



Erosional surfaces and glacial geology along the southwest flank of the Crazy Mountains, Montana  
by John P Bluemle

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  
© Copyright by John P Bluemle (1962)

**Abstract:**

Significant and interesting geomorphic-glacial relations along the southwest margin of the Crazy Mountains provide data for an understanding of a series of late Cenozoic surfaces. Paleocene (Fort Union) sandstones, into which stocks, sills and dikes have been intruded, comprise the relatively homogeneous sedimentary succession underlying the area. The gently northerly dipping beds do not greatly affect the geomorphology of the area.

Four surface systems, formed by laterally planating streams issuing from the Crazy Mountains, are of the following ages.

Surface I ----- early Pleistocene or late Pliocene Surface II ---- early to mid-Pleistocene Surface III---- early Wisconsin Surface IV ---- intra-Wisconsin Gravels, probably indicative of older surface remnants, are also present on high benches above surface I. Although the present Yellowstone River flows eastward, the presence in the Gallatin Valley of gravels from the Crazy Mountains, suggests that drainage prior to the cutting of surface I was directed westward.

In the north, erosion since the latest glacial advance has been confined to deep, narrow valleys, whereas in the south, where erosion has been more effective, valleys are wide and only small remnants of the earlier surfaces remain.

Ages of the two youngest surfaces were determined after appraisal of their relationships with glacial features. Two substages of Wisconsin glaciation are recognized; the latest moraine is fresh, the earliest quite subdued. They are easily distinguished in the field by comparison.

Contrary to Alden's (1932) belief, I have classified surface II as Pleistocene and therefore younger than the Flaxville Plain as it was defined in northern Montana.

Statistical studies indicate increasing sphericity and roundness and decreasing size with transport distance except on the oldest surface. The studies show that the three younger surfaces were stream-carved, but the oldest surface has undergone modifying influences, due either to its greater age and length of exposure or reworking by glaciers.

EROSIONAL SURFACES AND GLACIAL GEOLOGY  
ALONG THE SOUTHWEST FLANK OF THE  
CRAZY MOUNTAINS, MONTANA

by

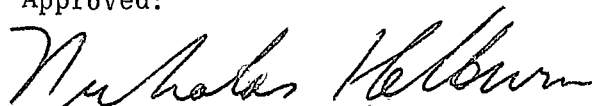
JOHN P. BLUEMLE

A thesis submitted to the Graduate Faculty in partial  
fulfillment of the requirements for the degree

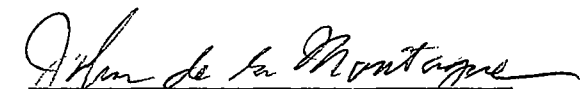
of

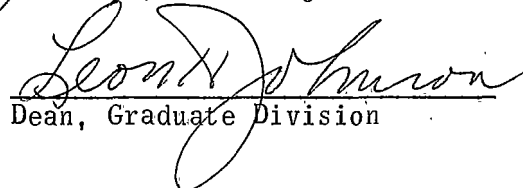
Master of Science in Applied Science  
with a major in Geology

Approved:



Head, Major Department

  
Chairman, Examining Committee

  
Dean, Graduate Division

MONTANA STATE COLLEGE  
Bozeman, Montana

April, 1962

## TABLE OF CONTENTS

	page
INTRODUCTION. . . . .	1
Location. . . . .	1
Purposes of This Study. . . . .	1
General Physiography. . . . .	2
Previous Investigations . . . . .	3
Acknowledgements. . . . .	4
REGIONAL GEOLOGY. . . . .	5
Introduction. . . . .	5
Stratigraphy. . . . .	5
Structure . . . . .	6
LIST OF MAJOR CONCLUSIONS . . . . .	9
PROMINENT IRREGULAR TOPOGRAPHIC FEATURES. . . . .	10
SURFACES SOUTHWEST OF THE MOUNTAINS . . . . .	16
Introduction. . . . .	16
Surface I. . . . .	17
Surface II. . . . .	24
Surface III . . . . .	32
Surface IV. . . . .	37
Shields River Terraces. . . . .	41
Alluvium. . . . .	42
RESULTS OF THE STATISTICAL STUDIES. . . . .	43
Method of Determining Sphericity. . . . .	44
Method of Determining Roundness . . . . .	44
Size of Particles . . . . .	45
Composition . . . . .	45
Discussion of the Graphs. . . . .	45
STREAM AND DRAINAGE CHARACTERISTICS . . . . .	52
Introduction. . . . .	52
Cottonwood Creek. . . . .	52
Rock Creek. . . . .	53
Other Streams . . . . .	55
GLACIATION AND ITS CONSEQUENCES . . . . .	57
Introduction. . . . .	57
Rock Creek Valley Glaciers. . . . .	58
Duck Creek Valley Glacier . . . . .	60
Cottonwood Creek Valley Glaciers. . . . .	62
Other Glacial Features and Summary. . . . .	67
CONCLUSIONS AND SUMMARY . . . . .	68
Number and Causes of Erosional Stages . . . . .	68
Methods of Surface Construction . . . . .	71
Discussion of the Flaxville Plain . . . . .	75
Ages of the Surfaces. . . . .	80
General Comparisons and Correlations. . . . .	87

APPENDIX A - TECHNICAL DATA. . . . . 91  
Base Map . . . . . 92  
Profiles . . . . . 92  
Photography. . . . . 93  
  
STATISTICAL STUDIES. . . . . 93  
  
APPENDIX B - SUMMARY OF THEORIES ADVANCED TO EXPLAIN THE FORMATION OF  
PEDIMENTS. . . . . 138  
Introduction . . . . . 139  
Major Ideas About the Origin of Pediments. . . . . 140  
  
SELECTED REFERENCES. . . . . 145

LIST OF TABLES

	page
Table 1 Regional correlation chart . . . . .	86
Table 2 Surface correlation table . . . . .	88

2

LIST OF FIGURES

	page
Figure 1	Geomorphic Map of the Southwest Crazy Mountain Area . . . in pocket
Figure 2	Index Map of Montana. . . . . 3
Figure 3	Major Tectonic Features Near the Crazy Mountains . . . . . 7
Figure 4	Ibex Mountain . . . . . 11
Figure 5	Dike South of Duck Creek Moraine. . . . . 12
Figure 6	Falls Creek Canyon. . . . . 13
Figure 7	Dike North of Falls Creek . . . . . 14
Figure 8	Squaw's Tit . . . . . 16
Figure 9	View of Surface I . . . . . 19
Figure 10	Gravel Cover on Surface I . . . . . 20
Figure 11	Schematic illustration showing how the amount of crystalline material being removed from the mountains increases with time. . . . . 21
Figure 12	View over Rock Creek at Surface II and Surface I. . . . . 25
Figure 13	View near the head of Surface II. . . . . 25
Figure 14	Remnants of Surface II. . . . . 26
Figure 15	Surface II about two miles northeast of Chadborn. . . . . 26
Figure 16	Panorama of several surfaces. . . . . 27
Figure 17	Typical gravel cap on Surface II. . . . . 28
Figure 18	Shields River near Chadborn . . . . . 33
Figure 19	Shields River valley north of Chadborn. . . . . 33
Figure 20	Shields River valley south of Chadborn. . . . . 34
Figure 21	Composite profiles of surfaces southwest of the Crazy Mountains assembled according to estimated relative positions. . . . . 40
Figure 22	Index map showing location of samples used in the statistical studies. . . . . 46
Figure 23	Graph showing sphericity vs. distance . . . . . 48
Figure 24	Graph showing composition vs. distance. . . . . 49
Figure 25	Graph showing roundness vs. distance. . . . . 50
Figure 26	Graph showing size vs. distance . . . . . 51
Figure 27	Panorama over Cottonwood valley . . . . . 54
Figure 28	U-shaped valley of Rock Creek . . . . . 59
Figure 29	Moraine of Sheep Creek Glacier. . . . . 61
Figure 30	End moraine west of Duck Creek. . . . . 61
Figure 31	Striated boulder near Duck Creek. . . . . 63
Figure 32	Typical kettle and kame topography in the Duck Creek Moraine. . . . . 63
Figure 33	Panorama showing lateral moraine of Duck Creek Glacier. . . 64
Figure 34	Physiographic expression of the oldest of the two glacial moraines . . . . . 65
Figure 35	Physiographic expression of early moraine . . . . . 66
Figure 36	Rock-terrace along Rock Creek . . . . . 72
Figure 37	View up Rock Creek. . . . . 73
Figure 38	Braiding channel of Rock Creek. . . . . 73
Figure 39	Profiles across Rock Creek valley and adjoining surfaces. 76
Figure 40	Profile across Rock Creek valley. . . . . 77
Figure 41	Hypothetical section showing difficulties encountered in assigning an age to a gravel outcrop . . . . . 79
Figure 42	Sample data sheet used in statistical studies . . . . in pocket

## ABSTRACT

Significant and interesting geomorphic-glacial relations along the southwest margin of the Crazy Mountains provide data for an understanding of a series of late Cenozoic surfaces. Paleocene (Fort Union) sandstones, into which stocks, sills and dikes have been intruded, comprise the relatively homogeneous sedimentary succession underlying the area. The gently northerly dipping beds do not greatly affect the geomorphology of the area.

Four surface systems, formed by laterally planating streams issuing from the Crazy Mountains, are of the following ages.

- Surface I ---- early Pleistocene or late Pliocene
- Surface II ---- early to mid-Pleistocene
- Surface III---- early Wisconsin
- Surface IV ---- intra-Wisconsin

Gravels, probably indicative of older surface remnants, are also present on high benches above surface I. Although the present Yellowstone River flows eastward, the presence in the Gallatin Valley of gravels from the Crazy Mountains, suggests that drainage prior to the cutting of surface I was directed westward.

In the north, erosion since the latest glacial advance has been confined to deep, narrow valleys, whereas in the south, where erosion has been more effective, valleys are wide and only small remnants of the earlier surfaces remain.

Ages of the two youngest surfaces were determined after appraisal of their relationships with glacial features. Two substages of Wisconsin glaciation are recognized; the latest moraine is fresh, the earliest quite subdued. They are easily distinguished in the field by comparison.

Contrary to Alden's (1932) belief, I have classified surface II as Pleistocene and therefore younger than the Flaxville Plain as it was defined in northern Montana.

Statistical studies indicate increasing sphericity and roundness and decreasing size with transport distance except on the oldest surface. The studies show that the three younger surfaces were stream-carved, but the oldest surface has undergone modifying influences, due either to its greater age and length of exposure or reworking by glaciers.

# EROSIONAL SURFACES AND GLACIAL GEOLOGY ALONG THE SOUTHWEST FLANK OF THE CRAZY MOUNTAINS, MONTANA

## INTRODUCTION

### Location

The area undertaken for study is located in northeastern Park County, Montana, on the southwestern flank of the Crazy Mountains. Approximate limits of the area are highway 89 on the west, 46°00' North latitude on the north, and the Park County line on the east. The southern limit lies along an east-west line about four miles north of the Yellowstone River. The area includes about 200 square miles but parts of it received much more concentrated study than others.

### Purposes of This Study

Primary purposes of the study were threefold. One goal was to describe the geomorphology of the area with particular reference to the broad, flat erosional surfaces which head near the mountains and extend westward to the Shields River. A second objective was to investigate the glacial deposits with particular attention to learning the relative ages of these deposits and the surfaces. Finally, an attempt was made to learn the manner in which the pediment-like surfaces were formed and, if possible, to extend these findings to a general understanding of the processes responsible for pediment formation, especially in areas of essentially homogeneous lithology.

The methods of the study, aside from simple field observation and deduction, included the statistical analyses of 42 gravel samples collected in selected localities. Study of the bedrock, insofar as it was pertinent



to the project, contributed to a greater understanding of the geomorphology.

### General Physiography

The overall topographic pattern is one of broad, flat erosional surfaces which are being deeply dissected by streams. Several gravel-capped remnants are all that remain of the surfaces in the southern part of the area which has been more thoroughly dissected than the northern part. The surfaces are interrupted and separated in places by large asymmetrical hills and ridges which have, with few exceptions, steep southern and gentle northern slopes. Near the mountains, relief is considerable; the terrain covered by glacial deposits is very hummocky.

The area is flanked by the towering southern Crazy Mountains which reach an elevation of 11,214 feet. In contrast, the southwestern part of the area has elevations as low as 4500 feet. Some of the larger streams, notably Cottonwood Creek and Rock Creek, flow in canyons over 400 feet deep.

In places, the subdued topography of the mapped area is broken by small dikes which stand above the general landscape; near the mountains several dikes stand as high as 40 feet above the surrounding landscape.

The higher areas are well watered; there are heavy snows in winter and frequent showers in summer, some of which are of a cloudburst nature. Character of vegetation varies with elevation, the lower reaches being covered by grass and sage, the higher by evergreen trees. Areas of moraine are extensively forested with thick evergreen growth and in some valleys aspen and cottonwood grow in abundance. Wheat is raised on the lower surfaces and alfalfa along the Shields River in irrigated areas.

Most drainages are directed southwestward toward the Shields River which in turn flows southeast into the Yellowstone River, the regional master stream. Several small perennial streams are spring-fed, but most are fed by surface runoff.

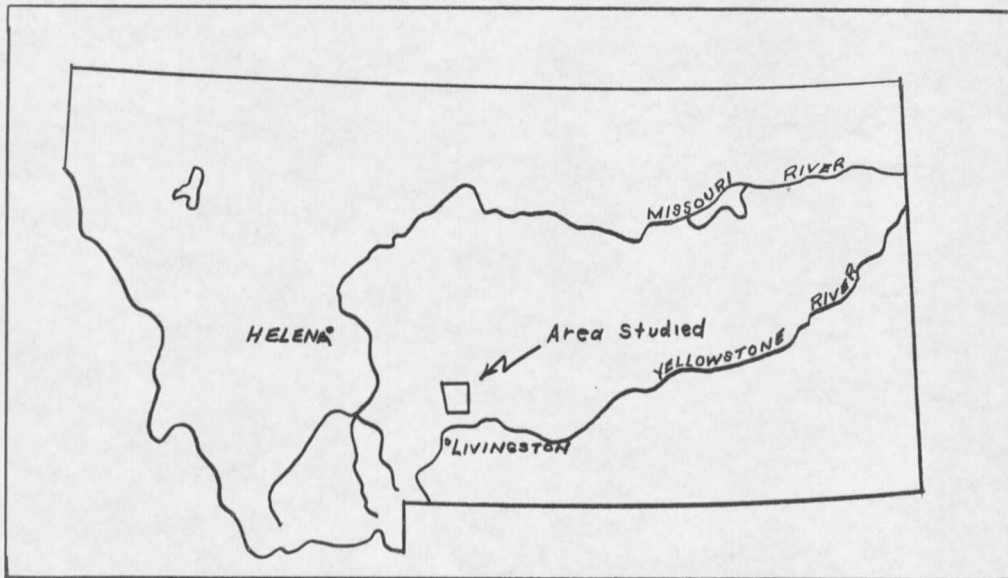


Figure 2.--Index Map of Montana

### Previous Investigations

In spite of accessibility, geomorphic investigations in the Crazy Mountains area have been limited. Lewis and Clark passed the southern foot of the mountains in 1806 and named the Shields River. F. V. Hayden in 1872 speaks of the distant range (he called them the "Crazy Woman Mountains"), and Captain Ludlow's expedition in 1873 passed down the south fork of the Musselshell River, at the north end of the range, where E. S. Dana, the accompanying geologist, noted the theralite sills of Comb Creek.

The first geologic exploration was made in 1883 by J. E. Wolff

working for the Northern Transcontinental Survey. Wolff (1891, 1938) published two papers of a general nature on the Crazy Mountains both primarily concerned with the igneous rocks of the area. Walter H. Weed, accompanied by J. P. Iddings and L. V. Pirsson, made trips in 1890 and 1895 for the United States Geological Survey. These workers described the areal and structural geology of the Livingston and Little Belt Mountains areas (Iddings and Weed, 1894; Weed, 1899).

G. R. Mansfield (1909) published a brief paper of a general nature on glaciation in the Crazy Mountains. Of interest too, is Alden's (1932) paper on the physiography and glacial geology of eastern Montana which treats briefly of the area.

Very little work has been done in recent years in the Crazy Mountains vicinity and although the Billings Geological Society did conduct a field conference in the Crazy Mountain Basin in 1957, very little of this was concerned with the geomorphology of the area.

#### Acknowledgments

Sincere appreciation is extended to Dr. John de la Montagne for his genuine interest and guidance during the preparation of this thesis. Dr. W. J. McMannis aided materially by his timely suggestions and instruction. Thanks are due also to Drs. C. C. Bradley, Nicholas Helburn, R. A. Chadwick, and Mr. M. J. Edie, of the Department of Earth Sciences at Montana State College. The Department of Earth Sciences supplied field equipment for the study.

I am indebted to Messrs. Bill and Ed Eyman for providing suitable

camping grounds and shelter during inclement weather as well as invaluable advice on local roads.

## REGIONAL GEOLOGY

### Introduction

The Crazy Mountains, southernmost and highest of several consanguineous isolated mountain masses extending through central Montana northward nearly to the Canadian boundary, lie between the meridians of  $110^{\circ}15'$  and  $110^{\circ}45'$  West longitude, and parallels of  $45^{\circ}45'$  and  $46^{\circ}30'$  North latitude. The general trend is a little west of north, their length about 45 miles, and their width 25 miles. They are a cluster of high and rugged peaks, whose structure, together with the unusual lime-alkalic character of the igneous rocks and the magnificent exposures, give them geologic interest. Bedrock consists of sandstones and shales of late Cretaceous to Paleocene age into which three cores of igneous rock of Eocene age have been injected accompanied by thousands of associated laccoliths, sills and dikes.

### Stratigraphy

Most of the sedimentary rocks exposed in the area are of Paleocene (Fort Union) age, and comprise the upper part of the Livingston formation which is widely distributed throughout the Crazy Mountain Basin. The Livingston formation consists of andesitic sandstones and shales of late Cretaceous to Paleocene age. Some writers prefer to restrict the Livingston rocks to the latest Cretaceous and call the Paleocene part Fort Union. McMannis (1955) mapped the top of the Hell Creek member of the Livingston formation several miles west of the Shields River and considered everything

to the east of this line to be of Paleocene age (see Figure 2). The Hell Creek is the uppermost Cretaceous member of the Livingston formation.

According to Wolff (1938), massive sandstones and some shales generally predominate west of the Crazy Mountains but in the mountains these give way to shales interbedded with a few thin limestones. Sandstones of the lower area near the Shields River are andesitic but they become less so toward the east. The rocks are mostly medium-grained drab, olive-gray to yellow, tuffaceous to arkosic sandstones. Clastic constituents are quite variable consisting of angular to sub-angular fragments of quartz, microcline, orthoclase, sodic to calcic plagioclase and a few grains of decomposed biotite, hornblende and augite as well as accessory minerals. Rounded fragments of limestone are commonly found interbedded and in places, carbonate fills interstices and replaces clastic grains. Wolff (1938) found a bed of conglomerate, 25 feet thick, at the extreme head of Cottonwood Creek interbedded in the sandstones. The pebbles are quartz, porphyritic igneous rocks, banded flinty slate, quartzite and a crinoidal limestone of Carboniferous age.

### Structure

An asymmetric syncline involving the youngest (Fort Union) beds and trending northeast passes just south of Wilsall. The mapped area lies on the southeast, gentle flank of this syncline which causes the Fort Union beds to dip northwest at angles of from  $5^{\circ}$  to  $15^{\circ}$ . The northwest flank of the syncline is vertical to overturned.

Structure has not been of paramount importance in fashioning the present landscape, but it has contributed in various ways. In the central part

















































































































































































































































































































































