by the younger diabases and by the main north-west faults. Fourteen ultramafic bodies were recorded during the mapping, the largest of which by far is the Wolf Creek pluton. Many of the bodies are too small to be shown on the map (pl. 2). The locations are:

1. Wolf Creek pluton. Sec. 35, T. 8 S., R. 7 W.; sec. 31, T. 8 S., R. 6 W.; secs. 1, 2, 11, T. 9 S., and sec. 6, T. 9 S., R. 6 W.
2. Timber Gulch ultramafic group. Three bodies, one in the northwest corner of sec. 34, the other two in sec. 33, T. 8 S., R. 7 W.
3. The Crystal graphite ultramafic group. Six small bodies, four in sec. 31, one in sec. 32, T. 8 S., R. 7 W., and one in the southeast part of sec. 36, T. 8 S., R. 8 W.
4. In the central part of sec. 32, T. 7 S., R. 6 W.
5. In sec. 12, T. 8 S., R. 7 W., on the east side of the Sweetwater road near the divide.

WOLF CREEK PLUTON

This extremely irregular intrusive trends generally N. 55° E. and is truncated on both ends by major faults (pl. 2). It consists chiefly of harzburgite, an olivine-orthorhombic pyroxene rock, with accessory spinel and magnetite. The texture of the weathered peridotite is knobby (pl. 5, C) owing to the relief of the large pyroxene anhedra. The peridotite body shows different types of alteration (Sinkler, 1942; Heinrich, 1959) to: 1) serpentinites, 2) anthophyllite rocks, 3) actinolite rocks, and 4) clinohumite-bearing rocks that contain small amounts of annabergite. In addition veins of anthophyllite, actinolite, serpentine, chlorite, talc, and calcite-garnet cut the peridotite. Anthophyllite and actinolite rocks also have been formed in the adjacent pre-Cherry Creek rocks, largely at the expense of hornblende gneiss.

TIMBER GULCH GROUP

The three Timber Gulch bodies are rounded in plan and may be erosional remnants of a single sheet-like intrusive that dipped gently to the northwest. The flat-lying remnants, the largest of which is 600 feet long, are apparently about 20 feet thick. They consist of a uniformly coarse-grained enstatite-olivine rock, with the large rounded poikilitic pyroxene crystals weathering into sharp relief. Some of the orthopyroxene is hypersthene. Olive to brown picotite, magnetite, and chromite rimmed by pyrrhotite are primary

accessories. Secondary minerals are actinolite, serpentine, dusty magnetite, chlorite, and talc.

CRYSTAL GRAPHITE GROUP

Near the Crystal graphite mine a sinuous peridotite dike, about 1,000 feet long, consists chiefly of enstatite, called augite by Winchell (1914, p. 39), and remnants of olivine, both replaced by actinolite and serpentine. Accessories are olive spinel and magnetite.

About a third of a mile east of this dike, on the bulldozer road toward the Birds Nest graphite mine, an enstatite-rich peridotite crops out poorly (sec. 32, T. 8 S., R. 7 W.). Microscopically it shows a rounded pseudobreccia texture of enstatite relicts replaced peripherally by anthophyllite and fine-grained magnetite, and crisscrossed by minute veinlets of talc.

On the knob overlooking the Crystal graphite mine to the north, an altered peridotite pod several tens of feet long intrudes hornblende gneiss. It consists of enstatite relicts, much olivine, olive spinel replaced in part by secondary magnetite, and abundant anthophyllite and serpentine. A similar pod is exposed on the high point south of the mine. Here an enstatite-olivine-spinel rock, cataclastically metamorphosed, is partly replaced by actinolite and magnetite.

On the ridge southeast of the mine is a lens several feet long of fine-grained peridotite that consists largely of enstatite altered markedly to pale-brown hornblende.

In the southeast part of sec. 36, T. 8 S., R. 8 W., another small peridotite pod along a meta-pegmatite-hornblende gneiss contact consists of poikilitic enstatite replaced by anthophyllite, actinolite, phlogopite, and rutile.

OTHER PERIDOTITES

In sec. 32, T. 7 S., R. 6 W., a lens of peridotite, 200 feet long and 6 feet thick, along a hornblende gneiss-Dillon granite gneiss contact, strikes N. 30° E. The enstatite-olivine-spinel rock is extensively replaced by phlogopite plus magnetite and by serpentine plus magnetite. The phlogopite flakes have pale buff centers and pale-green margins. In sec. 12, T. 8 S., R. 7 W., a sill of peridotite, 100 feet long and 15 feet thick, strikes N. 50° E. and dips 80° NW. along the contact between hornblende gneiss and Dillon gneiss. The sill weathers to rounded boulders. Enstatite-olivine-spinel peridotite is replaced somewhat by actinolite, serpentine, and calcite.

In sec. 19, T. 8 S., R. 7 W., a small lens of medium-grained serpentinized enstatite peridotite occurs near a large diabase dike. In sec. 15, T. 8 S., R. 6 W., a pod of peridotite several tens of feet long intrudes a layer of hornblende gneiss in the pre-Cherry Creek rocks. The enstatite-spinel rock is replaced by fine-grained actinolite and minor anthophyllite.

DIABASE DIKES

A series of generally parallel diabase dikes transects the metamorphic structures at nearly right angles, trending north-northwest (Heinrich, 1953). Some have been emplaced along major faults. The Axes Canyon dike (pl. 2) follows a fault in its southeastern part, and where the fault ends the diabase swings northeastward for a short distance along the metamorphic foliation. This dike, the largest, is over 6 miles long and as much as 600 feet thick. Numerous diabase dikes, too small to delineate on the map, are only a few feet to several tens of feet wide and from ten to several score feet long.

The dikes are topographically conspicuous, the outcrops being generally free of large vegetation. The diabase is among the least resistant of the rocks of the range and usually forms bare gullies (pl. 5, D). Where outcrops are present the rock weathers to rubbly surfaces covered with spheroids.

In general the intrusion of the dikes has had little effect on their wall rocks except where the rock is marble. These carbonate rocks have been baked to a very fine-grained light-red porcellanoid rock consisting of fine-grained calcite and ovoid patches of very fine-grained serpentine cut by numerous veins of calcite.

The diabases are relatively uniform in texture and composition, ranging from aphanitic to coarse-grained. Most are ophitic; in others the augite is subhedral to euhedral with interstitial euhedral to anhedral plagioclase. Some of the ophitic types also contain glomeroporphyritic groups of augite microphenocrysts, complexly twinned. Augite, labradorite, and magnetite are the main constituents; minor are apatite, ilemnite, pyrite, and pyrrhotite. Some types contain considerable interstitial granophyre or quartz.

The dikes are locally extensively altered to mixtures of mainly chlorite, serpentine, hornblende (both green and brown), carbonate, and magnetite. Other less common alteration products include hydromica, sericite, epidote, clinozoisite, biotite, and zeolites.

Microscopic vesicles are abundant locally, usually filled by chlorite, by a chlorite-calcite aggregate, or by marginal chlorite around central quartz, some of which is in euhedral crystals. Rare thin veins of epidote cut the dikes.

A complex one-inch vein, in a diabase near the Camp Creek corundum deposit, has thin selvages of parallel chlorite films, a lower half of comb-structure calcite and quartz, and an upper half of calcite and scatered pale-green actinolite-subhedra.

Deposits of disseminated chalcopyrite are associated with diabase dikes near Stone Creek and along Elk and Moose Creeks (pl. 2).

METALLIC MINERAL DEPOSITS

IRON

The main band of iron formation occurs on the southwest side of the Sweetwater fault in secs. 3, 9, and 10, T. 8 S., R. 7 W. The band is locally as much as 1,000 feet wide and has been traced for about 2 miles. The layer strikes northeasterly and is steeply dipping, usually to the northwest. It is bordered on the northwest side (from northeast to southwest) first by sillimanite schist and then hornblende gneiss and on its southeast side first by marble and then by hornblende gneiss.

The strongly magnetic rock is fine grained and minutely blended with banding commonly crumpled (pl. 4, E). The chief constituents are quartz, magnetite, and hypersthene. Some varieties are hypersthene-free; others contain grunerite, riebeckite, and apatite as locally significant species.

Estimates of the mineral composition based on measurements in thin sections are:

	Quartzose Bands	Magnetite bands
Magnetite	2 - 10%	25 - 65%
Iron silicates	1 - 5%	3 - 10%
Quartz	85 - 97%	25 - 72%

This deposit has been known to geologists since 1948, but efforts to interest iron companies in exploring it were fruitless, until 1956 when the deposit was "discovered" by mining engineers. In the summers of 1957 and 1958 the deposit was being explored by diamond drilling by the Minerals Engineering Company of Grand Junction, Colorado. It is reported that the initial exploration blocked out 52 million tons of ore and that estimates of reserves would be of the order of 280 million tons, which could yield 100 million tons of concentrate grading 63 to 65 percent iron.

In late 1958 the company announced plans to construct an $8 million concentrator at the deposit, to be built by North American Utilities Corporation of Montreal and to be operated by Minerals Engineering. The concentrator is to have a capacity of 3,000 tons per day, producing pellets at the rate of 1,000 tons per day.

None of the other occurrences of iron formation in the area appear to be of sufficient size to be of economic interest.

NICKEL AND CHROMITE

Nickel, in the form of the arsenate mineral, annabergite, occurs in the Wolf Creek ultramafic intrusive (Sinkler, 1942; Heinrich, 1959). Annabergite as thin fine-grained yellow-green crusts forms fracture coatings in olivine-orthopyroxene rock (harzburgite) partly altered to clinohumite (Lindberg, 1947), anthophyllite, actinolite, chlorite, phlogopite, and serpentine. The nickel mineral was found in relative abundance by the writer in only one small prospect pit in SE¼ NE¼ sec. 1, T. 9 S., R. 7 W. Small amounts were noted in two other parts of the peridotite. A partial analysis has been presented by Sinkler (1942).

As_2O_5	44.11 percent
NiO	28.71 percent
MgO	2.19 percent
H_2O	0.60 percent

All geological evidence indicates the annabergite is of supergene origin, with the nickel being derived by the breakdown of slightly nickeliferous orthopyroxene in the peridotite body. Thus it cannot be expected that more than small local concentrations will be found, or that the grade of the ore will increase with depth.

Chromite occurs locally as an accessory mineral in different parts of the Wolf Creek intrusive. It appears to be most abundant in that part of the body along the Elk Creek fault, associated with strongly serpentinized peridotite. Several small prospect pits have been dug here in searching for larger concentrations of the mineral. The spinel mineral, picotite, which is rather uniformly distributed through the Wolf Creek peridotite and through other peridotites as well, as an accessory mineral, also contains chromium. Thus these rocks all will yield tests for chromium without containing any significant amounts of chromite.

COPPER

Small deposits of oxidized and partly oxidized copper minerals are widespread in the Ruby Mountains. In most places chalcopyrite is the chief primary mineral. The deposits are chiefly in two groups:

1. Those along the southeastern end of the Elk Creek fault in diabase, pre-Cherry Creek rocks, and in the Wolf Creek peridotite body. Some six occurrences are recorded here along a northeast axis over a distance of about 2½ miles.
2. A group of five deposits north of Carter Creek extending essentially due north for 2 miles from a point about half a mile east-southeast of the Keystone talc mine. These occur mainly in hornblende gneisses of the Cherry Creek group. Several other deposits are known in the area including two at the front of the range 1½ to 2½ miles northeast of the emergence of Axes Creek (pl. 2).

Deposits of the first group contain disseminated grains of chalcopyrite in a gangue of white quartz and white calcite. They are tabular to irregular replacement bodies rarely more than a few feet across. Those of the second group are disseminations in hornblende rocks that have been in part altered to actinolitic serpentine. Deposits of group 1 are spatially and structurally related to the emplacement of the diabase dike along the Elk Creek fault. That they are also genetically related to the intrusion of the diabases is indicated by the presence of accessory pyrite, pyrrhotite, and chalcopyrite in diabase dikes of this part of the range.

Some of the deposits of group 2 are mentioned by Winchell (1914, p. 104), who also notes an occurrence on Hoffman Creek in which chalcopyrite and pyrrhotite with gangue quartz and calcite occur in a vein cutting "limestone" (i.e., marble). This deposit could not be located.

A small copper prospect has also been developed up the northeast fork of Stone Creek just east of the edge of the area mapped. The deposit is in granite gneiss, and the mineralization consists of copper sulfides, quartz, and sericite. The vein material contains angular fragments of highly sericitized wall rock up to 6 (?) inches across. The deposit lies very close to a major fault zone.

MANGANESE

Manganese mineralization is confined entirely to marble bands in which occur irregular replacement masses consisting chiefly of different manganese oxide minerals. Deposits occur:

1. Near the mouth of Axes Canyon just east of the Smith-Dillon talc mine;
2. On the northwest side of Proffitt Gulch;
3. On the north side of the valley overlooking the north fork of Axes Canyon;
4. In Stone Creek valley, about half a mile above its forks.

The chief manganese prospect is No. 1 (above) where a shallow shaft has been sunk on an irregular ore body replacing marble near its upper (northwestern) contact. Mineralization is generally low-grade but highly variable. The ore consists chiefly of black manganese oxide minerals, calcite, and chalcedony. The chief manganese minerals appear to be psilomelane and pyrolusite. The highest grade ore consists of small spheroids of psilomelane coated by fibrous pyrolusite projecting into small vugs. Some massive metallic oxide ore appears locally. Most of the ore has a pseudobreccia texture, consisting of angular tabular pieces an inch or less in size of fine-grained manganese minerals set in a matrix of coarse-grained white calcite. Abundant dark-red to dark-brown chalcedony also replaces marble as part of the manganese mineralization. The deposits are generally similar to the more widespread manganese deposits of the Cherry Creek (Pardee, 1918; Heinrich and Rabbitt, Pt. 1 of this report).

NON-METALLIC MINERAL DEPOSITS

ASBESTOS

Small occurrences of asbestos are widespread, particularly in marble:

1. Where diabase dikes have intruded the carbonate rocks;
2. Along the marble-hornblende gneiss contacts.

This asbestos is of the serpentinite (chrysotile) type. Serpentine asbestos also appears in veinlets in serpentine in the Wolf Creek ultramafic pluton, in which also occur veins of amphibole (anthophyllite) asbestos.

Cross-fiber serpentine asbestos is best developed in a small deposit along a diabase-marble contact in the northeast limb of the Carter Creek syncline, where ramifying veinlets of golden-yellow serpentine are as much as 1 to 1.5 inches wide. They are rarely more than several feet long, however, and their distribution is very irregular. The occurrence is similar to that of commercial significance at Cliff Lake, Madison County (Perry, 1948; Heinrich and Rabbitt, Pt. 1, this report).

CORUNDUM

The Camp Creek corundum deposit, discovered by the writer in June 1949, is in the NE¼ sec. 36, T. 8 S., R. 8 W. (Heinrich, 1950B). It consists of several north and north-northeast trending lenses of corundum rock in marble and biotite schist. The strike length is about 220 feet with a maximum thickness of 20 feet. The gray to blue corundum crystals average about a quarter of an inch in diameter, with some as much as an inch across. The grade of the rock ranges from 5 to 35 percent, with local richer concentrations. The small size of the deposit prevents it from being of economic significance.

GARNET

Garnetiferous gneisses and schists are widespread throughout the range, particularly in the pre-Cherry Creek group. Indeed, the name of the mountains, Ruby Range, stems from the early discovery of residual accumulations of red garnets (locally called "rubies"). Elluvial garnet concentrations are derived chiefly from the weathering of biotitic and sillimanitic garnet gneisses in which individual garnets range in diameter from about one-eighth of an inch to several inches. Many are about a quarter of an inch across. Pods of coarse garnet-quartz rock also appear (pl. 2). Some hornblende gneisses also contain large and abundant garnets which also may become concentrated in the soil. Very coarse garnets are abundant in the pre-Cherry Creek gneisses along contacts with the Wolf Creek ultramafic intrusive.

The largest and richest elluvial concentrations appear to be in the Sweetwater Basin, a short distance east of the edge of the map area (pl. 2) and north of the Sweetwater Road. These placers have been developed on pre-Cherry Creek rocks, and the deep-red garnets (almandite) average about a quarter of an inch in diameter.

GRAPHITE

The chief graphite deposit of the area is at the Crystal graphite mine in the NW¼ NE¼ sec. 31, T. 8 S., R. 7 W. (pl. 5, E). The deposit has been described by Winchell (1910, 1911, 1914), Bastin

(1912), Hum (1943), Armstrong and Full (1946, 1950), Perry (1948), Heinrich (1949A, 1949B), and Ford (1954). The graphite occurs chiefly as

1. Veins cutting micaceous gneisses and schists and pegmatites;
2. Disseminated flakes in gneisses.

The mineralized zone extends S. 45° - 65° W. and dips 60° - 85° NW. from the nose of a prominent marble layer which plunges northwest at 40° to 45°. The zone is 100 to 125 feet wide. The deposit was discovered in 1899 and mined intermittently between 1902 and 1920. Exploration was resumed in 1943 and in 1944 a small flotation mill was built below the mine opening. About 150 tons of concentrate were produced during the last operation. The mine has been idle since the mid-1940's.

Opinions differ considerably on the origin of the deposit. Since the writer's speculations (Heinrich, 1949B) have appeared, Ford (1954) has concluded that

1. None of the graphite is genetically related to the development of any of the pegmatites.
2. That the mineralization is epithermal in character.

That the bulk of the graphite is post-pegmatite was earlier maintained by the writer (Heinrich, 1949B), but it is likewise clear that a small amount of graphite was introduced in late stage quartz-albite-muscovite veinlets cutting previously crystallized pegmatite (Heinrich, 1949B, p. 328, figs. 8a, 8b). Such veinlets are not identical with " . . . quartz-albite material forming the walls of fractures", described by Ford (1954, p. 41). There remain therefore two possibilities:

1. That graphite was formed in two totally unrelated periods—a) a late pegmatitic stage in which graphite appears as a minor accessory, and—b) a later hydrothermal stage during which the graphite veins and the disseminations were developed;
2. That the two occurrences are genetically related and the main graphite mineralization is an extension of the process begun in late pegmatitic time.

The writer favors the latter. The designation of the deposits as epithermal is perilous, and Ford (1954) does it solely on the presence of comb structure, rosettes, and vugs. Actually vugs are not common at all, and "slip fibers" or random orientations also are common. The absence of a diagnostic gangue assemblage further complicates the designation of a specific intensity category.

PEGMATITE MINERALS

A number of pegmatites in the Ruby Mountains contain feldspar (microcline) and mica (muscovite) in small amounts (Heinrich, 1949A, 1949B). These are well-zoned pegmatites that are unmetamorphosed. Good examples of relatively large dikes that contain zones rich in block microcline are the Stone Creek and Keystone pegmatites (Heinrich, 1949B., p. 322, fig. 6, and p. 327, fig. 7). Limited amounts of high-quality potash feldspar could be produced from these and other similar deposits under favorable economic conditions.

Small books of muscovite occur scattered through a number of pegmatites on the southwest side of the range, in and near Proffitt Gulch. Some pegmatite zones contain as much as 3 to 4 percent mica, but books are generally small, ½ to 3 inches.

Rose quartz occurs in the Keystone pegmatite and also in several small dikes near the Timber Gulch talc mine.

SILLIMANITE

Occurrences of sillimanite are widespread in the area and some are of potential economic significance (Heinrich, 1948, 1950A; Bracken, 1949). Sillimanite is common as a constituent of granitized biotitic schists, some of which are garnetiferous. In some rocks the sillimanite occurs as disseminated needles, in others in sillimanite-quartz pods of varying size (pl. 4, D). Locally sillimanite also forms a nearly nonmineralic rock that occurs as pods and lenses up to several feet long in biotitic sillimanite gneiss along pegmatite contacts.

The most significant occurrences are:

1. In Proffitt Gulch and in its neighboring gulch to the south;
2. The Christensen deposit on the northeast side of Carter Creek;
3. Extending south from the Stone Creek forks.

The Christensen deposit, one of the most uniform, is estimated to average at least 5 percent sillimanite for 20 million tons of ore.

TALC

The talc deposits of the area have been described by Perry (1948). All occur in marble as replacement masses, in some places in the central parts of marble layers, in other places along contacts between marble and other rock bands. Most of the larger masses are pod-like or lensoid in plan. In most deposits talc is the only essential mineral present; most of it is cryptocrystalline and massive; some of it is in broad blades as long as three inches, pseudomorphous after tremolite. Other minerals found in the lenses in usually minor amounts include pods of massive milky quartz, rare milky quartz crystals, coarse grains of carbonate, films and books of chlorite as much as two inches in diameter, blades and ragged relicts of tremolite, disseminated parallel flakes of graphite a quarter-inch or less across, and minute limonite cubes pseudomorphous after pyrite.

Most of the talc is light-green, dark-green, or greenish-gray in color, although yellow, buff, pink, blue, and even black varieties occur locally.

The chief deposits are:

1. The Smith-Dillon talc mine on Axes Creek, operated by the Tri-State Minerals Company of Los Angeles (pl. 5, F);
2. The Keystone talc mine on the Sweetwater Road, northeast side of Carter Creek;
3. The Crescent mine in Timber Gulch. (See Analysis below)

Of these only the Smith-Dillon mine has been a recent producer with sorted and washed talc trucked to Barretts (a railroad point south of Dillon) for shipment.

Following is an analysis of talc from the Crescent talc mine, Axes Canyon, Dillon, Montana:

SiO_2	61.26%
MgO	33.14
CaO	0.20
Al_2O_8	0.79
Fe_2O_3	0.11
Na_2O	0.03
Ignition loss	4.35

In addition to the above three largest deposits, the writer has found numerous other outcrops of talc-bearing marbles. These include:

1. About four occurrences between Proffitt and Timber gulches;
2. Two deposits on Hoffman Creek;
3. Several occurrences on Stone Creek, east of the area mapped.

SUMMARY OF MINERAL DEPOSITS

Talc and graphite have been produced in important amounts in the past from the area, but presently only talc is being mined. Iron probably will be mined in the near future. The area is unusually rich in sillimanite deposits which are of potential interest. Deposits of other metallic and non-metallic minerals are marginal to uneconomic under present conditions.

SNOWCREST AREA

Brasher (1950), Klepper (1950), and the writer have studied the pre-Beltian block along the northwest flank of the Snowcrest Range in the upper reaches of the East Fork of Blacktail Creek (fig. 8). The area is Y-shaped, the eastern arm of which has been thrust onto Paleozoic rocks, the Quadrant formation, and Madison limestone. On the north, lower Paleozoic sediments are faulted against the eastern arm and unconformably overlie the western; Tertiary sediments overlap on the west; and at the base of the stem of the Y pre-Beltian rocks have been faulted against Paleozoic rocks.

Meta-sediments belonging to the Cherry Creek group crop out on the ridge just northwest of Indian Creek, but most of the rest of the area is underlain by reddish biotite-poor granitic gneisses that perhaps are related to the Dillon granite gneiss. The foliation and the layering in the Cherry Creek rocks strike North to N. 30° W. and dip steeply west or southwest.

In one place on the ridge a section from southwest to northwest consists of:

8. Dillon granitic gneiss
7. Anthophyllite amphibolite and hornblende gneiss ..... 5 feet
6. Partly covered, alternating layers of biotite schist and gneiss and hornblende gneiss, much pegmatite ..... 100 ± feet
5. Garnet-biotite gneiss ..... 6 feet
4. Hornblende gneiss ..... 15 feet
3. Sillimanite-biotite gneiss ..... 6 feet
2. Marble ..... 30 feet
1. Dillon (?) granitic gneiss

This block may represent a roof pendant or xenolith of Cherry Creek rocks in the Dillon (?) granite gneiss, for it appears to be completely surrounded by the gneiss.

To the north of the East Fork the foliation of the gneisses strikes generally to the northeast and dips northwestward.

The marble is light brown and irregular grained. Under the microscope much fine-grained chlorite appears as well as coarser scattered flakes of pennine. Some parts of the marble layer contain abundant tremolite in coarse pencil-like blades as much as 7 inches long, in parallel orientation.

The red-brown anthophyllite rock shows considerable variation in size of the amphibole crystals, some attaining a length of 3 inches; many blades measure 1 by ½ inch. The anthophyllite occurs in rosettes and unoriented blades with subordinate interstitial chalky feldspar. Here and there are patches of coarse-grained garnet-quartz-anthophyllite rock. Veinlets of fine-grained green chlorite cut the amphibole. The anthophyllite amphibolite is a subordinate phase of a thicker and more extensive layer of hornblende gneiss. The intrusion of a 6-foot pegmatite dike, containing quartz, microcline, plagioclase, garnet, and green sericite, apparently resulted in reaction with the hornblende gneiss and crystallization of the coarse non-foliated anthophyllite rock.

The red-brown Dillon (?) granite gneiss shows considerable variation in texture; some types are strongly gneissic, even with thin biotitic layers; others are essentialy granitoid, with only slight foliation. The grain size is fine to medium, but locally quartz-microcline pegmatite dikes are common, as are small rusty quartz veins, some of

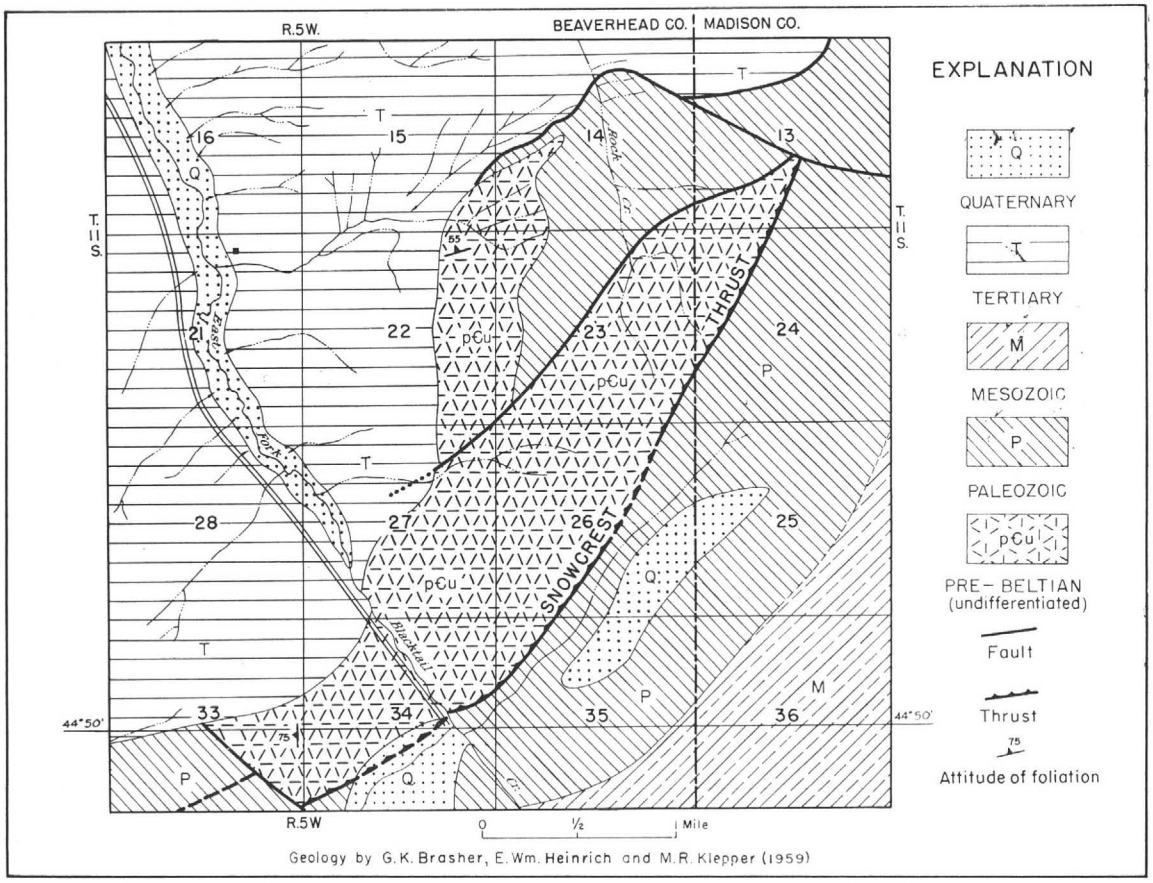


FIGURE 8.—Geologic map of the Snowcrest pre-Beltian area, Beaverhead County, Montana.

which have been prospected. The rock contains abundant microcline with characteristic quartz rims, oligoclase with thin, more sodic borders, elongate augen of coarse-grained quartz, and variable amounts of biotite in small thin flakes, largely altered to muscovite plus magnetite.

JAKE CREEK AREA

The Jake Creek area, in the southeastern half of the Blacktail Range in Beaverhead County, covers 45 square miles, extending from north of Ashbaugh Canyon to Prices Canyon along the southwest side of Blacktail Deer Creek (fig. 9). It has been mapped by Keenmon (1950); Keenmon and others, (1951), Scholten and others (1955), Bull (1949), Klepper (1950), and the writer. Brief mention of the peridotite body is made by Sinkler (1942). Part of teh area also has been mapped by J. M. Zeigler*.

The block is bounded on the northeast by the Blacktail fault along the front of the range, on the southeast, south, and west by Tertiary sediments and volcanics, and on the northwest by sediments of Paleozoic age.

Jake Creek occupies a prominent canyon that cuts northeastward across the area about two-thirds of the way from its southern margin. Exposures are generally good within this and other parallel canyons but are poor on top of the range, which is a gently undulating plateau-like upland capped locally by thin sheets of Tertiary sediments and the remnants of Tertiary volcanic flows.

GENERAL GEOLOGY

Three main rock units can be distinguished: A group of strongly foliated and folded gray to dark gneisses of various compositions which underlie the southeastern two-thirds of the block; a well to poorly foliated red granitic gneiss in the northwestern third of the area; and a sill of peridotite that crops out along the northwest side of Jake Creek canyon (fig. 9).

Because of the general similarities in lithology and because of their position with respect to the rocks directly across the valley in the Ruby Range, the southern gneiss group may be correlated with rocks in the Ruby Range that have been tentatively assigned to the Pre-Cherry Creek group.

The red granitic gneiss in the northern third of the range has petrologic characteristics that relate it to the Dillon granite gneiss, the type local-

* Personal communication

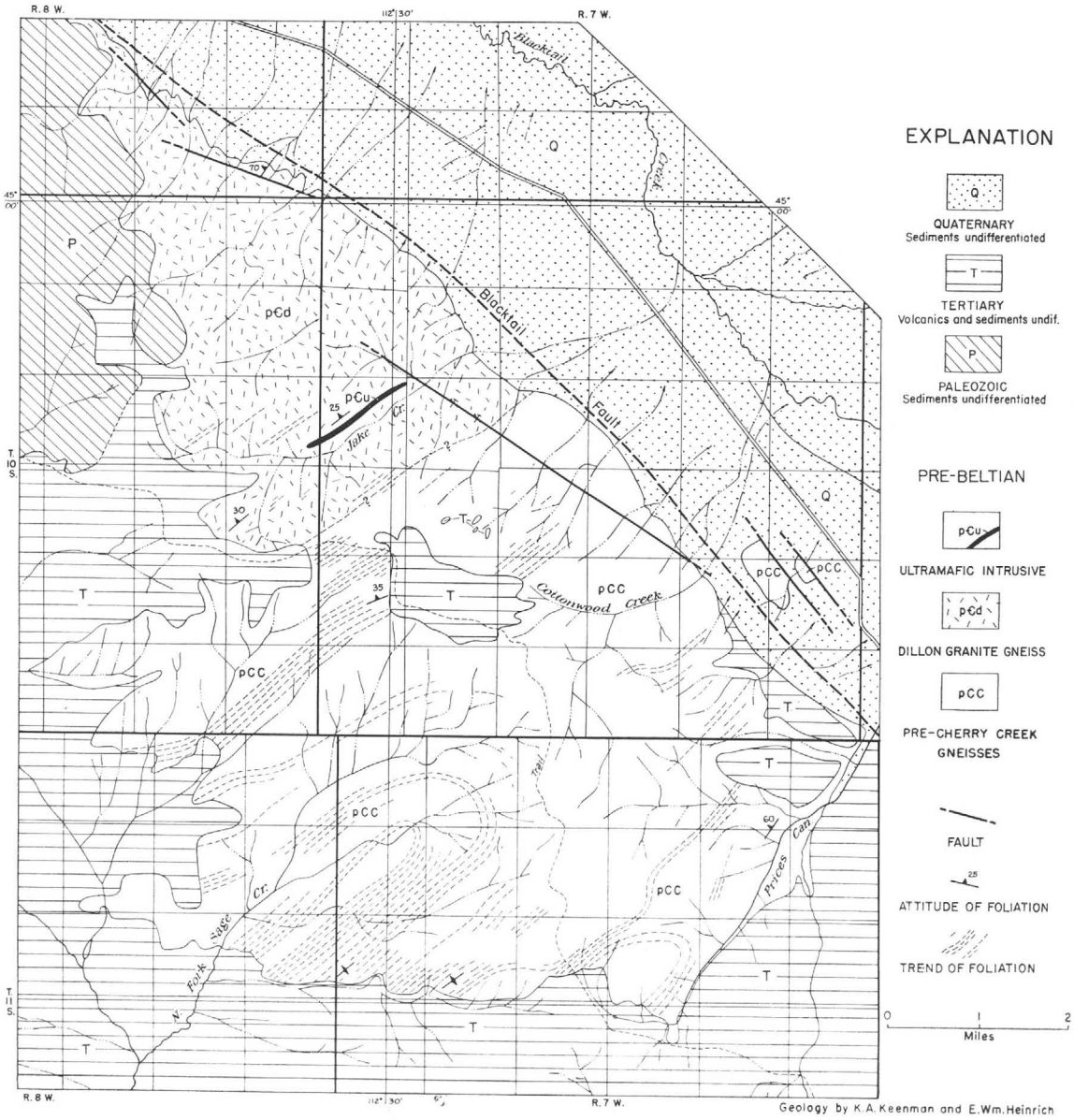


FIGURE 9.—Geologic map of the Jake Creek pre-Beltian area, Beaverhead County, Montana.

ity of which lies across the valley. The Jake Creek ultramafic intrusive shows mineralogical and petrographical similarities to the Wolf Creek ultramafic pluton, also across Blacktail Creek valley to the northeast.

The foliation of both the pre-Cherry Creek and Dillon rocks strikes between N. 75° E. to N. 5° E., averaging about N. 45° E., and dips generally to the northwest or is vertical. Local departures and reversals from this general attitude are very common. The pre-Cherry Creek gneisses have been isoclinally folded on a large scale, a feature also characteristic of similar rocks in the Ruby Range.

Several large faults, nearly parallel with the main Blacktail fault, cut the pre-Beltian rocks at nearly right angles to their foliation along the front of the range. Klepper (1950) also shows a fault separating pre-Beltian rocks from the Paleozoic sediments on the north.

THE PRE-CHERRY CREEK GROUP

Included in this group are biotite gneisses; quartz-feldspar (aplitic) gneisses, some containing garnet; augen gneisses; hornblende gneisses; and amphibolites. Light-colored types predominate, and the dark hornblende-rich varieties occur as scattered isolated layers. Fine-grained light-colored (aplitic) gneisses are common, containing chiefly quartz and orthoclase. The quartz is in elongate grains or aggregates. Sodic plagioclase is subordinate; zircon is accessory.

The hornblende gneisses and amphibolites range from rocks containing abundant hornblende with both plagioclase and quartz to some quartz-free types and to others in which very coarse blades of amphibole form the only important constituent. Associated with these rocks are small irregularly-shaped pods of pegmatite that consist of white to light grayish-green plagioclase in blocky crystals in a vuggy aggregate with prisms of dark-green hornblende two inches or less in cross section. The hornblende gneisses contain from 15 to 25 percent olive-green hornblende, andsine, subordinate quartz, pale-green augite, and accessory magnetite, apatite, and zircon. Most are banded.

The layers have been injected lit-par-lit by sills, lenses, and stringers of granitic material of Dillon granite gneiss, particularly in the vicinity of Jake Creek.

DILLON GRANITE GNEISS

The Dillon granite gneiss in the northern part of the area is a complex of reddish granite gneisses with variable amounts of meta-aplite, metapegmatite, and migmatite. Rounded slopes covered by a thin reddish sandy regolith form the characteristic surface expression. The typical rock is well foliated but not banded, red-brown in color, poor in mafic minerals, and fine to medium grained. Some specimens show biotite in sparsely scattered parallel flakes or streaks; a few contain red-brown garnets, an eighth of an inch in diameter. Microscopically the gneiss is seen to consist of microcline, quartz, oligoclase, uncommon biotite, and zircon, magnetite, garnet, and apatite as accessory minerals. Microcline, the most abundant mineral, is usually somewhat perthitic, may contain scattered rounded blebs of quartz, and may be bordered by thin rims of quartz, particularly at grain boundaries between microcline grains. The plagioclase commonly is zoned with very narrow sodic rims. The core may be selectively kaolinized. Some sodic plagioclase rims on microcline were noted by Keenmon (1950). Some quartz is included myrmekitically. Most of the quartz occurs in lenticles of relatively coarse grains; smaller grains are intergrown with the feldspars. Garnet is generally rounded. Biotite usually is replaced by chlorite-magnetite aggregates. Flakes of secondary muscovite are not uncommon.

Northeast of Lima, in sec. 20, T. 13 S., R. 7 W., both Klepper (1950) and Keenmon (1950) mapped a small body of granite in contact with Madison limestone on the east and covered by Tertiary sediments on the west. This rock, which shows no foliation under the microscope, contains quartz, sodic plagioclase, orthoclase, and minor chlorite. The quartz is anhedral, showing some strain. The subhedral moderately sericitized plagioclase is cut by thin quartz veinlets and is at least as abundant as the anhedral orthoclase. The rock does not appear to belong to the Dillon granite gneiss and may well be an intrusive of Laramide age related to the other similar granodiorite rocks in southwestern Montana.

The contact between the Dillon granite gneiss and gneisses of the pre-Cherry Creek group is diagrammatically shown in figure 9 as being on the crest of the divide south of Jake Creek. Actually a wide contact zone of injection gneiss and migmatite occurs. This is well exposed along Jake Creek, and the contact is exceedingly irregular in detail.

PERIDOTITE

The Jake Creek ultramafic body has been mentioned by Sinkler (1942). It extends diagonally northeastward across sec. 18, T. 10 S., R. 7 W., and is poorly exposed along the north wall of Jake Creek near its fork. Locally it may be as thick as 100 feet, but generally it is about 50 feet thick. It appears to strike parallel with the foliation of the injection gneisses, but it may lie nearly horizontal and thus be sheet-like in form and attitude.

Most of the body has been at least somewhat serpentinized and consists of fine-grained variegated green-white serpentinite. The unaltered rock contains mainly augite with abundant magnetite and olive-colored picotite. Some varieties seem to have contained olivine, judging from the shape of some talc pseudomorphs. Microscopically nearly all varieties show marked alteration, either to serpentine, which may be cut by one-inch cross-fiber veins of anthophyllite, or to aggregates of talc, serpentine, chlorite, phlogopite, tremolite, magnetite, and traces of pale-brown hornblende. Accessory calcic plagioclase is present in some varieties of the peridotite.

MINERAL DEPOSITS

The Jake Creek ultramafic sill is reported to contain as much as 2 percent nickel and traces of platinum locally (Sinkler, 1942, p. 137), but neither primary nor secondary nickel minerals have been discovered.

Copper minerals, chiefly chalcopyrite, malachite, and chrysocolla, occur sparsely in at least two very large massive quartz lenses that have been formed along a major fault zone that nearly parallels the range front fault of post-Laramide age (fig. 9).

GLOSSARY

Bohn striations—fine lamellae, lines, or bands in quartz marked by dusty inclusions.

Boudinage—a structure term describing the effect when beds in a yielding matrix are pulled apart into pillow-like segments so that in section, the structure resembles a string of sausages.

Clastic—a textural term applied to rocks composed of fragmental material derived from pre-existing rocks.

Cataclastic—a texture in metamorphic rocks in which brittle minerals have been broken and flattened in a direction at right angles to the pressure.

Cryptocrystalline—crystalline, but so fine-grained that the individual grains cannot be seen with a magnifying lens.

Endomorphic—the change produced in an igneous rock due to the partial or complete assimilation of portions of the rocks invaded by its magma. It is a contact metamorphic effect within the intrusive itself. See also exomorphic.

Euhedral—in well-shaped crystals.

Exomorphic—a term describing contact metamorphism and refers to changes in the intruded rock, as contrasted to endomorphic which refers to changes in the inrtusive rock.

Foliation—the laminated structure resulting from segregation of different minerals into layers parellel to the schistocity.

Flaser structure—a structure developed in certain rocks by dynamic metamorphism. Small lenses of granular material are separated by wavy ribbons and streaks of finely crystalline foliated material, usually aggregates of parallel scales in wavy or bent lines.

Glomeroporphyritic—a term applied to igneous rocks in which the phenocrysts are gathered into distinct clusters or clots.

Isocline—an anticline or syncline so closely folded that the rock beds of the two sides or limbs have the same dip.

Monomineralic—composed of only one mineral, or nearly so.

Meta—a prefix meaning change.

Mode—the actual mineral composition of an unaltered igneous rock.

Metamorphism—any change in a rock due to heat or pressure or both. Moisture may also be included as an agency causing change, if the processes of weathering are excluded, i.e., changes due to water under heat or pressure may be classed as metamorphism.

Mafic—composed of dominantly the magnesian rock-forming minerals. In general synonymous with "dark minerals."

Ophitic—a term applied to a texture characteristic of diabases in which euhedral or subhedral crystals of plagioclase are embedded in a matrix of pyroxene.

Poikiloblastic—a metamorphic texture due to development, during recrystallization, of a new mineral around numerous relics of the original minerals.

Porphyroblastic—texture of a recrystallized rock in which coarse grains, often euhedral or subhedral, are distributed in a finer ground mass.

Ptygmatic—refers to folds, especially of granitic and pegmatitic veins; often the folding is considered related to the processes that formed the veins.

Pluton—a body of igneous rocks that has formed beneath the surface of the earth by consolidation of a magma.

Regolith—a layer or mantle of loose, incoherent rock material overlying the hard bedrock.

Subhedral—crystals not as well-formed as with euhedral

Symplectite—a rock with a vermicular texture produced by the intergrowth of two different minerals.

Ultramafic—a very basic (dark-colored) igneous rock that contains less than 45 percent silica as silicates, and no quartz.

Xenolith—an inclusion of foreign rock in an igneous body.

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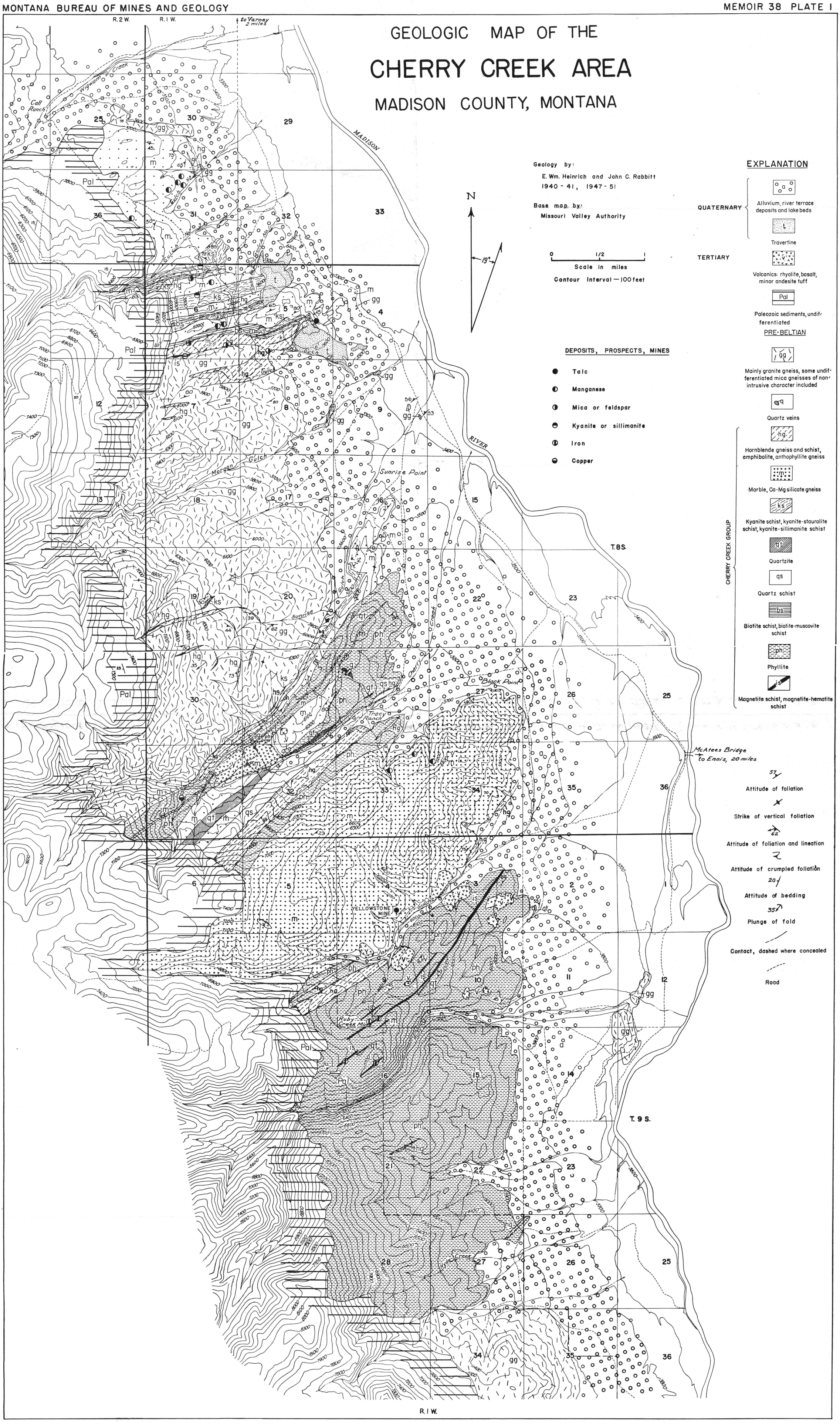
GEOLOGIC MAP OF THE
CHERRY CREEK AREA
MADISON COUNTY, MONTANA
Geology by:
E. Wm. Heinrich and John C. Rabbitt
1940 - 41, 1947 - 51
Base map by:
Missouri Valley Authority
0 1/2 1
Scale in miles
Contour Interval — 100 feet
N
19°
EXPLANATION
QUATERNARY
Alluvium, river terrace deposits and lake beds
Travertine
TERTIARY
Volcanics: rhyolite, basalt, minor andesite tuff
Pal
Paleozoic sediments, undifferentiated
PRE-BELTIAN
CHERRY CREEK GROUP
Mainly granite gneiss, some undifferentiated mica gneisses of non-intrusive character included
Quartz veins
Hornblende gneiss and schist, amphibolite, anthophyllite gneiss
Marble, Ca-Mg silicate gneiss
Kyanite schist, kyanite-staurolite schist, kyanite-sillimanite schist
Quartzite
Quartz schist
Biotite schist, biotite-muscovite schist
Phyllite
Magnetite schist, magnetite-hematite schist
DEPOSITS, PROSPECTS, MINES
Talc
Manganese
Mica or feldspar
Kyanite or sillimanite
Iron
Copper
Attitude of foliation
Strike of vertical foliation
Attitude of foliation and lineation
Attitude of crumpled foliation
Attitude of bedding
Plunge of fold
Contact, dashed where concealed
Road
MADISON RIVER
Wigwam Creek
Call Ranch
to Varney 2 miles
Sunrise Point
Black Point
Tracy Ranch
McAtees Bridge to Ennis, 20 miles
YELLOWSTONE MINE
Ruby Creek Mine
T. 8 S.
T. 9 S.
R. 2 W.
R. 1 W.

GEOLOGIC MAP OF THE SOUTHWESTERN PART OF THE RUBY MOUNTAINS

BEAVERHEAD AND MADISON COUNTIES, MONTANA

Geology by E. Wm. Heinrich - 1948, 1949, 1951

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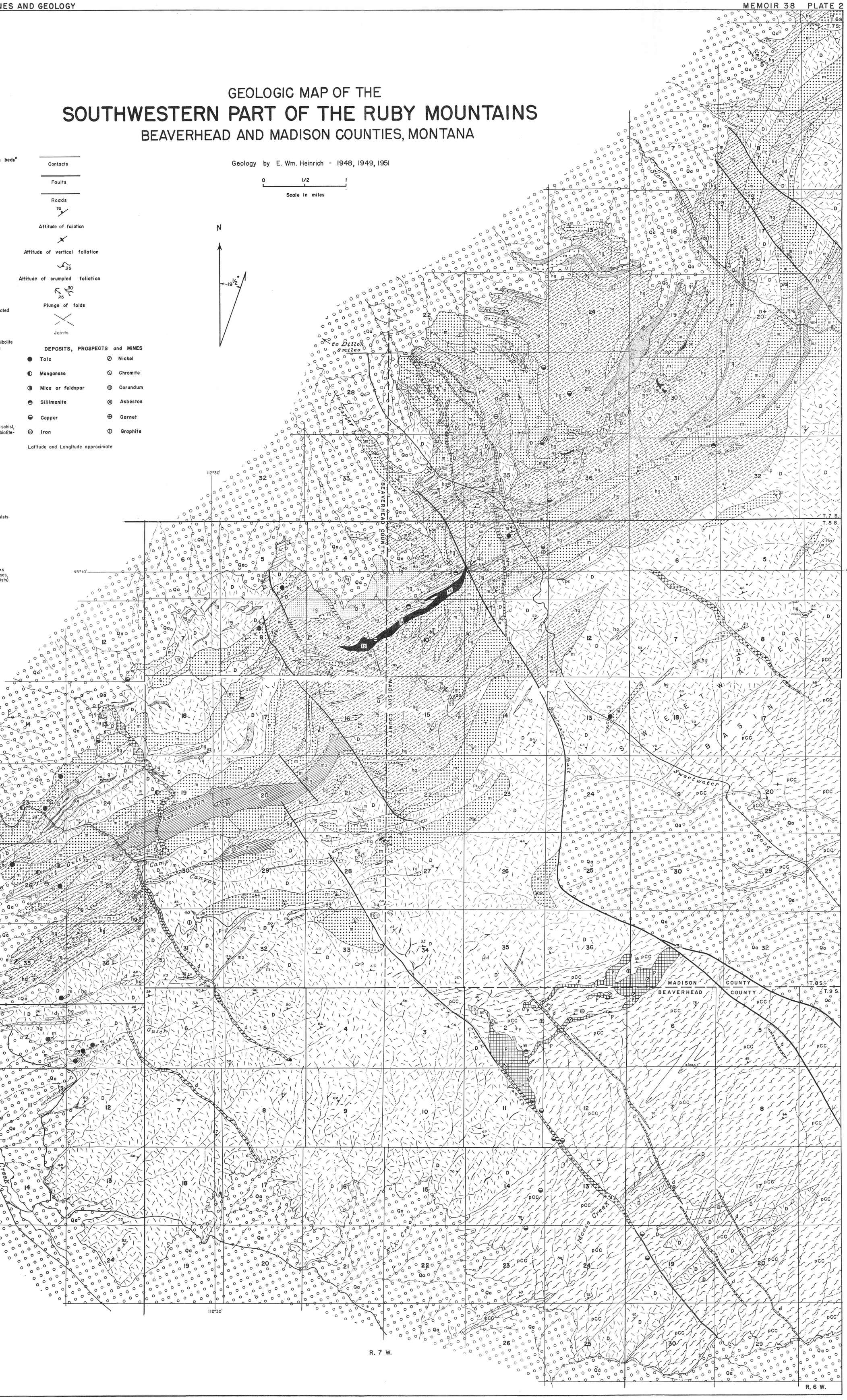
Scale in miles

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