Geology of a portion of the Norris quadrangle with emphasis on tertiary sediments Madison and Gallatin counties, Montana

by Sylvia Harrison Feichtinger

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Earth Sciences (Geology)
Montana State University

Abstract:
The purpose of this study was to map the geology of an area composed of approximately the northern half of the Norris quadrangle and to describe the rock units and geologic history, emphasizing Tertiary sediments and the structural and depositional history of the southwest part of the Three Forks basin.

Exposures in the map area consist of Precambrian gneiss and amphibolite, scattered outcrops of Middle Cambrian strata, a variety of igneous bodies, and Cenozoic sediments.

Two major northwest trending faults, the Elk Creek and the Cherry Creek, extend into the map area. Evidence indicates three stages of movement on the Cherry Creek fault, reverse during Lara-mide time and normal during Oligocene and Recent. The Laramide and Recent movements were paralleled by those of the Elk Creek fault. Middle Cambrian strata were folded prior to reverse movement on the Cherry Creek fault and later deformed by younger Laramide faults. Metamorphic rocks were apparently folded during the Precambrian.

The Red Mountain rhyolite body, a probable vent, may have been emplaced after folding of Middle Cambrian rocks. Breccias on the southern end are possibly extrusive. A lithologic unit northwest of Red Mountain is interpreted to be composed largely of rhyolite debris eroded from Red Mountain. Extensive flows of andesite partial ly cover this unit. Dacite sills in the Wolsey Shale are probably part of an extensive sill zone of middle Cretaceous age.

During Paleocene and Eocene time, the southern margin of the Three Forks basin was north of the map area, as north-side-up reverse fault movements produced a topographic high in the northern part of the area. During part of the Oligocene the basin margin was south of the map area and the predominantly lacustrine sediments of the lower Dunbar Creek Formation were deposited. Normal movement on the Cherry Creek fault resulted in the alluvial and sheet flood deposits of the upper Dunbar Creek. A lacustrine limestone unit, possi bly younger than Oligocene, is exposed near Norwegian Creek.

A high bench, probably cut by an ancestral Madison River during early Pleistocene time, is covered by a Belt quartzite gravel, possibly derived from conglomerates to the south such as those of the Paleocene Beaverhead Formation.

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Date *July 31, 1970*

GEOLOGY OF A PORTION OF THE NORRIS QUADRANGLE
WITH EMPHASIS ON TERTIARY SEDIMENTS
MADISON AND GALLATIN COUNTIES, MONTANA

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INTRODUCTION

The region covered in this study is comprised of approximately the northern half of the 15-minute Norris quadrangle, Madison and Gallatin Counties, Montana. Specifically, the area covers part of the southwest portion of the Three Forks basin and is bounded on the north and west by the edges of the Norris quadrangle, on the east by the Madison River, and on the south by outcrops of the Pre-cambrian metamorphic complex (see Index Map, Figure 1).

The purpose of the investigation was two-fold: first, to make a detailed study of the general geology of the area and second, to attempt to clarify the history of the southwest portion of the Cenozoic Three Forks basin, concurrently making any possible contributions to the rather meager knowledge of the Tertiary Bozeman Group.

There have been no previous detailed geologic investigations of this area and even the most recent workers have relied on Peale's seventy-five year old reconnaissance for general reference. Changes in stratigraphic conventions, and inaccuracies and omissions inevitable in a broad scale work such as Peale's, certainly warrant a closer study of the area.

Previous Work

The Norris quadrangle is the SE1/4 NW1/4 of the Three Forks sheet, the 1° quadrangle (45°-46°N and 111°-112°W), mapped by Peale (1896) from 1883 to 1889. Douglass (1899) briefly described the exposures on the west side of the Madison River in his study of the "Neocene lake beds". The 1933 reconnaissance of the Tobacco Root Mountains by Tansley and Schafer includes the western portion of the area, but geology is as grossly generalized as in Peale's work. Several cross-sections of the Three Forks Basin are included in Pardee's study of Cenozoic block faulting published in 1950. Alden (1953) briefly discusses some of the physiographic features along the Madison River in his paper on the physiography and glacial geology of western Montana. The southeast portion of the area, near Red Mountain, is included in Alsup and Andretta's (1960) general investigation of the Cenozoic history of the Norris-Elk Creek area and Red Mountain itself is one of a number of igneous bodies discussed in a masters thesis prepared by Kavanagh (1965). The Norris quadrangle is included in the 1965 gravity and magnetic geophysical investigations of Davis, Kinoshita, and Robinson.

The geology of the Three Forks quadrangle, just north of the Norris quadrangle, has been mapped in detail by Robinson and is the subject of an extensive professional paper published in 1963.

The Tansley and Schafer reconnaissance covers the area to the west. G. B. Schneider (1970) has made an investigation of the geology east of the Madison River for his masters thesis at Montana State University. McThenia (1960) has studied Precambrian rocks south of the map area and Kavanagh (1965) and other workers have investigated igneous bodies which lie to the south.

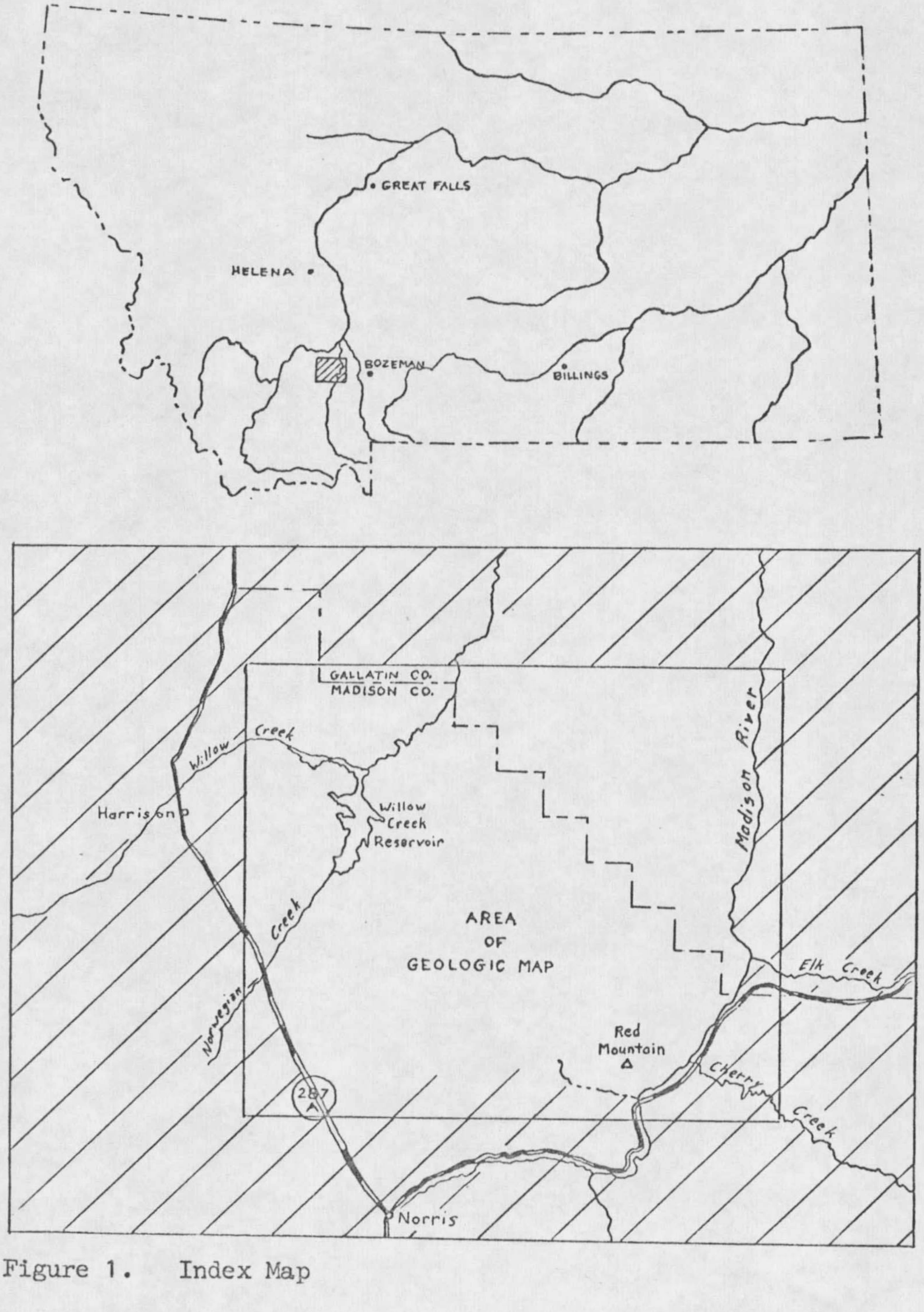

Figure 1. Index Map

STRATIGRAPHY

PRECAMBRIAN METAMORPHIC ROCKS

A detailed description of Precambrian rocks was not within the scope of this paper, but the extensive exposures of the rocks could provide material for a number of studies.

Precambrian exposures in the map area consist of metamorphic pre-Belt rocks, dominantly gneiss and amphibolite, with minor layers of schist and quartzite. The gneiss is generally banded white and black or pink and black and is composed mainly of quartz, feldspar, and biotite. Varieties with fewer ferro-magnesian minerals and consequently less pronounced banding appear to become increasingly abundant in the southern part of the area. Amphibolite occurs in layers or pods and ranges from types having about 40 per cent amphibole to types which are almost totally amphibole. Garnet is common in the amphibolite and locally is an important constituent in granitic layers. Discordant and concordant pegmatites are found throughout the area. The largest of these is about 1/5 mile long; most are considerably smaller. They consist mainly of quartz and feldspar. The schists are composed mainly of biotite with minor amounts of quartz or garnet.

Metamorphic rocks in the Tobacco Root Mountains have been divided into two series (Tansley, Schafer, and Hart, 1933), the Pony and the Cherry Creek. The Pony consists dominantly of gneiss and amphibolite with minor amounts of schist and quartzite (Reid, 1957). Early workers regarded the Pony series as the older of the two series and believed an unconformity separated them. However, Reid (1957) has found that in the type area, Pony metamorphics overlie the Cherry Creek. He discovered no evidence of an unconformity. As the rock groups appear to have undergone the same metamorphic history, he believes them to be broadly of the same age. No marble or sillimanite schist was found in the map area and according to McThenia (1960), this suggests that the metamorphic rocks may be equivalent to the Pony. However, the use of the term Pony this far from the type area may be questionable, particularly as Reid's work suggests that the traditional distinction between the two series could be re-evaluated.

SEDIMENTARY ROCKS

PALEOZOIC

Paleozoic and Mesozoic strata are absent from the map area with the exception of a deformed section of Middle Cambrian rocks northwest of Red Mountain and scattered outcrops of Flathead Quartzite.

Flathead Quartzite

The Middle Cambrian Flathead Quartzite unconformably overlies the Precambrian metamorphic rocks in a number of localities in the map area, all in the vicinity of the Cherry Creek fault zone. Complete sections of the formation are present in the Red Mountain area where the thickness of the formation, 325 feet, is somewhat greater than normal. Lithology is similar to Flathead outcrops elsewhere, consisting mainly of red medium-grained quartzite and quartz sandstone, in places varying in color from pinkish-white, to yellow or black. The formation is dominantly thick-bedded, but is thin-bedded in zones of crossbedding. The rock locally contains conglomeratic beds, with quartz pebbles up to 1/2 inch in size. In the Red Mountain area, highly glauconitic beds are found near the base of the unit. The formation grades upward into the Wolsey Shale.

Wolsey Shale

The Wolsey Shale is well exposed northwest of Red Mountain, particularly in the SW1/4 sec. 28, T. 2 S., R. 1 E. Lithologically, the Wolsey is similar to outcrops of the formation elsewhere in the region, consisting dominantly of gray-green or locally purple, very thinly laminated fissile micaceous shale. The shale commonly weathers to a distinct light blue. Light brown micaceous siltstone and fine-grained sandstone make up a minor part of the unit. These are usually thin-bedded and may be interbedded with shale. They are generally strongly calcareous. The shales may be calcareous along fractures and bedding planes, but are otherwise not notably calcareous, particularly in the upper part of the unit. Worm burrows are common.

Two dacite sills intrude the Wolsey Shale in the Red Mountain syncline. In this locality, one occurs about 100 feet from the base and is approximately 25 feet thick; the other occurs near the top and is approximately 57 feet thick. These sills are discussed in detail in the section on igneous rocks. The thickness of the Wolsey is about 290 feet in the SW1/4 sec. 28, T. 2 S., R. 1 E., including the thickness of the two sills. The contact with the overlying Meagher Limestone is gradational.

Meagher Limestone

The Meagher Limestone is well exposed in the Red Mountain syncline and in a small faulted anticline to the northwest. The lower part of the formation is typical gray and yellow mottled limestone, the silty yellow partings vaguely outlining beds about 1/2 to 1 inch in thickness. The middle portion of the unit is massive crystalline brownish weathering limestone, locally dolomitic or oolitic. This changes upward into "blue and gold" mottled fine crystalline limestone, somewhat darker than the lower mottled portion and with the gold mottles generally less continuous than in the lower limestone. The top part of the exposure in the Red Mountain syncline is highly silicified and is locally stained or altered red.

Large outcrops and blocks of red- to yellow-brown "jasper" are common in the area. These seem to be silicified Meagher Limestone altered as a result of contact of the andesite and rhyolite with the upper part of the Meagher exposure. The jasper is also found along faults in the Meagher. Again, the jasperization may be related to siliceous solutions derived from the igneous rocks.

CENOZOIC

Cenozoic rocks are by far the dominant sedimentary rocks in the map area. These are divided in this paper into three Tertiary and five Quaternary units. With the exception of work by Robinson (1963) and Schneider (1970), very little detailed petrographic work has been done on the Tertiary sediments of the area and consequently they received much of the attention in this study.

Tertiary

Robinson (1963) presents a comprehensive historical summary of work on the Tertiary sediments. Peale in 1896 described the Tertiary rocks of the region as the "Bozeman lake beds", a term avoided by Matthew (1899) and later workers, who believed a fluviatile and eolian origin more likely. Robinson's studies (1963) showed that all three genetic types (eolian, lacustrine, and fluviatile) are present. The term, Bozeman Group, was proposed by Robinson (1963) to include the Tertiary sedimentary rocks of the Three Forks basin. He subdivided the group into the Eocene Sphinx Conglomerate and Milligan Creek Formation, the middle or late Eocene to early Oligocene Climbing Arrow Formation, and the Oligocene Dunbar Creek Formation. The Dunbar Creek is the only one of Robinson's formations recognized in the map area. Besides the Dunbar Creek Formation, two other units of probable Tertiary age were mapped, referred to herein as the Red Mountain volcanic-sedimentary unit and the Norwegian Creek carbonate unit.

Red Mountain Volcanic-Sedimentary Unit

The Red Mountain volcanic-sedimentary unit, an informal name used herein, crops out in the N1/2 sec. 28 and W1/2 sec. 27, T. 2 S., R. 1 E. The unit is mapped separately from the Dunbar Creek because it is lithologically distinct and may well be older than the entire formation. It is not extensive enough to warrant formational status. The unit consists of flow-banded massive rhyolite, rhyolitic sedimentary breccias and sandstones, and possible mud flow deposits. These appear to be composed largely of material derived from Red Mountain. As rocks of these types are found in the conglomerates of the Dunbar Creek Formation and beneath the andesite body, they are clearly older than the upper part of the Dunbar Creek but younger than the rhyolite.

Massive rhyolite, some glassy and flow-banded, is similar to Red Mountain varieties and evidently underlies the epiclastic material. Its distribution is irregular and it appears to "blanket" older formations, possibly suggesting an extrusive origin. It is included within the Red Mountain unit in mapping.

The following sequence of rock types is found in the SE1/4 SW1/4 sec. 27. It is representative of the variation typical of the unit. Outcrops in a small gulch consist of white massive porous rock composed of biotite, angular quartz and rhyolite fragments in a fine matrix. The rock suggests a possible mud-flow but is monolithologic and could conceivably have formed as a friction breccia within an intrusion. A prominent exposure to the north of these outcrops consists of well stratified breccias dipping steeply away from Red Mountain, possible mud-flow breccias, and conglomeratic sandstones. The base of the exposure is pisolitic, and commonly iron and manganese stained. A chaotic breccia above the well stratified layers resembles the breccias of the southern part of Red Mountain (see page 29) but contains a much higher proportion of matrix. It could be a mud-flow deposit or a flow breccia. This breccia is overlain by thin-bedded pink and yellow conglomeratic sandstone containing sub-angular to sub-rounded quartz and angular rhyolite fragments. A pink pisolitic layer occurs at the top of the outcrop.

The breccia found beneath the andesite flow in the NW1/4 sec. 28 contains a higher proportion of quartz than those described above, a dilution of the rhyolite debris which might be expected as distance from source increased.

It should be noted that sedimentary features can form in an intrusive breccia (Irvine, 1965), a fact which makes the mode of origin of the Red Mountain unit rocks even more uncertain. Only those with an appreciable quartz content (quartz phenocrysts form less than five per cent of the rhyolite) can be regarded as clearly epiclastic. A detailed petrographic investigation might clear up some of the problems, and in the process, shed more light on the nature of the Red Mountain body.

Dunbar Creek Formation

The Dunbar Creek Formation was first described by Robinson (1963) and is the uppermost of his pre-Miocene subdivisions of the Bozeman Group. The formation crops out in the northeast and southeast portions of the Three Forks quadrangle and in the northeast portion of the Norris quadrangle. Exposures can be traced along the west bank of the Madison River from Robinson's designated type section south to the Cherry Creek fault. The formation is also fairly well exposed on the west side of the high bench, disappearing beneath colluvium in sec. 5, T. 2 S., R. 1 E. Isolated outcrops of sediments in sec. 19, T. 1 S., R. 1 E., and sec. 13, T. 1 S., R. 1 W., are probably also Dunbar Creek. The base of the formation is nowhere exposed in the map area and the stratigraphically highest rocks are covered by Quaternary gravel.

Robinson describes the formation as consisting of "white to grayish yellow thick bedded tuffaceous siltstone, partly lacustrine and partly eolian, intricately laced with fluviatile sandstone and conglomerate" (1963, page 77). He lists dark bentonitic clay and white limestone as rare components. Proportions of rock types in the formation are given as 80 per cent tuffaceous siltstone and sandstone, 15 per cent quartzose sandstone, sand and conglomerate, and 5 per cent limestone, clay and claystone (Robinson, 1963, page 78). The formation is better indurated than the Milligan Creek and

Climbing Arrow Formations. It has little limestone, whereas limestone is the dominant rock type of the Milligan Creek. Conglomerate and coarse sandstone are less important constituents than in the Climbing Arrow (Robinson, 1963, pages 77-78).

In the present study, a number of measured sections were made. These are presented in Appendix A. Correlations of the sections are shown in Plate II. The formation in the map area is exposed to a higher stratigraphic level than in the Three Forks quadrangle. As might be expected, several lithologic changes occur toward the southern margin of the Three Forks basin.

The stratigraphically lowest exposures of the formation in the map area occur in the northeast corner in the cliffs rising steeply from the west bank of the Madison River. Partial Stratigraphic Section IV of the Dunbar Creek was measured in this area, about three miles south of Robinson's designated type section. The upper part of the formation is largely covered, but outcrops consist dominantly of yellowish gray quartzose sandstone and conglomerate. The portion of the section measured in the NE1/4 sec. 24, T. 1 S., R. 1 E. forms striking white exposures, eroding locally to bad land-like topography. The rocks here consist mainly of white to light brown tuffaceous siltstone, massive to thinly laminated, and locally calcareous. Ash beds occur near the top of this portion. Yellowish gray coarse-grained conglomeratic sandstone containing dominantly quartz and gneiss fragments is common in the lower part of these exposures.

The rocks stratigraphically below those described above, measured in the N1/2 sec. 19, T. 1 S., R. 1 E., form a sequence similar to portions of the strata on the east side of the Madison River. These consist of alternating white thinly laminated fissile tuffaceous silt shale, massive "dendritic" siltstone and limestone, and coarse-grained to conglomeratic sandstone. Pink weathering layers of medium-bedded tuffaceous limestone become common near the top of this portion. The lowest exposures of the formation, measured above the river in the NE1/4 NE1/4 sec. 19, T. 1 S., R. 2 E., are a rather monotonous sequence of massive to thick-bedded light yellowish gray micaceous tuffaceous siltstone and sandstone with interbeds of coarse-grained olive weathering quartzose micaceous sandstone. These exposures are similar to the lower half of Robinson's type section.

The lower strata become progressively less well exposed southward.

Partial Stratigraphic Sections I and II, measured north of Red Mountain and south of the Cherry Creek fault respectively, are representative of the upper half of the exposures of the Dunbar Creek in the map area. They are characterized by a dominance of coarse conglomerate and "mud conglomerate", a term used informally to describe the typical pebbly siltstone of the formation. The highest exposures in the Red Mountain section, capped by the upper rounded gravel, consist of about 200 feet of gray calcareous conglomerate containing dominantly angular fragments of metamorphic rocks, particularly gneiss, up to 1 foot across, interbedded with mud conglomerate, a light brown calcareous tuffaceous siltstone with scattered rock fragments. Below the metamorphic conglomerates is a conspicuous andesite and rhyolite conglomerate which can be traced westward to an andesite breccia, and northward to the Elk Creek fault section. A pinkish brown massive cliff-forming siltstone occurs directly below the andesite conglomerate, forming a useful marker bed. The lower portion of the section consists of a light brown tuffaceous siltstone, finer conglomerates, and coarse sandstone, the finer rocks becoming dominant downward. The lowest exposures are white tuffaceous siltstone and silt shale with calcite cemented ash beds. This part of the section is correlated with the upper part of section IV (see Plate II).

The conglomerates become less coarse away from the Cherry Creek fault, and metamorphic rocks become more dominant in the upper conglomerates as distance from the rhyolite and andesite increases.

Ash beds in the strata are commonly cemented by calcite, which forms large sparite crystals up to 3 mm. across. The high porosity of the ash beds probably permits formation of the large crystals. Weathering of these layers sometimes produces a characteristic