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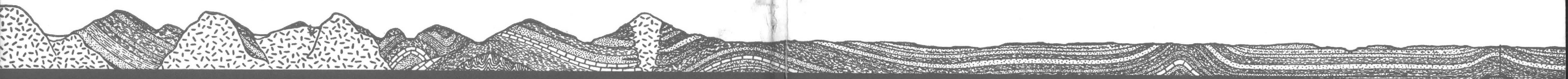
STATE OF MONTANA
J. Hugo Aronson, *Governor*
BUREAU OF MINES AND GEOLOGY
E. G. Koch, *Director*

MEMOIR 36
October 1957

BEDROCK GEOLOGY OF THE NORTH END OF THE TOBACCO ROOT MOUNTAINS MADISON COUNTY, MONTANA

By

ROLLAND R. REID



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Butte, Montana

ILLUSTRATIONS

GENERAL VIEW OF THE TOPOGRAPHY OF THE TOBACCO ROOT MOUNTAINS
Low-angle oblique aerial photograph, looking west.

CONTENTS

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BUREAU OF MINES AND GEOLOGY
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MEMOIR NO. 36

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FOREWORD

This report on the Tobacco Root Mountains is another forward step in the program of the Montana Bureau of Mines and Geology to map the geology and ore deposits of the state. It is largely concerned with the general geology of the area studied and deals only in a general way with ore deposits. Work on ore deposits in the Tobacco Roots is still in progress and will be described in subsequent publications. Only broad structural control for ore deposition is described herein. When the detailed study of the individual districts is completed, valuable guides for prospecting should be forthcoming.

In addition, this paper contributes to a more complete understanding of early geologic history of this region. The author has described evidence for two periods of metamorphism in pre-Beltian time, both of which have affected Cherry Creek and Pony gneisses.

Of especial interest is the discovery of hitherto undescribed deposits of magnetite, talc, graphite, vermiculite, and sillimanite in the pre-Beltian metamorphics of the Tobacco Root Mountains. Prospectors in coming years will do well to examine the metamorphics closely for such deposits. As our industrial appetite for such minerals continues to grow, the deposits in the Tobacco Roots may ultimately become economic.

Prospectors and mine operators will be particularly interested in the section entitled "Suggestions for prospecting." For these suggestions to be of most value, however, the basic geology of the area should be studied first.

E. G. KOCH,
Director

than the correct geologic name for the rock being described (diopside-garnet ortho-amphibolite). Tansley and Schafer recognized the metabasalt sills and described their structure briefly. (1933, p. 9)

Metabasalt sills and dikes occur scattered more or less randomly through both the Pony and the Cherry Creek. They are particularly abundant near the base of the Pony metamorphics. A few of the more prominent ones are shown on the geologic map (Plate 1). Most of them were considered too small to put on the map and too much time would have been required to trace out each of them.

Metabasalt sills occur as tabular bodies ranging from a few feet to a maximum of about 150 feet thick. They are parallel or nearly parallel to the foliation in the enclosing gneiss, locally cutting it at angles of 1° to 10° (pl. 4, A). In outcrop the rock is brown in color and has a much finer grain size than the enclosing gneiss or amphibolite. Foliation is moderately strong and parellel to foliation in the enclosing gneiss. The foliation appears to be caused by the presence of elongate lenticular grains or grain-clots of plagioclase. In outcrop, then, the rock has a very fine flaser structure. Flaser structure consist of tiny lenticular feldspar grains oriented parallel to foliation. Locally, xeonliths of gneiss or amphibolite are present within the sills. In some places the sills have been stretched and form large elongate boudin-like structures (pl. 4, B). Metabasalt dikes have the same appearance as the sills except that they strongly crosscut the foliation in the enclosing rock. Foliation within the dikes is parallel to the foliation in the enclosing rocks.

It is important to recognize the structural differences between the meta-basalts (fine-grained amphibolites) described in the previous paragraph and the main amphibolites of the Pony and Cherry Creek (those interlayered with the gneisses and other rocks). Metabasalt sills are locally discordant—partly parallel to and partly cutting across foliation in the enclosing rocks. The coarse-grained amphibolites and horblendites of Pony and Cherry Creek are, in contrast, completely concordant with the enclosing rocks. The author has nowhere observed one of these amphibolites to cut across foliation in the enclosing gneiss (or other rock).

The metabasalts in both Pony and Cherry Creek have identical mineralogy and texture. They are made up predominantly of hornblende and plagioclase andesine) with lesser amounts of diopside and garnet. Sphene and magnetite are the accessories generally present, although both may be entirely absent. Foliation is moderately strong, consisting largely of sub-parallel alignment of hornblende grains. As would be expected, the rock composition, based on the amount of each mineral present, is almost identical for each of the sills studied.

DISTINCTION BETWEEN PONY AND CHERRY CREEK METAMORPHICS

The principal rock types of both Pony and Cherry Creek appear to be leptite, gneiss, and amphibolite. In outcrop, in hand specimen, or under the microscope, Pony leptite, gneiss, or amphibolite exactly resemble Cherry Creek leptite, gneiss, or amphibolite—in texture, in structure, and in mineralogy.

Because many of the rock types in Pony and Cherry Creek are so alike, distinction between them may be difficult, if not impossible, in a particular outcrop. Distinction must rely upon the examination of a section 500 to 1,000 feet in thickness.

Gneiss, leptite, and amphibolite intermixed in layers of different thickness over a total section of 500 to 1,000 feet in thickness will probably belong to the Pony. Subordinate schist, thin quartzite layers (1 to 5 feet), serpentine, or anorthosite layers may be present. Locally, the examination of a still thicker section may be necessary.

The same three main rock types intermixed with layers of marble, thick greenish quartzite (5 to 50 feet), sillimanite schist (5 to 50 feet), anthophyllite schist (5 to 50 feet), or coarse garnet amphibolite will belong to the Cherry Creek. Heinrich (1950, p. 8, 9) emphasized that greenish quartzite and anthophyllite schists are characteristic of Cherry Creek.

It must be emphasized that the distinction between Pony and Cherry Creek depends not on peculiarities visible in every outcrop, but rather

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BEDROCK GEOLOGY OF THE NORTH END OF THE TOBACCO ROOT MOUNTAINS MADISON COUNTY, MONTANA

By

ROLAND R. REID

ABSTRACT

Cherry Creek and Pony metamorphic rocks in the Tobacco Roots have undergone the same sequence of metamorphic processes. After deposition of both Cherry Creek and Pony sediments (with accompanying subordinate amounts of igneous rocks?) a period of high temperature metamorphism (accompanied by introduction of sodium and potassium?) ensued. Structurally, the rocks were deformed into a series of recumbent (?) isoclinal folds with axial plane foliation. Pegmatites formed in at least some of the major fold crests. This was followed by a time in which basalt sills and dikes were injected into both Pony and Cherry Creek rocks. Still later came a period of metamorphism in which the flat-lying (?) foliation was warped into north-plunging open anticlines and synclines. Cherry Creek plunges beneath Pony in these folds in the Tobacco Roots. In this period, the basalt sills and dikes acquired a foliation parallel to the foliation of the enclosing gneisses and were converted to diopside-garnet orthoamphibolites. Still in pre-Beltian, pegmatites formed which cut the meta-basalts. Following this came the development, probably in Precambrian, of northwest faults with vertical displacements of several thousand feet. Horizontal displacement is not known, but may be of the same order of magnitude. These faults were reactivated in Laramide, with reversal of direction of movement from Precambrian occurring along some of them. Northeast faults of Laramide (?) age are present, but of small size.

The emplacement of the Tobacco Root batholith was controlled by the northwest faults. Post-batholith ore deposition appears to have been most strongly controlled by the northwest faults and less strongly controlled by the northeast fault.

Deposits of magnetite, talc, sillimanite, graphite, and vermiculite occur in the metamorphics.

INTRODUCTION

PURPOSE

This report represents a step in a project by the Montana Bureau of Mines and Geology to study the general geology and ore deposits in the Tobacco Root Mountains. It is felt that such a study may point the way to further exploration and may aid in the finding of new ore deposits.

The geology of the region is emphasized in this paper. Work on the ore deposits is still in progress. It is hoped that this report will aid those engaged in prospecting or mining in recognition of the major rock types and structures present as well as in the understanding of their significance.

GEOGRAPHY

TOPOGRAPHY

The area mapped, approximately 150 square miles, lies in the north end of the Tobacco Root Mountains (fig. 1). Relief in the area is slightly more than a mile, from approximately 5,400 feet in the north end of the area to approximately 10,700 feet at Mt. Jefferson.

The mountains have undergone rather strong glaciation in their higher parts, although none of the glaciers appear to have extended beyond the range margins. Indeed, most of them terminated well within the range.

Morainal deposits are rather abundant; some of the larger deposits are shown on the geologic map. Moraines obscured by heavy tree cover and moraines of smaller size were not mapped.

Timber cover is largely restricted to the north slopes, between the elevations of 5,500 feet and 9,500 feet.

TRANSPORTATION AND ACCESSIBILITY

Forest Service roads are present in most of the valleys in the range. The area is accessible through Harrison and Pony on the east; Whitehall, Cardwell, and Jefferson Island on the north; and, Twin Bridges, Silver Star, and Sheridan on the west. The Milwaukee and Northern Pacific railroads pass through Whitehall. Spur lines of the Northern Pacific railroad pass through both Twin Bridges and Harrison.

CLIMATE

Snow generally hampers access to the higher parts of the range from November until late June. During July, August, and September, the area is largely free of snow, although snow may fall in the higher parts of the range at any time of the year. Snow generally does not fall in sufficient amounts in October to interfere seriously with mining operations.

Tansley and Schafer (1933, p. 3) give figures of 12.67 inches (1930) for precipitation, and 90° F. and -30° F. for maximum summer and minimum winter temperatures.

WORKING CONDITIONS

This report is based on geologic mapping done in July and August of 1954, 1955, and 1956. Geology east of the 112th Meridian was mapped on enlarged aerial photographs and plotted on a base map made from preliminary sheets of the Harrison Quadrangle (U. S. Geological Survey) at a scale of 1:24,000.

The mapping area was extended west of the 112th Meridian midway in the summer of 1955. The only base readily obtainable for mapping (aerial photographs were not then available for that area) was an enlargement from the U. S. Forest Service map of the Beaverhead and Deer Lodge National Forests. Consequently, the map of the area west of the 112th Meridian must be regarded as a geologic sketch map, in no way comparable in accuracy of location and in detail to the map of the area east of the 112th Meridian.

In the laboratory, more than 420 thin sections of rocks were examined under the microscope.

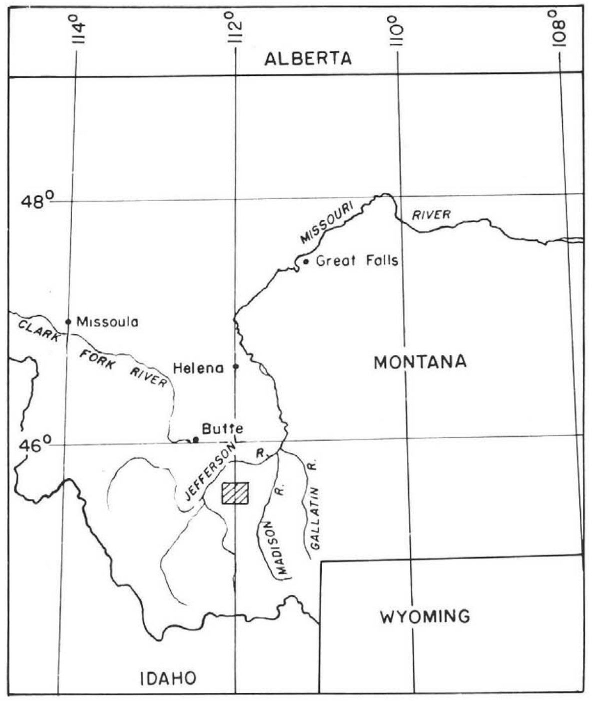


Figure 1.—Index map showing location of area mapped.

PREVIOUS WORK

Hayden (1872) did the earliest reconnaissance geology in this region. Peal (1896) made a reconnaissance study of the Three Forks Quadrangle, a small part of which is included within the area covered by the present report. Winchell (1914) briefly described the general geology in the several mining districts of the Dillon Quadrangle. Tansley, Schafer, and Hart (1933) studied the general geology and ore deposits of the Tobacco Root Mountains. Berry (1943) studied the stratigraphy and structure in the vicinity of Three Forks, Montana; the southwest corner of his map overlaps the northeast corner of the area covered by the present report.

ACKNOWLEDGMENTS

The write is grateful to J. R. Van Pelt, Director, during this study, and to W. S. March, Jr., Associate Director of the Montana Bureau of Mines and Geology, for helpful counsel given during the course of the field work. The writer was ably assisted in the field in successive summers by Ted Eyde, Marvin Lanphere, and Frank Koucky. Clem Bartzen of the Montana Bureau of Mines and Geology performed the assays. Frank Koucky, Bahngrell W. Brown, and Uuno Sahinen read the manuscript critically and made several valuable suggestions.

fifteen feet thick and about forty feet long were observed in a thick quartzite layer near Noble Lake. The different rock types are intermixed in thick to thin layers in the Cherry Creek metamorphics, just as in the Pony.

All the major rock types that occur in the Pony metamorphics also occur in the Cherry Creek: in addition, marble, sillimanite schist, anthophyllite schist, and coarse garnet amphibolite are present. Quartzite is far more abundant in the Cherry Creek than in the Pony. Leptite, amphibolite, and gneiss of the Cherry Creek are indistinguishable in hand specimen and in the microscope from their counterparts in the Pony. Individual layers seem to be about as continuous as layers in the Pony.

The marbles weather to a brownish color in outcrop. Quartzite generally weathers to a pale greenish color—when broken it is white to brownish-red. Anthophyllite schist, high in anthophyllite, weathers to a chocolate brown color. Coarse garnet amphibolite is a black rock with large reddish brown garnets generally half an inch to two inches in diameter (pl. 3, D).

Gneiss of the Cherry Creek is a prominently foliated rock in which quartz, plagioclase, and microcline are the main minerals. Lesser amounts of biotite or hornblende, or both, give the rock a gray to dark-gray color. The gneiss is, however, widely variable in composition. Epidote, actinolite, diopside, or garnet may be present in small amounts. Common accessory minerals include apatite, zircon, allanite, and magnetite.

Amphibolite consists predominantly of hornblende and plagioclase. However, small amounts of garnet, diopside, quartz, biotite, tremolite, or anthophyllite may be present. Accessories include rutile, apatite, sphene, and magnetite. Garnet in particular may exhibit strong chloritic alteration.

Leptite contains quartz, microcline, and plagioclase. It is strongly foliated, due largely to the elongation of quartz grains. Very small amounts of biotite, magnetite, hornblende, chlorite, or apatite may be present.

Quartzite is composed largely of quartz. Small amounts of sericite, chlorite, biotite, apatite, kyanite, garnet, anthophyllite, plagioclase, microcline, rutile, or hornblende may be present. All mineral gradations between leptite and quartzite appear to exist. Certain of the quartzites are rich in sillimanite.

In the foregoing rocks, the feldspars enclose the other minerals rather commonly and thus appear to be later.

Cherry Creek schists exhibit more mineralogic variation than any other rock type in the region. Quartz and mica are the predominant minerals, but lesser amounts of garnet, plagioclase, sillimanite, anthophyllite, graphite, kyanite, and microcline may occur. Zircon, magnetite, rutile, ilmenite, and apatite are the most common accessory minerals. Abundant sericite and chlorite occur in certain schists in which cataclastic deformation has occurred parallel to the existing foliation. Much of the biotite in these rocks is strongly rutilated.

Anthophyllite is so abundant in certain schists that it predominates over the other minerals. These schists then must be termed anthophyllite schists.

Ultrabasic rocks of the Cherry Creek include a variety of foliated rocks high in magnetite, hornblende, a rare colorless amphibole, talc, antigorite, or (locally) graphite.

Marble occurs in the Cherry Creek metamorphics within the map area only in the block of ground between the Bismark and Mammoth faults. It consists predominantly of calcite, and contains also diopside, tremolite, antigorite, or (locally) graphite.

As in the Pony metamorphics, feldspar shows a strong preferential distribution according to rock composition. Gneiss and leptite contain both microcline and sodic plagioclase (oligoclase) with microcline generally predominant. Certain gneisses may contain plagioclase, but no microcline. Amphibolites, on the other hand, contain predominantly more calcic plagioclase (andesine); microcline is very rarely present and then only in minor amount.

METABASALT SILLS AND DIKES

It must be made clear at the outset that the term "metabasalt" is used in a general sense. It is a less cumbersome term to use in writing plagioclase are predominant; less abundant are muscovite, biotite, or hornblende. Zircon is the most common accessory mineral.

Quartzite commonly contains significant amounts of plagioclase and microcline in addition to quartz. It is probably gradational into leptite. Sillimanite occurs locally in quartzite.

Mica schist is variable in composition; containing, in addition to quartz and biotite, small amounts of plagioclase, sillimanite, kyanite, hornblende, diopside, hypersthene, garnet, or cordierite. Common accessories are zircon, apatite, and magnetite. Chlorite and sericite may be abundantly present as alteration products in certain schists in which cataclastic deformation has occurred parallel to the existing foliation. Cataclastic deformation is a purely mechanical deformation in which the minerals are broken but not recrystallized.

The author has observed moderately strong cataclasis (result of cataclastic deformation) parallel to the foliation also in a specimen of gneiss collected in an area in the Bridger Range of Montana that has been described by McMannis (1956). This feature indicates low temperature deformation parallel to the existing foliation.

Hornblendite contains predominantly hornblende with lesser amounts of one or more of the following: diopside, quartz, plagioclase, pleonaste, olivine, enstatite, or garnet.

Serpentine, a soft black rock, contains magnetite, talc, antigorite, chlorite, tremolite, and diopside, all in widely variable amounts.

Anorthosite consists largely of plagioclase, although minor amounts of actinolite, hornblende, biotite, or chlorite may be present. The plagioclase of anorthosite ranges in composition from sodic (oligoclase) to calcic (bytownite). However, at any one place, the composition of the plagioclase in the anorthosite corresponds to the composition of the plagioclase in adjacent amphibolite. Anorthosite layers are less than three feet thick and appear to have rather short lateral extent. They are invariably interlayered with hornblendite or amphibolite.

Magnetite schist occurs in upper Dry Boulder Gulch. It is well exposed in the valley wall northeast of the upper lake. The layer is about 50 feet thick and has a strike length of about a mile. The rock is made up largely of magnetite, garnet, and pyroxene. Heinrich (1950, p. 8) observed similar rocks in the Ruby Range.

Worthy of emphasis is the strong preferential distribution of feldspar according to rock composition. The amphibolites have rather calcic plagioclase (andesine) as their principal feldspar. The gneisses and leptite, on the other hand, contain abundant microcline and sodic plagioclase (oligoclase); microcline is generally predominant. Certain gneisses contain only plagioclase feldspar; microcline is absent.

In all the feldspar-bearing rocks, the feldspars commonly enclose the other minerals. This may be taken to mean that the feldspars are later than the other minerals.

Thin section study reveals intermediate rock types transitional among all the main rock types described above. This serves to emphasize the variability of rock types present in the Pony metamorphics.

CHERRY CREEK METAMORPHICS

The Cherry Creek was first defined by Peale (1896, p. 2). His definition follows: "The Cherry Creek beds consists of a series of marbles, or crystalline limestones, and interlaminated mica schists, quartzites, and gneisses, well shown southwest of Madison Valley." Winchell (1914, p. 29) correlated the marble-bearing metamorphics of the Tobacco Roots with the Cherry Creek of Peale. "Schists, gneisses, and quartzites, with interbedded limestones, which are correlated with the Cherry Creek of Peale as described in the Three Forks folio, occupy the whole southern end of the Tobacco Root Mountains . . ."

Within the map area, the Cherry Creek metamorphics are confined to the southern and southwestern part, except for the area between the Bismark and Mammoth faults (plate 1). The rocks of the Cherry Creek range as widely in composition as those of the Pony, if not more so. As in the Pony, the single feature that all of the rocks have in common is that of strong planar foliation. Locally, the compositional layers are contorted in tight folds. Boudinage structure is not uncommon. Boudins of amphibolite

A.—CHARACTERISTIC PLANAR FOLIATION OF PONY METAMORPHICS

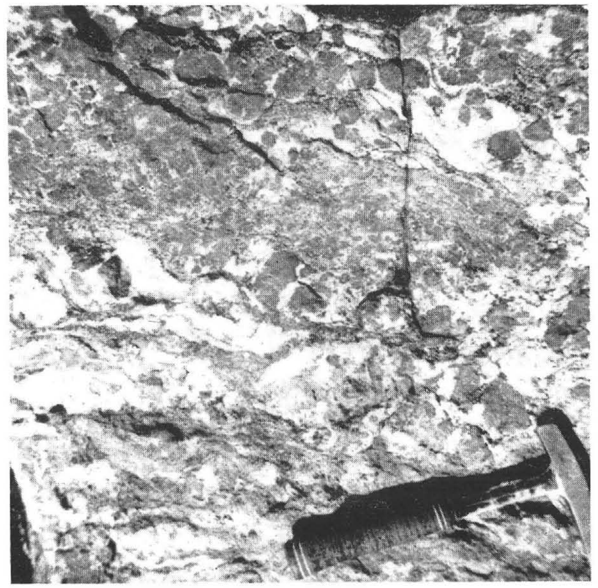
Picture taken looking along strike of alternating gneiss and amphibolite layers.

B.—MINOR FOLDING IN PONY METAMORPHICS

Alternating gneiss and amphibolite layers. Picture taken looking down the plunge of the fold.

C.—BOUDINAGE-LIKE STRUCTURE IN PONY GNEISS

Observe that foliation in the oval rock mass makes an angle with the foliation in the enclosing gneiss. Picture taken looking along strike. This may be a portion of a sheared-off fold crest.



D.—LARGE GARNETS (DARK SPOTS) IN AMPHIBOLITE OF THE UPPER CHERRY CREEK.

ROCK TYPES

GENERAL REMARKS

The area mapped in this study includes metamorphic rocks, igneous rocks and sedimentary rocks. Several varieties of each are present.

The metamorphics include rocks mapped as "Pony Series" and "Cherry Creek Series" by Tansley and Schafer (1933). The Tobacco Root batholith is the principal igneous rock body present. Most of the sedimentary rocks present are lower Paleozoic-Flathead sandstone of Cambrian age through the Madison limestone of Mississippian age. Tertiary basin deposits are present in the northwest part of the area.

METAMORPHIC ROCKS

PONY METAMORPHICS

The "Pony Series" was first defined by Tansley and Schafer (1933, p. 8); their definition follows: " . . . gneisses and schists . . . well exposed in the vicinity of Pony . . . will be called the Pony Series . . . " In this paper, the term "Pony metamorphics" will be used when referring to these rocks.

The Pony metamorphics are the most widespread rocks in the map area. They lie between the batholith on the south and the Paleozoic rocks on the north (plate 1) and are widespread in the west part of the area.

The rocks of the Pony metamorphics range widely in composition, from ultrabasic to acidic. The single feature that most of the rocks have in common is that of strong foliation. In most outcrops the foliation is planar. The term planar foliation as used here implies a tabular structure—compositional layers in the rock are relatively flat over distances of many feet (pl. 3, A). Less commonly, the compositional layers are contracted in tight folds (pl. 3, B). Flaky or rod-shaped minerals are aligned in parallel fashion.

In certain zones, boudinage structure is present. It consists of sausage-shaped or elongate lenticular masses formed by stretching of thin relatively brittle rock layers during folding. A similar-appearing structure may be formed by shearing-off of fold crests. The two may be difficult to distinguish, particularly if more or less rotation of the blocks has occurred (pl. 3, C).

The different rock types are intermixed in thick to thin layers; for example, dark-gray amphibolite and white quartz-feldspar schist (leptite) or gneiss may be intermixed in layers ranging from a fraction of an inch in thickness to several hundreds of feet in thickness. Most layers are continuous over considerable distances—those traced extend for distances of a few feet to distances of two miles.

The bulk of the Pony metamorphics is made up of biotite and hornblende gneiss and leptite; amphibolite, commonly present, is quantitatively subordinate. Locally thin layers of quartzite, hornblendite, anorthosite, mica schist, serpentine, or magnetite schist are present. Of these, anorthosite appears to occur in discontinuous lenses rather than in more continuous layers.

Hornblende gneiss is a dark gray rock; biotite gneiss has about the same color. Their distinction depends on recognition of the dark mineral present. Leptite is a white rock, free of dark mineral, in which quartz and feldspar are about equally abundant. Amphibolite is a gray-black rock high in plagioclase and hornblende. Hornblendite is black and is made up entirely of coarse hornblende. Serpentine is black, too, and can be distinguished from hornblendite by its softness; it can be scratched easily with a knife. Anorthosite strongly resembles quartzite—both are white and rather massive. Their distinction depends upon recognition of plagioclase (anorthosite) or quartz (quartzite). Mica schist is generally brownish to pale green and is rich in mica. All of these rocks are coarse-grained, with the single exception of serpentine.

Gneiss consists largely of quartz, microcline, and plagioclase with small amounts of biotite or hornblende or both. Locally, diopside or garnet may be present. Accessory minerals include zircon, magnetite, apatite, allanite, and sphene. Alteration products are generally chlorite, sericite, epidote, and clay minerals. Foliation is prominent (pl. 3, A).

Amphibolite consists mostly of hornblende and plagioclase; subordinate quartz, microcline, garnet, or diopside are not uncommon. Accessories include magnetite, apatite, and sphene.

Leptite may be regarded as gneiss virtually free of dark minerals. Quartz, microcline, and

and a lower "laminated limestone", after Peale. These units are now known respectively as the Mission Canyon member and the Lodgepole member. The Mission Canyon is a thick (600 feet) massive white-weathering limestone that stands up in massive cliffs. Freshly broken surfaces are gray to dark gray in color. The Lodgepole is thin-bedded or laminated limestone with shaly (?) partings and is also about 600 feet thick. It weathers to a gray color and is darker gray on fresh surfaces. It immediately underlies the Mission Canyon member.

The Sappington formation (60 feet) of yellow sandstone was included in the Three Forks formation in this mapping. It is considered to be Mississippian in age, but is lithologically similar to the Three Forks.

(2) The Three Forks formation (200 feet) of Devonian age underlies the Sappington. The Three Forks shale is a brownish-weathering rock made up of argillaceous limestone, black carbonaceous shale and greenish shales.

(3) The Jefferson formation of Devonian age underlies the Three Forks formation. The rock is dolomite, and it weathers to a dark grayish-brown color. It is approximately 450 feet thick and is distinguished by the odor of hydrogen sulfide upon freshly broken surfaces. Fresh surfaces are black to dark brown. Black chert concretions may be present.

Hanson (1952, p. 32) described the Cambrian section in South Boulder Creek, just north of the present map. The following units (listed from younger to older) described by him occur in the map area and were utilized as map units.

(4) The Maywood and Red Lion formations, of Devonian and Upper Cambrian ages respectively, were not differentiated in mapping. They underlie the Jefferson formation and are together approximately 60 feet thick. These two formations are composed of cream-colored dolomite, black and greenish shales, gray silstones, and gray, thin-bedded dolomite.

(5) The Pilgrim formation of Cambrian age underlies the Red Lion formation. It is about 360 feet thick and is composed predominantly of light-gray dolomite with more or less well-marked surface mottling in two shades of gray.

(6) The Park formation of Cambrian age underlies the Pilgrim formation. It is about 150 feet thick and is, in the map area, rather well exposed in part along the road at and near the Strawn mine. It is composed of green and black shales that weather to a brownish-gray color.

(7) The Meagher formation of Cambrian age underlies the Park shale. It is about 460 feet thick and is also well exposed in cuts along the road leading to the Strawn mine. Much of this formation is mottled in dark-gray to black matrix with small lenticular or irregular patches of tan to yellow—"black and gold marble" as it is commonly called. The upper part of the formation has mottling in two shades of gray, much like that in the Pilgrim formation.

(8) The Wolsey formation of Cambrian age underlies the Meagher limestone. It is about 240 feet thick and is composed largely of olive-colored shale with thin interbedded layers of brown shaly sandstone and flat-pebble limestone conglomerates.

(9) The Flathead formation of Cambrian age underlies the Wolsey shale and forms the bottom of the Cambrian sequence. In this area it lies unconformably on Pony metamorphics. The actual contact was nowhere observed in the map area; however, rock only a few feet below the unconformity is fresh and unweathered in appearance.

The Flathead consists of about 135 feet of vitreous pink silica-cemented sandstone; accordingly it is sometimes called the Flathead quartzite. It is important when calling it a quartzite to specify that it is a quartzite of sedimentary origin, i. e. an orthoquartzite, to avoid confusion with quartzite of metamorphic origin (metaquartzite).

The following table shows graphically the principal sedimentary rock units.

TERTIARY

Tertiary sediments occur in the northwest part of the map area. (Plate 1) In this area, the Tertiary sediments consist largely of coarse-to-fine conglomerate sediments deposited as alluvial fans during Tertiary uplift of the mountain range.

A.—METABASALT (DARK) IN CONTACT WITH GNEISS

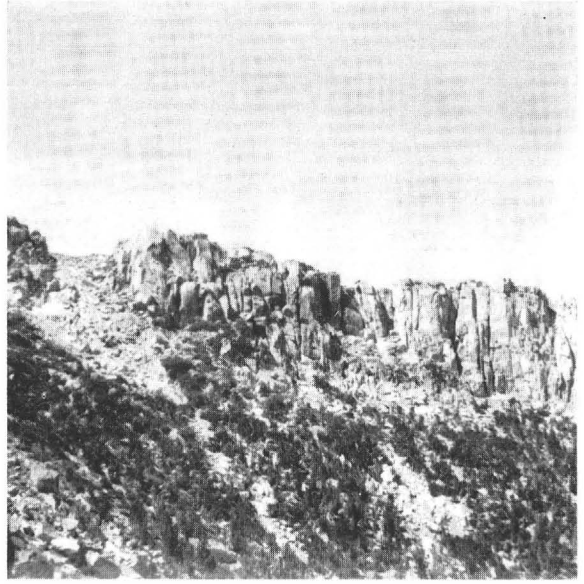
Note that the metabasalt cuts across the foliation in the gneiss at a small angle.

B.—LARGE METABASALT BOUDINAGE (DARK LAYER) IN PONY METAMORPHICS

The boudinage lies just left of the thick metabasalt body in the east wall of Sunrise Cirque, upper Wisconsin Creek.

C.—BENDING OF FOLIATION IN AMPHIBOLITE NEAR THE CONTACT OF A PEGMATITE II DIKE

Bending above the dike is in the reverse sense; the pegmatite has formed along a low-angle shear zone. West valley wall in upper Belle Creek.



D.—STRONG JOINTING IN GRANODIORITE

On northeast face of Mt. Jefferson. Joints strike northwesterly.

The andesite occurs mostly as sills in or near the contact between the Flathead sandstone and the Wolsey shale. The Wolsey shale exhibits slight baking effect. The large andesite sill in the north end of the area has abundant quartz crystals present within it. These are probably foreign crystals taken into the magma from the underlying Flathead sandstone.

Andesite also forms a small partly concordant, partly discordant body in the ridge west of Sailor Lakes in upper South Boulder Creek. The body cuts Pony metamorphics and contains abundant xenoliths of gneiss, amphibolite, and magnetite schist (from the nearby magnetite schist layer). Many of the xenoliths are of marble, a rock not present in the surrounding Pony metamorphics.

LATITE

Latite occurs on the west side of the map area. (See plate 1).

In outcrop, latite is a pinkish-gray rock, massive and dense with phenocrysts of orthoclase. Under the microscope, approximately equal amounts of orthoclase and plagioclase phenocrysts are observed, all strongly altered to sericite. The matrix is made up of fine-grained stubby prisms of orthoclase and plagioclase in which sericite alteration is moderately strong.

The latite occurs as small partly discordant, partly concordant bodies that have slightly baked or recrystallized the surrounding Paleozoic sedimentary rocks. Latite also cuts the Pony in places.

BASALT

Basalt has been observed at three localities within the map area. One small dike (two feet thick) cuts the batholith in the southeast part of the area. Basalt cuts Pony gneiss and quartz-microcline pegmatite in the north fork of Dry Boulder Creek. Basalt dikes, one of which is shown on the geologic map (plate 1), are present in and near the Mammoth fault in the northwestern part of the map area. They are five to fifty feet thick. In the batholith and along the Mammoth fault the basalt is strongly sheared, indicating post-basalt faulting movement. The basalt is made up of tiny plagioclase laths, stubby pigeonite prisms, somewhat altered to green hornblende, and accessory magnetite.

AGE OF IGNEOUS ROCKS

A lead-alpha age determination on zircon from sample 55 RR-1, granite, Tobacco Root batholith, near Pony, Montana, was made by H. W. Jaffe of the U. S. Geological Survey. The age of the zircon was determined to be 66 million years indicating that the granite was intruded in Late Cretaceous or early Tertiary time. (H. W. Jaffe, written communication.)

The andesite sills have been injected along bedding planes in the Paleozoic rocks and are thus later than Paleozoic. Workers in adjacent areas place andesitic rocks in the Cretaceous. Latite cuts Paleozoic rocks in several places.

Berry (1943, p. 23), for example, states that andesites making up the bulk of the Livingston formation were formed during the Laramide orogeny. Presumably, the andesite sills and stocks were emplaced during this time.

The present writer found andesite to be concordant and nearby latite to be partly concordant and partly discordant. He found no conclusive evidence with regard to age relations between latite and andesite.

Basalt is mentioned by Berry (1943, p. 23) as occurring both in the upper Livingston formation and in the Tertiary basin deposits. The basalt dike cutting the Tobacco Root batholith is certainly Tertiary. The basalt dikes in the Mammoth fault zone may be Precambrian, late Cretaceous, or Tertiary.

SEDIMENTARY ROCKS

PALEOZOIC

Most of the Paleozoic rocks within the map area occur in the north and west portions, i. e. within the area mapped on Forest Service map sheets. The generalized relationships were sketched on the map, but no important degree of accuracy is claimed. The Paleozoic rocks were not closely studied.

Berry (1943, p. 10-18) described the Devonian and Mississippian sedimentary rocks near Three Forks, Montana. The following units (listed from younger to older) described by him occur in the map area and were utilized as map units.

(1) The Madison formation of Mississippian age. He described an upper "massive limestone"

ment of magma and as a pathway for the later rise of mineralizing solutions.

APLITE AND PEGMATITE

Aplite dikes are confined to the batholith. Pegmatite dikes occur both inside and outside the batholith. Neither aplite nor pegmatite is present in sufficiently large bodies to show on the geologic map; both are uncommon in the batholith.. Aplites are sugary textured white rocks present in thin dikes (one inch to one foot thick) cutting the batholith rock. Pegmatites are coarse-grained white rocks cutting the batholith or the nearby metamorphic rocks. Individual crystal masses of pegmatite one to two feet in diameter are not uncommon.

Aplite and pegmatite within the batholith have approximately the same composition as the enclosing granodiorite. In other words, they are composed of quartz, plagioclase, and microcline. Garnet is locally present. The plagioclase in one aplite dike studied has the same composition as plagioclase in the enclosing granodiorite.

The aplite and pegmatite dikes cut sharply across the granodiorite and appear to be of intrusive origin. Within the dikes, complex textural gradations may be observed. For example, aplite may form an outer zone, pegmatite an inner zone, and massive white quartz the central zone. Massive tabular white quartz bodies, not uncommon near the batholith and within it, may have had their origin from pegmatite dikes.

Pegmatites formed by both igneous and metamorphic processes are present within the map area. Their distinction is not a simple matter; one origin or another cannot be assigned definitely to every pegmatite.

The metamorphic pegmatites in general are in tabular to lenticular bodies parallel to the foliation in the enclosing metamorphic rocks. They occur in a definite structural position, as in the crest of an isoclinal anticline. The minerals present are those of the surrounding metamorphic rock. Leptite, for example, gives rise to a quartz-plagioclase-microcline pegmatite. The pegmatite may still retain some of the foliation of the host rock. Certain minerals characteristic of metamorphic rocks, such as kyanite or sillimanite, may be present in the pegmatite.

The igneous pegmatites are in general in dikes crosscutting the batholith and the country rock. The minerals are those of the batholith.

However, igneous pegmatites may occur as sills, and metamorphic pegmatites may conceivably occur as dikes. These remarks give an idea of the difficulties involved.

To illustrate further the difficulties involved, a brief description is given of the pegmatites that are rather abundant in upper Belle Creek, upper Dry Boulder Creek and upper Bear Gulch. There pegmatites are composed predominantly of quartz and microcline, with subordinate plagioclase. They are massive and crosscut the metamorphics (and the meta-basalts). By the criteria listed above, these would be called igneous pegmatites.

On the ridge north of the Bielenberg and Higgins mine (Bear Gulch), the writer observed xenoliths of massive quartz-microcline pegmatite in an andesite dike. Inasmuch as the andesite is pre-batholith, the pegmatites, which are preandesite, are also pre-batholith, (and probably pre-Beltian). Pebbles of massive quartz-microcline pegmatite in the Lahood conglomerate (Belt) in the Jefferson Canyon, a few miles to the north, exactly resemble the afore-described pegmatites. These data permit the dating of the pegmatites as pre-Beltian and post-metabasalt. These pegmatites, therefore, are not associated with the Tobacco Root batholith.

It is not possible to say whether the pegmatites are definitely igneous or metamorphic. The features shown in figure 6 are in part analogous to the appearance of a porphyroblast in metamorphic rock. This tends to support a metamorphic origin for the pegmatite. On the other hand, the structural form of the largest body of this pegmatite in upper Dry Boulder Gulch is that of a stock. This tends to support an igneous origin for the pegmatite.

ANDESITE

Andesite occurs in the west and north parts of the map area. (Plate 1.) It is a reddish-brown rock in outcrop, massive, and has small angular phenocrysts of white plagioclase. The plagioclase is strongly altered to sericite. Much of the very fine-grained groundmass is also altered to sericite.

depends on the aggregate of rock types present in a rather thick section. Because of possible lateral variation in rock composition, the criteria listed above for distinction may be valid only in the immediate vicinity of the map area.

A representative section was measured which includes the contact between Pony and Cherry Creek as originally mapped by Tansley and Schafer (1933, p. 1) in upper South Boulder-Upper Wisconsin Creek divide. This section is by no means complete for either Cherry Creek or Pony, but it is a rather short section to show the kinds of rock present just below the contact. The section is given in the Appendix.

The section may be briefly summarized here. The lower Pony consists largely of gneiss, and metabasalt sills. The upper Cherry Creek consists largely of sillimanite quartzite, amphiboite, coarse garnet amphibolite, and anthophyllite schist. Beneath the measured section, still in upper Cherry Creek, is a zone predominantly of amphibolite, estimated to be 500 feet thick. Beneath this a zone predominantly of gneiss estimated to be 800 to 1,000 feet thick. Still beneath this is a zone of unknown thickness, extending south of the map area, of marble, quartzite, gneiss, and amphibolite.

METAMORPHIC PEGMATITES

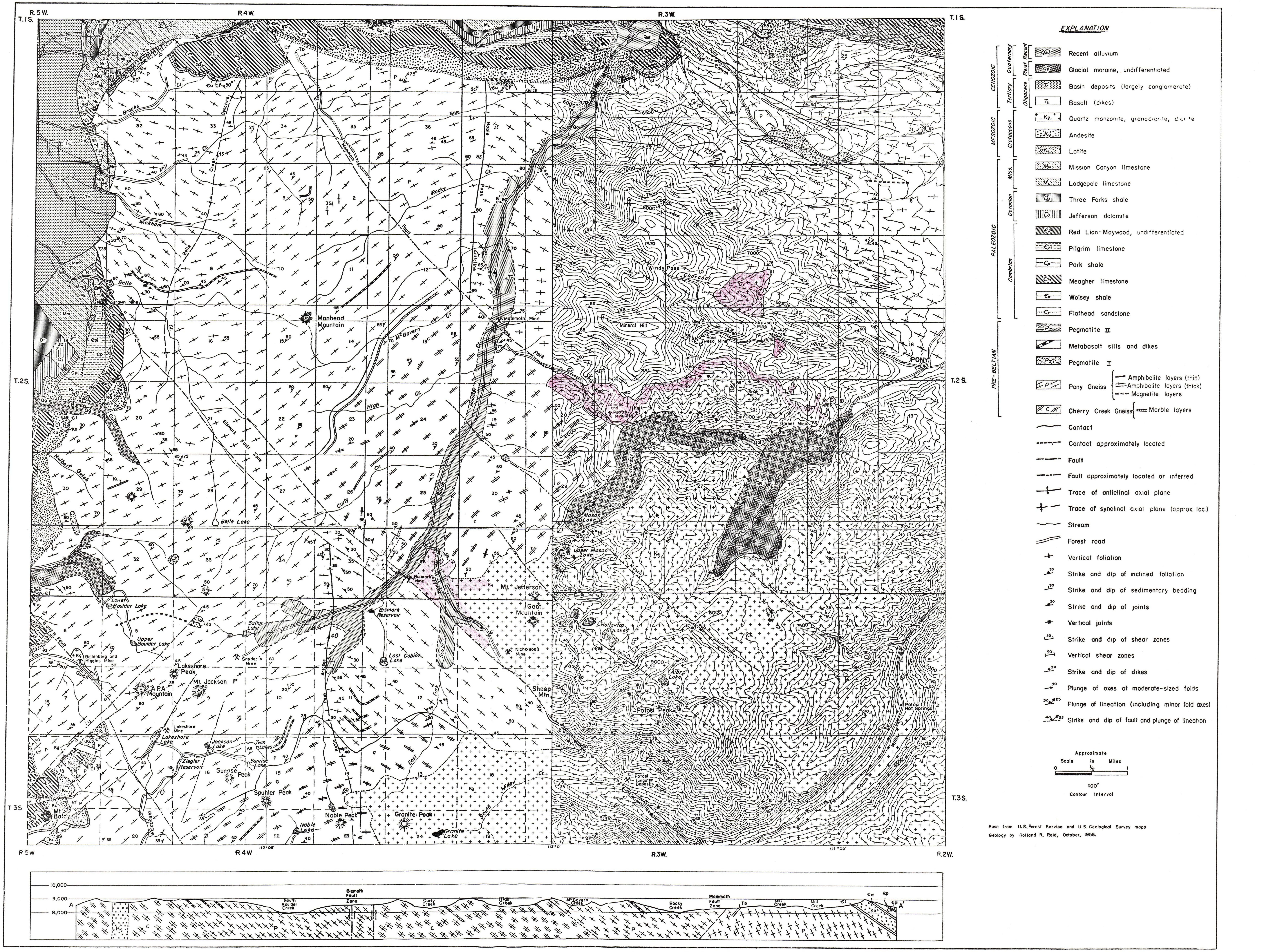
Metamorphic pegmatites are those pegmatites believed by the writer to have been formed by metamorphic processes. Metamorphic pegmatites are somewhat controversial; the writer adopts those views with regard to their origin set forth by Ramberg (1956, p. 209-210).

> "This is a metamorphic-metasomatic theory in which diffusional transfer is essential . . . The theory is based upon but two assumptions: (1) That diffusion may occur in rocks during regional metamorphism and (2) that, under regional metamorphism, the elements constituting quartz and alkali feldspar are generally considerably more diffusive than the elements of cafemic minerals . . . "

So far as the present author knows, no one questions that quartz-kyanite segregation veins in kyanite schist, for example, are formed by diffusion of the constituents of these minerals to cracks in the rock, formed late in the time of metamorphism. It does not seem illogical to suppose that quartz-kyanite-feldspar may diffuse to tensional zones (as fold crests) or to cracks formed late in the time of metamorphism — where the surrounding gneisses contain quartz, kyanite, and feldspar as in the Mineral Hill pegmatite. If the minerals are coarse grained, a pegmatite has been formed. Further, if a gneiss were rich only in quartz and feldspar, it might then give rise to a quartz-feldspar pegmatite. If diffusion to a tensional crack had occurred, the resulting tabular body would be identical in structure and appearance to a pegmatite of igneous origin.

Field study discloses two groups of pegmatites, shown on the geologic map (plate 1) as Pegmatite I and Pegmatite II. Pegmatite I, believed to be associated with the first period of pre-Beltian metamorphism, is best represented by a pegmatite body lying in section 26, T. 1 S., R. 3 W., Madison County, Montana. It will be called the Mineral Hill pegmatite in this report. This body is the largest encountered in field mapping. Smaller bodies of similar structure elsewhere were not mapped. Pegmatite II is represented by a swarm of pegmatites, mostly too small to show on the geologic map, occurring in upper Bear Gulch, upper Dry Boulder Gulch, and upper Belle Creek. The largest body occurs in the upper north fork of Dry Boulder Gulch and is shown on the geologic map (plate 1). Pegmatite II is associated with the second period of pre-Beltian metamorphism; it is included under this heading on scanty evidence.

Two large bodies of pegmatite (the larger being the Mineral Hill pegmatite) occur in the north end of the map area. More accurately, these bodies consist of an intermixture of pegmatitic material, gneiss, amphibolite, biotite schist, and serpentine-pyroxenite layers. They lie in the crests of two isoclinal anticlines that plunge about 55° northwesterly. These folds were revealed by detailed mapping in the north part of the map area where exposures are excellent, mapping more detailed than undertaken in the rest of the area. Similar structures are probably present elsewhere in the area, but were not revealed by reconnaissance-scale mapping. Because of probable faulting the trace of the anticlinal axial plane is shown for only a short distance on the map; it probably extends northwest beyond the map area.



Base from U.S. Forest Service and U.S. Geological Survey maps
Geology by Rolland R. Reid, October, 1956.