Cenozoic geology of the Madison bluffs area Gallatin County, Montana
by Gary Bradley Schneider

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

Abstract:
The Miocene-Pliocene Madison Valley Formation east of the Madison River contains three unconformable cyclic units each composed of a basal fluviatile sequence of cross-bedded, andesite conglomerate, coarse sandstone, and tuffaceous siltstone grading upward into sediments that vary laterally from lacustrine beach sands to laminated clays containing fish remains and ostracods. Tuffaceous claystones and siltstones containing carbonaceous dendrites and other plant debris are typically associated with these lake beds. The lake beds are in turn cut by the basal fluviatile sequence of the overlying unit. This basic pattern is seen in all three units, but there is considerable variation from unit to unit. Although the entire section is rich in ash beds 1/2 - 2 feet thick, and in tuffaceous siltstone, the majority of the fresh glass is concentrated in the lake beds of the middle unit. One sequence of ash beds near the top of this unit, has a maximum thickness of 15 feet and is used as the marker bed on which partial measured sections are huhg.

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Block faulting along the bluffs parallel to the Madison River and the distribution of Quaternary (?) gravels to the west and within the area indicate shift of the drainage from northeastward to its present northward position in post-middle Pliocene time.

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Date May 22, 1970

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ABSTRACT

The Miocene-Pliocene Madison Valley Formation east of the Madison River contains three unconformable cyclic units each composed of a basal fluviatile sequence of cross-bedded, andesite conglomerate, coarse sandstone, and tuffaceous siltstone grading upward into sediments that vary laterally from lacustrine beach sands to laminated clays containing fish remains and ostracods. Tuffaceous claystones and siltstones containing carbonaceous dendrites and other plant debris are typically associated with these lake beds. The lake beds are in turn cut by the basal fluviatile sequence of the overlying unit. This basic pattern is seen in all three units, but there is considerable variation from unit to unit. Although the entire section is rich in ash beds ½ - 2 feet thick, and in tuffaceous siltstone, the majority of the fresh glass is concentrated in the lake beds of the middle unit. One sequence of ash beds near the top of this unit has a maximum thickness of 15 feet and is used as the marker bed on which partial measured sections are hung.

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CENOZOIC GEOLOGY OF THE MADISON BLUFFS AREA GALLATIN COUNTY, MONTANA

INTRODUCTION

This paper is the result of geologic mapping in the bluffs area on the east side of the lower Madison River. It was undertaken as a thesis project in partial fulfillment of the requirements of the Master of Science in Earth Science with a major in geology at Montana State University. Field work was done during the spring and summer of 1969.

The principal objective of the study was to map in detail the Cenozoic sediments of the area, specifically working toward an understanding of the depositional history. An attempt has been made to find the stratigraphic position of fossil localities and formational units that have been previously described in the literature, but never accurately located geographically or stratigraphically.

The area mapped has been the subject of part of previous geologic investigations which were specialized in their objectives. It has not, however, been given the detailed coverage necessary to elucidate many of the relationships having definite bearing on the Cenozoic history. Choice of the area for study was determined by an interest in the paleontological work which has been done in the area and a desire to at least attempt to put that work in the proper stratigraphic setting. However, paleontological work is not the central theme here, and little effort was devoted to that end.

Previous Investigations

The earliest geological investigations in the region were made by Hayden (1861, 1884). The first extensive geological mapping was done by Peale (1893, 1896). His paper on the Three Forks quadrangle is of a reconnaissance nature, but serves as a good review of the general geology.

Douglass (1899, 1903, 1909) described vertebrate remains in the Tertiary strata of southwestern Montana, many of which were collected in the map area or adjacent to it. Later significant paleontological work was done by Wood (1933, 1938), Wood, and others (1941), Schultz and Falkenbach (1940, 1941, 1949), and Dorr (1956).

A regional study of the groundwater resources of the Gallatin Valley by Hackett, and others (1960) includes a general stratigraphic description and geological history of the area. Robinson (1963) published on the Three Forks quadrangle which adjoins part of the area on the west. Additional studies of the region and contiguous areas include Fix (1940), Klemme (1949), Tanner (1949), Pardee (1950), Alden (1953), McMannis (1955), Verrall (1955), Hall (1960), Robinson (1961), Mifflin (1963), Glancey (1964), Weber (1965), and Kuenzi (1966).

McMannis (1963) made a regional study of the distribution of the Precambrian Belt Supergroup. Detailed studies of the Precambrian metamorphic rocks in the areas nearby have been made by Tansley, Shafer, and Hart (1933), Clabaugh (1952), Reid (1957, 1963), and Kozak (1961).

Additional study of the metamorphic rocks, especially the tectonic features, may prove very useful in unraveling structural history of the basin.

GEOGRAPHY

Location

The map area (see Index Map, p. 5), occupying approximately 125 square miles, lies on the divide between the Madison and West Gallatin Rivers, just south and east of the headwaters of the Missouri River at Three Forks, Montana. This part of the Three Forks basin physiographic subdivision lies between the 111° 20' and 111° 30' meridians and the 45° 35' and 45° 50' parallels. The west boundary of the study area is the flood plain of the Madison River. The northern boundary is the Gallatin River. Manhattan, a small town, is situated just east of the northeast corner of the area, and Anceney, a grain terminal, is located just north of the southeast corner of the area. The southern boundary of the area is the Madison - Gallatin county line.

Topography

Elevation of the area varies from 4,100 feet on the flood plains of the rivers, to 5,200 feet on the divide between the Madison and West Gallatin rivers in the south central part of the area. The land surface rises abruptly from the Madison Valley on the west to the broad gently east- and north-sloping Madison Plateau which grades gently to the West Gallatin River on the east and the Gallatin River on the north. The plateau is deeply dissected on the bluff side. Away

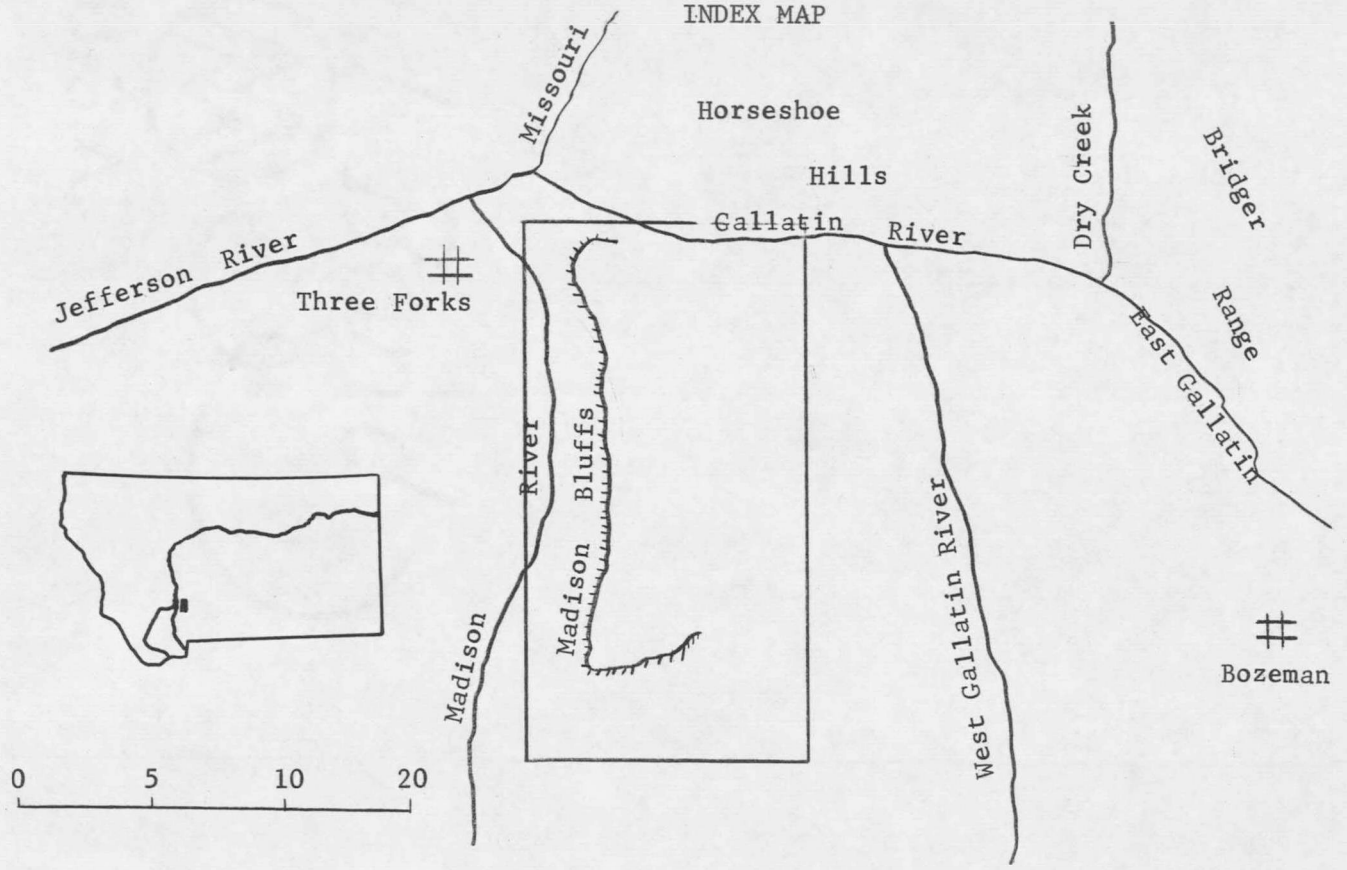

Figure 1. Index map showing location of the Madison Bluffs Area southeast of Three Forks, Montana.

from the river a series of steep-sided ravines separate flat to steeply sloping benches.

Climate

The average annual precipitation in the area according to calculations made in 1952 (Hackett, and others, 1960, p. 18) ranges between 11.5 and 15.5 inches. At Bozeman, 15 miles to the east, nearly two-thirds of the precipitation falls during the period from April to September. The precipitation in May and June amounts to about one-third of the annual total. A second maximum, much less than that in the spring, generally occurs in September. The precipitation from year to year, however, is characterized by many departures from the average.

Daily and seasonal fluctuations in temperature vary widely. Hackett, and others (1960) report that the average annual temperature at Bozeman is 42°F. and the extreme temperature ranges from above 110°F. to below -50°F. Snow cover in the area during the winter rarely exceeds two feet for any length of time. The best means of transportation for geologic field work is by four-wheel-drive vehicle in the summer months.

Land Economics

Most of the map area at present is in agricultural use, either as crop land or as pasture. Areas of low relief and good soil are used in the dryland production of wheat. Areas of steep or broken terrain are used for the grazing of cattle or sheep. Irrigated lands on the flood

plains of the rivers are used for the production of hay. Except for fishing accesses on the Madison River and the Madison Valley Buffalo Jump Archaeological Site all of the lands are privately owned.

At present there is little economic development of mineral deposits within the area. Gallatin County as well as some of the land owners operate gravel pits in the northwest part of the area. Little other development has taken place.

STRATIGRAPHY

Precambrian

Potassium feldspar-rich gneiss and hornblende gneiss are exposed in the southeastern corner of the area and in scattered outcrops along the southern border. Exposures of gneiss in the southwestern part of the area have a minimum surface relief of 610 feet, and are unconformably overlain by Tertiary and Quaternary sediments.

In the northern part of the area Precambrian strata of the Belt Supergroup (Verrall, 1955) crop out. These strata consist of arkosic sandstones and conglomerates, and intercalated dolomitic limestones and argillite. Presumably they unconformably overlie gneiss. They are in turn unconformably overlain by Tertiary and Quaternary sediments.

Paleozoic

Along the northern border of the area the Cambrian Flathead Sandstone, Wolsey Shale, Meagher Limestone, Pilgrim Limestone, and Snowy Range Formation, the Devonian Jefferson Dolomite, the Devonian-Mississippian Three Forks and Sappington formations, and the Mississippian Madison Group are exposed in Logan Canyon. Description of the lithologies of these formations are given by McMannis (1955), Verrall (1955), and Robinson (1963).

Cenozoic

Cenozoic sedimentary rocks, divided into eight map units, dominate the area. The units, all of nonmarine origin, have a maximum aggregate exposed thickness of 1500 feet, but total exposed thickness is probably nowhere greater than 1000 feet. The Cenozoic column here is composed of late Miocene to middle Pliocene (?) rocks, but the high part of the Madison Plateau is covered by a veneer of unconsolidated Quaternary alluvium, and much of the area is covered by loess and soil.

The Cenozoic of the area has been variously investigated since the publication of the Three Forks folio (Peale, 1896). Paleontological collections have been made and described by Douglass (1899, 1903, 1909), Matthew (1903), and Dorr (1956). Extensive collections have also been made by members of the Carnegie Museum of Pittsburgh, the Frick Laboratory, Princeton University, the University of Michigan, the University of Chicago, and other organizations, but little publication has yet resulted (Robinson, 1963).

Systematic study of the Cenozoic stratigraphy in this part of Montana has been undertaken only within the last two decades (Verrall, 1955; Dorr, 1956; Robinson, 1963; and Kuenzi, 1966). Much more work is needed in order to make firm correlations of the Cenozoic deposits in the area, and to obtain a comprehensive picture of the regional Cenozoic history.

The Three Forks basin is formed in soft Tertiary rocks that were laid down in a basin of dimensions similar to those of the modern one. The Madison Bluffs area, in the west-central part of the basin was also in the west-central part of the Tertiary basin as shown by Peale (1893, Pl. I). Rocks of known or inferred Tertiary age are exposed over approximately one-half of the surface and are thinly mantled by unconsolidated Quaternary deposits over an additional one-quarter of the surface.

Principal rock types are siltstone, sandstone, conglomerate, and claystone in subequal amounts, and minor amounts of limestone and travertine. About one-half of the Tertiary deposits were derived from erosion of the pre-Tertiary rocks, and one-half from pyroclastic debris. Few beds are free of volcanic ash, and many strata are made up wholly of such material, much of which is fresh glass (Robinson, 1963).

The Tertiary rocks, of late Miocene to middle Pliocene (?) age (Wood, 1941; Dorr, 1956; Robinson, 1963), may be divided naturally into three units, designated here lower, middle, and upper (see Composite General Section, p.12), each of which reflects a definite cycle of sedimentation. No attempt has been made to assign formal formational names to the units, however, detailed work in the adjoining areas may make this feasible in the future. (see Figure 2.).

Generally, the units consist of basal sandstone - conglomerate channels that represent an episode of through-running drainage in the basin. These channels are unconformable on the underlying strata and

grade upward into sands and silts which are laterally variable, and represent the onshore-nearshore facies of a lake sequence. Typical variation in the onshore-nearshore phase ranges from eolian sands to ripple-marked siltstones to carbonaceous claystone that resembles a paleosol, all laterally separated by a few miles, but at the same stratigraphic horizon. The onshore-nearshore sequence is interbedded with and overlain by laminated clays and very fine silts that contain fish remains and ostracods. These lake deposits are of finite geographical extent within the area and can be traced and delineated in the field (see Figure 3.).

The laminated clays are not all in the same stratigraphic position in all of the units or within one unit. In some instances the lake sediments are of sufficient thickness and lateral distribution to indicate a persistant lake of considerable size - with a maximum measurable dimension at one place of 7 miles (see Geologic Map).

The lake beds are overlain by sandstone and siltstone which have the same general characteristics as the underlying shoreline phase. This probably represents a lateral shift in the position of the lake or a decrease in the size of the lake, the magnitude of which can not be determined from the present outcrops.

The entire unit is unconformably overlain by the channels of the next higher unit which reflects the renewal of through-flowing drainage and the beginning of the next depositional cycle.

TABLE I

COMPOSITE GENERALIZED STRATIGRAPHIC SECTION
TERTIARY AND QUATERNARY SEDIMENTS
MADISON BLUFFS AREA, GALLATIN COUNTY, MONTANA

Quaternary

7. Loess and soil; medium gray loess and soil present over much of the area and best developed on the Madison Plateau section of the map. Obscures the bedrock geology over much of the area..... 10'

6. Gravel; clasts ranging from 6" down to sand size. Cobbles and pebbles are predominantly Belt quartzite, with a few igneous clasts, and lesser amounts of gneiss and Paleozoic sandstone. Spills down slopes and makes the thickness difficult to estimate..... 25'

(?) Pliocene

5. Claystone and sandstone interbedded; yellow to white. Sandstone is channel-form within claystone, and also at some horizons has an onshore-nearshore aspect. Some lake sediments were found within this sequence..... 190'

UPPER UNIT

4. Conglomerate and sandstone; large scale, widespread channel deposits that form prominent cliffs in the central part of the Bluffs exposure. Contains proboscidian material referred to Serridentinus progressus. Sequence varies greatly in thickness. Maximum.... 50'

Miocene

MIDDLE UNIT

3. Sandstone; yellow to gray-white. Sandstone composed of quartz sand with clay matrix, and interbedded with numerous beds of fresh glassy ash. Sequence contains well developed lake beds exposed along the central and northern parts of the Bluffs. Equivalent to Anceney Beds of Dorr (1956). Maximum..... 250'

2. Conglomerate and sandstone; large-scale and widespread channel deposits distinguishable in the lower part of the Bluffs and forming a prominent vertical cliff in the north..... 60'

LOWER UNIT

1. Claystone interbedded with sandstone and conglomerate in minor channels, and gray siltstone; unit more variable lithologically both vertically and laterally than those above. Contains Leuciscus turneri beds of Wood (1940) in about the middle of the exposed section. Thickness variable, base covered by recent alluvium.....125'

Total Thickness 710'

General transport direction (see Preliminary Paleocurrent Map, Plate II) indicated by numerous measurements of the cross-bedding and imbrication of the coarser parts of the channels of all three units indicates a drainage pattern with a general trend of N. 40° E. The composition of the sediments and the direction of transport indicate that the material was probably transported from the mountains to the west or southwest of the area.