General geology and geomorphology of the Emigrant Gulch-Mill Creek area, Park County, Montana
by Wayne Adams Van Voast

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE in Applied Science
Montana State University

Abstract:
Rocks ranging in age from Precambrian through Late Jurassic are present along the Beartboth Mountain front between Emigrant Gulch and Mill Creek. The Middle Cambrian strata have been intruded by a silllike pluton of dacitic magma which possibly caused upthrusting and warping of the overlying sedimentary sequence. The crystallized magma is concentrated at the point of convergence of the Mill Creek fault zone, the Cooke City zone, and the Deep Creek fault suggesting a cause and effect relationship.' Uplift of the west flank of the Beartooth massif is attributed to range-front movement along the Deep Creek fault, the trace of which is postulated to be buried beneath alluvium and glacial deposits on the valley floor within the map area. Its presence is implied by springs and travertine deposits in the. Chico vicinity and by recent scarps projecting into the map area along the mountain front.

Tertiary sediments on the valley floor at Wanigan were dated as late Miocene - early Pliocene and correlated with similar deposits of that age five miles to the south at White Cliffs.

Wisconsin glacial features cover a pre-Wisconsin topography of considerable relief on the valley floor and include two outwash plains and two piedmont terminal moraines of different ages. Analyses of preservation of these glacial features, weathering of debris, soil profile development, stratigraphic relationships, and physiographic relationships indicate at least two Wisconsin piedmont glacial advances. However, evidence for correlation with "standard" Bull Lake and Pinedale substages is inconclusive.

The post-glacial history of the valley is characterized by recurrent structural movement along the mountain fronts and sporadic downcutting and lateral erosion by the Yellowstone River and its tributaries.

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MASTER OF SCIENCE

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Applied Science

Approved:

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MONTANA STATE COLLEGE
Bozeman, Montana

June, 1964

ACKNOWLEDGEMENTS

Sincere appreciation is extended to the National Science Foundation for providing the grant which made this study possible and to the Department of Earth Sciences, Montana State College for rendering a portion of that grant available to support my research. In particular I would like to thank Dr. John Montagne for his valuable suggestions and time as well as his editorial aid and Drs. William J. McMannis and Robert A. Chadwick for critical advice on structural, stratigraphic, and igneous problems. I would also like to thank Dr. Morris F. Skinner of the American Museum of Natural History and Dr. Bryan Patterson of the Harvard Museum of Comparative Zoology for their identification of vertebrate fossils. Appreciation is also extended to Donna Smith for typing and helping to prepare the final manuscript, to the many ranchers in the map area who provided accessibility to their property, and to Mr. John Reed for his aid in drafting the maps and tables for this paper.

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ABSTRACT

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INTRODUCTION

Geographic Setting

The area of this field study is located along the west flank of the Beartooth Range in the mountains of south-central Montana, part of the northern Rocky Mountain chain. This area includes part of the valley on the east side of the Yellowstone River directly south of the small community of Pray, Montana, about 25 miles south of Livingston. The map area (see figure 3) is bounded by the Yellowstone River on the west, Emigrant Creek on the south, and Mill Creek on the north. The eastern boundary is a hypothetical line paralleling the mountain front and extending from White City to Mill Creek. This line nearly coincides with the saddles between the more subdued ridges and the steep front of the main Beartooth massif.

Previous Investigations

Bedrock geology of the map area was first studied by Iddings and Weed, whose work was published in 1893 in the U. S. Geological Survey's Livingston Folio. Their map and descriptiom of the area is very general. The area was later mapped in more detail by J. T. Wilson (1937) as part of his Ph. D. thesis at Princeton University but this work was never published. However, his map was used in the compilation of the state geologic map of Montana (1955).

Geomorphic studies which included the map area have been published by Weed (1893) and by Horberg (1940). Horberg's work was done in considerably more detail but the most important geomorphic interpretations can be attributed to Weed. Alden (1932) made several trips through the

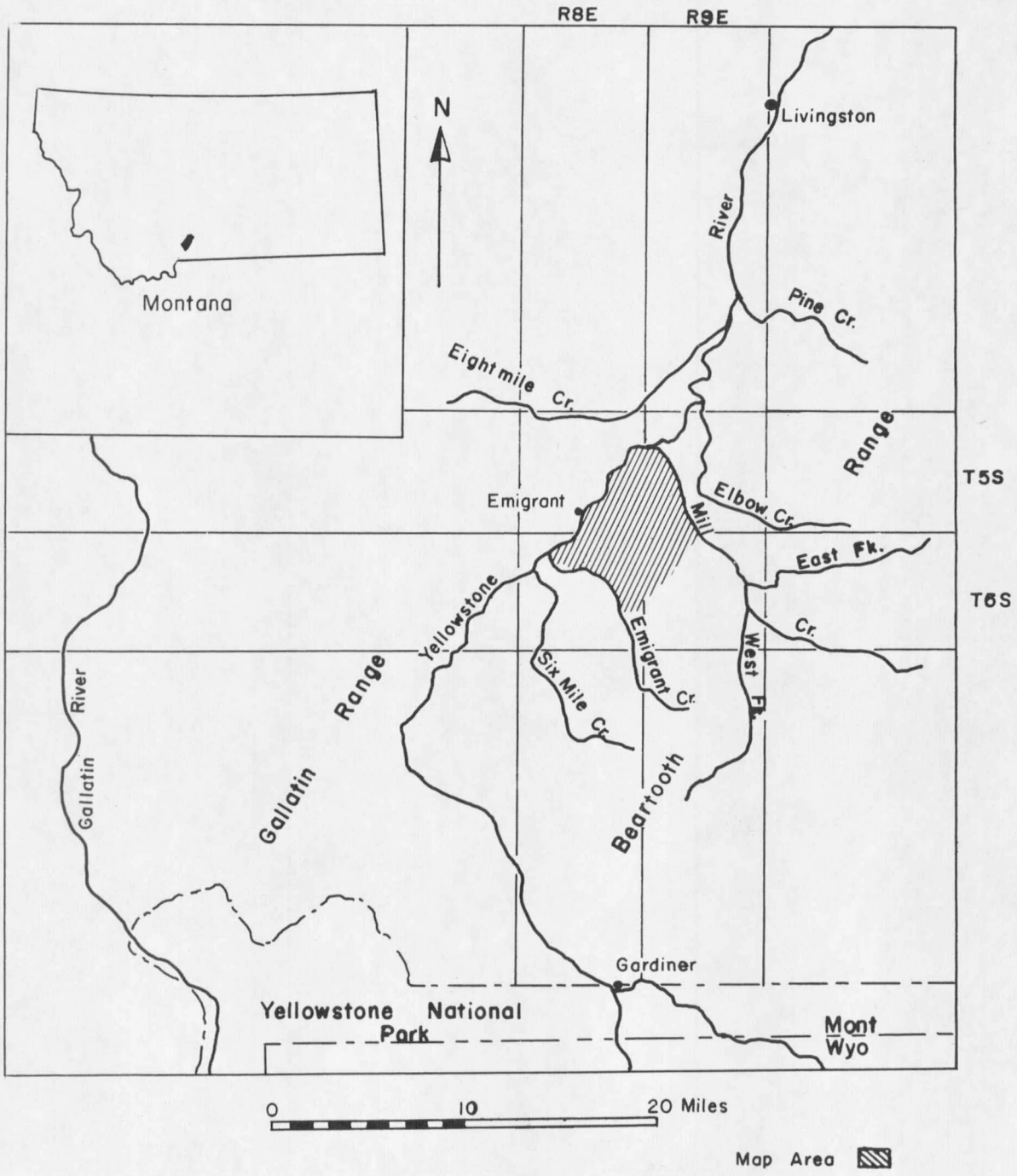

Figure 3. Index Map

area but relied essentially on Weed's work in presenting some interesting suggestions regarding correlation of surfaces on a regional basis.

The most recent work in the area has been done by John Montagne in 1961, '62, and '63. Montagne's research was concentrated on the evidence for high-level pre-Wisconsin glaciation in the valley but the general geology was also noted. The results of his work have not yet been published.

Objectives

The objectives of this study were to construct an accurate geologic map of the area, to describe rock units and structural and geomorphic relationships, and to propose a likely Quaternary through Recent geomorphic history of the area. Other problems considered in this study include the possibility of range front faulting and the age of Tertiary sediments on the valley floor.

Age	Stratigraphic Unit		Approx. Thickness	Character
Morrison Formation and overlying Mesozoic units not exposed.				
U. Jurassic	Ellis Group	Swift Formation	80'	Calcareous fossiliferous cross-bedded glauconitic sandstone.
		disconformity		
M. Jurassic		Rierdon Formation	95'	Calcareous olive-gray shale overlying thin zone of gray fossiliferous oolitic limestone.
M. Jurassic		Sawtooth Formation	250'	About 160' of dense gray, brown, and yellow shale overlying about 80' of yellow to gray silty and sandy shale.
		disconformity		
Pennsylvanian		Quadrant Formation	115'	Light-yellowish-gray to light-reddish-gray fine-grained quartzite or quartz sandstone.
Pennsylvanian and Mississippian		Amsden Formation	80'	Non-resistant beds of red shale and siltstone. Interbedded limestone and varicolored shale. Basal sandstone containing fragments of underlying Madison Limestone. Weathers to red soil.
		disconformity		
Mississippian		Mission Canyon Limestone	580'	Light gray siliceous limestone. Chert nodules and lenses commonly parallel to bedding. Generally massive, dense, and devoid of fossils.
		Lodgepole Limestone	400'	Light gray thin-bedded to massive fossiliferous fragmental limestone. Chert nodules and lenses commonly parallel to bedding.
		disconformity		

TABLE I. - Generalized Paleozoic and Mesozoic Stratigraphic Section near Mill Creek

U. Devonian	Three Forks Shale	85'	Thin-bedded orange-brown shales interbedded with gray to orange-gray dolomite. Thin beds of yellow cross-bedded arenaceous dolomite. Salt casts and ripple marks common in some beds.
U. Devonian	Jefferson Limestone	258'	Dark gray to black medium-bedded to massive fine-grained dolomitic limestone. Weathers to medium to dark brown color and gives "petroliferous" odor from fresh fractures. Contains Amphipora and has calcite veinlets in fractures. Solution breccias common in a few zones.
	disconformity		
U. Ordovician	Bighorn Dolomite	80'	Buff to gray massive fine-grained dolomite. Crinoid stems are common. Siliceous stringers cause weathering to "honey-comb-like" rough pitted surface.
	disconformity		
U. Cambrian	Snowy Range Formation — Grove Creek Limestone Member	30'	Medium-bedded buff limestone pebble conglomerate. Well-rounded greenish-coated limestone pebbles with little or no limestone matrix.
	Snowy Range Formation — Sage Pebble Conglomerate Member	160'	Medium-bedded to massive flat pebble conglomerate with interbedded gray-green thin-bedded shales. Conglomerate composed of dense limestone pebbles in a crystalline limestone matrix.
	Snowy Range Formation — Dry Creek Shale Member	90'	Gray-green and dark green, thin-bedded shales intercalated with a few beds of brown, sandy shales.
	Pilgrim Limestone	202'	Approximately 100 ft. of light gray to buff mottled thick-bedded oolitic crystalline limestone overlying

TABLE I. - (Continued)

			about 100 ft. of gray-green coarse edgewise conglomerate irregularly bedded with intercalated thin beds of gray and green shales.
M. Cambrian	Park Shale	200'	Gray-green fissile micaceous shale. A few thin beds of gray crystalline limestone in the middle of the unit.
	Meagher Limestone	150'	Gray thin-bedded limestone with silty yellow partings. Weathers to yellowish-gray soil. Middle part is most resistant. Yellow silty partings give a mottled appearance.
	Wolsey Shale	110'	Gray-green and maroon fissile micaceous shale with some thin beds of lighter micaceous siltstone. Worm trails and burrows are common.
	Flathead Quartzite	75'	Buff to red medium-to coarse-grained medium-to-thick-bedded cross-bedded quartz sandstone or quartzite. Conglomeratic near base.
	unconformity		
Precambrian (Archean)			Dark green schist with many veins and veinlets of quartz generally parallel to foliation.

TABLE I. - (Continued)

STRATIGRAPHY

Lithologic units in the map area range in age from Precambrian (Archean) to Recent. Formations typical of the interval from Precambrian through Upper Jurassic are exposed along the west side of the Beartooth Range between Emigrant Gulch and Mill Creek. Exposures are generally poor but suffice for field-mapping. The poor exposures make it necessary to draw upon information from other areas for descriptions of Paleozoic and Mesozoic units. Significant thicknesses of Middle Cenozoic and Recent sediments are confined to the area west of the mountain front and are well exposed only along road-cuts and stream channels.

Precambrian

In the map area, Precambrian rocks are exposed mainly along the north side of Emigrant Gulch. A small patch was also mapped in sec.7, T. 6 S., R. 9 E. in the bottom of Conlin Gulch on the basis of float. Where exposed in Emigrant Gulch the Precambrian consists of dark green to black schist containing many small quartz veins. The quartz veins are randomly distributed and tend to parallel the foliation of the schist. The foliation generally parallels the mountain front striking at about N. 60° E. and dipping steeply to the northwest.

Although no radiogenic age determinations have been made on the metamorphic rocks in the map area, an age of 2420 m.y. was determined from K - Ar analysis of biotite in phyllite from Jardine, about 20 miles from Emigrant, on the southwest corner of the Beartooth massif by Bruno Gilletti (oral communication, William J. McMannis, 1963). This age may be similar to that of the Precambrian schist in the map area and

indicates that the metamorphic rocks of the western Beartooth Mountains are pre-Belt in age.

Cambrian

Cambrian stratigraphic units in the thesis area were mapped as ϵ_{fw} - Middle Cambrian Flathead Quartzite and Wolsey Shale, ϵ_m - Middle Cambrian Meagher Limestone, and as ϵ_u - Middle Cambrian Park Shale and Upper Cambrian Pilgrim Limestone and Snowy Range Formation. The Cambrian section approaches 1000 feet in thickness in the map area. Each unit is discussed below.

Flathead Quartzite

The oldest Cambrian unit in the map area is the Flathead Quartzite which unconformably overlies Precambrian metamorphic rock. The only exposure of this contact found in the area is on the ridge along the north side of Emigrant Gulch. At this contact the angular discordance between the Flathead and the Precambrian schist is as great as 80°. The Flathead is present along the bottom of Conlin Gulch and in sec. 3, T. 6 S., R. 9 E. on the south side of Mill Creek Canyon. All exposures of Flathead in the map area consist of a buff to red medium-to coarse-grained quartzite. Cross-bedding is prominant in some zones. Thin lenses of conglomerate containing subrounded quartz pebbles also characterize the unit. Where exposed near the map area and studied by other workers, the Flathead Quartzite generally consists of 50 to 125 feet of quartz sandstone and quartzite with a characteristic buff and red mottling which is independent of bedding planes. A basal arkosic and somewhat conglomeratic zone with a varying

thickness is found in some areas.

The thickness of the Flathead was not measured but appears to be about 75 feet on the north side of Conlin Gulch. This is the only place where what is believed to be a full thickness is present in the map area. This thickness agrees with that measured by Richards (1957) near Livingston and that reported by J. T. Wilson (unpublished Ph. D. thesis, Princeton U., 1937) near the mouth of Mill Creek. The Flathead was deposited on an irregular Precambrian surface so local variations in thickness are common (Lochman-Balk, 1956, p. 593).

At most places in the map area, the Flathead is closely associated with Tertiary dacite porphyry which has intruded along the Cambrian-Precambrian contact. Contact metamorphism has baked the quartzite to a dark red to black extremely brittle material in some places. In other places along the contact the quartzite has been bleached to a medium gray and the iron oxide has accumulated along fractures.

Wolsey Shale

Although the Wolsey Shale is present at several places in the map area it crops out only at one location in a road-cut about one-quarter mile south of Chico Hot Springs. About 40 feet of the unit is exposed in fault contact with Devonian Jefferson Limestone and intrusive contact with Tertiary dacite porphyry. At this outcrop the Wolsey consists of gray-green and maroon fissile micaceous shale with some thin beds of micaceous siltstone. No trilobite fragments were found although they are common in the Wolsey in adjacent areas. Worm trails and burrows which characterize the

Wolsey in other areas are very common in this exposure.

Wherever the Wolsey is present in the map area it is closely associated with porphyritic intrusive rock. Contact metamorphism has considerably altered the character of the shale near the contact with the porphyry. Such a contact is exposed just upstream from the mouth of Mill Creek Canyon (see figure 4.) where the originally green micaceous shale has been metamorphosed to a dark gray to black siliceous hornfels. The bedding plane fissility of the shale for as much as two inches from the contact has almost completely disappeared. Also, this two-inch-thick metamorphosed zone contains a few scattered porphyroblasts of quartz and is extensively iron-stained along fractures. The hornfels has retained much of the original mica and does not contain any metamorphic minerals.

The contact between the Wolsey Shale and the underlying Flathead Quartzite is poorly exposed in the map area. Near Livingston (Richards, 1957) and in the Garnet Mountain Quadrangle west of the map area (McMannis and Chadwick, in press) the top of the Flathead grades into the base of the Wolsey and the contact is placed above the highest prominent sandstone or quartzite ledge. Isopach maps (Hanson, 1952) indicate that the Wolsey Shale should be about 110 feet thick in the map area. This agrees reasonably with the thickness of 105 feet measured by Richards (1957) near Livingston.

Meagher Limestone

The Meagher Limestone is Middle Cambrian in age and conformably overlies the Wolsey Shale. The contact is not exposed in the map area but is