Geology of a part of the north end of the Gallatin Range, Gallatin County, Montana
by Russell Gene Tysdal

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN APPLIED SCIENCE With a Major in Geology
Montana State University

Abstract:
In a 50-square mile area at the north end of the Gallatin Range, Gallatin County, Montana, about 4, 000 feet of sedimentary strata, ranging in age from Cambrian to Recent, is exposed. Rocks-of the Paleozoic arid Mesozoic systems comprise a sedimentary sequence that does not exceed 3, 200 feet in thickness, which is uncommonly thin when compared to equivalent sequences in neighboring areas.

The map area was apparently one of slower subsidence, and deposition of sediments proceeded less continuously or at a slower rate. Ordovician, Silurian, Permian, Triassic, and Upper Cretaceous strata are absent. Trilobites of the genus Glossopleura were found in the Cambrian Flathead Quartzite and are the only known trilobites from the formation. Eocene volcanic rock overlies a major part of the sequence, whereas Precambrian metamorphic rock underlies the entire sequence.

Analysis of the structural features of the map area and the adjoining region indicates that deformation could have resulted from an east-northeast compressive stress applied during the Laramide orogeny. The major northwest-trending fault in the map area is the South Cottonwood Creek fault, a reverse fault with greater than 4,000 feet of throw. Sufficient evidence is presented to prove the existence of the Gallatin Range front fault, a post-Laramide normal fault truncating the range on the north.

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R. G. T.

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ABSTRACT

In a 50 square mile area at the north end of the Gallatin Range, Gallatin County, Montana, about 4,000 feet of sedimentary strata, ranging in age from Cambrian to Recent, is exposed. Rocks of the Paleozoic and Mesozoic systems comprise a sedimentary sequence that does not exceed 3,200 feet in thickness, which is uncommonly thin when compared to equivalent sequences in neighboring areas. The map area was apparently one of slower subsidence, and deposition of sediments proceeded less continuously or at a slower rate. Ordovician, Silurian, Permian, Triassic, and Upper Cretaceous strata are absent. Trilobites of the genus Glossopleura were found in the Cambrian Flathead Quartzite and are the only known trilobites from the formation. Eocene volcanic rock overlies a major part of the sequence, whereas Precambrian metamorphic rock underlies the entire sequence.

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INTRODUCTION

Previous Investigations

The first geologic mapping in this and contiguous areas was by Peale in 1889, the results of which were published in 1896. His study of the Three Forks one-degree quadrangle was of a reconnaissance nature. Hackett and others (1960) mapped and briefly described the basin deposits of the adjacent Gallatin Valley. M. D. Mifflin (1963, Unpub. M. S. Thesis, Montana State Univ., Bozeman) and Robinson (1961) have also described some of the same basin deposits. Davis, Kinoshita, and Robinson (1965) published gravity and aeromagnetic data which contains pertinent structural data for the included part of the Gallatin Valley. W. M. Weber (1965, Unpub. M.S. Thesis, Montana State Univ., Bozeman) mapped the Middle Creek area just east of the margin of the present writer's map area. Unpublished data has been made available by W. J. McMannis which has aided materially in the interpretation of relationships, both within the map area and in nearby areas.

Location

The Gallatin Range, of which the map area is a part, lies within the southeastern part of the Northern Rocky Mountain physiographic province of Fenneman (1931). The map area encompasses approximately

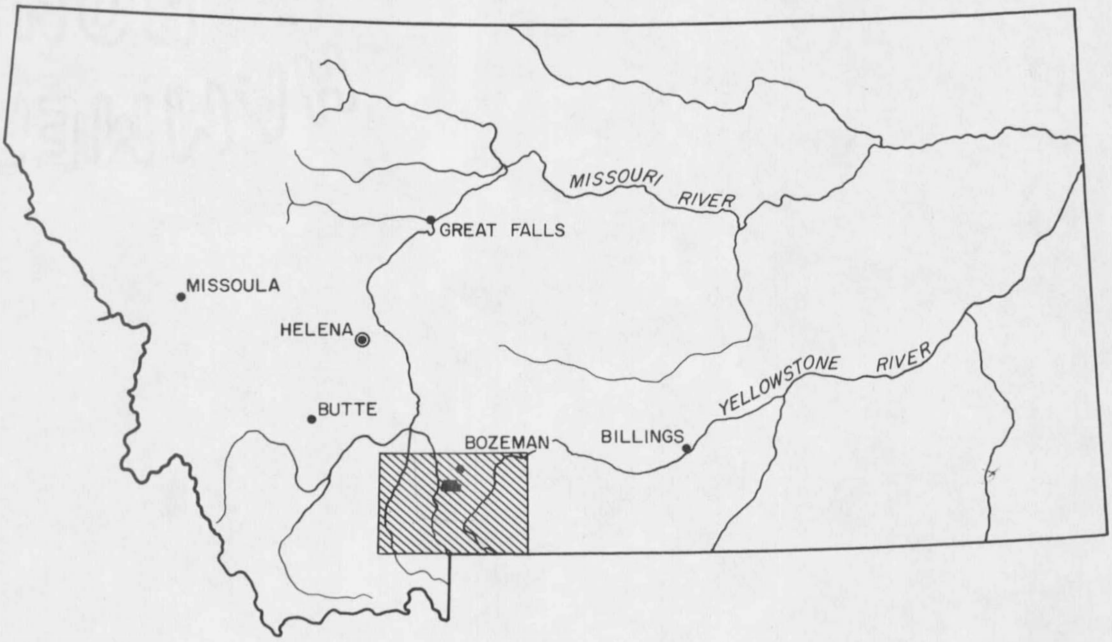
55 square miles in the northern part of the Gallatin Range and foothills at the front of the range, the Bozeman quadrangle between the 111°01' and 111°14' meridians and the 45°30' and 45°35' parallels. The small town of Gallatin Gateway lies approximately one mile north of the northwestern corner of the map area, and the town of Bozeman is approximately seven miles north of the northeast corner of the map area.

Topography

Elevation of the land ranges from 5,000 feet at the northwest margin to greater than 8,600 feet atop Wheeler Mountain in the southeast. Three-fourths of the area consists of rugged, heavily forested terrain with local relief commonly varying between 1,500 feet and 2,200 feet. The best rock exposures are generally found elsewhere than on the northeast sides of mountains; this side is usually very heavily forested with small (2 inch diameter) evergreens and brush, and has a thick soil mantle. At the range front the area consists of gently inclined surfaces interrupted by stream incised valleys.

Climate

As is typical of higher elevations in the Rocky Mountains, daily and seasonal fluctuations of temperature range widely. Midday temperatures during the summer months average between 70° F and 80° F, with occasional extremes in the nineties. Winter daytime temperatures are generally near or below freezing, and periods of below



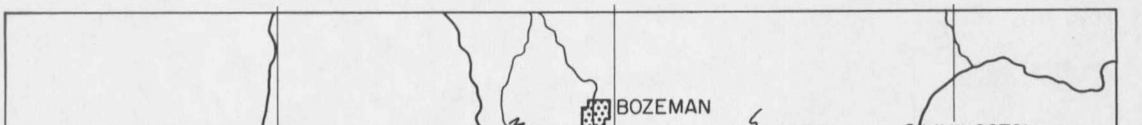


Figure 1 - Index Map

zero temperatures are common in January and February. Rare extreme wintertime temperatures may go as low as -50°F. Snow depths in the higher portions of the map area may average as much as 50 inches during the middle winter and early part of spring. The average annual precipitation varies from 20 inches in the lower part of the map area to about 30 inches at the higher elevations. Geologic field work is feasible from May through October at lower elevations and June through September at the higher elevations.

The above climatological data is based on annual summaries contained in the U. S. Weather Bureau's publication, Climatological Data.

Land Economies

The mountainous regions of the map area is owned partly by the Northern Pacific Railroad and partly by the federal government. The region is heavily timbered, and the main enterprise is tree harvesting by independent logging concerns. During the summer and early fall, high open areas are used as grazing land for beef cattle. The lower reaches of the map area--the foothills--are privately owned and are dominantly used as pasture. The remainder of the land is used for dryland and/or irrigated grain production, alfalfa or other hay crops.

Access

Numerous roads permit year around access by car to the foothills at the front of the range. Two roads penetrate the mountainous area;

one leads up Middle Creek, the other up Big Bear Creek. Numerous logging roads branch from these two roads, permitting vehicular access to some of the higher elevations of the map area. A four-wheel drive vehicle provides the best conveyance on these roads, although a conventional pickup will suffice if the roads are dry. By far the greatest part of the area is accessible only on foot or on horseback.

Objectives

The objectives of this study were to construct a geologic map of the bedrock within the mountainous part of the map area, and of the surficial deposits at the front of the range; to describe the rock units and structural relationships encountered in compiling the geologic map; and to describe the geologic events that have lead to the observed relationships.

STRATIGRAPHY

Precambrian

Metamorphic Rocks

Precambrian metamorphic rocks are extensively exposed in the southwestern and northeastern parts of the map area, and to a lesser extent in the south-central part of the map area. Gneiss, amphibolite, schist, and metaquartzite--in that order of abundance--make up the metamorphic complex. Layering is well developed and generally strikes N45-70E and dips 50-75S, with variation in dip occurring especially where the rocks are associated with faulting; foliation is parallel to layering. Resistant outcrops are generally scattered, with deeply weathered surface exposures occurring inbetween. Locally, deeply weathered metamorphic rocks are directly overlain by the Flathead Quartzite, suggesting that part of the weathering occurred prior to deposition of the overlying sedimentary sequence.

Most of the metamorphic rocks of the map area consist of alternating bands of medium-gray gneiss, pink gneiss, and amphibolite. The bands commonly grade into one another and range in thickness from a few feet to more than 100 feet. The medium-gray gneiss is the most common of the three types and is medium-grained; compositionally it consists of quartz (40-50%), microcline (15-30%), biotite (10-15%), and muscovite (5-10%). The biotite is dominantly brown and is present both as individual flakes and in minute books; much of the feldspar is altered to sericite. The pink gneiss is medium- to coarse-grained and consists of quartz (20-35%), microcline (25-40%), oligoclose (25-35%), and biotite (5-10%). Much of the oligoclase is untwined; it and the microcline are easily mistaken for orthoclase megascopically. The amphibolite is dark, medium- to coarse-grained, gneissic, and rarely schistose. It consists of hornblende, plagioclase, quartz, biotite, and rarely garnet, in that order of abundance; hornblende is by far the most common mineral, but the percentages of all constitutents vary so greatly that an average composition would be misleading. The hornblende is black and commonly occurs as stubby prisms. Feldspar grains are generally clear, but some are thoroughly saussuritized. The quartz is clear and forms only a minor percentage of the rock, as does the biotite which occurs as gold-brown flakes. Garnet amphibolite is not common in the map area, and where present the garnets are poorly developed. At one locality a nearly 100% black-green hornblende amphibolite may represent an intrusive body metamorphosed after emplacement.

Metamorphic rocks exposed along the Hyalite Canyon road differ from the above mentioned types in that they are apparently more intensely deformed--ptygmatic folding is very common. The predominant rock type is similar to the previously mentioned medium-gray gneiss except that oligoclase is present and garnets occur locally; sericitization of the feldspars is less common. The folia are generally steeply dipping; some folia dip steeply to the northwest as opposed to the general southeast dip of the metamorphic rocks in the rest of the map area. The dip reversals may be due to faulting, some of which may have occurred in Precambrian time.

It is commonly believed that the rocks were originally a thick sedimentary sequence that was metamorphosed and intruded by igneous magmas, and subsequently underwent additional phases of metamorphism (e. g., see Reid, 1957, 1963; M. D. Mifflin, 1963, Unpub. M.S. Thesis, Mont. State Univ., Bozeman). In the Tobacco Root Mountains west of the map area, detailed study of the metamorphic complex by Reid (1963) indicates that the rocks have undergone three major metamorphic episodes and two stages of retrograde metamorphism. The metamorphic rocks present in the map area and adjacent areas support Reid's (1963) interpretation of several phases of metamorphism, as they include minerals and rock types characteristic of low to high grade metamorphism. An example of low grade metamorphic rock occurs immediately to the south of the map area in the NW 1/4 sec. 14, T. 4S., R. 4E., (Garnet Mountain quadrangle) where an actinolite schist is present. The gneiss of the map area (previously described) is of medium to high grade. Approximately 6 miles northwest of the map area high grade metamorphic rocks are represented by corundum bearing schists.

The metamorphic rocks of the map area are pre-Belt in age and are similar to those termed Pony metamorphics in nearby areas (as opposed to Cherry Creek metamorphics). Recent work by Reid (1957; 1963) indicates that the Pony (younger) and Cherry Creek (older) metamorphics are part of the same depositional sequence and, therefore, the unconformity that has been said to lie between the two (see Peale, 1896; Tansley, Schafer, and Hart, 1933) apparently does not exist. Consequently, it is the recommendation of the Stratigraphic and Nomenclature Committee of the Billings Geological Society that the Precambrian metamorphic rocks be termed "pre-Belt" and thus discontinue use of the terms Pony and Cherry Creek, except in the type localities of those units (W. J. McMannis, personal communication, 1965).

Giletti (unpublished manuscript) has recently summarized preliminary work of radiogenic age dating in southwestern Montana. His data indicate that a major phase of regional metamorphism occurred about 1600 m. y. ago, and that the southeast margin of this metamorphism is located along a northeast-southwest trending "line" crossing the Gravelly Range and the Gallatin River Canyon. Southeast of this line the rocks may be 3200 m. y. old or older. He tentatively suggests that some of the rocks in the 1600 m. y. terrane are considerably older than 1600 m. y., but were remetamorphosed 1600 m. y. ago.

Radiogenic age determinations have not been made on any of the rocks of the map area, but Giletti (unpublished manuscript) has dated some samples from nearby areas. Approximately 10 miles northwest of the map area, in the Anceney quadrangle (sec. 23, T. 2S., R. 2 E.), a biotite schist was dated as 1550 m. y. old. South of the map area, in the Garnet Mountain quadrangle, the following dates were obtained:

1690 m. y. (Granitic gneiss; sec. 15, T. 5S., R. 4 E.), 1790 m. y. (psammitic gneiss; sec. 36, T. 5 S., R. 4 E.), and 3220 m. y. and 3270 m. y. (granitic gneiss; sec. 13, T. 6 S., R. 4 E.). The localities occur approximately 7, 10, and 13 miles, respectively, south of the map area. The southeast margin of the 1600 m. y. ago metamorphism apparently lies between 10 and 13 miles south of the map area.

Belt Supergroup

Rocks of the Belt Supergroup are not present in the map area; the nearest occurrence of Belt strata is immediately north of an east-west trending line which transects the central part of the Bridger Range on the east and the Highland Mountains on the west. The line is believed to be a fault zone that was active in Precambrian Belt time, permitting a thick sequence of very coarse arkosic Belt sediments to accumulate on the north side (McMannis, 1963).

Cambrian

Flathead Quartzite

The Flathead Quartzite of the map area is fairly consistent in thickness (40-75 feet) and unconformably overlies Precambrian metamorphic rock with marked angular discordance. The formation consists of maroon, tan, brown, pink, and white medium- to thick-bedded and massive cross-bedded quartz sandstone. Locally present is a cream and dull brick red mottled quartz sandstone, the mottling being independent of bedding planes. The sand grains vary in size from medium to coarse and are subangular to angular. Locally present at the Flathead-Precambrian contact is (1) a conglomerate consisting of well rounded white vitreous quartz cobbles in a matrix of coarse-grained quartz sandstone, and (2) arkosic material that is in places difficult to differentiate from the underlying deeply weathered Precambrian metamorphic rock. Near the top of the formation the sandstone commonly contains glauconite and greenish-gray micaceous shale. The Flathead is gradational with the overlying Wolsey Shale and the contact is therefore arbitrary; the author chose the base of the first prominent shale zone as the contact. This boundary is in agreement with that of Deiss (1936) who emended the definition and type section of the formation. The Flathead is generally poorly indurated, but seems to be better indurated where the formation is thicker; the term sandstone is more appropriate than quartzite for the formation in the map area.

The Flathead is a basal, slightly transgressive sandstone of the Cambrian sequence, being older in the west than in the east. Because of the almost total absence of fossils in the Flathead, the age of the formation has been inferred from the (conformable) superjacent Wolsey Shale. This procedure suggests that the Flathead was deposited during the early Middle Cambrian--Albertella zone time--(Lochman, Balk, 1956, p. 616; Lochman, 1957, p. 132). However, in a surficial deposit in the SW 1/4 SE 1/4 sec. 26, T. 3 S., R. 4 E., the writer found trilobites of the genus Glossopleura which are definitely from the Flathead (the fossils were identified by

A. R. Palmer, U. S. Geological Survey, Washington, D. C.), indicating that the formation in the map area is slightly younger than previously believed. It is definitely younger than the Flathead in the western part of the state where the Albertella faunal elements occur in shale beds well up in the overlying Wolsey equivalent (Silver Hill Formation), and the Glossopleura zone there is in the upper part of the same formation (see fig. 2). Approximately 35 miles northwest of the map area the Glossopleura fauna occurs in the lower part of the Wolsey (A. R. Palmer, 1965, written communication to W. J. McMannis).

Wolsey Shale

The Wolsey Shale rests conformably on the Flathead Quartzite and is clearly transitional between the latter and the overlying Meagher Limestone. The Wolsey ranges from 40 feet to 195 feet in thickness, increasing toward the south. The 195 foot thickness is high when compared to the common range of 40 feet to 80 feet in the map area and may represent deposition on a irregular Middle Cambrian sea floor; the Wolsey is thicker where the Flathead is thicker. Commonly, the formation is poorly exposed and forms grass covered slopes.

The basal part of the Wolsey consists of gray-green soft fissile micaceous shale interstratified with reddish-brown fine- to medium-grained thin-bedded and cross-bedded glauconitic quartz sandstone. Locally the sandstone of the basal part is medium- and thick-bedded and of the type found in the Flathead. The upper part (3/4) of the formation contains chocolate brown to green fissile micaceous shale,