Quaternary glacial geology and geomorphology of the Teton drainage area, Teton County, Montana
by Ann Leslie Chalmers

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 the Teton River drainage area, Teton County, Montana, the Bull Lake substage of Wisconsin glaciation does not have readily definable moraines. From the data available in the mapped region, it appears that the Bull Lake mountain and Bull Lake continental ice met at Choteau. Previous to their melting, a lake-was present in early Bull Lake time which became smaller as the two ice sheets met. The Bull Lake continental ice reached nearly to the top of the Flaxville Terrace, an elevation of 3980 feet, and extended farther west and south than was previously thought.

The Pinedale mountain ice has well defined limits and extended about four miles east of the mountain front. The lake deposits are of Pinedale age, as indicated by the ash deposits found by the writer, and tentatively identified in the field by Dr. Ray Wilcox, U.S.G.S., Denver, Colorado, as ash deposits of both Mount Mazama and Glacier Peak. The Pinedale continental ice has attenuated edges which enter the northeast section of the mapped area.

QUATERNARY GLACIAL GEOLOGY AND GEOMORPHOLOGY OF THE TETON DRAINAGE AREA, TETON COUNTY, MONTANA

by
Ann Leslie Chalmers

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.

Approved:

Milton J. Edie
Head, Major Department

John Montagne
Chairman, Examining Committee

K Goering
Graduate Dean

Montana State University
Bozeman, Montana

August, 1968

ACKNOWLEDGEMENTS

Many people have given inspiration and assistance to the writer. My parents and brother and sister deserve first mention for their patience, encouragement, and help rendered.

Thanks are due Gerald M. Richmond of the United States Geological Survey, Denver, Colorado, for suggesting the problem considered in this paper.

Dr. John Montagne is given special thanks for his sincere interest and help. Special thanks go also to Dr. Robert Chadwick, Dr. William McMannis, and Mr. Milton Edie for their aid and interest. Sincere thanks to Dr. Melvin Monson for his unceasing encouragement and to Dr. Lawrence Kavich and Dr. Robert Thibeault for their interest.

Thanks also to the people who so willingly let me study areas of their property and who gave me directions to reach different areas and who gave information on phenomena which they had observed.

My thanks to the Teton County Soil Conservation Service personnel who willingly gave of their time and who let me use their equipment, and to Mr. Raymond Kelly for taking some of the pictures and helping develop the prints.

Thanks to the people who typed the paper and put it in its final form.

To the many others that helped in various ways, my sincere thanks.

TABLE OF CONTENTS

	Page
VITA	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF PLATES AND FIGURES	vi
ABSTRACT	viii
PART I	
CHAPTER I. A PROSPECTUS	1
History	1
Introduction	2
Location	6
Natural Setting	6
Flora and Fauna	8
Previous Investigations	8
Problem	9
Hypothesis	11
Alternate Hypothesis	11
Propositions	14
Procedures	14
CHAPTER II. GEOMORPHOLOGY, GENERAL AND SPECIFIC	15
Flaxville Plain	15
Number Two Terrace	17
Number Three Terrace	19
Effects of Ice Age on Drainges	21
Correlation of High Level Surfaces	23
Ice Marginal Stream Features	25
Outwash Channel and Outwash	25
PART II. GLACIAL DEPOSITS AND THEIR DESCRIPTION AND RELATIONSHIPS	
CHAPTER III. PRE-BULL LAKE GLACIATION	26
Flaxville Terrace	26

Number Two Terrace 27
Number Three Terrace 29
Summary 29

CHAPTER IV. BULL LAKE GLACIATION 31
Mountain 31
Continental 38
Summary 41

CHAPTER V. PINEDALE GLACIATION 44
Mountain 44
Lake 56
Continental 71
Summary 73

CHAPTER VI. CONCLUSIONS 76

APPENDIX A. METEOROLOGY 78

REFERENCES CITED 82

LIST OF PLATES AND FIGURES

PLATES

		Page
PLATE 1.	Quaternary Glacial and Geomorphic Map of the Teton River Drainage, Montana	Pocket
PLATE 2.	Profile of Outwash and Moraines	22
PLATE 3.	Diagramatic Columnar Section of Bull Lake and Pinedale	42

FIGURES

FIGURE 1.	Index Map	4
FIGURE 2.	Pinedale Moraine Showing Lakes	12
FIGURE 3.	Pinedale Moraine Showing Erratics	13
FIGURE 4.	Flat Erosional Surfaces	16
FIGURE 5.	Breached Anticline and Ice Polished Shoulder . . .	20
FIGURE 6.	Gravel-capped Number Two Terrace Remnants	28
FIGURE 7.	Map Showing Strategic Field Stations	32
FIGURE 8.	Apparently Reworked Bull Lake (?) Till	34
FIGURE 9.	Pine Butte	37
FIGURE 10.	Source Area for Ice	46
FIGURE 11.	North Side of Pinedale Mountain Moraine	47
FIGURE 12.	South Side of Pinedale Mountain Moraine	48
FIGURE 13.	South Pinedale Mountain Lateral Moraine and Outwash	51
FIGURE 14.	Pinedale Mountain Moraine Draped on Bull Lake (?) Outwash	53

FIGURE 15. Pinedale Outwash Plain Exhibiting Braided Pattern 54

FIGURE 16. Slide in Pinedale Lake Sediments 59

FIGURE 17. Ash Layer in Pinedale Lake Sediments 60

FIGURE 18. Indian Fireplace in Loess Above Pinedale Lake Sediments 62

FIGURE 19. View of Pinedale Lake Sediments 64

FIGURE 20. Close-up of Pinedale Lake Sediments 65

FIGURE 21. Disrupted Clay Layer in Pinedale Lake 69

FIGURE 22. Disrupted Clay and Silt Layers in Pinedale Lake . 69

FIGURE 23. Disrupted Layers in Pinedale Lake 69

FIGURE 24. Pinedale Continental Moraine 72

FIGURE 25. Close-up of Pinedale Continental Moraine 74

ABSTRACT

In the Teton River drainage area, Teton County, Montana, the Bull Lake substage of Wisconsin glaciation does not have readily definable moraines. From the data available in the mapped region, it appears that the Bull Lake mountain and Bull Lake continental ice met at Choteau. Previous to their melting, a lake was present in early Bull Lake time which became smaller as the two ice sheets met. The Bull Lake continental ice reached nearly to the top of the Flaxville Terrace, an elevation of 3980 feet, and extended farther west and south than was previously thought.

The Pinedale mountain ice has well defined limits and extended about four miles east of the mountain front. The lake deposits are of Pinedale age, as indicated by the ash deposits found by the writer, and tentatively identified in the field by Dr. Ray Wilcox, U.S.G.S., Denver, Colorado, as ash deposits of both Mount Mazama and Glacier Peak. The Pinedale continental ice has attenuated edges which enter the northeast section of the mapped area.

PART I

GENERAL COMMENTS

CHAPTER I

A PROSPECTUS

History. The southernmost boundary of known continental glacial drift was first mapped across the entire United States in the late 1880's. The eastern half of the boundary was quite well known as much as twenty years earlier from the work of previous observers. The most striking feature of the western boundary of the continental drift is the fact that it does not extend as far south as its easternmost counterpart. The west segment of the drift may be up to 550 miles less in southward extent than the eastern half. This phenomenon may be accounted for by the more arid climate of the Great Plains and the wide Cordilleran belt, as far west as the Cascades, which had the effect of limiting the mountain and continental glaciation in Montana and farther west. The probable reason for the drier climate east of the Cascades is that their elevation was sufficiently high, at that time, to create a rain shadow on their leeward side. The prevailing west wind carried moist air from the oceans over the land to the mountains, where orographic lifting occurred, resulting in condensation and precipitation on the windward side. Thus, the air being

pushed over to the east side of the Cascades was drier, resulting in a somewhat arid climate in the region just described. Farther east maritime tropical air probably moved north and mixed with polar continental air. This would explain the more abundant moisture in the east, which gave rise to a greater accumulation of ice in the east, and farther extension south than the western segment of the continental moraine.

The center or source region for the Wisconsin continental ice sheet is known as the Keewatin center. This center developed when the ice on the plains reached the same level as the ice field in the mountains at about 55° north latitude, thus developing another center of outflow. This center changed position with the varying thickness, shape, and extent of the ice. During the most extensive Wisconsin glaciation, the center evidently lay on a line just east of Athabasca and Great Slave Lake (Antevs, 1934). This, then, is the source region for the continental drift in the Teton River drainage area. A plausible explanation for the creation of the great expanse of ice is found in Appendix A.

Introduction. The large area known as the Great Plains, with its vast smooth ground area, slopes gently upward to the west. Here and there the smoothness is interrupted by a coulee, or a stream cutting downward in the never-ending process of erosion. It is a land of few trees which, where found, are mainly along rivers or

coulees. The northern edge of the Great Plains in the United States is not so smooth, but rather is characterized by knobs and low spots, in some areas holding water in their hollows. This is where once huge glaciers dominated and now are gone. Beyond the western edge of these plains are the headwaters of the Missouri River, the Jefferson, Madison, and Gallatin Rivers meeting to create it, with the Sun, Teton, and Marias joining later to add their waters to the already large river. Even the Missouri River did not escape the effects of the ice and during the Wisconsin stage of glaciation was moved south, out of the bed where the Milk River now flows, to its present position.

The Teton River and its drainage area also came under the influence of ice, and evidence of this can be readily seen. The Great Plains meet the mountains (Figure 1) in the vicinity of the Teton River drainage. The plains in the Teton area rise to the mountains from an elevation of 3440 feet in the east with a slope of approximately thirty-five feet to the mile, until the area is reached where the transformation from plains to mountains occurs, with the plains finally attaining an altitude of about 4800 feet and a slope of about eighty feet per mile. Here also can be seen flat-topped benches and buttes which rise 250 to 500 feet above the plain. The mountains tower some 4000 feet above the structurally complex and topographically subdued western edge of the Great Plains. As the Teton River leaves the lofty peaks of the Rocky Mountains and rushes out onto the sudden

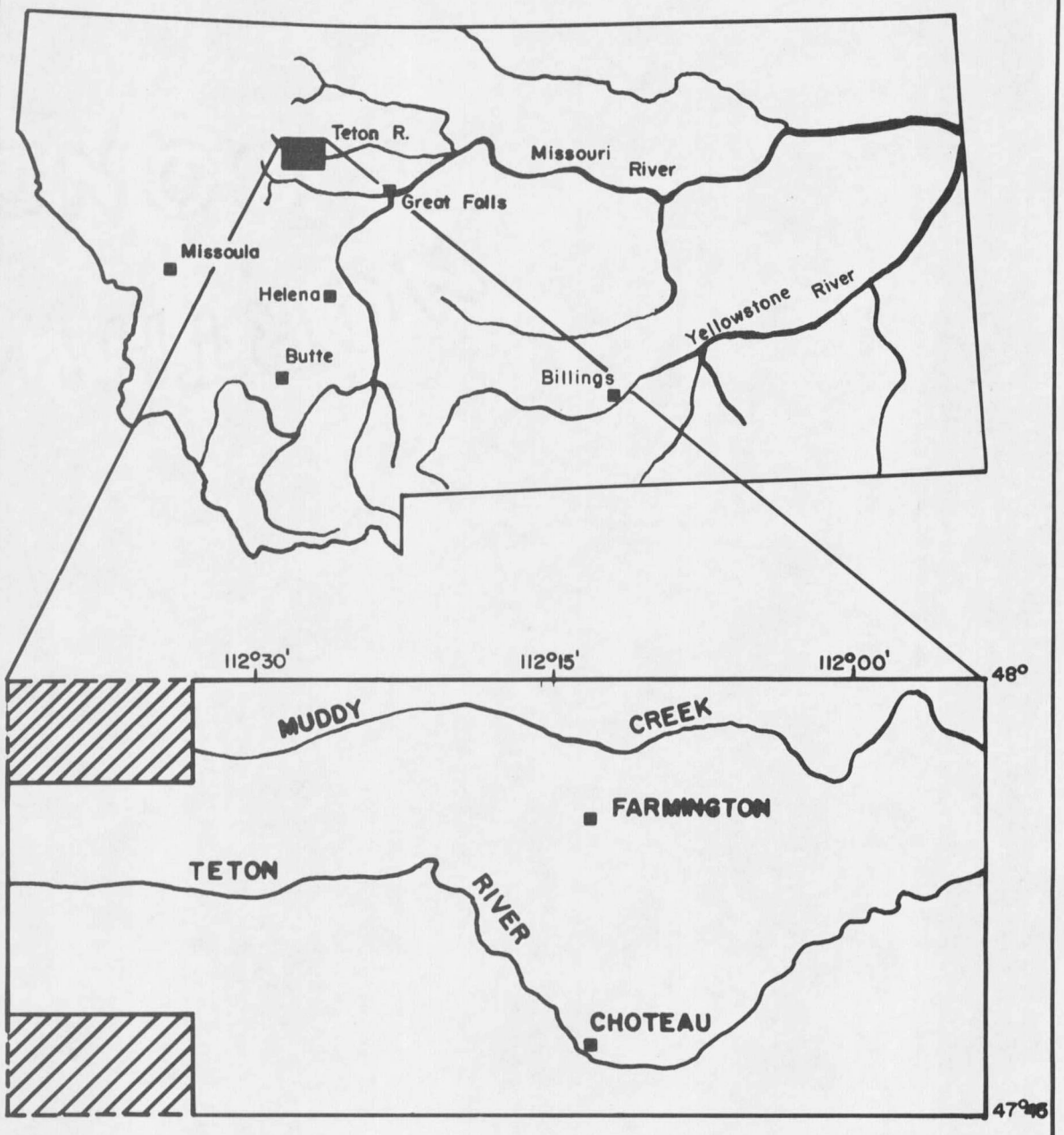

Figure 1

INDEX MAP

flatness of the plain, it first makes its way more than four miles through hummocky terrain sheltering small lakes in its irregularities. It then flows on beyond the "hills", which arch out from the mountains, and continues east on a flat plain protected by a layer of cobbles, well-rounded by miles of fluvial transport. It cuts into the basal slopes of the higher, flat-topped plains and hills. About nineteen miles east of the morainal area it begins to cut into soft, very thinly layered lacustrine silts and clays having a layer of ash about eight to ten feet below the top. Flat-topped hills lie close on both sides for about two miles, and to the east the river cuts its way into the soft sediments creating cutbanks fifty feet in height; in places these banks slide, creating shear faces and a hummocky topography. Some of these slides have temporarily blocked the river and stopped its flow, but it eventually cut through the material of the slide or changed its course and circumvented it. Some of the slides are fresh and show a brown gash of newly exposed thinly layered beds, and others are somewhat modified by rounding and protected by a mantle of grass. For nearly ten miles this situation prevails, and then the river runs through increasingly more hummocky terrain which becomes stronger in character eastward. The cutbanks here reveal unsorted materials containing clay, sand, silt, small and large rocks, even up to several tons in weight, all mixed together. Perched up on the humps are more huge boulders, some as much as five to seven feet across. The river continues eastward, in places cutting into river terraces, to where

it enters the Marias River.

Location. The area just described extends westward from the town of Choteau into the marginal part of the Rocky Mountains (Plate 1, in pocket), and runs east from Choteau nearly seventeen miles. It extends northward about twelve miles to Muddy Creek and goes southwest and thence west until it is four miles north of the Teton River, and from there the boundary is drawn westward to the mountains. The southern boundary east of Choteau extends along the Teton Ridge, thence westward through the T L Gap and westward along the Belleview Road into the mountains.

The area mapped comprises nearly 520 square miles. Another 500 square miles were generally examined to more accurately analyze the relationships which were observed in the area outlined above. Most of the area is accessible for field work all year, but parts are accessible only during the dry season or when frozen in winter. Easy access to much of the area is available by way of Highways 89, 287, and 221, which intersect at Choteau. There are many gravel roads which crisscross the eastern part of the area. To the west access consists of two main gravel roads and some cow trails.

Natural Setting. The economy of the region depends on grain and cattle ranching. Due to the area's location east of the Rocky Mountains it is fairly dry, classified as Bsk (A middle-latitude, cold Steppe climate). The area also has the chinook (Blackfoot meaning, snow eater) winds which often blow from the southwest. These are warm,

dessicating winds which descend the abrupt mountain slope and cut short what would otherwise be long cold spells, and give clear, sunny winter weather. The temperature may rise forty degrees or more in a short time due to these winds. Blizzards are common and may have sixty mile per hour northerly winds and snow which give zero visibility. They may last several days and pile snow into ten foot drifts.

Winter temperatures sometimes drop to fifty degrees Fahrenheit below zero, but these times are of a few days' duration only. Summer temperatures average in the eighties in the daytime and about forty-five degrees at night, averaging out to about sixty-three degrees in a normal year. There are about one hundred five frost-free days a year if the area immediately adjacent to the mountains is not taken into account.

Precipitation varies, averaging eleven and a half inches at Choteau and Bynum, whereas near the mountains it is fifteen inches. Some of the higher mountains are believed to receive sixty inches or more of precipitation. In the mountainous area more than fifty percent of the precipitation falls as snow. The measured annual precipitation is most concentrated in the period of April to September, especially in the lower areas (from precipitation records at Teton County Extension Office).

The area has a great deal of clear, sunny weather, interspersed with thunderstorms in the summer, most common during July and August. Fog is rarely observed. In winter the area receives some snow, which

rarely remains because of the chinook. All year long the area is swept by winds, usually westerly.

Flora and Fauna. The mountain glacier moraine supports a thick growth of jack pines, with grass and forbes also present. The mountains support a moderate cover of pine trees, interspersed with grassy meadows and locally swampy areas. To the east on the plains grows a sparse covering of grass and forbes, with cottonwoods and willows along the creeks and rivers. East of Choteau most of the area contains grainfields, and good exposures of subsurface materials are found only along rivers and manmade excavations. West of Choteau the area is mostly unimproved rangeland, and exposures are somewhat more common.

Various types of birds, such as Hungarian partridges, eagles, pheasants, grouse, a few prairie chickens, etc., and animals such as deer, antelope, and rattlesnakes are the most common wildlife of the plains region, although black bears and mountain lions venture as far east as the Choteau area occasionally. The mountain area and the adjacent plain have an abundance of deer, antelope, brown and black bears, grizzlies, mountain lions, bobcats, beaver, and, a bit farther east, also rattlesnakes.

Previous Investigations. The only relatively detailed study of the area under consideration was made by Alden in 1932, who published his results in U. S. Geological Survey Professional Paper Number 174. In the 1932 paper he defined some of the limits of continental and

mountain ice and also the number one, two, and three terraces, in part, but the paper was still of a reconnaisance nature. The adjacent area of Glacier Park and the land east of it has been studied by such observers as Alden and Clinton, 1912; Alden, 1924; and Hobbs, 1921. The Sun River region has been studied by Mudge, 1967, and by Martin, 1917. A glacial map of Montana east of the Rocky Mountains by Colton, Lemke, and Lindvall (1961) shows the approximate boundaries of the mountain and continental ice and Lake Choteau, as well as features in the surrounding area. These and other studies are cited in appropriate subjects in the paper.

Problem. The Bull Lake substage of the Wisconsin glacial stage has not been defined in the Teton River drainage area. Indeed, it is questionable if Bull Lake ice ever extended farther than ice of the later Pinedale substage of mountain ice. The highest extent of Lake Choteau during the Bull Lake and Pinedale substages also was not known precisely. This study was made in order to delineate the extent of the Bull Lake, Pinedale, mountain and continental ice, and also Lake Choteau. Another primary objective was to construct a map of glacial features showing the relationships, and to interpret the glacial history.

In most areas in the Rocky Mountains where Wisconsin mountain glaciation has occurred there are two very readily definable stages of glaciation. The earliest is the Bull Lake glaciation, type area

near Bull Lake, Wyoming (Blackwelder, 1915). According to Richmond, 1965, in most cases Bull Lake ice extended farther from the mountains than the next later stage of glaciation. It is characterized at the type area by two moraines having smooth slopes and large boulders sparsely scattered on the slopes. The till contains a great deal of silt and clay. It extends out from the mountains about thirty to forty miles at Bull Lake, Wyoming. The age of the Bull Lake was found to be greater than 42,000 YBP by Trimble and Carr in 1961, according to Richmond, 1965. The age was determined by dating peat found four meters below the top of the lake beds near American Falls, Idaho.

The Bull Lake in the map area has subdued knob and kettle topography with a few limestone boulders scattered on its surface. The kettles generally do not contain lakes and the terrain is not swampy. There is little limestone left in the till, possibly because it has been removed by solution.

The Pinedale mountain glaciation followed the Bull Lake and its till most commonly lies within the Bull Lake deposits. The Pinedale type area is near Pinedale, Wyoming, and generally consists of three moraines. At Pinedale the first two are close together, the third and latest farther back and closer to the source area. The end moraine seldom has lakes and may be narrowly breached by rivers. The lateral moraines are unmodified (Blackwelder, 1915).

In northern Montana the Pinedale moraine has very sharply defined lateral and terminal moraines. The slopes are hummocky and covered

by an abundance of fresh appearing limestone boulders. The inner moraines contain ponds and lakes in the hollows and also have swampy areas (Figures 2 and 3).

The continental ice, according to all available literature and as indicated by its content of crystalline metamorphic debris, emanated from the Keewatin center. Debris is characterized by large granite, schist, and gneiss erratics, but the till grades down to gravel size material. It has knob and kettle topography which diminishes in sharpness toward its outermost extension, perhaps because of saturation by waters of Glacial Lake Choteau.

Glacial Lake Choteau was formed when continental and mountain ice dammed the rivers and ponded their waters (Plate 1). The trapped water formed very finely varved clay and silt deposits which now delineate its minimum extent. The preceding properties characteristic of the Bull Lake, Pinedale and continental ice deposits and the lake sediments were used to define the extent of the glacial activity.

Hypothesis. The Bull Lake ice in the Teton River drainage extended farther east onto the plains than the Pinedale ice.

The contimental ice extended farther west and south than is presently thought.

Alternate Hypothesis. In the Teton River drainage the Bull Lake ice did not extend as far from the mountains as the Pinedale