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MEMOIR 41

December 1967

BEDROCK GEOLOGY of the SHERIDAN DISTRICT, MADISON COUNTY, MONTANA

by
H. Robert Burger, III
Smith College, Northampton, Massachusetts

MONTANA BUREAU
of
MINES AND GEOLOGY
Butte, Montana

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MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
Butte, Montana
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trict follow a broad but consistent pattern (Pl. 2). Almost all mines are situated on or close to a marble bed; many are near an intrusive mass; and many are in the vicinity of fold crests. In many mines, although intrusive rock is not exposed at surface, there is evidence of a possible concealed mass. Most veins follow one of several established regional joint trends, a N. 30° E. trend being dominant. This relationship between mines and geologic controls should provide some general guide for future prospecting.

GEOLOGIC HISTORY

The Sheridan district was originally underlain by approximately 9,000 feet of marginal-eugeosynclinal intrusive and sedimentary rocks, including basic flows and sills, ultrabasic intrusive bodies, graywacke, calcareous shale, sandstone, clay-rich sandstone, and dolomitic limestone interbedded with chert or pure sandstone. During an intense orogenic episode this sequence was complexly folded, refolded, overturned, and metamorphosed.

During this deformation the deepest rocks were metamorphosed to the hornblende-granulite subfacies. Deepest burial was approximately 8 miles and temperatures were on the order of 600°C. Local variations in water-vapor pressure resulted in intermingling of the almandine-amphibolite facies and the hornblende-granulite subfacies. Rocks metamorphosed at progressively higher structural levels and therefore progressively lower temperatures and pressures were subjected to almandine-amphibolite facies and cordierite-amphibolite facies conditions.

A compressive stress directed slightly south of west was exerted in the area during the Laramide orogeny. This stress reactivated the Precambrian fracture trends and controlled the intrusion of the Tobacco Root batholith. After intrusion of the batholith, about 66 million years ago, high-angle faults cut the northeastern and western limits of the Sheridan district. After this episode of intrusion and fracturing, quartz monzonite and quartz-monzonite porphyry stocks were intruded. These were controlled by fracture and foliation trends in the country rock. The Tertiary intrusions were accompanied by widespread ore mineralization.

Ore mineralization associated with these stocks was localized by an interaction of geologic controls. Major veins followed regional fracture systems but especially favored at N. 30° E. trend. Marble beds interacting with intrusive quartz monzonite played an essential role in localizing the ore deposits. In addition, the crests of major folds were more fractured than surrounding country rock, thus providing a more favorable zone for mineralizing solutions.

Subsequent uplift of the entire area, erosion of the sedimentary cover, and dissection of the metamorphic bedrock exposed the area as it is seen today.

REFERENCES CITED

ENGEL, A. E. J., and ENGEL, C. G., 1962, Progressive metamorphism of amphibolite, northwest Adirondack Mountains, New York: Geol. Soc. America Buddington Vol., p. 37-82.

GILETTI, B. J., and GAST, P. W., 1961, Absolute age of Precambrian rocks in Montana and Wyoming: New York Acad. Sci. Annals, v. 91, p. 454-458.

HAYDEN, R. J., 1959, Potassium-argon dating in western Montana (abs.): Geol. Soc. America Bull., v. 70, p. 1778-1779.

HEINRICH, E. W., 1960, Pre-Beltian geology of the Cherry Creek and Ruby Mountain areas, southwestern Montana: Montana Bur. Mines and Geol. Mem. 38, 40 p.

JOHNS, W. M., 1961, Geology and ore deposits of the southern Tidal Wave mining district, Madison County, Montana: Montana Bur. Mines and Geol. Bull. 24, 53 p.

LEVANDOWSKI, D. W., 1956, Geology and mineral deposits of the Sheridan-Alder area, Madison County, Montana: unpub. Ph. D. thesis, Michigan Univ.

LORAIN, S. H., 1937, Gold lode mining in the Tobacco Root Mountains, Madison County, Montana: U. S. Bur. Mines Inf. Circ. 6972, 72 p.

PEALE, A. C., 1896, Description of the Three Forks quadrangle: U. S. Geol. Survey Geol. Atlas, Folio 24 (Three Forks).

REID, R. R., 1957, Bedrock geology of the north end of the Tobacco Root Mountains, Madison County, Montana: Montana Bur. Mines and Geol. Mem. 36, 25 p.

———, 1959, Crystalline rocks of the northern Tobacco Root Mountains, Madison County, Montana: unpub. Ph. D. thesis, Washington Univ.

———, 1963, Metamorphic rocks of the northern Tobacco Root Mountains, Madison County, Montana: Geol. Soc. America Bull., v. 74, p. 293-306.

RUNNER, J. J., and THOMAS, L. C., 1928, Stratigraphic relations of the Cherry Creek Group in the Madison Valley, Montana (abs.): Geol. Soc. America Bull., v. 39, p. 202-203.

SMITH, J. L., 1965, Geologic investigations of the Tobacco Root batholith, Madison County, Montana: The Compass, v. 42, p. 256-264.

TANSLEY, WILFRED, SCHAFER, P. A., and HART, L. H., 1933, A geological reconnaissance of the Tobacco Root Mountains, Madison County, Montana: Montana Bur. Mines and Geol. Mem. 9, 57 p.

THOMPSON, W. D., 1960, Geology of the northern part of Cherry Creek metamorphic rocks, Madison County, Montana: Billings Geol. Soc., 11th Ann. Field Conf., p. 135-147.

WINCHELL, A. N., 1914, Mining districts of the Dillon quadrangle, Montana, and adjacent areas: U. S. Geol. Survey Bull. 574, 191 p.

WINKLER, H. G. F., 1965, Petrogenesis of metamorphic rocks: New York, Springer-Verlag New York Inc., 220 p.

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Figure 6.—Paragenetic diagram for the Occidental mine

extensive replacement of galena by chalcocite and by spotty occurrence of covellite, followed this period of deformation and gangue deposition. No fractures cut chalcocite, whereas covellite veinlets seem to follow what may be reopened fractures. Covellite is definitely later than chalcocite, as it appears only on the edges of large areas of chalcocite replacement and forms embayments into the chalcocite.

Graphite is ubiquitous but is mainly confined within minute fractures in pyrite masses. Because of its relative non-reflectivity, however, no definite relations could be established.

The inferred sequence of deposition is presented in a paragenetic diagram (Fig. 6).

Red Pine mine.—The Red Pine mine was described briefly, and little additional information is available. Only the lower workings were examined, because the upper adit is now inaccessible. All veins containing significant amounts of ore are within marble and seem to be fissure fillings as opposed to replacement.

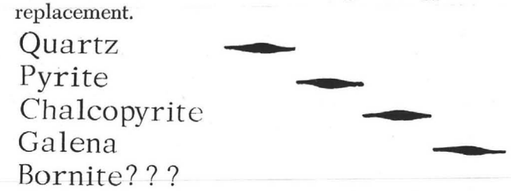

Figure 7.—Paragenetic diagram for the Red Pine mine

Four polished sections revealed a normal mineralization sequence, which is presented in the paragenetic diagram for this mine (Fig. 7). The only noteworthy observation is the consistent rimming of chalcopyrite by galena (Fig. 5b). This is important from a recovery standpoint, as gold is associated with the sulfides and might be lost if an improper recovery technique were to be used. Some bornite was reported in mining but none was observed in the samples.

CONCLUSIONS—ECONOMIC GEOLOGY

Ore deposits in the Sheridan district are formed by filling of fissure veins and by metasomatic replacement of gneiss and marble country rock. The deposits associated with the fissure veins are mainly within marble beds or along marble-gneiss contacts, but some are wholly within gneiss. Almost every fissure vein parallels regional fracture systems; most follow a N. 30° E., 40° NW. fracture system (Fig. 4). Metasomatic replacement deposits are almost confined to marble beds. Replacement is localized along fractures cutting across marble beds; along marble-gneiss contacts, especially where these contacts parallel a fracture system; and along shear zones parallel to foliation, most likely developed by shearing related to intrusion.

The sequence of deposition of the various minerals may be complex or simple and differs markedly in adjacent mines. No zonal arrangement of minerals is evident within the Sheridan district, but the hypothesis that larger percentages of lead, silver, and zinc are a measure of distance from, or above, the batholith (Lorain, 1937, p. 16) is not precluded. The validity of this idea is questionable, however, as the Occidental mine, which is close to the batholith, has a major lead-zinc content.

Future prospects for this region are questionable. The only active mines are the Red Pine, which is marginal; the Occidental, which because of its location is somewhat inaccessible; and Quartz Hill, which is a tenuous operation. This report does indicate, however, that the mineral deposits of the Sheridan dis-

must have overlapped the sphalerite deposition, as textural relations give conflicting chronological evidence. First-generation pyrite was replaced by galena (Fig. 5a, b). The deposition of galena is believed to mark the end of the first mineralization period.

The beginning of the second period of mineralization was marked by replacement of galena by pyrite. Evidence of a second generation of sphalerite deposition is mainly a non-iron-rich variety of sphalerite replacing galena (Fig. 5a). Chalcopyrite replaces both the second generation sphalerite and galena (Fig. 5b).

Deformation of galena and quartz, and veinlets of calcite that cut other second-generation minerals, both suggest a post-mineralization period of minor shear deformation. Supergene enrichment, marked by

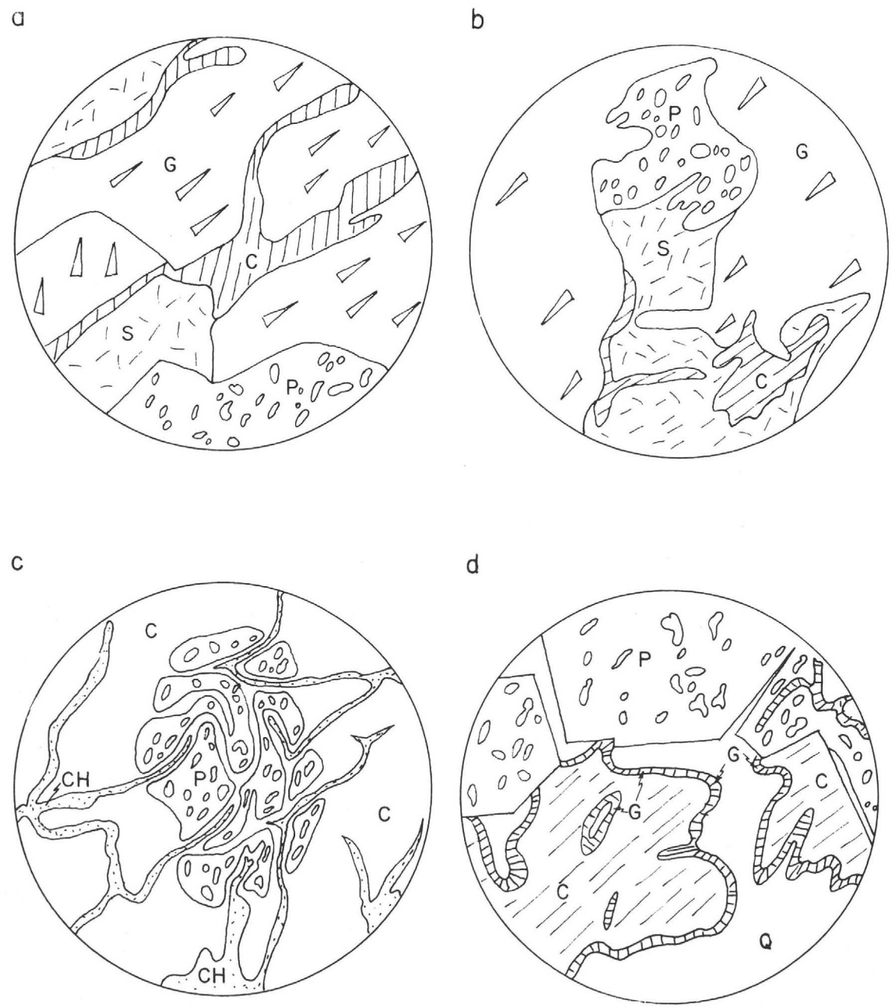

Figure 5b.—Textural relationships of ore minerals.

(a) Sketch of chalcopyrite (C) replacing galena (G); pyrite (P), sphalerite (S). Diameter of sketch = 30 mm.

(b) Sketch of galena (G) and second-generation sphalerite (S) replacing first-generation pyrite (P). Sphalerite also replaces galena; chalcopyrite (C). Diameter of sketch = 30 mm.

(c) Sketch of chalcocite (CH) replacing chalcopyrite (C), which replaces pyrite (P). Diameter of sketch = 30 mm.

(d) Sketch of galena (G) replacing chalcopyrite (C); quartz (Q), pyrite (P). Diameter of sketch = 30 mm.

BEDROCK GEOLOGY

of the

SHERIDAN DISTRICT, MADISON COUNTY, MONTANA

by

H. Robert Burger, III

ABSTRACT

The Sheridan district, covering approximately 60 square miles, is on the western flank of the Tobacco Root Mountains, Madison County, Montana. The exposed metamorphic bedrock is divided into the following major mappable units: quartzo-feldspathic gneiss assemblage, amphibolite-hornblende gneiss assemblage, anthophyllite gneiss assemblage, intermediate gneiss assemblage, and marble. Detailed study of 150 thin sections, 23 modal analyses, and 24 chemical analyses indicates that these metamorphic rock assemblages were derived from a 9,000-foot sequence of graywacke, clay-rich sandstone, sandstone, calcareous shale, dolomitic limestone interbedded with chert or pure sandstone, basic sills and flows, and ultrabasic intrusive bodies.

Geologic map patterns delineate a series of slightly overturned, isoclinal antiforms and synforms, which plunge N. 10° W., 24° NW. In the northern part of the map area the nose of the Wisconsin Creek antiform is overturned, detached, and refolded, thereby producing a nappe structure.

In the southern half of the Horse Creek synform, Eclipse Gulch antiform, and Bitney synform the hornblende-granulite subfacies rank of metamorphism was locally obtained. Temperature of metamorphism is estimated to have been 600°C.; depth of burial, based on structural evidence, approached 8 miles. Metamorphic rank decreases to the north where the sillimanite-almandine-orthoclase subfacies, almandine-amphibolite facies predominates. Metamorphic rocks to the northeast of the Noble fault belong to the sillimanite-cordierite-muscovite - almandine subfacies, cordierite - amphibolite facies.

Joint systems within the Sheridan district are a result of both Precambrian and Laramide deformations. Dominant, nearly vertical, joint planes having average trends of N. 75° W., N. 45° W., N. 2° E., and N. 65° E. are believed to have originated in the Precambrian, on the basis of close agreement with theoretical trends.

Dominant fracture systems probably controlled the intrusion of the Tobacco Root batholith and the orientations of the Noble, Booth, and Parson faults, which are all associated with the Laramide orogeny.

Later Tertiary intrusive stocks of quartz monzonite and quartz-monzonite porphyry are associated with widespread mineralization. Mineralization was controlled by the contact of stocks with marble beds and by existing fracture systems. Major veins especially favored a N. 30° E. fracture trend.

INTRODUCTION

LOCATION AND PHYSICAL SETTING

The Sheridan district is east of the town of Sheridan on the southwest flank of the Tobacco Root Mountains in southwestern Montana and includes portions of the Waterloo, Sheridan, and Copper Mountain quadrangles. Lorain (1937) first used the term Sheridan district to refer to a complex of gold mines scattered throughout this general region. As the present investigation encompasses approximately the same area as that originally designated by Lorain, the name Sheridan district is used in this report. The area of investigation extends westward from long 112° W. to the western limits of the Tobacco Root Mountains; lat 45°34′ N. and lat 45°27′30″ N. form the northern

and southern limits of this area. These boundaries outline an area of slightly less than 60 square miles (Fig. 1).

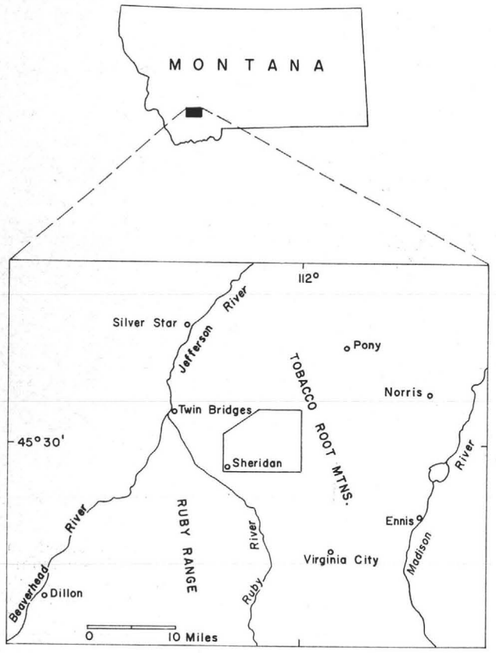

Figure 1.—Index map showing location of Sheridan area.

Relief in this region differs markedly. The westernmost exposures of metamorphic rocks are found at altitudes of 6,000 feet, but the mountains rise abruptly to the northeast, reaching an average altitude of 9,000 feet. Many of the higher peaks range from 10,000 to 10,200 feet in altitude. Three major streams, Wisconsin Creek, Indian Creek, and Mill Creek, flow southwestward nearly perpendicular to the regional strike of the metamorphic rocks. The greater part of the area is within the Beaverhead National Forest.

Most of the Sheridan district is underlain by Cherry Creek metamorphic rocks (pre-Beltian) as defined by Peale (1896, p. 2). Pony metamorphic rocks, as defined by Tansley and Schafer (1933, p. 8), supposedly crop out farther northwest. The distinction between these two units is not well understood and is irrelevant to the objectives of this investigation; no detailed discussion of this problem will be presented.

In the northeastern part of the Sheridan district the metamorphic rocks are intruded by the Tobacco Root batholith, of late Cretaceous-early Tertiary age. Numerous localized stocks of probable Tertiary age are scattered over the entire area. No Paleozoic rocks are present, but they are exposed directly northwest of the area. Tertiary basin deposits cover the metamorphic rocks along the western fringe of the mountain range; Pleistocene glacial deposits and Recent alluvium are restricted to narrow tracts within the drainage systems.

PREVIOUS WORK

Previous work within the Sheridan district has been fairly generalized. Winchell (1914) and Lorain (1937) published reports describing the mines within the area. Tansley, Schafer, and Hart (1933) conducted a reconnaissance survey of the Tobacco Root Mountains. Their geologic map delineates several prominent marble beds exposed throughout the Sheridan district. Several of these beds are shown, although incorrectly, as joined to produce fold patterns. Levandowski (1956) mapped an area 3 to 4 miles wide extending from the southern limit of the Sheridan district southward to the town of Alder. Several interesting fold patterns are outlined on his geologic map. Unfortunately, however, the strip of mapping is parallel to the major geologic structure within the area and does not reveal much lateral detail of overall structural patterns. Reid (1957, 1959, 1963) mapped a considerable extent of Pony and Cherry Creek metamorphic rocks in the northern Tobacco Root Mountains. Although he presents much lithologic detail in his text, his mapping distinguishes only between these two major groups of metamorphic rocks and shows no patterns of units within the large groups.

Runner and Thomas (1928), Thompson (1960), and Heinrich (1960) published reports dealing with the stratigraphy and mineralogy of Cherry Creek metamorphic rocks. These reports, however, deal with areas in the Ruby Mountains and on the eastern flank of the Tobacco Root Mountains.

PURPOSE OF INVESTIGATION

The objectives of this study of the bedrock geology of the Sheridan district are: (1) an interpretation of the interrelation of various rock types and their origin, (2) a logical explanation of the structural features observed in the metamorphic rocks, and (3) a determination of the nature and importance of structural and lithologic controls of mineral deposits.

A survey of the literature dealing with the Precambrian rocks of the Tobacco Root Mountains emphasizes the lack of any detailed structural studies. Because of this previous lack of detailed geologic mapping, the present study concentrated heavily on detailed field relationships.

An episode of quartz deposition preceded pyrite, which was then followed by pyrrhotite. The pyrrhotite partly replaced the pyrite, as all pyrrhotite contains rounded and corroded pyrite cores (Fig. 5a). The pyrrhotite also exhibits structures suggesting colloidal deposition. All pyrrhotite globules are in turn surrounded by a second generation of pyrite, which probably represents only a slight change in environmental conditions but which may correlate with the second-generation pyrite discussed later. Marmotite, the iron-rich variety of sphalerite, followed pyrite, but no evidence is available concerning its relation with pyrrhotite. They may or may not have been contemporaneous. Galena was deposited next and

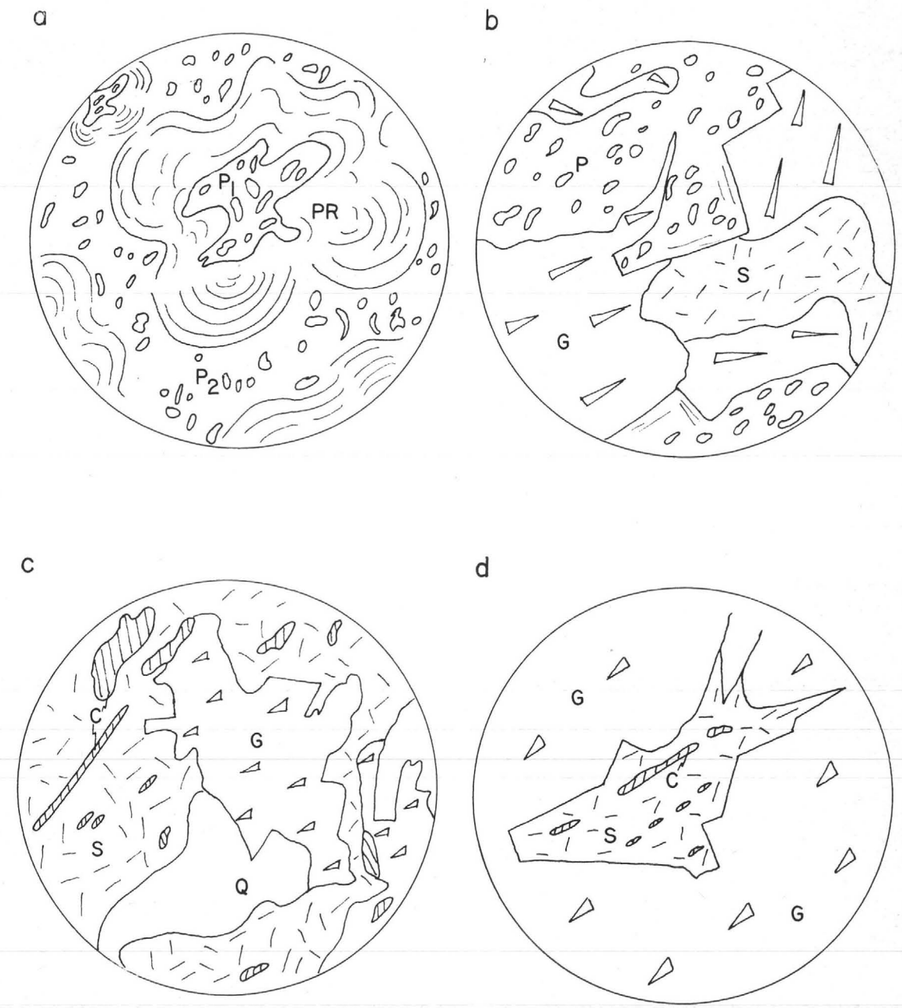

Figure 5a.—Textural relationships of ore minerals.

(a) Sketch showing replacement of first-generation pyrite (P_1) by pyrrhotite (PR), which is replaced by second-generation pyrite (P_2). Diameter of sketch = 30 mm.

(b) Sketch of galena (G) replacing first-generation pyrite (P); sphalerite (S). Diameter of sketch = 30 mm.

(c) Sketch showing second-generation sphalerite (S) replacing galena (G); chalcopyrite (C), quartz (Q). Diameter of sketch = 30 mm.

(d) Sketch of second-generation sphalerite (S) replacing galena (G); chalcopyrite (C). Diameter of sketch = 30 mm.

Leiter mine.—The Leiter mine, although once one of the most important producers in the district, is apparently somewhat anomalous in respect to mineralization controls. The two major veins in which ore was found strike N. 70° E. and N. 25° E., and dips are steep to vertical (Tansley, Schafer, and Hart, 1933, p. 42). These attitudes conform to regional fracture systems. No marble beds are exposed, although a continuation of a marble layer through this area is hypothesized on the basis of structural conditions and marble float. No intrusive bodies were observed in this part of the area.

Lucky Strike mine.—The Lucky Strike mine is 11½ miles from Sheridan on Indian Creek at an altitude of 9,500 feet. A quartz vein striking E. -W. and dipping 45° N. contained all the ore mined from this small mine. Gold and silver accounted for all the value recovered.

Noble mine.—Mineralization in the Noble mine is confined to a vein striking N. 30° E. and dipping 45° NW., especially where it is in contact with a basaltic intrusive mass. The ore is dominantly auriferous pyrite and chalcopyrite (Tansley, Schafer, and Hart, 1933, p. 42). The proximity of this mine to a thick marble bed and Tertiary intrusive masses once again emphasizes recurring mineralization controls. The attitude of the vein coincides with regional trends, which are especially well developed in this area.

Occidental mine.—As the Occidental mine provided good access to present workings, a detailed study was possible. The structure and mineralization will be described in detail in the following pages.

Quartz Hill mine.—The Quartz Hill mine is currently being worked by the Gateway Mining Company. The ore is found in thin replacement lenses within marble beds adjacent to stringers of quartz-monzonite intrusive rock. All value is in gold disseminated in oxidized iron-rich gangue.

Red Pine mine.—The Red Pine mine is on Indian Creek, 8½ miles from Sheridan. The dominant ore bodies are confined to a fissure vein striking N. 20° E. and dipping 50° NW. All productive ore shoots have been localized in the marble beds crossing the area. The main tunnel, which yielded most of the production from this mine, is now inaccessible. A secondary adit, 400 feet below the main adit, has intersected several veins but has not yielded significant production. A description of the mineralization is given farther along in this report.

Silver Bullion mine.—The mineralization at the Silver Bullion mine at the head of Horse Creek is similar to that of the Broadgauge-Tamarack mines. All value is in silver, which is restricted to replacement zones within marble. Widespread, extensive silicification of the marble layer suggests the presence of an intrusive mass at depth.

Smuggler mine.—The Smuggler mine is on Mill Creek, 7 miles east of Sheridan. Ore is found in a vein occupying a strong fault zone in gneiss country rocks. The vein strikes N. 75° W. and dips 75° SW. (Tansley, Schafer, and Hart, 1933, p. 44). Although detailed information is lacking, the close proximity of a major marble bed and the similarity of the strike of the vein to a dominant regional trend again suggests regional control of the mineralization.

Sunbeam mine.—Few data are available concerning the nature of the deposits in the Sunbeam mine, which is directly above the Occidental mine. Ore consists of gold and silver in telluride and is confined to a marble bed.

Sunnyside mine.—The Sunnyside mine is at the head of Cow Creek adjacent to a prominent marble bed. Dominant vein attitudes are N. 60° W., 35° NE. and N. 39° W., 35° SW. These are closely similar to regional fracture trends and to the dominant joints in the area. The important vein is within gneiss beds and contains pyrite and galena (Tansley, Schafer, and Hart, 1933, p. 44).

Toledo mine.—The Toledo mine is similar in most respects to the Buckeye mine.

DETAILED DESCRIPTIONS

Occidental mine.—The Occidental mine is developed by two adits approximately parallel to a well-defined contact between gneiss and marble. The major ore-bearing vein strikes N. 49° to 52° W., and dips regularly at 40° NW.; this orientation parallels one of the dominant regional fracture systems. Mineralization is most intense where this fracture trend coincides with the strike of the gneiss-marble contact. Replacement of the marble bed is extensive. The numerous other veins in the mine are relatively barren.

In the ore vein the minerals are predominantly galena and sphalerite; they are accompanied by a minor amount of pyrite. In the replacement area, chalcopyrite, chalcocite, covellite, pyrrhotite, and graphite are present in addition to the above minerals listed for the ore vein. Galena is by far the most common ore mineral.

Twenty polished sections of samples gathered from the replacement area and from the major ore vein were examined under reflected light. These point to a more involved paragenetic sequence than would be expected or inferred from the simple appearance of the deposit. At least two episodes of mineralization are apparent.

Although, as previously mentioned, the many gold mines within the Sheridan district have been briefly described, no general controls of mineralization have been identified. The study of structural relationships was therefore extended to include information concerning structural control of mineral deposits.

METHOD OF STUDY

Field relationships were recorded on aerial photographs and topographic maps at scales of 1:15,840 and 1:24,000, respectively. Normal geologic mapping methods were used, supplemented by field techniques common in advanced structural investigations. Sampling of the various lithologies was more concentrated during the early phases of the study and was reduced as knowledge of lithologic types increased. Locations of contacts are more accurately mapped in areas of low and medium altitude. Mapping at higher altitude was based principally on ridge-line traverses.

Four hundred and fifty specimens were collected for study. Three hundred thin sections were prepared and examined; one hundred and fifty were studied in detail. Twenty-four chemical analyses were prepared in order to provide information about lithology of rocks of unknown origin.

Various structural projections and geometric constructions were used to aid in the evaluation and interpretation of structural data, derived from both field and microscopic measurements.

ACKNOWLEDGMENTS

This study was conducted under the supervision of Dr. Thomas E. Hendrix of the Department of Geology, Indiana University, whose continued encouragement, criticism, and suggestions are sincerely appreciated. Thanks are extended to Dr. Judson Mead, Dr. John Patton, and Dr. Charles Vitaliano for aid and suggestions throughout the course of this study.

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Special thanks and appreciation are due Ann Burger, who ably served as field assistant during the field seasons of 1963 and 1964 and who willingly performed some of the more tedious tasks associated with data preparation and condensation. Raymond Rene′ served as field assistant during the summer of 1965.

METAMORPHIC ROCKS

The dominant rock types exposed within the Sheridan district are quartzo-feldspathic gneiss, hornblende gneiss, amphibolite, anthophyllite - garnet gneiss, marble, quartzite, and meta-intrusive rocks. These various lithologies are intimately intermixed even within small areas, and thus are not suitable as map units unless mapping is done in extreme detail. If, however, long traverses are made using the marble beds as markers, a persistent pattern emerges. On one side of the major marble bed, most of the rocks are quartzo-feldspathic gneiss, quartzite, and granulite. More basic gneiss is common within this sequence, however, and may constitute as much as 20 percent of the total assemblage. Locally, individual units within this sequence are traceable but not for a distance that would reveal structural relationships. On the other side of the marble bed the dominant rocks are amphibolite and hornblende gneiss intermixed with quartzo-feldspathic gneiss, which constitutes only 10 to 20 percent of the total assemblage, however. This consistent relationship was exploited by mapping a quartzo-feldspathic gneiss assemblage consisting dominantly of quartzo-feldspathic gneiss and granulite and minor quartzite, and an amphibolite-hornblende gneiss assemblage consisting dominantly of amphibolite and hornblende gneiss and minor less-basic gneiss interlayers. These assemblages retain consistent and predictable relations with the continuous marble bed throughout the area and are believed to represent original sedimentary or igneous sequences.

In addition to these assemblages, a sequence composed of nearly equal proportions of (1) quartzo-feldspathic gneiss and (2) hornblende gneiss and amphibolite occurs at certain places within the amphibolite-hornblende gneiss assemblage. A distinctive quartz-plagioclase-biotite gneiss within this particular sequence facilitated recognition during mapping. This sequence is called the intermediate gneiss assemblage.

In the northeastern part of the Sheridan district a distinctive assemblage of anthophyllite gneiss, garnet-plagioclase gneiss, amphibolite, green quartzite, and sillimanite schist is exposed. This association is called the anthophyllite gneiss assemblage.

These four assemblages, in addition to marble, form the main map units. In general, no subdivisions of these units were made during field mapping. It is desirable, however, to describe in detail distinctive rocks within the major units in order to provide a

basis for interpretation of original sedimentary or igneous parentage and to permit positive recognition of the various assemblages in the field.

MARBLE AND CALC-SILICATE ROCKS

Two marble beds are exposed in the Sheridan district. The dominant bed is continuous and is exposed throughout the entire area, whereas the other bed is exposed only as a layer within the quartzo-feldspathic assemblage in the vicinity of Bridge Canyon (Pl. 1). Thickness of the marble ranges from 100 feet to 800 feet and averages 300 feet. Both marble beds display identical weathering characteristics and similar variations in mineral compositions.

Detailed descriptions. — The mineral assemblage most often encountered is calcite-forsterite-diopside, an assemblage typical of metamorphosed silica-deficient calcareous sedimentary rocks. Calcite ranges from 52 to 85 percent, forsterite 1 to 9 percent, but diopside is rarely found in quantities greater than 5 percent. Magnetite is a constant minor constituent.

Calcite-dolomite-forsterite marble is common, but it is difficult to estimate relative percentages in comparison to calcite-forsterite-diopside marble because of the extensive serpentinization that has affected both types. Both assemblages seem identical in hand specimen, and as calcite is more abundant than dolomite in most specimens, both varieties react strongly with hydrochloric acid.

Distributed throughout most of the marble outcrops are boudins and isolated remnants of folds consisting dominantly of quartz surrounded by rims of diopside. At first glance these quartz pods seem to be segregation phenomena, but where a continuous exposure is available, the pods are seen to be oriented in discrete planes. This relation suggests that they represent original layers of siliceous material, such as pure sandstone or chert, which have been disrupted by flowage of the marble.

Calc-silicate rocks are uncommon and occur sporadically, but where present are associated with marble. No constant pattern of occurrence is discernable. The mineral assemblages associated with this rock type are complex, owing to the fine laminations of contrasting compositions. Recurring dominant minerals are calcite, quartz, plagioclase, microcline, tremolite, diopside, and clinozoisite. Accessories are sphene, apatite, magnetite, zircon, garnet, and talc.

A fine-grained rusty-brown severely contorted quartz-garnet-biotite-sillimanite schist occurs either within or adjacent to the marble at several places. Representative layers of this unit are found at the mouth of Cow Creek, at the Sunbeam mine on Indian Creek, in the marble southwest of Leggat Mountain, and north of Durham reservoir.

The recurring silica-deficient assemblages suggest metamorphism of dolomitic limestone in which silica is the only impurity. The quartz pods probably represent original chert or pure sandstone layers that were broken during flowage of the marble. During metamorphism these quartz pods reacted with the enclosing marble to form diopside rims, which protected the quartz from further reaction. Local intercalations of material containing more clay are represented by some of the calc-silicate assemblages; the fine-grained schist represents such a thin but persistent and widespread clay-rich layer.

QUARTZO-FELDSPATHIC GNEISS ASSEMBLAGE

The quartzo-feldspathic gneiss assemblage is the most widespread assemblage in the Sheridan district, being exposed over slightly more area than the amphibolite-hornblende gneiss assemblage. Three major areas of outcrop are: the Quartz Creek-Bridge Canyon drainage systems, the Eclipse Gulch-Skihi Peak area, and the Butterfly Flats-Cloudrest Peak area (Pl. 1). Thicknesses are somewhat difficult to estimate, owing to considerable flowage and recumbent folding of these rocks, but a maximum thickness of 3,000 feet is likely.

Where accessory minerals are abundant, these rocks show well-developed gneissic banding accompanied by apparent migmatitic injection. In most places, however, accessory minerals are present in only small amounts, and do not seem to be confined to discrete layers, but the quartz and feldspar still show signs of segregation, flattening, and elongation.

Thin-section study defines four dominant mineral assemblages, but unfortunately shows little consistency between mineral composition and hand-specimen appearance, where relatively pure quartz-feldspar rocks are concerned, but these types do constitute 60 to 70 percent of the total assemblage. Observable differences in hand specimens depend mainly on textural relations, which were controlled by behavior of the rock during deformation and by the degree of metamorphism to which it was subjected.

Detailed descriptions.—(1) Quartz-perthite-plagioclase gneiss and granulite constitute a distinct mineralogical and textural assemblage. Good representatives of this variety may be distinguished by granulitic texture and by the abundance of perthite, which is present in amounts as great as 45 percent. Quartz is flattened into elongate lenticles in individual grains 1 to 2 mm long. Between these thin quartz layers are grains of quartz, perthite, and plagioclase having a

ore-bearing veins and the major minerals present in each mine. No detailed investigation of the entire area has been published. Levandowski (1956) and Johns (1961) have written relatively detailed reports of the mineralization of areas adjacent to the Sheridan district.

Unfortunately, most of the mines encountered during research for this report were in a state of extreme disrepair, making detailed investigations impossible. Detailed investigations were almost confined to the Red Pine and Occidental mines, both of which are currently active.

DESCRIPTIONS OF INDIVIDUAL MINES

Much material presented in the following descriptions is gathered from previous publications, supplemented by new data where possible. This brief summary of mining localities is intended to provide a convenient compilation for reference and to provide a basis for later conclusions. All mine locations are shown on Plate 2.

Table 3.—Chemical composition and mineral assemblages of Tertiary intrusive rocks.

Constituent	Sample 79	135	188	191
SiO_2		64.72	63.24	
Al_2O_3		16.23	17.88	
Fe_2O_3		.89	1.53	
FeO		2.09	1.74	
MgO		1.91	.95	
CaO		3.05	4.36	
Na_2O		3.45	4.36	
K_2O		3.08	1.64	
MnO		.05	.10	
TiO_2		.37	.32	
P_2O_5		.22	.20	
S		ND	ND	
H_2O^-		.25	.16	
H_2O^+		2.40	3.20	
CO_2		.01	.02	
		98.72	99.70	
Minerals				
Quartz	X	X	X	X
Plagioclase	X	X	X	X
Orthoclase	X	X	X	X
Hornblende	--	X	--	X
Biotite	--	X	--	--
Clinopyroxene	--	--	--	X
Magnetite	X	X	X	X
Chlorite	--	X	X	--
Sphene	--	--	--	X
Apatite	--	X	X	X
Calcite	--	--	X	--
Limonite	X	--	--	--

135. Quartz-monzonite porphyry; SW¼ NW¼ sec. 20, T. 4 S., R. 4 W.
188. Quartz-monzonite porphyry; NW¼ NE¼ sec. 13, T. 4 S., R. 4 W.
Analyses by the author.

Broadgauge-Tamarack mines.—The Broadgauge-Tamarack group of claims is located 4½ miles northeast of the town of Sheridan; it produced 5,055 ounces of gold and 380 ounces of silver in the period from 1908 to 1935 (Lorain, 1937, p. 63). The ore bodies occupy replacement zones within marble layers adjacent to intrusive masses. All the ore is completely oxidized. The major fracture systems are the Broadgauge (N. 30° E., 45° NW.) and the Tamarack (E. -W., 35° N.) (Lorain, 1937, p. 63). Although the E. -W. fracture trends do not seem to be related to a regional trend, the N. 30° E. trends obviously are related to a dominant regional joint system. Strong vein structures are found along the marble-gneiss contacts, but the significant deposits occur along shear zones in the marble paralleling foliation, indeed, extensive shearing within the marble is evident. Some of this shearing has undoubtedly been produced during emplacement of the large intrusive mass exposed over most of this part of the area.

Buckeye mine.—The Buckeye mine is adjacent to the Broadgauge-Tamarack claims, and the ore seems to have been subjected to the same mineralization controls. The major fracture system at this locality trends N. 30° E. and dips 35° NW. The vein is completely within a local quartz-monzonite intrusive body and is again of the replacement variety (Tansley, Schafer, and Hart, 1933, p. 43). Ore minerals consist chiefly of auriferous pyrite, argentiferous galena, sphalerite, and chalcopyrite. Alteration is intense.

Fairview mine.—The Fairview mine, located at the junction of Noble Fork and Wisconsin Creek, yielded predominantly pyrite and galena ore, enriched with gold in the oxide zone (Tansley, Schafer, and Hart, 1933, p. 42). The major mineralization is localized along an oreshoot controlled by shear zones paralleling foliation in a marble bed (Lorain, 1937, p. 66). Ore is confined to replacements and quartz stringers within these zones.

Jonquil mine.—The value in the Jonquil mine was gold associated with pyrite and galena. The major vein orientation is identical to that of the Leiter mine, and it has been suggested that this is a continuation of the Leiter vein (Tansley, Schafer, and Hart, 1933, p. 42). This explanation seems unlikely, because of the distance between the two mines. The vein orientation is probably due to the pervasive fracture system in this area. Here too an intimate relationship between marble and intrusive rock is evident.

Conclusions drawn from study of joint orientations in the Sheridan district are (1) joint patterns in the metamorphic rocks are primarily due to Precambrian stresses, and (2) these joints were reactivated by Laramide stresses and possibly controlled the shape of the Tobacco Root batholith.

AGE OF DEFORMATION AND METAMORPHISM

Absolute age dates are available for Cherry Creek and Pony metamorphic rocks in southwestern Montana. Giletti and Gast (1961) reported dates of 1,650 million years for Cherry Creek and Pony rocks exposed in the vicinity of Dillon and Virginia City, Montana. Hayden (1959) reported ages of 1,690 million years for metamorphic rocks at Niehart and Norris, Montana. No traces of rocks of an older age (2,540 million years) such as those in the Beartooth Mountains, have been found in Cherry Creek and Pony rocks.

Although the age dates are few and do not definitely establish the time of deformation and metamorphism of Cherry Creek rocks, they tend to strengthen the hypothesis that structural and metamorphic relationships in the Sheridan district are primarily due to one orogenic period, which occurred approximately 1,600-1,700 million years ago.

UNMETAMORPHOSED IGNEOUS ROCKS

TOBACCO ROOT BATHOLITH

A part of the Tobacco Root batholith crops out in the northeast corner of the Sheridan district. The contact of the batholith with the enclosing metamorphic rocks was carefully mapped and any obvious intrusive relationships were noted, but detailed studies were not undertaken, as such studies are currently being performed by students under the direction of Dr. Charles Vitaliano, Department of Geology, Indiana University.

The part of the batholith indicated on the geologic map (Pl. 1) is composed dominantly of tonalite (quartz diorite). Xenoliths of metamorphic rock occur within the batholith near the contact; the degree of assimilation of these xenoliths differs markedly within short distances. No absolute evidence of forceful injection is noticeable, but the metamorphic rocks are more intensely fractured near the contact. Most exposures of the contact are at the highest elevations within the area; thus, the increased fracturing could easily be a climatically controlled phenomenon.

The one age determination available for rock of the Tobacco Root batholith is 66 million years (Reid, 1957, p. 11).

TERTIARY INTRUSIVE ROCKS

Numerous stock-like masses of quartz monzonite and quartz-monzonite porphyry are scattered randomly throughout the Sheridan district. No criteria exist in the map area by which these intrusive bodies may be assigned a definite age. They are therefore classified provisionally as Tertiary in age (Reid, 1957; Heinrich, 1960). These intrusive bodies are definitely later than the batholith, as they intrude the batholith near its margin.

Injection of the stocks was partly by forceful mechanisms. Most outcrops of the stocks are so extensively fractured that no exposed blocks are in place. Most of these intrusive bodies also exhibit a brecciated border phase consisting of angular fragments of metamorphic rock imbedded in a matrix of quartz monzonite. The intrusive bodies, although fairly irregular, in general seem elongate parallel to foliation trends, suggesting possible structural control.

Phenocrysts of quartz and feldspar are common, ranging in size from 1 to 2 mm. The groundmass is extremely fine grained, much of it too fine to be identified through the petrographic microscope. Typical accessories are hornblende, biotite, magnetite, chlorite, and apatite.

Chemical compositions and typical mineral assemblages of the Tertiary intrusive rocks are presented in Table 3. Although the silica percentage is very slightly lower than is typical for quartz monzonite, the large percentage of orthoclase (25 to 35 percent) in normal samples suggests that the rocks are best placed in this category.

ECONOMIC GEOLOGY

Extensive economic development of the Sheridan district quickly followed the discovery of gold in Alder Gulch in 1863. The Noble and Leiter mines (Pl. 2) were the first important mines to be worked in the district; development of most of the other mines in the area soon followed. Winchell (1914), Tansley, Schafer, and Hart (1933), and Lorain (1937) all have briefly described the various mines that have produced noteworthy amounts of ore. These reports, however, describe only the attitudes of important

grain size of 0.25 to 1 mm. Accessory minerals are rutile, apatite, magnetite, zircon, spinel, antiperthite, and garnet. Sphene is absent, and biotite is present only in amounts of less than 1 percent.

(2) Quartz-perthite-microcline-plagioclase gneiss and granulite include grains that display poorly developed quadrille patterns suggesting the presence of microcline. These rocks in general exhibit less development of granulitic texture, slightly more biotite (as much as 3 percent), and sporadic traces of sphene.

(3) The third quartzo-feldspathic gneiss assemblage, quartz - plagioclase - garnet - orthoclase gneiss, is somewhat more common than granulite and associated gneiss. This gneiss is locally intermixed with the granulite in exposures south of Indian Creek; the reverse is true north of Indian Creek.

Quartz is consistantly the dominant mineral in this lithology, but total feldspar content may approach or surpass quartz. Some of the orthoclase is slightly perthitic. Garnet is abundant in this mineral assemblage, ranging from 5 to 25 percent; some dark-green or brown hornblende is present in most samples and is accompanied by diopside and minor biotite in many.

(4) Some rocks within the quartzo-feldspathic gneiss assemblage tend to be gradational between quartzo-feldspathic gneiss and hornblende gneiss, both in appearance and composition. These are designated plagioclase-quartz-hornblende-biotite gneiss. They are true gneiss and exhibit none of the characteristics of granulite. Abrupt contact between light and dark layers is the rule. Typical estimated percentages of the major constituents are as follows: (1) light layer—hornblende-garnet-biotite, 15 percent; quartz, 30 percent; and plagioclase, 50 to 60 percent; (2) dark layer—hornblende-diopside-garnet, 60 to 70 percent; plagioclase, 20 percent; and quartz, 10 percent.

(5) In addition to the four main rock types mentioned above, several subordinate types are present. Quartzite in thin persistent beds is dispersed throughout the entire gneiss assemblage. It is not thick enough to be mapped at the scale used in this study. The quartzite is very coarsely crystalline, individual quartz grains having diameters as large as 6 mm. These particular beds are almost pure; biotite is the only common accompanying mineral and rarely exceeds 5 percent. Quartz-garnet-kyanite gneiss is present but only in small quantity. Garnet makes up 40 percent of the rock, quartz 45 percent, and kyanite 15 percent. Augen gneiss is uncommon.

Recurring mineral assemblages in the quartzo-feldspathic gneiss (Table 2.) suggest that these rocks were formed mainly by metamorphism of graywacke, shale, and clay-rich sandstone.

AMPHIBOLITE-HORNBLENDE GNEISS ASSEMBLAGE

The amphibolite-hornblende gneiss assemblage is composed of approximately equal proportions of amphibolite and hornblende gneisses, but may contain as much as 20 percent quartzo-feldspathic gneiss. Most of the quartzo-feldspathic gneiss, however, contains significant percentages of hornblende, diopside, and garnet. Thickness once again is difficult to estimate, but as these rocks do not exhibit the severe flowage that affected the quartzo-feldspathic gneiss assemblage, thickness estimates are somewhat more reliable. Maximum thickness is no greater than 3,000 feet; thickness less than 1,000 feet was not found.

Although this assemblage is one of the more interesting from a mineralogical standpoint, it is, unfortunately, poorly exposed. Principal exposures are concentrated between the drainages of Cow Creek and Bridge Canyon, in the Leggat Mountain area, along a strip south of Old Baldy Mountain, and in the Durham reservoir-Tom Graham Pass area. Most of this ground is heavily forested.

Detailed descriptions.—(1) Several samples of pyroxene granulite were collected along the ridge just south of the junction of the north and south forks of Indian Creek. Hypersthene is the dominant constituent of these rocks and constitutes 40 to 55 percent. Quartz averages 8 percent and surrounds the hypersthene. Garnet is slightly more abundant than quartz; plagioclase constitutes 15 to 20 percent of the rock. Hornblende approaches 10 percent but is restricted to the hypersthene grains, which it has obviously replaced in part.

(2) Hornblende granulite is a dominant assemblage in certain restricted areas, and as expected, is associated with the pyroxene granulite, but in addition it is present east of the mouth of Cow Creek and just north of the Tamarack mine on Spring Park Creek. Hornblende is the dominant mineral and makes up 30 to 60 percent of the rock. Hypersthene ranges from 7 to 45 percent; diopside and garnet are present in significant amounts of 4 to 32 percent. Quartz, biotite, magnetite, zircon, rutile, and apatite are common accessories.

(3) Garnet-diopside amphibolite is intermixed with hornblende granulite. The two assemblages are similar in many respects, but hornblende is less abundant in the amphibolite, in which diopside and garnet predominate; they are approximately twice as abundant as hornblende. These rocks are more equigranular than the hornblende granulite because of the small percentage of hornblende; grain size ranges from 0.25 to 1 mm. The hornblende is either brown

or dark greenish brown; biotite is dark brown or reddish brown.

(4) Garnet-cummingtonite-quartz gneiss is rare and is restricted to an area just east of the mouth of Cow Creek—in an area of hornblende granulite and diopside-garnet amphibolite. Estimated mineral percentages are: garnet, 45 percent; cummingtonite, 30 percent; quartz, 20 percent; and accessories, 5 percent.

(5) Hornblende-plagioclase amphibolite and hornblende-diopside-plagioclase-garnet-quartz gneiss are the dominant members within the amphibolite-hornblende gneiss assemblage and are found throughout all exposures of this assemblage. They are much less abundant in areas of hornblende granulite and garnet-diopside amphibolite. In hand specimen, the hornblende-plagioclase amphibolite is nearly identical in appearance to the hornblende granulite. One outstanding difference, however, is the appearance of numerous segregation lenses of quartz and plagioclase, which develop a migmatized appearance in the rock. Brown or dark-greenish-brown hornblende contributes more than half the bulk of the amphibolite. Plagioclase ranges from 15 to 25 percent; the percentages of garnet and diopside vary markedly but in very few specimens do they constitute more than 30 percent of the rock.

(6) The rocks designated as hornblende-diopside-plagioclase gneiss are the most variable in mineralogy within the amphibolite-hornblende gneiss assemblage. These rocks are characterized by well-developed segregation layering and by a greater quartz content. Their distribution is similar to that of the hornblende-plagioclase amphibolite. Diopside is noticeably less abundant, and garnet is similarly though less drastically reduced. Mineral assemblages are listed in Table 2.

Chemical analyses. — An important unanswered question is the pre-metamorphic nature of most of the rocks within the amphibolite-hornblende gneiss assemblage. Twelve chemical analyses were prepared, and various plots of oxide ratios were drawn in order to determine whether the analyses are characteristic of basalt, diabase, and basic tuff or of calcareous or dolomite shale. Representative analyses are given in Table 1. The samples for the analyses were collected by traversing parallel to Mill Creek from Bridge Canyon to Cow Creek (Pl. 1), a section containing most of the rock types present in this assemblage.

The results obtained from the series of plots of oxide ratios firmly establish an igneous origin for a large percentage of rocks in the amphibolite-hornblende gneiss assemblage, but unfortunately not all rock types could be analyzed. Those that were analyzed and are believed to be igneous in origin are hornblende granulite, garnet-diopside amphibolite, and hornblende-plagioclase amphibolite. The amphibolite-hornblende gneiss assemblage is therefore believed to represent a thick sequence of intrusive or extrusive igneous rocks, which seem to have been intercalated with clay and marl and other clay-rich sediment.

ANTHOPHYLLITE GNEISS ASSEMBLAGE

The anthophyllite gneiss assemblage represents a complex sequence of meta-igneous and meta-sedimentary rocks. This assemblage is restricted to a narrow belt of outcrop in the northeastern part of the Sheridan district, roughly paralleling the contact of the Tobacco Root batholith with the metamorphic country rocks. Certain distinctive rock types permit immediate recognition of this assemblage in the field. These are garnet-quartz-plagioclase gneiss, garnet-anthophyllite-plagioclase-quartz gneiss, sillimanite-

Table 1.—Chemical analyses of rocks in the Sheridan district.

Constituent	Sample					
	A-1	A-5	A-13	V-1	V-4	114
SiO_2	45.60	49.80	50.30	44.60	61.50	49.80
Al_2O_3	11.40	5.65	14.30	9.33	25.60	10.80
Fe_2O_3	3.28	1.45	.33	1.68	.74	1.20
FeO	16.10	12.80	10.10	14.10	3.10	17.00
MgO	5.45	13.80	8.27	12.10	1.72	11.80
CaO	10.00	12.40	11.00	11.60	.17	6.13
Na_2O	2.16	.87	2.71	.68	.39	.20
K_2O	.44	.44	.21	.36	1.53	.12
MnO	.30	.20	.20	.20	.06	.20
TiO_2	3.30	.77	.84	2.95	1.39	.48
P_2O_5	.28	.09	.08	.51	.03	.01
S	.00	.00	.03	.05	.00	.04
H_2O^-	.15	.09	.11	.27	.39	.09
H_2O^+	.07	.32	.29	1.21	2.75	.02
NiO	.00	.10	.02	.07	.00	.42
VO_3	.30	.03	.03	.05	.03	.03
Cr_2O_3	.00	.16	.05	.13	.02	.62
	98.76	98.97	98.87	99.89	99.14	98.96

A-1. Garnet-diopside amphibolite; SW¼ SE¼ sec. 15, T. 4 S., R. 4 W.
A-5. Hornblende granulite; SW¼ SE¼ sec. 15, T. 4 S., R. 4 W.
A-13. Hornblende-plagioclase amphibolite; SE¼ NE¼ sec. 21, T. 4 S., R. 4 W.
V-1. Amphibolite; Lonesome Peak area.
V-4. Sillimanite - quartz - muscovite - biotite schist; Lonesome Peak area.
114. Garnet - cummingtonite - plagioclase - quartz gneiss; Thompson Peak area.

Analyses by the Indiana Geological Survey.

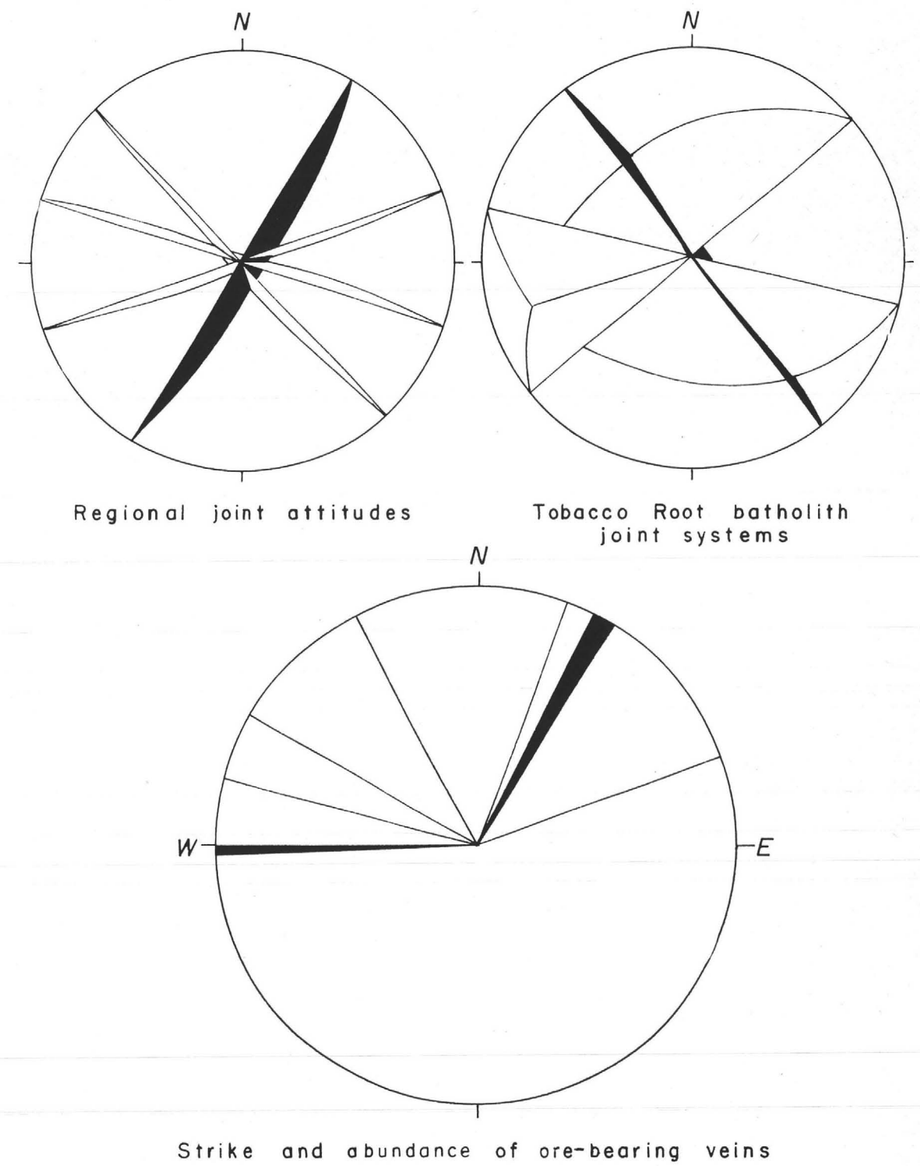


Figure 4.—Joint systems in the Sheridan district.

in the northeast corner of the map area, parallels the margin of the Tobacco Root batholith and separates the anthophyllite gneiss assemblage from all other rock types. Unfortunately, no exposure of the fault plane nor any shear zones can be seen, but the existence of this fault is firmly established by the following three criteria:

(1) Various rock types and foliation trends are suddenly interrupted and replaced by contrasting rock types and foliation trends along the mapped trace of the fault. Excellent examples are found northwest of Leggat Mountain in sec. 6, T. 4 S., R. 3 W., and in the area between Noble Peak and Mustard Pass.

(2) The anthophyllite gneiss assemblage lies in contact with the quartzo-feldspathic gneiss assemblage, the amphibolite-hornblende gneiss assemblage, the intermediate gneiss assemblage, and marble along the fault trace but is not exposed in any other part of the Sheridan district.

(3) The proposed fault separates rocks with contrasting high-temperature metamorphic facies: a high-pressure facies southwest of the fault and a low-pressure facies northeast of the fault.

The Noble fault dips northeast at angles ranging from 45 to 60 degrees, as calculated from topographic influence upon the trace of the fault plane. Directions of movement are indeterminate, owing to lack of exposure of the fault plane and the uncertain stratigraphic position of the anthophyllite gneiss assemblage. North of the Sheridan district, additional faults of similar trend and extent displace portions of the Tobacco Root batholith and metamorphic country rock; definite movement directions can be assigned to these faults (Smith, 1965, p. 260). The Noble fault is assumed to have moved similarly.

The Booth and Parsons faults are in sec. 1, T. 4 S., R. 5 W., and, as along the Noble fault, no fault planes or shear zones are exposed. These faults are mapped on the basis of distinct offsets and contrasting lithologies (Pl. 1). A minimum displacement of 2,000 feet is required to explain the absence of the amphibolite-hornblende gneiss assemblage west of the Booth fault and the offset of the intermediate gneiss assemblage by the Parson fault. The order of magnitude of these figures agrees with that of figures calculated by Johns (1961, p. 19) for displacements of Paleozoic sedimentary rocks in the Tidal Wave mining district, 2 miles northwest of the Parson and Booth faults, which are probably extensions of the Tidal Wave fracture system.

With the exception of the three faults discussed above, which are near the outer limits of the Sheridan district, no large faults were observed, although local shearing and jointing are extensive.

INTERPRETATION OF JOINT SYSTEMS

Prominent joint patterns in the Sheridan district reveal important structural data. Most outcrops of all rocks except marble reveal two or three joint sets; joints in marble are somewhat erratic. Most joints are open, but healed fractures do occur and, where measurable, parallel dominant joint trends. Unfortunately, it was not possible to obtain a sense of shear on any of the exposed joints.

Principal joint planes in the metamorphic rocks of the Sheridan district are shown as regional joint attitudes in Figure 4. Various detailed methods of investigation all substantiate the idea that the fracture directions shown as unshaded regional joint attitudes (Fig. 4) have a Precambrian origin.

Two problems remain, however. First, the N. 30°-35° E. set of joints does not fit any of the Precambrian patterns. Many joints trend in this direction throughout the Tobacco Root batholith (Smith, 1965, p. 263) and as this is a preferred direction for mineralized structures (Fig. 4), these joints are assigned to a later (Tertiary) stress episode.

The second problem concerns the ubiquitous occurrence, both in the metamorphic rocks and in the batholith, of a joint set striking N. 35°-45° W. and dipping at steep angles. This joint set is believed to follow a prominent joint direction produced by Precambrian stresses, but its presence in the batholith raises serious questions. Laramide stresses are thought to have been oriented slightly south of west in this general area (Johns, 1961, p. 1), and, therefore, could easily reactivate Precambrian joint systems that were produced by a stress oriented approximately east-west or slightly north of west. The hypothesis that northwest-trending lines of weakness existed before the intrusion of the batholith (and therefore before production of northwest-trending joints in the batholith) is supported by the dominant northwest trend of the batholith itself. An approximate average of joint trends in the batholith (Hendrix, T. E., personal communication) is illustrated in Figure 4. It is very interesting to note that other joint sets in the batholith do not coincide with any joint sets seen in the metamorphic rocks. Also significant is the very large triangle of intersection of joints within the batholith, which supports the idea that these directions may represent a composite result of two or more stress episodes or that some of the trends may be influenced by preexisting trends.

quartz-muscovite schist, and green quartzite. Amphibolite, hornblende gneiss, and quartzo-feldspathic gneiss also are interbedded throughout this sequence and are similar to corresponding rocks in other assemblages. Because of the intrusion of the Tobacco Root batholith and displacement along the Noble fault (Pl. 1), the total thickness of this assemblage is nowhere observed; in the map area the maximum thickness exposed is slightly more than 2,000 feet.

Detailed descriptions. — (1) Garnet-quartz-plagioclase gneiss is coarse-grained rock in which grain size differs considerably from place to place. Garnet constitutes more than 50 percent of the rock, and the grains are 5 to 15 mm in diameter. Quartz and plagioclase in nearly equal amounts make up most of the rest. Biotite may be as much as 6 percent; anthophyllite, variety gedrite, is present in minor amount.

(2) Undoubtedly the most striking rock in the Sheridan district is garnet-anthophyllite-plagioclase-quartz gneiss. The garnet is coarse and of the same size range seen in the garnet-quartz-plagioclase gneiss. The garnet is accompanied by brown to dark-brown blades of anthophyllite or gedrite that average 10 mm in length, but lengths of 50 to 100 mm are not uncommon. Other constituents that may form as much as 10 percent of the rock are quartz, biotite, cummingtonite, talc, and possible cordierite. Cummingtonite is present to some extent in most sections and replaces anthophyllite or gedrite.

(3) The mineralogy of the garnet-cummingtonite-plagioclase-quartz gneiss is identical in all respects to the anthophyllite gneiss except that cummingtonite is present instead of anthophyllite or gedrite. Garnet and cummingtonite are the dominant constituents and are very coarse. Quartz ranges from 13 to 25 percent; plagioclase from 2 to 25 percent. Talc is present in most samples; common accessories are magnetite, apatite, biotite, rutile, and chlorite. Mineral assemblages are given in Table 2.

(4) Sillimanite-quartz-muscovite-biotite schist occurs in layers interspersed with amphibolite but is restricted to one definite zone and was therefore mapped as one unit. (This contrasts with the anthophyllite and cummingtonite gneisses, which are widespread throughout the anthophyllite gneiss assemblage.) Quartz and sillimanite are present in nearly equal amounts, each averaging approximately 30 percent. Cordierite is consistently present in amounts not exceeding 5 percent. Biotite and muscovite may be as much as 25 percent of the rock. Accessories are rutile, sphene, graphite, talc, zircon, magnetite, apatite, and kyanite. Sillimanite occurs in masses of fibers 1 to 20 mm in length. Slight segregation into layers composed of quartz, of sillimanite-cordierite, and of muscovite-biotite was noted.

(5) Green quartzite is the final distinctive rock contained in the anthophyllite gneiss assemblage. Most of these layers of quartzite are not thick enough to serve as mappable units, but one such layer is shown on the geologic map (Pl. 1). This unit is coarse-grained quartzite containing scattered patches of green chrome mica.

(6) Another rock type common in this assemblage is garnet-plagioclase-hornblende-biotite gneiss. It is similar in appearance to other hornblende gneiss throughout the area.

(7) Quartz-biotite-plagioclase schist is not one of the more common rock types in the anthophyllite gneiss assemblage, but its consistently large percentage of biotite (an average of 35 percent) does allow it to be easily identified. Average percentages for the other constituents are: quartz, 40 percent; plagioclose, 15 percent; and sillimanite and garnet, 10 percent.

(8) Amphibolite is dispersed throughout the entire assemblage and, at first glance, resembles that in the amphibolite-hornblende gneiss assemblage. Several important differences delineate contrasts in the mineralogy of the two units. Diopside is absent from the amphibolite of the anthophyllite gneiss assemblage. Although garnet may be present, it is only in small amount. Hornblende and plagioclase are the dominant minerals in these rocks; hornblende makes up 30 to 70 percent and plagioclase averages 30 percent. Biotite and quartz are present in significant amounts.

Chemical analyses.—Eleven chemical analyses of rocks in the anthophyllite gneiss assemblage were prepared (as were those for the amphibolite-hornblende gneiss assemblage) in order to gain information concerning the original or pre-metamorphic identity of many of the rock types in this assemblage. Samples to be analyzed were collected during a traverse along the ridge extending southwest from Lonesome Peak (Pl. 1). The most typical and widespread rocks of the anthophyllite gneiss assemblage are well exposed along this ridge, thereby allowing representative samples to be collected; representative analyses are listed in Table 1. Plots used to interpret these analyses are identical to those employed for the amphibolite-hornblende gneiss assemblage.

Chemical properties and trace-element content prove that the garnet-quartz-plagioclase gneiss, garnet-anthophyllite-plagioclase gneiss, garnet-cummingtonite-plagioclase gneiss, and hornblende-plagioclase amphibolite are the product of metamorphism of basic and ultrabasic rocks. The sillimanite-quartz-muscovite

Table 2.—Mineralogy of major assemblages.

Quartzo-feldspathic gneiss assemblage

Constituent	Sample							
	202	9	127	65	37	150	11	215
Quartz	X	X	X	X	X	X	X	X
Plagioclase	X	X	X	X	..	..	X	X
Perthite	X	X	X	..	X	..	..	..
Antiperthite	..	..	..	..	..	..	..	..
Microcline	..	X	..	..	..	..	..	..
Orthoclase	..	..	..	..	..	..	X	X
Garnet	..	..	X	X	..	X	X	X
Biotite	X	X	X	X	..	X	..	..
Hornblende	..	..	..	X	X	..	..	..
Diopside	..	..	..	..	X	..	..	X
Kyanite	..	..	..	..	..	X	..	..
Epidote	X	X	..	X	X	..	X	X
Muscovite	..	..	..	..	X	X	..	..
Chlorite	X	..	X	..	..	..	..	..
Magnetite	X	X	X	X	X	..	X	..
Sphene	..	..	..	..	X	..	..	X
Spinel	..	..	X	..	..	..	..	..
Rutile	..	X	..	..	X	X	..	..
Zircon	X	X	X	X	..	X	X	X
Apatite	X	X	..	X	X	..	X	X

Anthophyllite gneiss assemblage

Constituent	Sample							
	V-8	108	189	190	134	173	111	V-2
Garnet	X	X	X	X	X	X	X	..
Anthophyllite	..	..	X	..	..	..	X	..
Cummingtonite	X	..	..	..	..	..	..	..
Gedrite	..	X	..	..	..	..	..	..
Sillimanite	..	..	..	..	..	..	..	X
Quartz	X	X	X	..	X	X	X	X
Plagioclase	X	X	X	X	X	X	X	..
Biotite	X	X	X	..	X	..	X	X
Cordierite	..	..	..	..	..	..	..	X
Hornblende	..	..	..	X	X	X	..	..
Muscovite	..	..	..	..	..	..	..	X
Kyanite	..	..	..	..	..	..	..	X
Graphite	..	..	..	..	..	..	..	X
Magnetite	X	X	X	X	X	X	X	X
Chlorite	..	..	..	X	..	..	..	X
Talc	..	..	..	..	..	..	..	..
Rutile	..	X	X	..	..	..	X	X
Hematite	..	..	..	..	..	..	..	..
Epidote	X	..	..	X	..	..	..	..
Sphene	..	..	..	..	..	..	..	..
Zircon	..	..	..	..	X	..	..	X
Apatite	..	X	X	..	X	..	X	..
An content of plagioclase	27	46	28	38	28	48	46	

Amphibolite-hornblende gneiss assemblage

Constituent	Sample							
	219	14	130	64	61	57	40	20
Hornblende	X	X	X	..	X	X	X	X
Diopside	..	X	X	..	X	..	..	X
Garnet	X	..	X	X	..	X	..	X
Hypersthene	X	X	..	..	..	..	..	..
Biotite	..	..	..	..	..	..	X	..
Plagioclase	X	..	X	..	..	X	X	X
Quartz	X	X	..	X	..	..	X	X
Cummingtonite	..	..	..	X	..	..	..	..
Perthite	..	X	..	..	..	..	..	..
Antiperthite	..	..	..	..	..	..	..	..
Magnetite	X	X	X	..	X	X	X	..
Epidote	..	..	X	..	..	X	..	..
Chlorite	..	..	..	..	..	X	..	..
Rutile	..	..	..	..	..	X	X	..
Sphene	..	..	..	X	X	..	..	..
Apatite	..	X	..	X	..	..	X	X
Zircon	..	..	X	..	..	..	X	X
An content of plagioclase	38		44			40	32	28

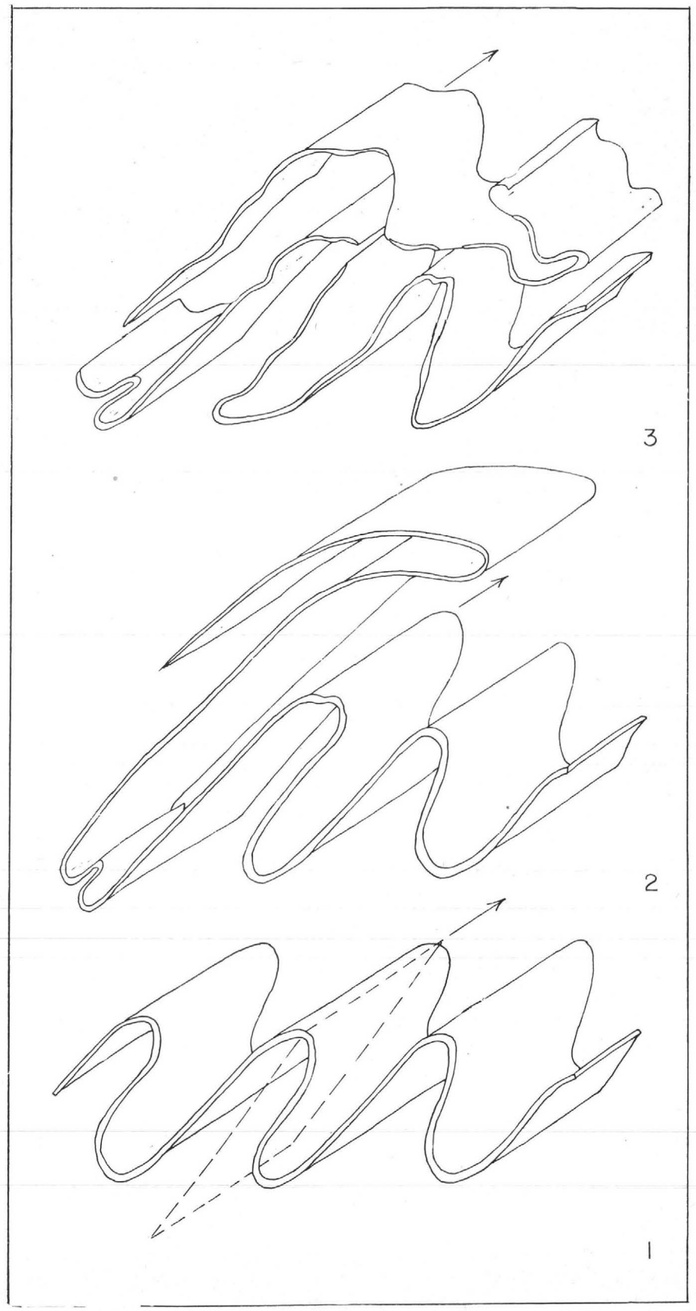


Figure 3.—Inferred evolution of structural elements.

CROSS SECTIONS

Three standard geologic cross sections are presented in Plate 1; their positions within the Sheridan district are designated on the plate. These are included to serve as an aid in visualizing structural relationships.

INTERPRETATION OF FOLDING

At first glance the fold pattern of the Sheridan district is dominated by a series of relatively simple antiforms and synforms, which have been locally torn and sheared. Stratigraphic relations of the various assemblages are constant and predictable. A closer examination, however, exposes certain anomalous relations. Normally marble is situated between thick sequences of amphibolite-hornblende gneiss on one side and quartzo-feldspathic gneiss on the other. A thick section of marble is exposed southwest of Leggat Mountain, but here the sequence does not hold. The amphibolite-hornblende gneiss assemblage is found on both sides of the marble, as is the included intermediate gneiss assemblage. Another anomalous situation is the presence of the quartzo-feldspathic assemblage on both sides of marble in the vicinity of Butterfly Flats (north-central part of map area).

A third important anomalous relation is the stratigraphic position of the marble bed at Spuhler Saddle. This bed is the same marble bed as that exposed directly to the south but occupies a higher stratigraphic position.

These relations are satisfactorily explained by assuming that the marble south of Leggat Mountain was originally attached to the marble exposed at Spuhler Saddle but has since become detached. The author believes that it flowed eastward from its original position, and was then folded back on itself. The diagram illustrating the interpretation of folding (Fig. 2) shows this hypothesis most vividly. The entire detached mass consists of the intermediate gneiss assemblage, presently draped over the crest of the Quartz Creek antiform and refolded with the marble, and a sequence of amphibolite-hornblende gneiss. The repetition of units on each side of the marble south of Leggat Mountain identifies this as a folded sequence. In addition, this same sequence of assemblages exactly matches a sequence at Spuhler Saddle, which at that point becomes discontinuous. This interpretation of refolding accounts for all stratigraphic sequences within the Sheridan district and removes the stratigraphic and structural anomalies noted above.

A hypothetical folding sequence is recreated as follows (Fig. 3). In stage 1, nearly upright, almost isoclinal antiforms and synforms are formed. Folding is dominated by flow. The time of production of foliation is unknown, but once the foliation is formed it consistently remains parallel to bedding. As intensity of deformation increases, the crest of the Wisconsin Creek antiform begins to advance eastward at the expense of the adjacent synform. In stage 2 progressive advance causes this lobe to "flop" over the crests of adjacent antiforms. Extensive thinning of marble results in breakage along the limbs of the refolded segment. Eventually, (stage 3) the entire nose of the Wisconsin Creek antiform becomes detached, riding over the crest of the Quartz Creek antiform and into the Ramshorn synform where it becomes partly refolded. At all times folding is consistently around the same axis (as indicated by the orientation of the arrow in Figure 2), and all refolding is produced during one deformational episode.

Extremely interesting are the broad open folds produced in the overturned amphibolite-hornblende gneiss assemblage at the extreme northern part of the map area. The broad open antiform, produced by draping of the amphibolite-hornblende gneiss assemblage over the Eclipse Gulch antiform, is located at the southern end of Reid's Noble Peak anticline (Reid, 1957), but separates the Eclipse Gulch antiform from the Noble Peak anticline. Reid (1963, p. 298) attributed the Noble Creek anticline to concentric refolding of initially flat-lying recumbent isoclinal folds, and he called upon multiple fold episodes (five in all) to produce the observed structural relationships. The integrated folding scheme as postulated in this report makes the many folding episodes of Reid completely unnecessary, but in no way invalidates his refolding of recumbent folds, especially if the complete rock mass associated with the Wisconsin Creek antiform is refolded in a manner analogous to the detached fold nose south of Leggat Mountain.

The geologic structure section BB′ (Pl. 1) presents an interpretive view of stratigraphic relationships between the allochthonous (transported marble, intermediate gneiss, and quartzo-feldspathic gneiss) and autochthonous (nontransported) units; the hypothetical boundary of separation is indicated by a dashed line. The transported mass may properly be defined as a nappe.

FAULTS

Only three faults of any great extent displace the rocks exposed in the Sheridan district, although local faulting and fracturing are widespread. These major faults are the Noble fault, Parson fault, and Booth fault, so named on Plate 2. The Noble fault,

schist is obviously a derivative of alumina-rich clay and shale as would be predicted from the chemical composition and mineralogical assemblage. The presence of interbedded quartzite, schist, and various gneisses that are products of original sedimentary sandstone and various clay and shale beds delineates a complex sedimentary and igneous history for the rocks of the anthophyllite gneiss assemblage.

INTERMEDIATE GNEISS ASSEMBLAGE

The intermediate gneiss assemblage is both the least distinctive assemblage exposed in the map area and the most critical for certain structural interpretations. Composed of nearly equal proportions of hornblende gneiss and quartzo-feldspathic gneiss, it would be one of the most difficult assemblages to recognize in the field were it not for the distinctive quartz-plagioclase-biotite gneiss and schist dispersed throughout the assemblage. Exposures indicate a consistent thickness of roughly 1,000 feet for the intermediate gneiss assemblage.

Detailed descriptions.—The hornblende gneiss and quartzo-feldspathic gneiss of this assemblage are essentially similar in mineralogy and appearance to those in the quartzo-feldspathic gneiss and amphibolite-hornblende gneiss assemblages. No further decription of them will be given here.

The quartz-plagioclase-biotite schist and gneiss are generally schistose in appearance even though a degree of segregation banding occurs. Quartz is the dominant constituent, 20 to 30 percent. Plagioclase or microline and biotite are almost as abundant as quartz, making up 20 to 25 percent of the rock; garnet ranges from 5 to 15 percent. Biotite is abundant and well oriented; quartz forms discrete lenticular pods as much as 1.5 mm in length. Common accessories are hornblende, magnetite, zircon, apatite, muscovite, epidote, and chlorite.

The distinctiveness of this rock type is partly the schistose appearance, which is due to abundant biotite, and partly the irregularity of foliation surfaces because of resistant garnets. Hornblende, where present, is vividly outlined on the foliation surface in well-oriented prisms.

META-INTRUSIVE ROCKS

Meta-basalt and metamorphosed ultrabasic intrusive rocks are exposed throughout the Sheridan district. Most bodies are too thin to be mapped; most of the thicker bodies are lensoid and can be traced for only short distances. An exception is the extensive sill-like body that is exposed along the slope west of Eclipse Gulch (Pl. 1). These very basic rocks weather light or dark brown; the thicker bodies consistently exhibit blocky weathering charactertistics similar to those of basaltic intrusions. All varieties exhibit faint but consistent foliation, which is outlined by preferential distribution of garnet or biotite. This foliation is in most places parallel to foliation in surrounding rocks, but it is at a slight angle to these other foliations where the meta-basalt cuts directly across compositional layering (as do certain protuberances from the extensive exposure previously mentioned).

Detailed descriptions.—Two distinctive mineralogical assemblages are found within the meta-basalt, although all exposures exhibit the same general appearance. These assemblages are hornblende-plagioclase-biotite and plagioclase-diopside-garnet. Plagioclase-diopside-garnet meta-basalt consists of 30 percent plagioclase, 25 percent garnet, 25 percent diopside, and 8 to 10 percent hornblende. Garnet and diopside percentages are consistent in all samples, but hornblende and plagioclase vary greatly in abundance. These rocks are all fine grained and equigranular, grain size ranging from 0.05 to 0.1 mm. Garnets are preferentially associated with layers deficient in plagioclase.

The hornblende-plagioclase-biotite meta-basalt has the same textural characteristics as the plagioclase-diopside-garnet meta-basalt but differs mineralogically, as emphasized by the general absence of diopside, the abundance of hornblende and biotite, and the relative lack of garnet.

Two intrusive bodies of ultrabasic rock crop out in the map area, one northwest of the junction of the north and south forks of Indian Creek, the other just west of the mouth of Cow Creek. Both are stock-like masses and both exhibit only very slight foliation. The mineral assemblages are decidedly different, however.

The mass near Cow Creek consists of diopside, hypersthene, and cummingtonite; rutile is an accessory. The hypersthene is rimmed by cummingtonite and is locally replaced by the cummingtonite. The Indian Creek intrusive contains both enstatite and olivine, which are extensively altered to serpentine, variety antigorite. Size of the original enstatite crystals, as estimated from relict boundaries, averaged 5 mm.

MAGNETITE GNEISS

A thin belt of magnetite gneiss is exposed in the southeast part of the map area (Pl. 1). Detailed study and analysis of its mineralogy are omitted because

the rock contributes little to interpretation of structural or metamorphic history of the area. Dominant constituents are magnetite and garnet; hypersthene, hornblende, and plagioclase are accessories. These minerals are segregated into layers of magnetite-garnet and plagioclase-hornblende-hypersthene.

METAMORPHIC FACIES

Rocks in the southern part of the Sheridan district were subjected to hornblende-granulite subfacies conditions during a major metamorphic episode. Maximum temperature of metamorphism probably was on the order of 600° C. Retrogressive effects are evident but slight, and can be attributed to waning temperature during the same metamorphic episode.

Metamorphic grade decreases northward where the sillimanite-almandine-orthoclase subfacies, almandine-amphibolite facies assemblages dominate. Temperatures probably ranged between 525° C. and 550° C.

A relatively restricted group of rocks, the anthophyllite gneiss assemblage, was subjected to sillimanite-cordierite-muscovite-almandine subfacies, cordierite-amphibolite facies conditions. Temperatures of metamorphism equalled those producing the sillimanite-almandine-orthoclase subfacies assemblages, but pressures were lower, probably on the order of 3,000 bars or roughly equivalent to a depth of burial of 10 km (Winkler, 1965, p. 105). Unfortunately, this distinctive lithologic assemblage is nowhere seen in other than fault contact with the other rocks exposed in the map area, and therefore structure cannot accurately be reconstructed. Reid (1957, appendix) noted that rocks resembling the anthophyllite gneiss assemblage of this report lie at the top of the Cherry Creek sequence. If this inference is correct and if these rocks were metamorphosed at a depth of 10 km, structural reconstruction would place the depth of burial of the hornblende-granulite assemblage at 13 to 14 km or approximately 8 miles. Such a depth correlates well with the depth of 5 to 7 miles (or deeper) advanced by Engel and Engel (1962, p. 39) for high-grade metamorphic rocks in the Adirondacks.

No evidence demands multiple metamorphisms to explain present mineralogic relations. Such intermingling of facies as observed in the Sheridan district is explained by other authors as due to one metamorphic episode occurring under varying conditions. It distinctly parallels well-documented examples in other terranes.

Local Cretaceous or Tertiary igneous intrusion caused slight retrogressive effects.

STRUCTURAL GEOLOGY

GENERAL DESCRIPTIONS

Bedding.—The consistent and predictable relationship of major lithologic assemblages (marble, quartzo-feldspathic gneiss assemblage, and amphibolite-hornblende gneiss assemblage) in the Sheridan district supports the conclusion that these units represent original sedimentary and igneous (concordant intrusive or extrusive) layers and that major bedding relationships have not been destroyed or transposed by deformation.

Foliation.—Most of the rocks in the Sheridan district exhibit only one identifiable planar foliation. This is principally defined by compositional layering, but granulitic texture, lenticular aggregates of quartz and feldspar, and planar attitude of biotite also contribute to the foliation in various degrees. The foliation is invariably parallel to contacts between individual units in marble, amphibolite, quartzite, and quartzo-feldspathic gneiss sequences. It is, in addition, parallel to surfaces that separate the major lithologic assemblages.

Reid (1963, p. 293) stated that this foliation in the Tobacco Root Mountains is parallel to the axial planes of recumbent isoclinal folds. He envisaged folding about northeast-trending axes, during high-grade metamorphic conditions, which produced recumbent isoclinal folds. As foliation is parallel to the axial planes of tight isoclinal folds on an outcrop-size scale and passes through the crests of these folds, Reid identified this structure as axial-plane foliation. This foliation was subsequently deformed into large open north-plunging folds (Reid, 1963, p. 298).

Fold styles are well documented in the Sheridan district, and fold styles such as those advanced by Reid are not present on a regional scale. Recumbent isoclinal folds are present on an outcrop-size scale, but these are primarily due to flowage during deformation and have no bearing on regional fold styles. True, isoclinal folds (not recumbent) are present, and foliation in the limbs does parallel axial planes, but this same foliation curves undisturbed around the hinges of major folds and therefore must be regarded as bedding foliation (in the sense that it parallels and is controlled by bedding).

Several samples collected in the quartzo-feldspathic assemblage in the SE¼ sec. 9, T. 4 S., R. 4 W., contain a second planar foliation, which cuts the primary planar foliation at various angles. In most samples this second foliation is defined by a parallelism of biotite flakes and hornblende. This second foliation is rarely developed in the Sheridan district, hence little can be said concerning its origin.

Lineation.—Six distinct varieties of lineation may be observed in the Sheridan district. All types plunge in approximately the same direction.

(1) Fold axes: Fold axes constitute the most common measurable lineation and are best developed in the quartzo-feldspathic gneiss.

(2) Foliation intersections: The intersection of the primary foliation with the second foliation defines a lineation. This lineation is simply the line produced by the intersection of two planes.

(3) Rodding: Many exposures contain rod-like linear trends that cannot be ascribed a definite origin. These rods generally are less than ½ inch in diameter and less than 4 inches long.

(4) Boudinage: A significant amount of boudinage occurs within the quartz layers contained in marble and in amphibolite and hornblende gneiss contained in quartzo-feldspathic gneiss.

(5) Mineral streaks: Irregular streaks and blebs of mineral segregations, most of which are quartz and feldspar, define a vague but persistent lineation.

(6) Mineral parallelism: Parallel orientation of minerals ranges from mineral streaks to elongate quartz pods to parallel laths of hornblende.

MAJOR FOLDS

Six major folds are present in the Sheridan district. These are readily apparent on the geologic map (Pl. 1); they are named on the map showing major tectonic elements in the map area (Pl. 2). The six folds are, from west to east: Wisconsin Creek antiform, Bitney synform, Eclipse Gulch antiform, Horse Creek synform, Quartz Creek antiform, and Ramshorn synform. These folds are termed antiforms and synforms instead of anticlines and synclines because no evidence is available to show which are the youngest beds.

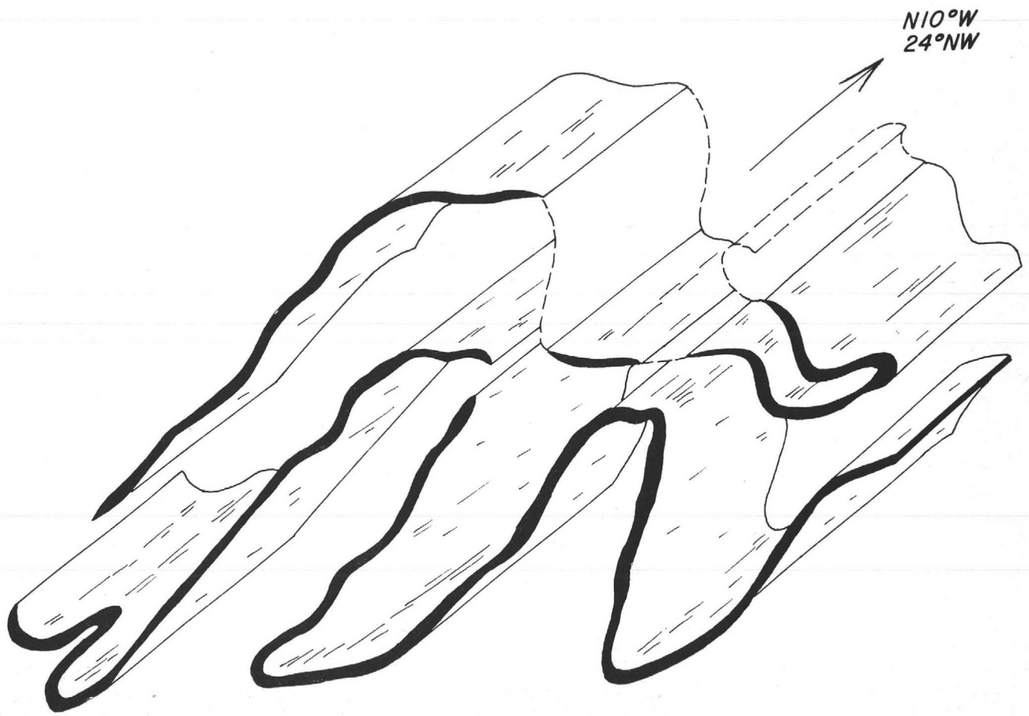


Figure 2.—Fold geometry within the Sheridan district.

EXPLANATION

Q	ALLUVIUM	QUATERNARY
Tqm	QUARTZ MONZONITE	TERTIARY
Tb	BASALT	TERTIARY
Kt	TONALITE	CRETACEOUS
hg	AMPHIBOLITE – HORNBLENDE GNEISS ASSEMBLAGE	PRECAMBRIAN
ig	INTERMEDIATE GNEISS ASSEMBLAGE	PRECAMBRIAN
m	MARBLE	PRECAMBRIAN
qg	QUARTZO – FELDSPATHIC GNEISS ASSEMBLAGE	PRECAMBRIAN
ag	ANTHOPHYLLITE – GARNET GNEISS ASSEMBLAGE	PRECAMBRIAN
q	QUARTZITE	PRECAMBRIAN
ss	SILLIMANITE SCHIST	PRECAMBRIAN
mg	MAGNETITE GNEISS	PRECAMBRIAN
d	META – DIABASE SILLS AND DIKES	PRECAMBRIAN

CONTACT (DASHED WHERE APPROXIMATE)

INFERRED CONTACT

FAULT, SHOWING RELATIVE MOVEMENT

SYNFORM (SHOWING TRACE OF AXIAL PLANE)

ANTIFORM, SHOWING PLUNGE OF AXIS

OVERTURNED SYNFORM (SHOWING DIRECTION OF DIP OF LIMBS)

OVERTURNED ANTIFORM

STRIKE AND DIP OF FOLIATION

STRIKE OF VERTICAL FOLIATION

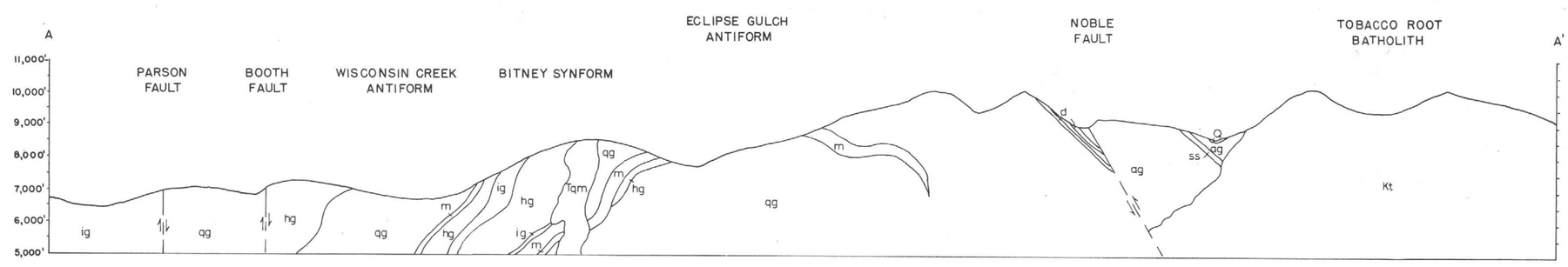
BEARING AND PLUNGE OF LINEATION

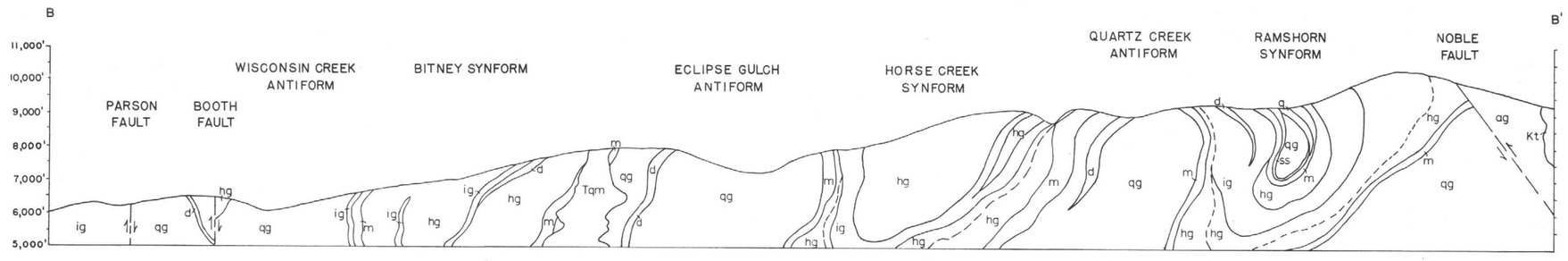
STRIKE AND DIP OF FOLIATION AND PLUNGE OF LINEATION

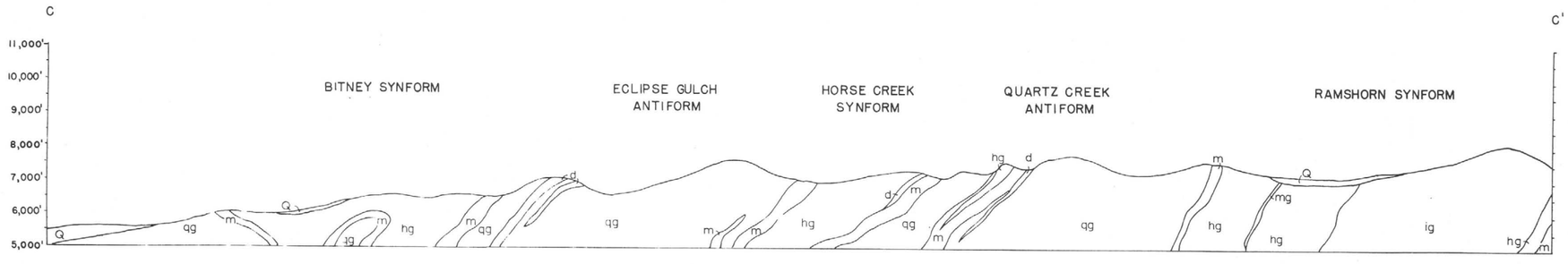
STRIKE AND DIP OF SECOND FOLIATION

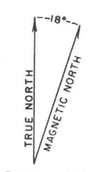
STRIKE AND DIP OF JOINTS

STRIKE OF VERTICAL JOINTS

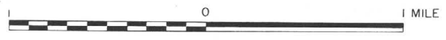








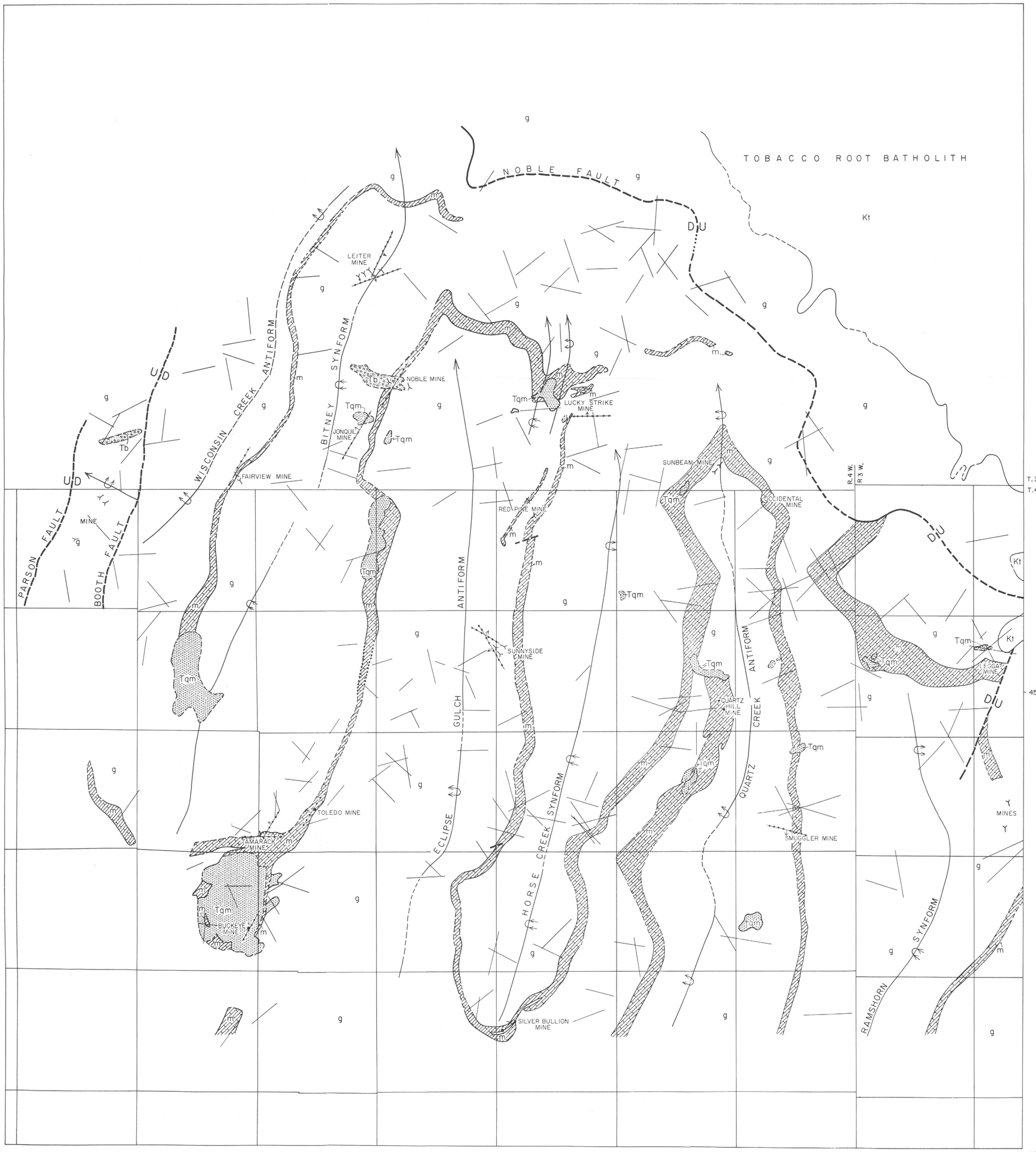
APPROXIMATE MEAN DECLINATION, 1964



LOCATION OF MAP AREA

BEDROCK GEOLOGIC MAP AND SECTIONS OF THE SHERIDAN DISTRICT, MADISON COUNTY, MONTANA

BY
H. ROBERT BURGER
1966



EXPLANATION

- Tqm — QUARTZ MONZONITE
- Tb — BASALT
- Kt — TONALITE
- m — MARBLE
- g — UNDIFFERENTIATED GNEISS

TERTIARY
CRETACEOUS
PRECAMBRIAN

CONTACT (DASHED WHERE APPROXIMATE)

INFERRED CONTACT

U D — FAULT, SHOWING RELATIVE MOVEMENT

SYNFORM (SHOWING TRACE OF AXIAL PLANE)

ANTIFORM (SHOWING PLUNGE OF AXIS)

OVERTURNED SYNFORM (SHOWING DIRECTION OF DIP OF LIMBS)

OVERTURNED ANTIFORM

STRIKE OF MAJOR FRACTURES

STRIKE AND DIRECTION OF DIP OF ORE VEINS

VERTICAL MINE SHAFT

PORTAL OF TUNNEL OR ADIT

N

MAJOR TECTONIC ELEMENTS AND ECONOMIC GEOLOGY OF THE SHERIDAN DISTRICT, MADISON COUNTY, MONTANA