Preliminary report on the geology and mineral deposits of the northern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana

By Harry W. Smedes

Trace Elements Investigations Report 557

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UNITED STATES DEPARTMENT OF THE INTERIOR

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PRELIMINARY REPORT ON THE GEOLOGY AND MINERAL DEPOSITS OF THE NORTHERN ELKHORN MOUNTAINS, JEFFERSON AND BROADWATER COUNTIES, MONTANA*

By

Harry W. Smedes

September 1955

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PRELIMINARY REPORT ON THE GEOLOGY AND MINERAL DEPOSITS OF THE NORTHERN ELKHORN MOUNTAINS, JEFFERSON AND BROADWATER COUNTIES, MONTANA

By Harry W. Smedes

ABSTRACT

The northern Elkhorn Mountains include an area of approximately 130 square miles of the Clancy and East Helena quadrangles in Jefferson and Broadwater Counties, Montana. Rocks of the area comprise a narrow belt of late Precambrian, Paleozoic, and Mesozoic sedimentary rocks near the northern edge of the map area, a thick sequence of late Cretaceous volcanic and associated intrusive rocks in the eastern part, and plutonic rocks of the Boulder batholith in the western part. Small bodies of Tertiary volcanic rocks also occur in the western part. Poorly consolidated and unconsolidated Tertiary and Quaternary deposits occur along the northern edge of the map area and are part of the valley fill of the broad Helena valley which lies mostly north of the map area.

There is a slight angular unconformity at the base of the Paleozoic rocks, but the Paleozoic and Mesozoic rocks are essentially conformable with one another. The main episode of structural disturbance began during late Colorado time of the Upper Cretaceous period and culminated during the close of, or following, late Cretaceous volcanism, at which time the rocks were folded into a broad northeast-trending syncline in the eastern part, and an east-trending steep homocline near the northern edge. Emplacement of the Boulder batholith followed the period of folding. Block faults, some of large displacement, were formed both before and after emplacement of the batholith.

The batholith was emplaced in three major stages: an early stage of gabbroic granodioritic composition, a main stage of quartz monzonitic and minor grandioritic composition, and a final stage of granitic composition represented by aplite, alaskite, pegmatite, alkali granite, and tourmaline granite.

Low-grade thermal metamorphism was caused by andesitic and basaltic intrusions into the Cretaceous volcanic pile forming mineral assemblages of the green-schist facies. Intrusion of the batholith produced thermal metamorphism which locally formed minerals of pyroxene-granulite facies in the inner contact zone, but more commonly formed minerals of the somewhat lower-grade amphibolite facies. In one place the intrusion caused intense shearing of the country rock walls, converting them into schist, amphibolite, and mylonite; elsewhere the intrusion produced no recognizable deformation of the country rock.

Tertiary rhyolitic and dacitic volcanism was followed by faulting, uplift, and erosion which produced a mature surface which was modified by glaciation and subsequent stream erosion.

The ore deposits of the district are quartz veins that contain ore shoots of base and precious metals. Uranium is associated with some of these quartz veins and with chalcedony vein zones. The primary metallic minerals include pyrite, chalcopyrite, sphalerite, galena, arsenopyrite, tetrahedrite, molybdenite, and uraninite. Minerals of later origin include malachite, azurite, native silver and gold, plumbojarosite(?), pyromorphite, and hydrous iron oxides.

Anomalous radioactivity was detected in and adjacent to quartz and chalcedony veins in two distinct areas. The western of these areas is continuous with a large group of anomalies west of the map area.

Uranium ore is being recovered from small ore bodies in the W. Wilson chalcedony vein system, and plans have been made for uranium exploration along the White Pine quartz vein. There is possibility of finding other small uranium ore bodies in other chalcedony and quartz veins.

INTRODUCTION

The area described in this report comprises the north half of the Clancy 15 minute quadrangle and about 37 square miles of the south half of the East Helena 15 minute quadrangle, Jefferson and Broadwater Counties, Mont. (fig. 1). The northern and western parts of this area are low rolling, sparsely timbered to treeless grassy hills with altitudes of 4,100-4,500 feet and are readily accessible by county and forest roads. Helena is 3½ miles northwest of the area on U. S. Highway 91, which serves the western edge of the map area. The southeastern part is heavily wooded and mountainous terrain with altitudes up to 8,770 feet and is accessible only by foot or on horseback from the ends of gravel roads leading up Beaver Creek from Winston on the east, from Wilson Creek on the south, or from McClellan Creek within the map area.

Field work was done by the U. S. Geological Survey during the summers of 1953 and 1954 partly on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

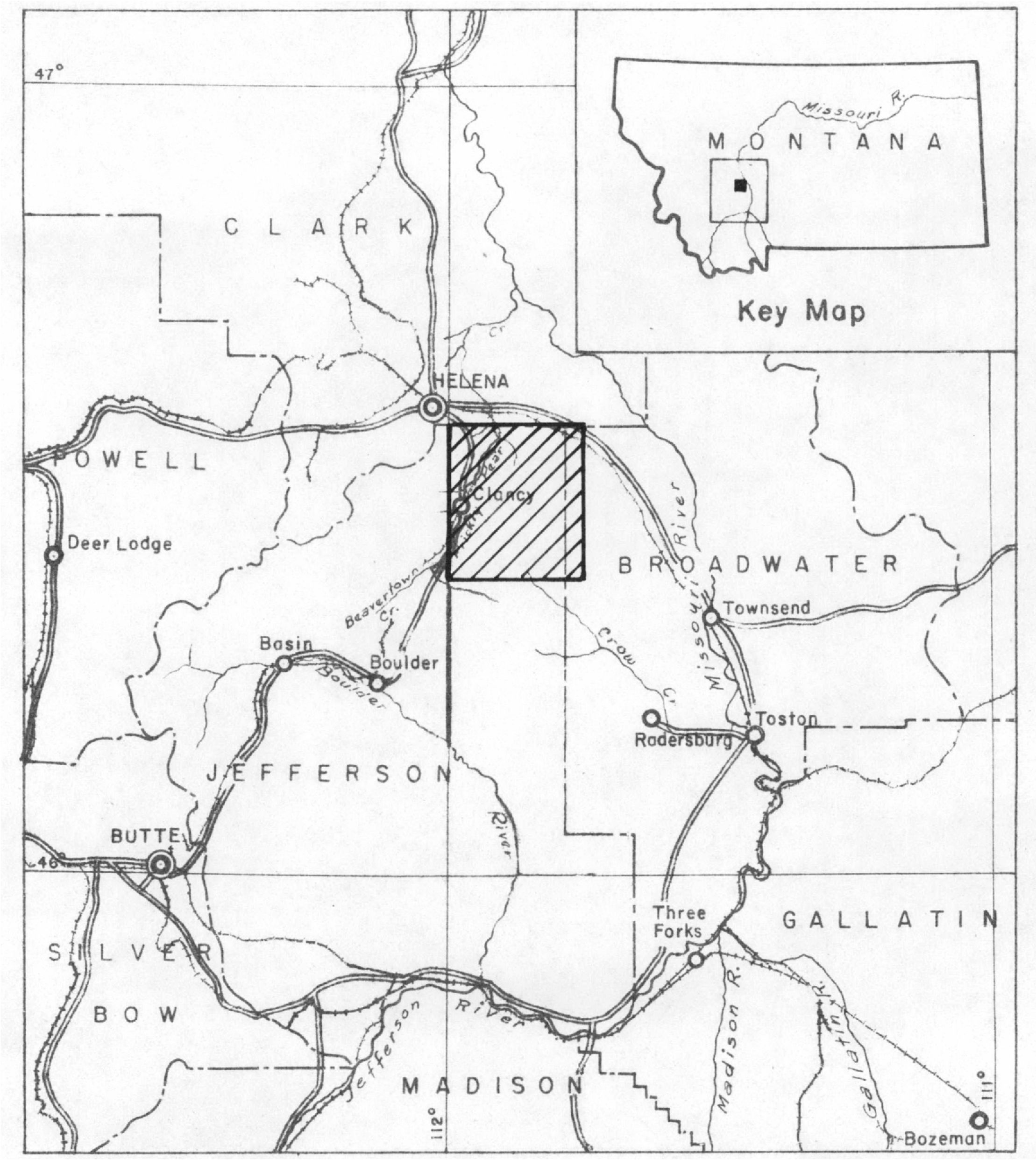

Figure 1. Index map showing location of northern Elkhorn Mountains

0 5 10 15 20 25 Miles

The geology of about 2½ square miles west and southwest of Clancy was mapped and described by Roberts and Gude in 1953 (Roberts and Gude, 1953). Crowley mapped an area around Mountain City of which about 2½ square miles lies in the present map area (F. A. Crowley, 1954, unpublished thesis, Montana School of Mines). For the sake of uniformity of treatment, their maps have been somewhat revised in the present study. Attitudes of flow banding in the rhyolite plugs have been generalized from Crowley's data.

In addition to these two detailed studies, reconnaissance geologic work in the area had been done by Stone (1910), Knopf (1913), and Pardee and Schrader (1933). Detailed mapping by the U. S. Geological Survey is in progress in adjacent areas.

GEOLOGIC SETTING

The map area (pl. 1) includes parts of three major geologic units: a narrow belt of folded and faulted late Precambrian, Paleozoic, and Mesozoic sedimentary rocks near the northern edge; a folded and faulted sequence of late Cretaceous volcanic rocks and related intrusive rocks in the eastern half; and plutonic rocks of the Boulder batholith, with small bodies of Tertiary volcanic rocks, in the western half.

The stratigraphy and major geologic events are summarized in table 1.

Table 1.--Summary of stratigraphy and major geologic events, northern Elkhorn Mountains

<table>
<tr><th colspan="2">Age</th><th>Formation</th><th>Lithology</th><th>Approx. Thickness (feet)</th></tr>
<tr><td rowspan="2">Quaternary</td><td>Recent</td><td>Flood plain deposits, recent valley fill, and hillwash</td><td rowspan="2">Generally unconsolidated gravel, sand and clay</td><td>unknown</td></tr>
<tr><td>Pleistocene</td><td>Several levels of terrace gravel; glacial outwash and morainal debris.</td><td>unknown</td></tr>
<tr><td colspan="5">Erosion
Faulting and tilting
Formation of quartz (?) and chalcedony veins
Faulting</td></tr>
<tr><td colspan="2">Tertiary</td><td>Lava flows and tuffs, lake beds</td><td>Rhyolite and dacite flows and intrusives, probably contemporaneous with some of the lake beds, tuffs, and admixed and intercalated gravel and ash.</td><td>unknown</td></tr>
<tr><td colspan="5">? — ?</td></tr>
<tr><td colspan="5">Uplift and erosion
Formation of quartz veins
Intrusion of Boulder batholith
Faulting
Folding</td></tr>
</table>

Table 1.--Summary of stratigraphy and major geologic events, northern Elkhorn Mountains--Continued

Age	Formation		Lithology	Approx. Thickness (feet)
Upper Cretaceous	Elkhorn Mountains volcanics		Andesitic sedimentary and pyroclastic rocks and quartz latitic tuff flow rocks; sparse lava flows; contemporaneous andesitic and basaltic hypabyssal intrusive rocks	unknown, but over 7,000
	Slim Sam formation		Andesitic sedimentary rock, tuff and lapilli tuff	530
	Erosion Local weak folding and probably faulting			
	Colorado group	Middle unit	Cherty sandstone and siltstone, siliceous mudstone and very minor siliceous shale	1,370
-----?------		Lower unit	Sandstone, siltstone and black shale	190
Lower Cretaceous	Kootenai formation		Sandstone, siltstone and shale with 2 beds of fresh-water limestone near top	620
Upper Jurassic	Morrison formation		Siltstone and calcareous sandstone	270+
	Swift formation		Carbonate sandstone	50
Probable erosion				
Permian	Phosphoria formation		Quartzite, chert, and limestone; phosphatic quartzite in lower part	90

Table 1. Summary of stratigraphy and major geologic events, northern Elkhorn Mountains--Continued

Age	Formation	Lithology	Approx. Thickness (feet)
Pennsylvanian	Quadrant formation	Quartzite and limestone	440
Pennsylvanian & Mississippian	Amsden formation	Siltstone and limestone	180
Mississippian	Madison group	Massive dark gray granular limestone with light gray thin to medium-bedded limestone in lower part	Not measured, but about 4,500 feet total
Devonian	Three Forks shale	Brown siltstone and shale with few thin limestone beds. Cream and light gray, fine-grained quartzite bed below middle of formation	
	Jefferson formation	Honey-colored, ribboned dolomite	
	Maywood formation	Argillaceous and calcareous rocks. Mapped with unit below.	
Erosion			
Upper Cambrian	Red Lion formation	Argillaceous and calcareous rocks. Mapped with unit above.	
	Pilgrim limestone	Cream colored, massive limestone at base with light and dark gray mottled limestone above	
Middle Cambrian	Park shale	Thin-bedded, black, brown, purple, and dark green shale with local calcareous shale lenses.	
	Meagher limestone	Dark gray, light and blue gray mottled and ribboned limestone with a bed of massive limestone in the middle	

Table 1. Summary of stratigraphy and major geologic events, northern Elkhorn Mountains--Concluded

Age		Formation	Lithology	Approx. Thickness (feet)
Middle Cambrian		Worley shale	Thin-bedded, black and brown calcareous shales with a 20 ft. bed of grayish-blue ribboned limestone in the middle	
		Flathead quartzite	Siliceous quartzite; coarse and vitreous; weathers red	
Slight folding and erosion				
Late Precambrian	Belt series	Helena dolomite	Tremolite marble, dolomite, and interbedded siliceous shale. Mapped as a unit with Empire shale	2,400(?)
		Empire shale	Green, red and gray siliceous argillites. Mapped as a unit with Helena dolomite	600(?)

SEDIMENTARY ROCKS

Precambrian rocks

Large areas of rocks of the Precambrain Belt series are exposed north of the area mapped, but within the map area only the Helena dolomite and Empire shale are exposed. These two formations consist of recrystallized dolomite, tremolite-marble, and green, red, purple and gray siliceous argillite. Because of extensive cover by younger gravel and tuff, the two formations were not mapped separately, nor could their mutual structural relations be determined.

Paleozoic rocks

Paleozoic rocks occupy a relatively narrow east-trending belt near the northern edge of the area. The basal Paleozoic formation, the Flathead quartzite of Middle Cambrian age, rests with slight angular unconformity on the Helena dolomite and is conformably overlain by a series of carbonate rocks and subordinate shale and quartzite, dominantly of marine origin, of Middle and Late Cambrian, Late Devonian, Carboniferous and Permian age. The lithology of these beds has not been studied in detail.

Mesozoic rocks

Mesozoic rocks overlie the Paleozoic sequence along the northern edge of the area and extend southward in a broad zone in the eastern part and beyond the limits of the map area. The basal Mesozoic formation in the area, the Upper Jurassic Swift formation, is thought to lie with erosional unconformity on the uppermost Paleozoic unit, the Permian

Phosphoria formation. The marine carbonate sandstone of the Swift formation is apparently conformably overlain by the Morrison formation, also of late Jurassic age, which consists of calcareous sandstone, siltstone and shale of continental origin. Because of faulting, a complete Morrison section is not discernible in the map area.

The Morrison formation is conformably overlain by the Kootenai formation of early Cretaceous age. In the map area the Kootenai consists of sandstone, siltstone and shale of continental origin, and a conspicuous unit of fresh-water gastropod-bearing limestone near the top of the formation. This unit comprises two limestone beds separated by siltstone and shale, and was mapped as a separate marker unit within the Kootenai formation.

Lower and Upper Cretaceous rocks of the Colorado group lie conformably on the Kootenai formation. The lower unit consists of sandstone, siltstone and black shale; the middle unit consists of cherty sandstone and siltstone, siliceous mudstone and subordinate siliceous shale. An upper black shale unit which occurs in areas to the southeast is not present in the map area. It is believed that the absence of the upper black shale unit is due to erosion prior to the deposition of andesitic siltstone, sandstone tuff which comprise the Slim Sam formation._/

The Slim Sam formation grades into the overlying sequence of Upper Cretaceous andesitic volcanic rocks called the Elkhorn Mountains volcanics._/

_/ Formation name proposed by Klepper, M. R., Weeks, R. A., and Ruppel, E. T., in preparation, Geology of the southern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U. S. Geol. Survey Prof. Paper.

The base of the Elkhorn Mountains volcanics is placed at the appearance of the first lava flow, tuff flow or volcanic breccia. Because of facies changes or local extent of flows and breccia, this base is likely to be placed at different stratigraphic levels in different areas, and for this reason, the contact is mapped as gradational.

Cenozoic deposits

The lowland in the northern part of the area is mantled with Tertiary ash, tuff, admixed and intercalated sediments, and Pleistocene and Recent gravel. These deposits underlie the broad gentle slopes leading into the Helena valley and comprise the valley fill, much of which consists of Tertiary tuffaceous fluviatile and lacustrine debris. Glacial moraine is moderately extensive in the higher mountains and gravel terraces along all major streams in the area are thought to be glacial outwash deposits. Some of these gravels are gold-bearing. Moderate glaciation is thought to have modified the geomorphic features of some of the low hilly country in the Maupin Creek area to as low as 5,000 feet altitude. The probability of such low-level glaciation is strengthened by the presence of a well-preserved moraine at altitude of 4,600 feet at the northernmost tip of the mountains south of Clasoil.

IGNEOUS ROCKS

The oldest rocks of igneous derivation in the northern Elkhorn Mountains are andesitic sandstone and tuff comprising the Upper Cretaceous Slim Sam formation. These rocks contain varying amounts of non-volcanic material and grade upward into the Elkhorn Mountains volcanics which comprise rocks almost entirely of local valcanic derivation. South of the map area tuffaceous layers have been observed in the upper Colorado shales immediately underlying the Slim Sam formation.

The Elkhorn Mountains volcanics and older rocks are intruded by the Boulder batholith. The youngest igneous activity is recorded by rhyolite and dacite intrusives, flows, and pyroclastic rocks of Tertiary age.

Elkhorn Mountains volcanics

The Elkhorn Mountains volcanics are of Late Cretaceous age and consist dominantly of andesitic pyroclastic rocks and quartz latitic tuff flows with very subordinate lava flows, although in places it is difficult to distinguish between crystal tuff and flow rock. The tuff flows (Fenner, 1948) are the best and, for practical purposes, the only mappable stratigraphic marker units in the entire volcanic sequence. As shown on the geologic map (pl. 1) most tuff flows are traceable for over two miles, whereas interbedded pyroclastic rocks lens out, change facies, or for some other reason generally cannot be traced over a quarter of a mile. The lowest tuff flow shown in Beaver Creek extends east of the area and then re-enters the map area in the north, a total length of over four miles. These tuff flows are the "wispy" or "streaky" flows of workers[1]

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[1] Klepper, M. R., Weeks, R. A., and Ruppel, E. T., in preparation, Geology of the southern Elkhorn Mountains, Jefferson and Broadwater Counties, Montana: U. S. Geol. Survey Prof. Paper.

to the south and are characterized by a tuffaceous texture, generally with a pronounced interrupted banding due to the flattening of formerly hot, plastic, glassy fragments. Other fragments are equidimensional and were apparently solid when deposited. The fine shards and "wisps" in the matrix are bent and draped about these solid fragments, resulting in an apparent turbulent flow structure. With few local exceptions, the banding throughout a tuff flow conforms with the layering in subjacent pyroclastic beds. These beds are thought to represent tuff flows not only because of their texture and structure, but also because of their broad aerial extent, even though they may be as little as 20 feet thick. Strongly contorted banding is very local and minor, whereas minute crenulations of the bands are common. The bands and turbulent structures are thought to be largely or entirely due to compaction after deposition rather than due to flow, because the bands appear as equidimensional plates in the plane of flattening and because the turbulent structures are diversely oriented even within a single hand specimen.

One characteristic feature of this volcanic pile is the similarity between coarse pyroclastic rocks and intrusive breccia, because the pyroclastics are composed entirely of fragments of intrusive rocks. Another characteristic feature is the very close similarity between crystal tuff and extrusive rocks or fine-grained intrusive rocks. Thermal metamorphism makes the distinctions even less certain.

Because of many small and some large scale steep faults and the abundance of intrusive rocks, a satisfactory estimate of the thickness of volcanic rocks in this area, cannot be made but the volcanics are considered to be well over 7,000 feet thick. The original top is nowhere preserved; it has been eroded away in the eastern part of the area and engulfed by the batholith in the western part.

Andesitic and basaltic sills, dikes, and irregular and compound plutons have intruded the pre-batholithic rocks of the area. The sills are largely apophyses of the plutons and were injected in great abundance into bedded, water-laid volcanic mudstone and siltstone, and tuff flow rock. In poorly bedded pyroclastics the sills and sheets are commonly divergent by forking or by offsetting to different horizons, whereas in bedded volcanic breccia the sills have gradational, ill-defined contacts masked by recrystallization and local assimilation of the country rock. Some sills were intruded into moist, semi-consolidated volcanic sediments to produce vesicular rocks with intimately admixed stringers, pods and blocks of country rock. Sills have not formed in thick structureless breccias, probably because no regular bedding surfaces existed along which magma could spread; instead, large irregular plutons formed in such an environment. These large plutons comprise several intrusions or separate surges of magma; intrusive and autoclastic breccias were formed during these surges.

The intrusives are in large part contemporaneous with the extrusive volcanic activity of the Elkhorn Mountains volcanics but probably began a little earlier and perhaps continued a little later than the volcanics. Fragments of such intrusive rocks occur sparsely in the Slim Sam formation and profusely, though intermittently, throughout the entire exposed volcanic section. This circumstance, coupled with the evidence that there were intrusions into moist semi-consolidated sediments, prompts the conclusion that the depth of cover must have been slight. Some intrusions only gently deformed the country rock whereas others rather strongly folded and faulted the country rock. These intrusive bodies are considered to be part of the Elkhorn Mountains volcanics.

Rocks of the Boulder batholith

The part of the Boulder batholith within the map area cuts the Elkhorn Mountains volcanics and also rocks as old as Devonian. Just north of the map area batholith rocks invade Precambrian Belt strata (Knopf, 1913, map). The batholith here comprises three main stages: (1) an early stage consisting of gabbro, diorite, monzonite, and granodiorite, (2) the large bulk of quartz monzonite and lesser granodiorite which comprises the main stage of intrusive activity, and (3) a late stage consisting of aplite, alaskite, pegmatite, alkali granite, tourmaline granite, and very minor lamprophyre.

Rocks of the early stage are in contact with older rocks to the north, whereas to the south they are in part gradational into and in part intruded by quartz monzonite of the main batholith stage. Rocks of this early stage range in composition from gabbro to granodiorite and include rare bands of pyroxenite in the gabbro and local zones of shonkinite, orthoclase rock, and scapolite-rich rock along contacts with calcareous country rock and xenoliths. None of these rocks were mapped separately. These early rocks have locally thermally metamorphosed the country rocks to produce hornfels and tactite zones several hundred yards in breadth. Thermally metamorphosed xenoliths as much as 200 yards long abound locally. The distribution and attitude of very large remnants suggest that many are pendants and that, therefore, very little of the batholith has been removed by erosion.

The main stage of the batholith comprises many textural varities of rocks in the quartz monzonite-granodiorite range and one body of granite. These rocks typically contain crypto-perthite as the alkali feldspar. In the field granodiorite cannot be distinguished from quartz monzonite, even in the coarse-grained rocks. The map units are based upon a field classification involving grain size, color, and mineralogic and/or textural peculiarities.

The main stage of intrusion was followed by a period of cooling and local deformation of the walls which in turn was followed by a series of intrusions of lamprophyre, aplite, alaskite, pegmatite, alkali granite and tourmaline granite of the final stage. All but the lamprophyre are characterized by an abundance of tourmaline.

The southern 6 miles of contact of the batholith with Elkhorn Mountains volcanics is remarkably straight, very steep, and characterized by an irregular but generally very narrow thermally metamorphosed contact zone. The same kind of contact continues for several miles south of the map area. To the north the contact is very irregular in trend and dip; furthermore, the contact metamorphic effects are widespread and thorough--the original nature of the country rock being obliterated throughout a broad hornfelsed zone. In addition, there is commonly a narrow zone of aplite and fine-grained quartz monzonite at the contact.

The main quartz monzonite stage probably does not represent a series of separate plutons, but rather an essentially single mass with textural differences due to irregularities of the roof and walls with resulting complexities of convection, cooling rates, crystallization and late magmatic replacement processes, as well as to difference in depth of batholith exposed to view. Chemical differences probably are due to local differentiation, and assimilation of wall rock.

The southern part of the batholith is thought to have been emplaced by a late stage fault or by reactivation of an older fault during a late stage which brought partially consolidated quartz monzonite into its present position, where it rapidly cooled with no appreciable stoping or assimilation and with only a narrow zone of thermal metamorphism of its wall rocks.

The northern part of the batholith is believed to have been emplaced by extensive stoping and assimilation of the country rock in its present position.

Tertiary volcanic rocks

Tertiary igneous rocks comprised of plugs, dikes, and flows of rhyolite and dacite, and local accumulations of well-indurated rhyolitic pyroclastics are almost exclusively restricted to the areas of batholith rocks and cut them or rest unconformably upon them. Extensive deposits of poorly consolidated and unconsolidated rhyolitic tuff and ash of Tertiary age mantle the broad gentle slopes of the Helena valley and extend back into the low hilly areas bordering the valley.

Age relations between the dacite and rhyolite are not known. The large rhyolite mass of Burnt Mountain comprises tuffs, breccias and tuff flow rocks. Lava Mountain is a faulted complex mass of rhyolitic sandstones and tuffs in contact with batholith rocks and with flow-banded rhyolite invaded on the west end by a rhyolite breccia plug and breccia dike and invaded on the east end by a structureless rhyolite porphyry whose areal extent is unknown.

Smaller rhyolite masses on Strawberry Butte, Shingle Butte and Bacon knob are either flows or excellently flow-banded intrusive bodies. The four smaller rhyolite bodies in the vicinity of Montana City (pl. 1) are intrusive plugs similarly flow-banded. Some flow-banded rhyolites in areas west of the map area are definitely flows, so flow-banding is of no value in distinguishing between extrusive and intrusive rhyolites.

Dacite occurs as dikes and small irregular masses except for one large plug in the Maupin Creek area. Flow structure is common and is evidenced by alinement of hornblende needles and in places of plagioclase laths.

Biotite and hornblende are common and conspicuous in dacite; sanidine is characteristic of rhyolite. Structureless rhyolite porphyry typically contains large pyramidal smoky quartz phenocrysts, and flow-banded rhyolite has an abundance of topaz as well formed crystals up to 30 mm long.

METAMORPHISM

The intrusive rocks associated with the Elkhorn Mountains volcanics have caused low-grade metamorphism of a large part of the volcanic pile. The metamorphic effects are irregular in intensity and degree of development and are clearly distinguishable from those caused by intrusion of the batholithic rocks. Minerals of the green-schist facies (epidote, albite, calcite, chlorite, biotite, quartz) formed to some extent almost everywhere, and locally minerals of the higher-grade epidote-amphibolite facies (actinolite, locally garnet) formed. Zeolites are occasionally found in both intrusive and extrusive rocks. The hornfels developed is typically very fine-grained and even-textured and a spotted hornfels is rare. Generally the hornfels texture is recognizable only under the microscope, but the metamorphism is evidenced by the green color of the rocks imparted by epidote, chlorite, or actinolite. The minerals formed by this thermal metamorphism are the same as those formed by deuteric processes in the penecontemporaneous intrusive masses which are considered to have been the chief source of heat for the metamorphism.

Some tuff flows and parts of tuff flows have been altered to a rock rich in quartz and sericite which commonly contains disseminated pyrite or specularite. The alteration involves a thorough recrystallization of quartz and intense sericitization of groundmass materials. Plagioclase is moderately, to thoroughly sericitized and ferro-magnesian minerals have been replaced leaving only locally magnetite or hematite pseudomorphs. A streaky band structure is generally preserved, though usually very faintly. This metasomatic alteration was selective, affecting only the beds of quartz latitic tuff flow rocks; interbedded andesitic and basaltic pyroclastic or intrusive rocks are fresh or show only slight silicification, or more commonly only pyritization. The alteration is not confined to narrow zones but rather occurs in varying degree over broad areas. There is no apparent relationship between these altered rocks and the proximity of the surface exposures of the batholith or of older intrusives.

Magma of the early stage of the batholith metamorphosed its host rocks to a greater degree than did the earlier magma which was associated with the Elkhorn Mountains volcanics. Carbonate rocks and impure argillaceous rocks were most strongly affected. Carbonate rocks were converted into coarse-grained tactite composed of vesuvianite, garnet, diopside, spinel, clinotonite, scapolite, tremolite, orthoclase, calcite, and axinite. Reaction between magma and carbonate rocks locally produced narrow zones of shonkinite, syenite, and orthoclase rock. Impure argillaceous rocks were converted into fine- or medium-grained granulitic rocks containing biotite, hornblende, feldspars, and lesser amounts of calc-silicate minerals such as diopside, hedenbergite, tremolite, and minerals of the epidote group. Dumortierite was observed in one sample.

Magma of the main batholith stage produced broad zones of intensely thermally and metasomatically altered rock along the northern part of the contact but very narrow zones along the southern part of the contact.

In the north the rocks have been recrystallized with generally coarse grain growth. Biotite was the principal new mineral formed while potash and silica were commonly added to the rocks to make much quartz and potash feldspar. Only the porphyritic andesite and basalt intrusive rocks are faintly distinguishable in the intensely hornfelsed zone; all other rocks are completely transformed texturally.

Although the metamorphosed zone along the southern part of the batholith contact in the area is very narrow, the grade of metamorphism was higher than that observed in the northern part, for here minerals of the pyroxene granulite facies have been formed. Clinopyroxenes were typically formed in the inner contact zone and locally orthorhombic pyroxene (enstatite) was formed.

A narrow belt of highly sheared volcanic rocks occur in a septum of country rock which lies between the main batholith mass and an eastern batholith lobe between upper Crystal and Jackson Creeks. The country rocks were converted into schist and amphibolite and later recrystallized and enriched in potash. Relict breccia blocks are preserved in some sheared rocks as long stringers, commonly segmented into streamlined "eyes" generally with pegmatitic patches between segments. In these rocks the matrix is a schist.

STRUCTURAL GEOLOGY

The most conspicuous structural features of the area as shown on the structure map (pl. 2) are: (1) the east-trending belt of sedimentary rocks with two local scallops apexing southward into the gabbro-monzonite complex; (2) several block faults with displacements probably greater than 2,000 feet in the Elkhorn Mountains volcanics; (3) the localization of the Moose Creek and Casey Peak plutons along the trough of a NNE-trending regional syncline whose identity on a local scale is commonly obscured by deformation caused by the plutons and by faults; and (4) the straight segment of batholith contact referred to earlier.

Smaller scale, or less apparent structural features include: (1) a predominantly east trend of mineralized veins; (2) a predominantly east trend of chalcedony veins; and (3) the strong domination of vertical north-south and east-west joints over all other joints in batholith rocks. Trends of faults and lineaments are each concentrated into two directions which do not coincide with each other or with trend maxima of other structural elements. These features were clearly brought out as a result of plotting hundreds of measurements. Statistical summaries of these structural elements are shown on plate 2.

Planar structures interpreted as flow structures in the batholith rocks are sparse and generally difficult to detect; where present they are faintly to moderately developed and rarely strongly developed. These planar structures are found alone or with a subtle lineation--both being shown most commonly by alinement of ferro-magnesian minerals and less commonly (or less conspicuously) by alinement of feldspar crystals.

The only generalization that can be made on the basis of 26 measurements of foliation is that the strikes lie dominantly in the NW quadrant.

Joints are abundant in the batholith rocks. The result of plotting 260 joints recorded from the batholith rocks shows two strong maxima, the greatest nearly due N and vertical, the other nearly due E and vertical. Joints follow these trends throughout the batholith in the map area regardless of the nearness or orientation of wall rock, and are interpreted as due to regional post-batholith stresses.

The poles of all measured joints in batholith rocks were plotted on the lower hemisphere of a spherical projection with the aid of an equal-area Schmidt stereographic net and were contoured in the standard manner (Ingerson, 1938, p. 245-251) (pl. 2). The solid black area labelled $>$10 (11)% means that 10% but no greater than 11% of all the poles plotted lie within an area equal to one percent of the total area of the diagram. Joints in pre-batholith rocks were not as thoroughly studied in the field. Generally joints are more variable in short distances and in the volcanics are questionable because of local strong magnetic deviation. Joints within older intrusives are commonly clearly related to those intrusives rather than to regional structures.

The strikes of all chalcedony veins mapped in this area are summarized in the rosette which appears on plate 2. The strikes of each 500 feet of all mapped chalcedony veins were recorded as units; each vein with a mapped length less than 500 feet was also plotted as a unit. Tallies were made of the number of units in each 5° of arc; the combined tallies were converted into percentages of measured units in each 5° of arc in terms of the total 698 units recorded. Many strikes were on the boundary between two 5° sectors; these were arbitrarily plotted in the sector of higher azimuth. To balance such injustices the percentages were evened by means of moving averages. Each figure used in plotting the rosette is the average of the original percentage for the direction shown and the percentage for the two sectors lying 5° each side of it. Faults, lineaments, and metalliferous quartz veins were similarly analyzed by means of moving averages and plotted as rosettes (pl. 2).

Strikes of aplite dikes were not studied because many of these are quite flat and the trend is more a function of topography than of structure in the host rocks. Exposures generally did not permit the writer to distinguish between steep and flat dikes.

ORE DEPOSITS

Ore deposits in the area comprise metalliferous quartz and chalcedony veins, a small replacement deposit, a small disseminated deposit, and several placers. The Dobler mine explores a replacement body along a gouge zone of a steep bedding-plane fault; values are reported by Mr. R. Dobler (oral communication, 1954) to be in gold, with silver and lead becoming important at depth. Pyromorphite occurs locally. Caved workings on Lava Mountain explore a mineralized zone in Tertiary rhyolite. Judging from dump samples the deposit consists of sparse galena, sphalerite, and colorless, purple, and green fluorite along cracks and disseminated in lithophysal rhyolite.

Gold placer deposits in Pleistocene gravel were extensively worked along Prickly Pear Creek and less extensively along the upper part of Mitchell Gulch. Local placer operations have been carried out in McClellan Creek near the junction with Maupin Creek.

Veins are of two types: (1) quartz veins contain varying amounts of pyrite, sphalerite, galena, arsenopyrite, chalcopyrite, tetrahedrite, sparse gold, ruby silver, native silver, molybdenite, and pitchblende, and in the gangue, carbonate minerals, micro-crystalline quartz, chalcedony, and local barite; and (2) chalcedony veins, stringers, and zones mostly are devoid of metallic minerals but a few contain sparse silver or uranium minerals, pyrite, galena, chalcopyrite, sphalerite, calcite, barite, and opal.

The metalliferous quartz veins occupy fault zones in the batholith and older rocks. Most trend nearly east-west, some are as much as 6 feet wide and over 4,000 feet long. At least one vein, the Fleming (Bell) is cut by rhyolite dikes and all are probably older than both the rhyolite and dacite. These veins may be subdivided into three groups on the basis of proportions of contained base and precious metals, and type of gangue as follows: (1) high-grade silver, (2) base metal - silver, and (3) gold, The high-grade silver quartz veins carry minor amounts of gold and varying amounts of lead, zinc, and copper. Ore minerals are native silver, ruby silver, argentiferous galena, sphalerite, and tetrahedrite. These ore minerals are associated with vuggy comb quartz. Younger gangue minerals are chalcedony, microcrystalline quartz, carbonate minerals, and locally barite, which fill the vugs and occur as stringers and veinlets cutting the milky quartz and sulfides. The presence of chalcedony veinlets cutting these quartz-sulfide veins suggests that perhaps all the chalcedony veins in the area are younger than the quartz veins. Examples of this group of quartz veins are those in the Legal Tender, Liverpool, Meadow, and Mammoth mines.

Base-metal quartz veins were mined principally for lead and zinc, but most of the veins also contained significant amounts of silver and gold and a little copper. Vein minerals are principally pyrite, sphalerite, chalcopyrite, galena, and arsenopyrite. The gangue is quartz with locally small amounts of carbonate minerals and rarely tourmaline. Examples of this group of veins are the White Pine, Bell, Carbonate Chief, B & G, and Willard group.

Quartz veins of the third group were mined principally for gold, but minor silver, lead, zinc, and copper were recovered from some of them. The chief metalliferous vein minerals are pyrite and arsenopyrite; chalcopyrite, sphalerite, and galena are common in some of the veins. Locally there are abundant carbonate minerals in the gangue. These veins differ from the base-metal veins only in the proportion of silver to gold and of base to precious metals. Some quartz-pyrite-arsenopyrite veins of this group are essentially barren of ore. Representatives of this group of gold veins are the Euclid, Pilot, Katie, Bosphorous, and Economy.

Most of the chalcedony veins are devoid of ore minerals, or virtually so; a few contain uranium minerals or sparse amounts of tetrahedrite or ruby silver, galena, sphalerite, pyrite, chalcopyrite, and arsenopyrite(?). Silica of several types and ages is commonly present. Much is chalcedony, but significant amounts of micro-crystalline quartz are present. Earlier generations of chalcedony are commonly brecciated and cemented by later ones. Silica veins are various shades of red, yellow, brown, and gray to almost black. The black color is probably due to the presence of dispersed very finely divided pyrite, chalcopyrite, and possibly arsenopyrite (D. Y. Meschter, 1953, written communication). In the W. Wilson mine commercial quantities of uranium occur in veins of this type and in altered wall rock adjacent to the veins.

URANIUM DEPOSITS AND RADIOACTIVITY

All major and most minor dumps and all accessible underground workings in the area were tested with a scintillation counter for radioactivity by the writer and/or Fred McGarry during 1954. All anomalous radioactivity detected is plotted on plate 1 and is summarized in table 2. The points plotted include observations along both metalliferous quartz veins and chalcedony veins. The points fall into two distinct groups. The smaller, eastern group of anomalies is associated with metalliferous quartz veins. The larger group to the west includes anomalies associated with both metalliferous quartz veins and chalcedony veins, and is the eastern part of a larger group of anomalies that extends

Table 2. Localities with anomalous radioactivity

Locality	Type of vein	Type of sample	Radioactivity in mr/hr: background	Radioactivity in mr/hr: anomaly, above background	(anomaly + background) ÷ (background)	% U C-chem. E-equiv.	Remarks
W. Wilson and vicinity	Chalcedony U	- -	1.7	8.3	4.9	over 1.0 C	Pitchblende & secondary uranium minerals
White Pine	Quartz Pb-Ag-Zn-Cu	6" sample	- -	- -		.016-0.003 E	
		select high-grade from vein at face	- -	- -		0.125 E	Very spotty distribution
		select high-grade from cavein near face	- -	- -	- -	0.645 C 0.21 E 0.014 C 0.046 E	
		select from dump	- -	- -	- -	1.37 C 0.47 E 0.15 E	
B & G	Quartz Pb-Ag-Zn-Cu	select high-grade, dump	- -	- -	- -	0.26 E	On strike of White Pine vein.
Carbonate Chief	Quartz Pb-Ag-Zn-Cu	select high-grade, dump	0.012	0.062	6.2	- -	15 ft. south of shaft, lower elsewhere
Legal Tender	Quartz High-grade Ag	select high-grade, dump	0.001	0.004	5.0	- -	East shaft
			0.010	0.021	3.1	- -	Trend along vein
			0.007	0.019	3.7	- -	West shaft
S½ Sec. 10, T. 8 N., R. 3 W.	Chalcedony Barren	select high-grade	0.008	0.030	4.8	- -	
			0.008	0.019	3.4	- -	1000' west
Liverpool	Quartz Ag-Pb	select high-grade, dump	0.011	0.035	4.2	- -	Main shaft
			0.011	0.013	2.2	- -	Pitchblende reported
			0.008	0.018	3.3	- -	Shaft 1200' N of main shaft
War Eagle	Quartz Pb-Ag-Zn-Cu	4 ft. altered and gouge zone	0.018	0.652	4.1	0.038 E 0.07 E trace C	Radioactivity probably associated with limonite. Many zones of lower radioactivity
N½, NE¼, sec. 3, T. 8 N., R. 3 W.	Quartz Ag-Pb	select high-grade, dump	0.010	0.017	2.7	- -	Lower radioactivity on east side of Strawberry Creek
SE¼, NW¼, Sec. 30, T. 8 N., R. 2 W. caved adit	Not known, meager dump samples show sparse galena sphalerite and fluorite along cracks in rhyolite		X	1.5 X	2.5	- -	Small creek largely from mine drainage Dump area radioactivity lower
Black Bear	Quartz Au-Ag	select high-grade, dump	0.010	0.013	2.3	- -	
Meadow	Quartz Ag-Pb	select high-grade, dump	0.011	0.012	2.1	- -	Perhaps the extension of Liverpool vein
Mammoth Lode	Quartz Ag-Pb	select high-grade, dump	0.008	0.008	2.0	- -	100' from portal
			0.008	0.007	1.9	- -	SW Corner
			- -	- -	- -	- -	Lower radioactivity on dump of discovery shaft and underground
Alhambra Uranium mine	Chalcedony Barren	several inches of chalcedony & silicified quartz monzonite with abundant barite.				0.03 E	
Willard group	Quartz Ag-Pb-Au	select high-grade	0.009	0.008	1.9	- -	Fe-stained quartz monzonite at shaft edge
		- -	- -	- -	- -	- -	Lower radioactivity of dump samples of high gangue ore

to the west about 2½ miles (Becraft and others/; Roberts and Gude, 1953).

/ Becraft, G. E., Gude, A. J., 3rd., Meschter, D. Y., Pinckney, D. M., and others, 1954, Anomalous radioactivity in the Jefferson City quadrangle, Montana: U. S. Geol. Survey Open-File map.

This belt of anomalies roughly coincides with a zone of abundant chalcedony veins and aplite and dacite dikes.

Uranium ore has been mined sporadically from small ore bodies at the W. Wilson mine near Clancy since 1951. The ore bodies are in a chalcedony vein system in quartz monzonite of the Boulder batholith.

The greatest radioactivity detected within the map area is at the W. Wilson and vicinity, including the President and A. Lincoln-G. Washington chalcedony vein system. Detailed studies and reports on these deposits have been made by Meschter (1953, written communication), Bieler and Wright (1952, written communication), Wright and Bieler (1953, written communication), Wright and others (1954, written communication), and Roberts and Gude (1953). Uranium minerals they identified include pitchblende, meta-autunite, metatorbernite, uranophane, beta-uranophane, uranocircite(?), metazeunerite(?), phosphuranylite(?), and voglite(?).

Radioactivity has been recorded from a number of metalliferous quartz veins. The most promising of these are a system of parallel veins in the batholith along the middle of Warm Springs Creek and probably the best uranium potential is somewhere in this vein system. The veins in this system strike east-west and include the War Eagle, Bell, Carbonate Chief, B and G, and White Pine veins. The Bell and Carbonate Chief workings are inaccessible but earlier work in these mines was extensive.

The White Pine vein is exposed in places along 600 feet of recent workings. The vein carries lead, zinc, and silver in irregular pods and has been subjected to post-mineralization shearing. Radioactivity was detected in only a few places in underground exposures. The most radioactive of these was in highly sheered vein matter at the face of the drift, where a small select sample analyzed 0.125 percent eU. A 6-inch zone of altered country rock and sheared vein matter had high radioactivity underground, but the maximum eU of any part of this zone was only 0.016 percent as measured in the laboratory. Perhaps the radioactivity was concentrated in the clay and limonite parts, most of which fell away from the sample and were not collected. Radioactivity was detected in a rock fall near the face. Samples from this rock pile are reported to contain 0.76 percent eU_3O_8 (Atomic Energy Commission, Butte sub-office, Monthly Report, Nov. 1953, page 13). No uranium minerals have been detected. Several radioactive samples were found on the dump.

The War Eagle and Bell veins just north of the White Pine are perhaps even more promising than the White Pine vein, for greater radioactivity was detected in underground exposures of the War Eagle vein than in the White Pine vein, and water draining the caved Bell workings has a higher uranium content than does water from the White Pine workings. A diamond drill hole from the White Pine vein 150 feet into the south wall has a heavy flow of water which has higher uranium content than does water draining the White Pine vein (Philip Fix, written communication).

The most radioactive of several zones in the War Eagle adit gave a reading of 0.652 mr/hr above the background count of 0.018 mr/hr. This zone comprises four feet of altered quartz monzonite and gouge with several thin stringers of sheared sulfide.

The B and G mine lies approximately on a westward projection of the White Pine vein. A dump sample was reported to contain 0.31 percent eU. (Atomic Energy Commission, Butte sub-office, Monthly Report, Nov. 1953, page 13).

A sample of pitchblende has been reported from the dump of the Liverpool mine. The Liverpool vein is a metalliferous quartz vein carrying lead and high-grade silver in a gangue of comb quartz, chalcedony, and abundant carbonate. The writer detected no uranium minerals on this dump, but selected samples have a radioactivity of 0.035 mr/hr above background radiation of 0.011 mr/hr.

In addition to the veins lescribed above there is possibility of finding other small ore bodies in other chalcedony and quartz veins in the map area. The most promising areas for future uranium prospecting are those in which numerous radioactivity anomalies have been detected, as described earlier in this section of the report.

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EXPLANATION

Dike rocks
Rhyolite, dacite, lamprophyre, aplite, alaskite, pegmatite, quartz monzonite, andesite, and basalt, undivided

Kvi
Andesitic and basaltic intrusives of Elkhorn Mountains volcanics

Xenoliths

Chalcedony vein

Metalliferous quartz vein

Contacts of selected geologic marker units, dashed where indefinite

70
Strike and dip of beds

90
Strike of vertical beds

80
Strike and dip of overturned beds

Anticline showing direction of plunge, dashed where approximately located

Syncline showing direction of plunge, dashed where approximately located

60
80
Isoclinal folds
showing strike and dip of axial plane and plunge of fold axes

65
Fold axes
Showing direction and amount of plunge (used where individual folds are too small to be shown separately)

90
Strike of vertical foliation

32
55
Strike and dip of foliation showing direction and amount of plunge of lineation

?
Fault, dashed where inferred or indefinite, queried where doubtful or probable.

30
Thrust or reverse fault, showing dip (saw-teeth on upper plate)

Pre-intrusive fault forming boundary along margin of intrusive bodies

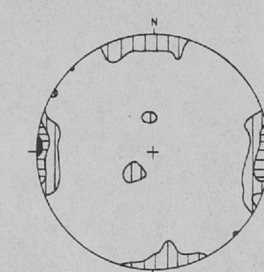
62
Strike and dip of joints

Strike of vertical joints

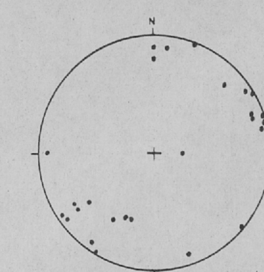
80 62
Strikes and dips of multiple joint sets

Lineaments
Straight linear surface features plotted from aerial photographs

STATISTICAL SUMMARIES OF STRUCTURAL FEATURES



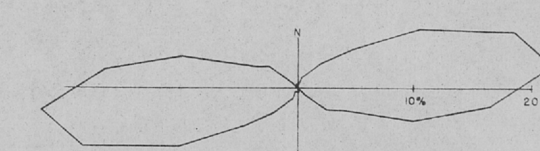
Joint diagram
Contour diagram of 260 poles of joints in batholith rocks. Contours 2-6-10 (11). Equal-area stereographic projection of lower hemisphere.



Foliation diagram
Point diagram of 26 poles of foliation planes in batholith rocks. Equal-area stereographic projection of lower hemisphere.

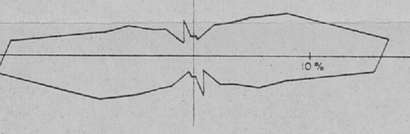
Rosettes showing relative abundance of high angle planar structures of different trends.

(One unit represents 500 feet. Method of construction of rosette is explained in the text.)

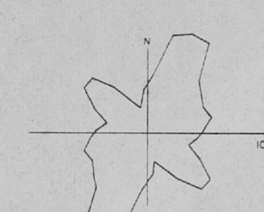


Metalliferous quartz veins

190 units represented



Chalcedony veins
698 units represented from area west of long-dashed line near west edge of map.



Faults

889 units represented

Lineaments

1214 units represented

Base from Stereo compilation by Fairchild Surveys, Inc; field checked by U.S. Geological Survey. This map is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

PLATE 2
STRUCTURE MAP OF THE NORTHERN ELKHORN MOUNTAINS
JEFFERSON AND BROADWATER COUNTIES MONTANA

0 ½ 1 2 3 Miles

19°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1950

Geology mapped in 1953 and 1954 by H.W. Smedes, assisted in 1953 by P.E. Myers.

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PLATE 1
GEOLOGIC MAP OF THE
NORTHERN ELKHORN MOUNTAINS
JEFFERSON AND BROADWATER COUNTIES, MONTANA

0 ½ 1 2 3 Miles

TRUE NORTH — MAGNETIC NORTH — 19°
APPROXIMATE MEAN DECLINATION, 1950

Geology mapped in 1953 and 1954 by H.W. Smedes, assisted in 1953 by P.E. Myers.

EXPLANATION

SEDIMENTARY ROCKS

PLEISTOCENE and RECENT

- Qal — Alluvium
- Qls — Landslide
- Qgr — Gravel
- Qh — Travertine at Alhambra Hot Springs
- Qf (Qf1, Qf2, Qf3) — Fan gravel; Qf_1 - older fan; Qf_2 - younger fan
- Qg (Qgm, Qgo) — Glacial deposits; Qgm, moraine; Qgo, outwash

ANGULAR UNCONFORMITY

TERTIARY

- Tu — Ash, gravel, sand, and tuff, undivided

ANGULAR UNCONFORMITY

CRETACEOUS

Upper Cretaceous

- Kv — Undivided
- Kvb / Kvtb — Coarse-grained pyroclastics; Kvb, volcanic breccia; Kvtb, tuff-breccia
- Kvlt / Kvt — Fine-grained pyroclastics; Kvlt, lapilli tuff; Kvt, tuff
- Kvts — Tuff flow rocks
- Kvs — Andesitic sedimentary rocks

Elkhorn Mountains volcanics
Dominantly andesitic volcanic rocks and quartz latitic tuff flows; includes contemporaneous andesitic and basaltic intrusive rocks shown as Kvi on igneous rock legend

- Ks — Slim Sam formation

ANGULAR UNCONFORMITY

- Kcm — Middle unit
- Kcl — Lower unit

Lower Cretaceous

- Kk (ls) — Kootenai formation; ls, gastropod-bearing limestone unit

JURASSIC

Upper Jurassic

- Jm — Morrison formation
- Js — Swift formation
- Ju — Morrison and Swift formations, undivided

EROSIONAL UNCONFORMITY

PERMIAN

- Pp — Phosphoria formation

PENNSYLVANIAN

- IPq — Quadrant formation
- MPa — Amsden formation

MISSISSIPPIAN

- Mm — Madison group, undivided

DEVONIAN

- Dt — Three Forks shale
- Dj — Jefferson formation

EROSIONAL UNCONFORMITY

CAMBRIAN

Upper Cambrian

- €D — Maywood and Red Lion formations, undivided
- €pi — Pilgrim limestone

Middle Cambrian

- €pa — Park shale
- €m — Meagher limestone
- €w — Wolsey shale
- €f — Flathead quartzite

ANGULAR UNCONFORMITY

PRE CAMBRIAN

Belt series

- p€b — Helena dolomite and Empire shale, undivided

IGNEOUS ROCKS

- Tr / Tri / Trt — Tr, rhyolite, undivided; Tri, rhyolite intrusives; Trt, rhyolite tuff
- Tdi — Dacite intrusives

BOULDER BATHOLITH

Late stage

- a — Aplite, alaskite, pegmatite, and alkali granite, undivided
- tgr — Tourmaline granite
- L — Lamprophyre
- gr — Granite, porphyritic, with hornblende and potash feldspar phenocrysts

Main stage — Quartz Monzonite and Granodiorite

- b / b+a — b, quartz monzonite and granodiorite, undivided; b+a, cut by aplite, alaskite and pegmatite dikes
- bcl / bcl+a — bcl, coarse-grained; light gray; bcl+a, cut by aplite, alaskite, and pegmatic dikes
- bcla / bcla+a — bcla, coarse-grained, light gray, porphyritic; bcla+a, cut by aplite, alaskite, and pegmatite dikes
- bml — Medium grained, light gray
- bm2 / bm2a — bm2, medium-grained, medium gray; bm2a, rich in mafics
- bfl / bflb — bfl, fine-grained, light gray; bflb, porphyritic with aplitic groundmass
- bfld — Very fine-grained, light gray, porphyritic with large phenocrysts of quartz, potash feldspar, and hornblende

Early stage

- g / g+a — g, monzonite, granodiorite, diorite, and gabbro; g+a, cut by aplite or quartz monzonite dikes

- Kvi — Andesitic and basaltic intrusives

METAMORPHIC ROCKS

- Kvm — Altered tuff flow rock
- Thermally metamorphosed rocks
- ta — Tactite
- Schist, amphibolite, and mylonite

VEINS AND ALTERED ROCKS

- Metalliferous quartz vein
- Chalcedony vein or vein zone
- S — Silicified rock; Silica probably deposited in part by meteoric water
- Hydrothermally altered rock (largely sericitized or kaolinized)

Contact
Long-dashed where approximately located, short-dashed where inferred or indefinite, dotted where concealed

Gradational contact

Fault
Long-dashed where approximately located, short-dashed where inferred or indefinite, dotted where concealed

— ? — — ? —
Probable fault

70
Strike and dip of beds

Quarry

Shaft
Short bar indicates inclined; circle indicates caved or flooded

Adit
Short bar indicates caved

Trench

×
Prospect

9
Number identifying mine in list below

1. Bonanza Chief
2. Overland
3. Economy (Smith)
4. Dobler
5. Liverpool
6. Tycoon
7. Meadow
8. New Stake
9. Legal Tender
10. Mammoth
11. Alhambra
12. W. Wilson
13. President
14. Copper Jack
15. Tall Pine
16. Badger
17. Pilot
18. Golden Gate and Euclid
19. Katie
20. Willard group
21. Good Cheer (?)
22. Black Bear
23. Middlesex
24. B & G
25. Eagle's Nest
26. White Pine
27. War Eagle
28. Fleming (Bell)
29. Carbonate Chief
30. Bosphorus

ANOMALOUS RADIOACTIVITY

- Anomalous radioactivity associated with metalliferous quartz veins
- Metalliferous quartz veins or altered wall rock from which samples containing more than 0.1 percent U_3O_8 have been collected
- Anomalous radioactivity associated with chalcedony veins
- Chalcedony veins or altered wall rock from which samples containing more than 0.1 percent U_3O_8 have been collected