CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

The following file is part of the Grover Heinrichs Mining Collection

ACCESS STATEMENT

These digitized collections are accessible for purposes of education and research. We have indicated what we know about copyright and rights of privacy, publicity, or trademark. Due to the nature of archival collections, we are not always able to identify this information. We are eager to hear from any rights owners, so that we may obtain accurate information. Upon request, we will remove material from public view while we address a rights issue.

CONSTRAINTS STATEMENT

The Arizona Geological Survey does not claim to control all rights for all materials in its collection. These rights include, but are not limited to: copyright, privacy rights, and cultural protection rights. The User hereby assumes all responsibility for obtaining any rights to use the material in excess of "fair use."

The Survey makes no intellectual property claims to the products created by individual authors in the manuscript collections, except when the author deeded those rights to the Survey or when those authors were employed by the State of Arizona and created intellectual products as a function of their official duties. The Survey does maintain property rights to the physical and digital representations of the works.

QUALITY STATEMENT

The Arizona Geological Survey is not responsible for the accuracy of the records, information, or opinions that may be contained in the files. The Survey collects, catalogs, and archives data on mineral properties regardless of its views of the veracity or accuracy of those data.

THE MONTANA BUREAU OF MINES AND GEOLOGY IS A PUBLIC SERVICE AGENCY FOR THE STATE OF MONTANA. ITS PURPOSE IS TO ASSIST IN DEVELOPING THE STATE'S MINERAL RESOURCES. IT CONDUCTS FIELD STUDIES OF MONTANA GEOLOGY AND MINERAL DEPOSITS, INCLUDING METALS, OIL AND GAS, COAL, AND OTHER NONMETALLIC MINERALS, AND GROUND WATER. IT ALSO CARRIES OUT RESEARCH IN MINERAL BENEFICIATION, EXTRACTIVE METALLURGY, AND ECONOMIC PROBLEMS CONNECTED WITH THE MINERAL INDUSTRY IN MONTANA. THE RESULTS OF THESE STUDIES ARE PUBLISHED IN REPORTS SUCH AS THIS.

FOR FURTHER INFORMATION, ADDRESS THE DIRECTOR, MONTANA BUREAU OF MINES AND GEOLOGY, MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY, BUTTE.

ARTCRAFT PRINTERS

STATE OF MONTANA
Forrest H. Anderson, Governor

BUREAU OF MINES AND GEOLOGY
U. M. Sahinen, Director

BULLETIN 79
SEPTEMBER 1970

Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana

by

Willis M. Johns

This bulletin has been prepared by the Montana Bureau of Mines and Geology under a cooperative agreement with the Great Northern Railway Company and the Pacific Power & Light Company

34. Map showing location of mining properties in the Cabinet Mountains, northern Thompson Falls area, Lincoln and Sanders Counties 122
35. Workings on Gold Hill claims, Viking mine, northern Thompson Falls area, Lincoln County 123
36. Geologic map of Vermilion upper adit, northern Thompson Falls area, Sanders County 124
37. Map showing location of properties in northern Whitefish Range, Eureka district, Lincoln County 126
38. Composite plan of workings, Independence mine, Eureka district 127
39. Geologic map of lower adit (No. 3), Independence mine, Eureka district 128
40. Claim map of Blue Bird Lode (8502), Swansea Rosa Lode (8503), and Peterson property (10136), Eureka district 129
41. Geologic map of lower adit, Jager prospect, Eureka district 130
42. Map showing locations of properties in Star Meadow district, Salish Mountains, Flathead County 132
43. Geologic map of lower and upper adits, Foolsberg mine, Star Meadow district 133
44. Surface plan of Blacktail mine, Star Meadow district 134
45. Surface plan of Blue Grouse prospect, Star Meadow district 136
46. Map showing locations of mining properties in the Hog Heaven district, Flathead County 138
47. Geologic map of West Flathead mine, Hog Heaven district 139
48. Geologic map of Ole mine, Hog Heaven district 141
49. Geologic map of Birdseye mine, Hog Heaven district 142
50. Geologic map of west drifts, Martin mine, Hog Heaven district 143
51. Geologic map of Unawah prospect, southeastern Flathead County 145
52. Claim map of Little Darling (5353) and Jeanette (5354) lodes, southeastern Flathead County 146
53. Geologic map of Rainy Creek pluton, Rainy Creek district, Lincoln County 147
54. Claim map of Poston property, Rainy Creek district 148
55. Claim map of Kotschevar (Copper Mountain) barite property, Troy district 150
56. Surface plan and section of Kenelty barite, Lincoln County 151
57. Diamond drill plan of Lynx Creek talc deposit, Lincoln County 152

TABLES

Table ....
1. Analyses of limestone and siliceous-calcareous argillite (Belt Series) and dolomite and limestone (Cambrian and Devonian) 174
2. Analyses of siliceous and calcareous argillite (Belt Series) 174
3. Analyses of quartzite and argillaceous quartzite (Belt Series) 175
4. Analyses of miscellaneous Belt rocks 176
5. Production of gold and silver from placer operations, 1906-64, Lincoln County 176
6. Production of gold, silver, copper, lead, and zinc from Lincoln County, 1900-64 177
7. Production of gold, silver, copper, lead, and zinc from Flathead County, 1900-64 178

STATE OF MONTANA
BUREAU OF MINES AND GEOLOGY

U. M. Sahinen, Director

BULLETIN 79

Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana

by

Willis M. Johns
Montana Bureau of Mines and Geology

This report has been prepared by the Montana Bureau of Mines and Geology under a cooperative agreement with the Great Northern Railway Company and the Pacific Power & Light Company

MONTANA COLLEGE OF MINERAL SCIENCE AND TECHNOLOGY
Butte, Montana
1970

For sale by

Montana Bureau of Mines and Geology
Room 203-B, Main Hall
Montana College of Mineral Science and Technology
Butte, Montana 59701

Price $2.50

Lynx Creek 152
Tremolite 153
Esther May 153
Larue-Cripe 153
Wollastonite 153
Clay 153
Stone 153
Tufa 153
Limestone 154
Quartzite 154
Feldspar 155
Gravel and sand 155
Coal and peat 155
Asphaltite 156
Oil and natural gas 156
Conclusions 157
Glossary of terms 157
References 159
Appendix 165
Index 179

ILLUSTRATIONS

Plate — Page

1. Geologic map and sections of western Lincoln County and part of northern Sanders County, Montana (west of 115°) ..... (in pocket)
2. Geologic map and sections of eastern Lincoln County and western and northeastern Flathead County, Montana (114-115°) ..... (in pocket)
3. Geologic map and sections of southeastern Flathead County, Montana (113-114°) ..... (in pocket)

Figure

1. Index map showing location of Lincoln and Flathead Counties 3
2. Index map of northwest Montana showing mountain ranges 6
3. Map showing extent and direction of movement of Cordilleran ice sheet and valley glaciers 8
4. Map showing terraces and flood plain adjacent to Star Creek and the Kootenai and Yaak Rivers 11
5. Correlation of Belt strata (Precambrian) in northwest Montana, northern Idaho, and southeast British Columbia 17
6. Upper part of Prichard Formation, Pre-Ravalli Group, section on west slope of Elk Mountain 19
7. Ravalli Group undifferentiated, section on Elk Mountain 21
8. Lower Piegan (P_1) and part of Siyeh Formation, section on east slope of Elk Mountain 27
9. Paleozoic, Mesozoic, and Cenozoic rocks in eastern Flathead County 41
10. Profile of Flathead and Gordon Formations, Whitcomb Peak 43
11. Map showing placer deposits in Lincoln County 80
12. Sketch map of Big Eight placer, Lincoln County 83
13. Map showing placer deposits in Flathead County 84
14. Frank Langford placer claims, T. 34 N., R. 20 W., Flathead County 85
15. Claim map of the Snowshoe mine area and north-south section through Snowshoe mine, Libby district, Lincoln County 86
16. Map of properties along Snowshoe fault and Libby and Cherry Creeks, Libby district 87
17. Adit 1 (Hoist Level), Snowshoe mine, Lincoln County 88
18. Zero tunnel, Snowshoe mine, and Silver-tip prospect, Libby district 89
19. East Side Shaughnessy Hill group, Glacier Silver-Lead (formerly Lukins-Hazel, Hazel T.), N½ sec. 5, T. 29 N., R. 31 W., Libby district 91
20. Claim map and mine map of Big Sky property, Snowshoe fault area, Libby district 94
21. Sketch of Grizzly property, formerly Missouri group 95
22. Lower tunnel and north tunnel of Grizzly property, Libby district 96
23. Geologic map of Adits 6 and 7, Snowstorm mine, Troy district, Lincoln County 98
24. Claim map of Giant Sunrise property, Troy district 100
25. Sketch of Last Chance No. 2 adit, Troy district 102
26. Claim map of Montana Morning group and sketch of No. 2 adit, Troy district 103
27. Sketch of claims in Bramlet Lake area, West Fisher district, Lincoln County 106
28. Plan of Fisher Creek mine, West Fisher district 106
29. Geologic sketch of lower, middle, and upper adits, Wayup mine, West Fisher district 109
30. Geologic sketch of Mother Lode adit, West Fisher district 111
31. Surface plan of Second Chance prospect, Ural area, Lincoln County 119
32. Geologic sketch of Hansen adit, Ural area 120
33. Sketch of Caribou Creek area, northwest of Robinson Mountain, northern Lincoln County 121

Hiawatha 103
Bimetallic 104
Daniel Lee 104
Spar Lake Copper 104
Bear 105
West Fisher (Cabinet) district 105
Midas 105
Fisher Creek 106
Jumbo 107
American Kootenai 107
Union 108
Hannegan 108
Irish Boy 108
Gloria 108
Wayup 109
Williams 110
Mustang 110
Betty Mae 110
Diamond John 111
Mother Lode 111
Yaak River area 111
New Morning Glory 111
Duplex 112
Oro 112
Black Diamond 112
State Line 113
Yaak Falls 113
Rankin 113
McEwen 113
Ferrel 113
Canuck Copper 113
Phillips 114
Hoerner 114
Other prospects and veins 114
Thompson Lakes area 114
Montezuma 114
Waylett group 115
Potter 116
Kirkpatrick 116
Boulder Hill 117
Strodtbeck 117
Raven 117
Hathaway 117
Kennedy 118
Other prospects and veins 118
Ural area 119
Second Chance 119
Hansen 120
Hoyt (North Star) group 120
Kenelty 120
Big Creek 120
Big Creek Extension 121
Other prospects and veins 121
Northern Thompson Falls area 121
Viking 121
King 122
Vermilion 124
Sales 125
Sims 125
Snowfall 125
Gold King 126
Martin 126
Price 126
Undeveloped surface veins and other prospects 126
Eureka district 126
Independence 126
Blue Bird 127
Swansea Rosa 127
Peterson 129
Tetrault 130
Jager 130
Other prospects and veins 131
Star Meadow district 131
West Virginia 131
Foolsberg 131
Blacktail 133
Humdinger 134
Yukon 134
Copper King 134
Moonlight 135
Griffin Creek 135
Sanko 135
Lucky Strike 135
Blue Grouse 135
Horse Hill 136
Crosley-Sucetti 136
Stahl 136
Other prospects and veins 137
Hog Heaven district 137
Flathead 137
West Flathead 140
Ole 140
Birdseye and Maryann 142
Martin and Battle Butte 142
Other deposits 142
Kalispell area 143
Wort 143
Micho 143
Seek 143
Other prospects and veins 143
Chief Cliff district 144
Jumbo 144
Big Four 144
Mosher 144
Unawah 145
Other prospects and veins 145
Nonmetallic deposits 146
Vermiculite 146
Barite 149
Kotschevar 149
Kenelty barite 149
Bonnett-Hoerner 151
Moen 151
Bob Marshall Wilderness Area deposit 152
Other deposits 152
Talc 152

FOREWORD

This publication represents an outstanding example of cooperation between industry and a state agency in an attempt to assist and promote mineral development in Montana. The Great Northern Railway Company (now Burlington Northern Inc.), the Pacific Power & Light Company, and the Montana Bureau of Mines and Geology combined their talents and resources in this effort to improve the economy of northwestern Montana by surveying the potential for mineral development in Lincoln and Flathead Counties. The intended result would be a broader tax base for the state and the counties, increased power sales by PP&L, and increased transportation sales by Burlington Northern.

The emphasis of the report is on metalliferous mineral occurrences and the related geology. The area is a promising mineral province; the geologic structures and host rocks are favorable for the accumulation of ore deposits. Geochemical studies indicated several anomalous areas that are recommended for detailed exploration, as reported in Montana Bureau of Mines and Geology Bulletins 48 and 61.

This area seems to have some geologic resemblance to the Coeur d'Alene mining district a short distance to the west in Idaho. Similarities in host rocks, structures, and mineralization have long been known, and recent studies indicate similarity in the geologic age of the ore deposits.

Lincoln and Flathead Counties have produced about $11.5 million from metalliferous mineral deposits, but the region is not thoroughly explored or developed and has a much greater potential for future production. In fact, partly as a result of this program, a major mining company has announced plans to develop a copper deposit, which promises to be a significant producer.

It is hoped that this survey will encourage additional mineral exploration, and that the resulting discoveries and production will enhance the development and economy of the region as a whole.

Uuno M. Sahinen, Director

CONTENTS

Foreword ... iii
Abstract ... 1
Introduction ... 2
Previous work ... 2
Acknowledgments ... 4
Geography ... 5
General statement ... 5
Physiography ... 6
Glaciation ... 7
Glacial topographic features ... 9
Pleistocene glacial lakes ... 10
Stratigraphy ... 12
Precambrian—Beltian rocks ... 12
General considerations ... 13
Pre-Ravalli Group ... 18
Prichard Formation ... 18
Ravalli Group—Western phase ... 20
Ravalli Group—Eastern phase ... 24
Appekunny Formation ... 24
Grinnell Formation ... 24
Piegan Group—Western phase ... 25
Wallace Formation ... 25
Piegan Group—Eastern phase ... 26
Lower Piegan (P_1 unit) ... 26
Siyeh Formation ... 28
Upper Piegan (P_3 unit) ... 29
Missoula Group—Western phase ... 31
Striped Peak Formation ... 31
Libby Formation ... 31
Missoula Group—North-central phase ... 32
Purcell Lava ... 32
Shepard Formation ... 33
Kintla Formation ... 34
Phillips Formation ... 34
Roosville Formation ... 35
Missoula Group—Eastern phase ... 35
Snowslip Formation ... 36
Shepard Formation ... 36
Shields Formation ... 37
Bonner Formation ... 37
McNamara Formation ... 37
Main body (Ross) ... 38
Grayish-green argillite ... 38
Unnamed sequence (Childers) ... 38
Miller Peak Argillite ... 38
Cayuse Limestone ... 38
Hoadley and Ahorn Formations ... 39
Paleozoic ... 39
Cambrian—Western Lincoln County ... 40
Cambrian—Northern Flathead County ... 40
Cambrian—Southeast Flathead County ... 40
Flathead Sandstone ... 40
Gordon Shale ... 42
Cambrian undifferentiated ... 43
Devils Glen Dolomite ... 44
Devonian—Northern Flathead County ... 45
Devonian—Southeastern Flathead County ... 45
White Ridge Limestone—Glen Creek Shale ... 45
Upper Devonian limestone ... 46
Mississippian—Northern Flathead County ... 47
Banff (and Exshaw?) Formations ... 47
Livingstone Formation ... 47
Mount Head Formation ... 47
Etherington Formation ... 48
Mississippian—Southeastern Flathead County ... 48
Hannan Limestone ... 49
Permo-Pennsylvanian ... 50
Rocky Mountain Formation ... 50
Mesozoic ... 50
Jurassic ... 50
Fernie Formation ... 50
Cretaceous ... 51
Kootenai Formation ... 51
Cenozoic ... 51
Tertiary ... 51
Kishenehn Formation ... 51
Quaternary ... 52
Glacial deposits ... 52
Recent alluvium ... 52
Igneous rocks ... 52
Precambrian ... 52
Metadiorite dikes, sills, and stocks ... 52
Age ... 54
Mesozoic ... 54
Granitic stocks and dikes ... 54
Dry Creek stock ... 54
Granite Creek stock ... 54
Hayes Ridge stock ... 55
Parmenter Creek stock ... 55
Bobtail Creek stock ... 55
Warland stock ... 55
Other stocks ... 56
Age ... 56
Quartz latite prophyry and diorite dikes ... 57
Age of dikes ... 57
Basic stocks ... 57
Rainy Creek stock ... 57
Age ... 58
Tertiary ... 58
Volcanic intrusive and extrusive rocks ... 58
Porphyritic andesite ... 58
Porphyritic latite ... 59
Andesitic tuffs ... 59
Porphyritic quartz latite ... 60
Basalt ... 60
Relationships of flows and hypabyssal rocks ... 60

Structural geology ... 61
Faults ... 61
Leonia fault ... 62
Bull Lake fault ... 62
O'Brien Creek fault ... 63
Savage Lake fault ... 63
Snowshoe fault ... 63
Rock Lake fault ... 64
Quartz Creek fault ... 64
Poole Lake fault ... 64
Thompson Lakes fault ... 64
Rainy Creek fault ... 65
Pinkham thrust ... 65
Dunsire thrust ... 65
Mission fault ... 66
Swan-Whitefish fault ... 66
Stryker fault ... 67
Flathead-Tuchuck fault ... 67
Lewis overthrust ... 68
Barron Creek fault ... 68
Shroder fault ... 68
Elk Divide fault ... 68
Ashley Mountain fault ... 69
Folds ... 69
Sylvanite anticline ... 69
Poole Lake syncline ... 69
Yaak River syncline ... 69
Kootenai anticline ... 69
North Fork anticline ... 70
Rainy Creek syncline ... 70
Snowshoe anticline ... 70
Spar Lake syncline ... 70
Fairview anticline ... 70
Elk Mountain anticline ... 70
Ingalls syncline ... 70
Mount Creek syncline ... 70
Silvertip syncline ... 70
Fracture cleavage ... 70
Joints ... 71
Summary of structure ... 71
Age of folds and faults ... 72
Ore deposits ... 73
General features ... 73
History and production ... 73
Placers ... 74
Nonmetallics ... 74
Classification ... 75
Lodes ... 75
Distribution ... 75
Mineralogy ... 75
Secondary enrichment ... 76
Host rocks ... 77
Origin of deposits ... 77
Placers ... 78
Location and origin of deposits ... 78
Description of placers ... 79
Libby district ... 79
Bolyard placer ... 79
Nugget placer ... 79
Red Gulch placer ... 79
Libby Creek Gold Mining Company ... 79
Comet placer ... 81
Libby placer ... 81
Montana placer ... 81
Howard placer ... 81
Yaak River district ... 81
Snipetown placer ... 81
China Lake placer ... 81
Solo Joe placer ... 81
Copeland placer ... 81
Thompson Lakes district ... 82
Miller placer ... 82
Tideman placer ... 82
Big Eight placer ... 82
Darling placer ... 82
Getner placer ... 82
Other placers ... 82
Ural area ... 83
Stonehill placer ... 83
Sutton Creek placer ... 83
Pioneer placer ... 83
Northern Thompson Falls area ... 83
Ajax placer ... 83
Waylett placer ... 84
Other placers ... 85
Pleasant Valley area ... 85
Herrig placer ... 85
Langford placers ... 85
Other placers ... 85
Description of lode mining properties ... 85
Libby district ... 85
Snowshoe ... 85
Silvertip ... 89
St. Paul ... 90
Copper Reward ... 90
Seattle ... 90
Glacier Silver-Lead ... 90
Victor-Empire ... 92
Silver Mountain ... 93
Granite Creek ... 93
Big Sky ... 93
Grizzly ... 95
Silver Cable ... 95
Statesman ... 97
Halfmoon ... 97
Herbert ... 97
Remp ... 97
Troy district ... 98
Snowstorm ... 98
Big Eight ... 99
Giant Sunrise ... 100
Grouse Mountain ... 100
Liberty Metals ... 101
Iron Mask ... 101
Silver King ... 102
Silver Grouse ... 102
Last Chance ... 102
Montana Morning ... 103

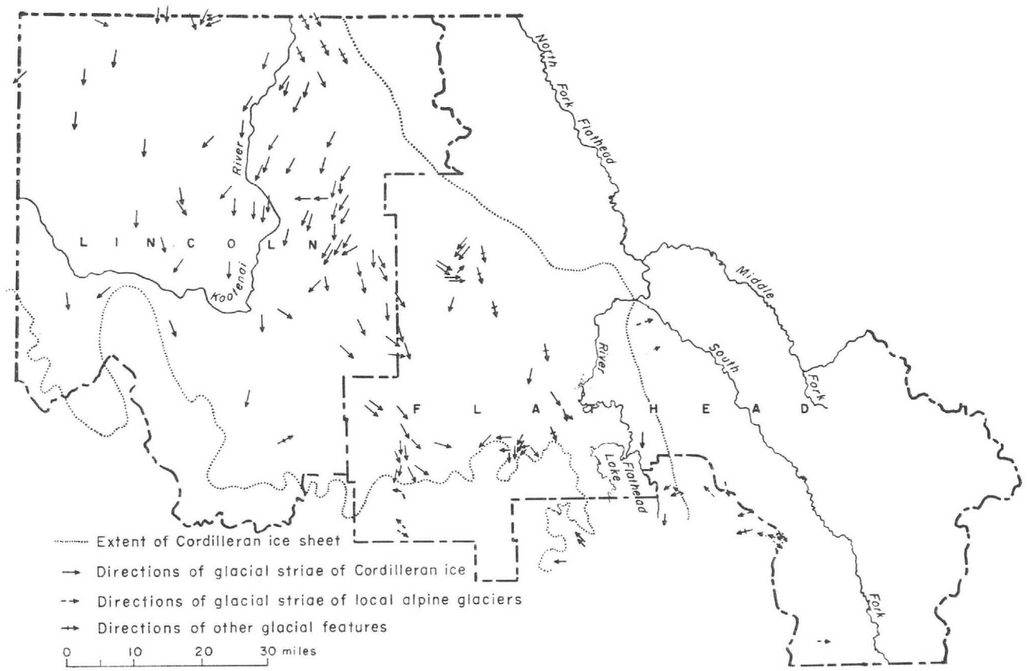


Figure 3.—Map showing extent and direction of movement of Cordilleran ice sheet and valley glaciers.

and west of the lake, west of Big Arm. Furthermore, it was augmented at Columbia Falls by glaciers that came down the valleys of North Fork and South Fork of Flathead River (Erdmann, 1944, p. 64) and near Bigfork by a large valley glacier that came down the Swan Valley.

As the main lobe moved down the Stillwater Valley it was crowded against the west flank of the Whitefish Range. East of the north end of Whitefish Lake, striae that trend S. 50 to 57° E. indicate that the ice diagonally overrode the south end of the range.

Alpine glaciers on the east flank of the Swan Range and on the west flank of the Lewis and Clark Range merged to form an intermontane glacier that moved northwest down the valley of the South Fork of Flathead River. Combining with valley glaciers that followed down the valleys of the Middle Fork and the North Fork Flathead River, the whole mass turned abruptly westward through Badrock Canyon to join the Flathead lobe of the Cordilleran sheet at Columbia Falls.

From Badrock Canyon to Lake Blaine, the ice was crowded against the west flank of the Swan Range. Faceting of the spurs on this part of the Swan Range has been attributed to glacial action (Davis, 1921, p. 89), but Konizeski, Brietkrietz, and McMurtrey (1968, p. 9) ascribed the spurs to recent fault movement.

Near the junction of the Swan and Flathead Valleys, south of Lake Blaine, is a strip characterized by low interconnecting ridges between small lakes locally termed "The Potholes". This area marks the confluence of the Swan Valley glacier with the Flathead lobe of the Cordilleran ice sheet. Alpine glaciers from the east flank of the north part of the Mission Range and from the west flank of the Swan Range coalesced to form one of the largest valley glaciers, which moved north-northwest down the Swan Valley.

Partly because of the local topography, but also partly because of the convergence with the valley glaciers along the east side of the Flathead Valley, a sublobe of the Flathead lobe was diverted to the southwest at Kalispell and moved up the valleys of Ashley Creek, Boorman Creek, Mount Creek, and smaller valleys. On the east side of the Flathead Valley, the ice sheet was forced to override the northern part of the Mission Range. Southward to a point near Mission Wells the crestline was beveled to a flat or smoothly rounded surface, now covered with glacial drift. From Mission Wells the ice margin descended diagonally across the west face of the Mission Range to the valley floor at Polson.

Geology and Mineral Deposits of Lincoln and Flathead Counties, Montana

by

Willis M. Johns

ABSTRACT

Lincoln and Flathead Counties occupy an area of 8,500 square miles in the northwest corner of Montana in the northern Rocky Mountain physiographic province, which fronts the Great Plains east of the Continental Divide. The area is characterized by high, rugged forested northwest-trending mountain ranges separated by narrow valleys. Tributaries of the upper Columbia River drainage system occupy these linear valleys.

The late Wisconsin Cordilleran ice advancing south from British Columbia covered the land surfaces of northwest Montana to altitudes of 6,000 feet or more. Thickness of the ice ranged from about 4,000 feet at the International Boundary to at least 2,000 feet near Kalispell, then decreased rapidly to the margin near Polson. Alpine glaciers from the high mountain ranges merged with the Cordilleran ice. The southern limit of the ice conforms approximately to the south boundary of the map in the Flathead Lake-Thompson River area, then swings diagonally northwest to the Idaho border; the Cabinet Mountains acted as a barrier to the advancing ice. Glacial stratified and nonstratified surficial deposits including drumlins and kame terraces, till, and outwash floor the valleys. Glacial Lake Missoula, covering an area of about 3,3000 square miles, was created by glacial melt water; the northern arms of the lake probably extended up the Vermilion, Thompson, and Little Bitterroot Rivers, and Mission Valley.

In the map area, the Belt (late Precambrian) consists of fine-grained clastic and carbonate rocks 17,000 to 40,000 feet thick, which have undergone regional low-grade metamorphism (greenschist facies). Belt rocks crop out in northwest-trending patterns and underlie the whole area, but are overlain by Paleozoic and Mesozoic sedimentary rocks in the northwestern and southeastern parts of Flathead County.

Major facies changes complicate the study of Belt stratigraphy. The Prichard Formation of the Pre-Ravalli Group is the lowest Belt unit exposed; a calcareous zone near the top of the formation seems to thicken eastward from central Lincoln County. From west-central Lincoln County, the overlying Ravalli Group thins northward, and from the west to the east side of the Rocky Mountain Trench, Ravalli strata exhibit a fairly abrupt color change from gray to grayish red purple (Grinnell Formation). Several hundred feet of upper Ravalli strata southeast of Vermilion River are assigned to the St. Regis Formation, but equivalent strata were not recognized to the northwest. From western Lincoln County eastward, the next younger group, the Piegan Group (Wallace Formation) thins and becomes increasingly calcareous, to the extent that the Middle Piegan (Siyeh Formation) in the Salish Range is mapped as an impure limestone. The lower part of the Striped Peak member of the Missoula Group, which overlies the Piegan or Wallace, is quartzite in the Thompson Lakes-Fisher River area, but is argillite and shaly argillite farther north.

Paleozoic sandstone, shale, limestone, and dolomite total 4,500 to 5,300 feet in thickness. Mesozoic fissile shale and fossiliferous carbonate rock 500 to 1,500 feet thick occupy small areas. A Tertiary lignitic siltstone, sandstone, claystone, and conglomerate sequence 3,000 feet thick is exposed in the valley of the Flathead River (North Fork). Late Cenozoic deposits fill the Flathead Valley and other major valleys to depths locally exceeding 1,400 feet.

Dikes, sills, and stocks ranging in composition from granitic to ultrabasic rocks intrude Belt strata in the map area; these igneous rocks are most abundant in western Lincoln County and are scarce elsewhere. Tertiary volcanic rocks of latite, andesite, and sparse basalt overlie the Ravalli Group in southwestern Flathead County (Hog Heaven district).

Major faults strike between north and northwest and are parallel or subparallel to folds. Major west-dipping or vertical reverse and normal faults include the Leonia, Pinkham, Mission, Swan-Whitefish, and Flathead-Tuchuck Faults. Subsidiary east- and northeast-striking structures displace earlier northwest faults. The master fault of the region, the Lewis Thrust, parallels the eastern front of the Rocky Mountains from Roosevelt Pass southeastward. Tight to broad symmetrical, asymmetrical, and overturned folds plunge north or south; some are double plunging. Traces of some axial planes have been mapped for distances of 40 miles, but most folds are much shorter.

Mineral deposits have yielded silver, lead, gold, zinc, copper, and tungsten in eight mining districts within the area mapped. Significant amounts of placer gold have been produced from Lincoln County. The major precious and base metal production has come from the Flathead mine, in Flathead County, and the Snowstorm and Snowshoe mines, in Lincoln County, Vremiculite, mined from the Rainy Creek pluton in Lincoln County, has been the major mines, in Lincoln County. Vermiculite, mined from the Rainy Creek pluton in Lincoln County, has been the major nonmetallic mineral produced from the area; barite, talc, clay, tremolite, sand and gravel, and stone deposits are mentioned, and of these, production of stone may very well become significant.

Although the total base and precious metal production from Lincoln and Flathead Counties is valued at only $11.5 million, the region shows a greater potential future production. A major mining company is developing a promising copper deposit in the western part of the area, and geochemical work done by the Bureau as part of this project but described in separate reports (Bull. 48 and 61), indicates other areas in which further exploration may yield additional discoveries.

INTRODUCTION

With the common interest and purpose of furthering the economic development and stimulating growth of population and business in their service area in northwestern Montana, the Pacific Power & Light Company and the Great Northern Railway Company entered into an agreement with the Montana Bureau of Mines and Geology "To cooperate in a project of exploration and geological survey and mapping work designed to discover and make available to the parties and to the general public as much additional geological information as possible concerning the area, in the form of maps, reports, and studies." The project known as the Kootenai-Flathead project was started in June 1958. Although originally intended as a five-year project, mapping was continued for six years. Two additional years were spent in geochemical investigations, the results of which appear in other reports of the Bureau (Bull. 48 and 61).

A field office was established at Kalispell for the duration of the project, to provide mineral- and rock-identification service to prospectors of the area, and to advise them on mineral exploration and development.

Six progress reports on geologic mapping and mines and two on geochemical sampling (Bull. 48 and 61) have been issued. This report will be the final summary report on mapping and will supersede Bulletins 12, 17, 23, 29, 36, and 42.

Geologic data were plotted on U. S. Forest Service planimetric base maps (2 inches to 1 mile) and on aerial photographs (1:20,000). Enlargements of U. S. Geological Survey 30-minute topographic sheets of the Thompson Lakes, Stryker, Kintla Lakes, and Silvertip quadrangles were also used. In this report, however, the quadrangle names are not used, as the U. S. Geological Survey, Topographic Branch, is remapping the area on 7½-minute quadrangle maps, some of which have the same names as the now obsolete 30-minute sheets.

The Kootenai-Flathead project area is bounded on the west by the Idaho border at longitude 116°2'52.99" west (Van Zandt, 1966, p. 236) and on the north by the International Boundary at latitude 49° north. The east boundary corresponds to the west and south boundary of Glacier National Park from the 49th parallel southeastward down North Fork and up Middle Fork Flathead Rivers to Bear Creek and northeastward up Bear Creek to Marias Pass; from Marias Pass southeastward to the north line of Powell County the project area is bounded on the east by the Continental Divide. From the Continental Divide, the south boundary extends west along the north boundary of Powell and Missoula Counties to the eastern boundary of Lake County, thence northward along the Lake County boundary to latitude 47°52'30", thence west along this parallel as far as the 115th meridian, thence north up the meridian to the 48th parallel, thence west to the boundary between Lincoln and Sanders Counties, thence generally westward along the county line to the Idaho border (Fig. 1). The project area includes all of Lincoln and Flathead Counties, the north part of Lake County, and two small tracts in the northeast part of Sanders County. The mapped area totals about 9,200 square miles, of which 160 square miles is water.

The project area is crossed by U. S. Highway 2 from the Idaho boundary eastward through Troy, Libby, Kalispell, and West Glacier to Marias Pass, and by U. S. Highway 93 from Dayton northwestward through Kalispell and Eureka to Roosville. State Highway 37 extends northeast from Libby along the Kootenai Valley to U. S. Highway 93 just north of Eureka. State Highway 35 follows the east shore of Flathead Lake north from Polson and joins U. S. Highway 2 just east of Kalispell. Other access is provided by county and forest service roads, logging spur roads, mine access roads, and in more remote areas by forest service trails. Four-wheel-drive vehicles are needed to reach a few areas, but most roads are passable by passenger car.

The main line of the Great Northern Railway follows the Kootenai Valley from Leonia via Troy and Libby to Rexford, the Tobacco River and Flathead valleys through Eureka, Whitefish, and Columbia Falls, and the Glacier Park boundary from West Glacier through Marias Pass. Plans for construction of the Libby Dam on the Kootenai south of Warland necessitated rerouting of the main line via Wolf Creek and Fortine Creek to Whitefish.

PREVIOUS WORK

Many reports have been published on geography, geology, and mining activities throughout northwest Montana. Gibbs (1873), one of the first investigators, described the physical geography along the Canadian boundary. Some early references to mines and prospects in eastern Flathead County were included in forest reserve studies by Ayres (1899, 1901) and Chapman (1900). Willis (1902) made the first comprehen-

the valley of Flathead River (North Fork) averages 8 miles in width. Throughout the area the smaller tributaries are perpendicular to the main streams, and they have cut narrow valleys or gorges down the mountain slopes.

Physiographic history of the Northern Rocky Mountains in Idaho and western Montana is complex. Workers are not in agreement on the course of events nor on the amount of reduction of land forms that took place during early and middle Cenezoic time (Fenneman, 1931; Atwood, 1916; Umpleby, 1912, 1913; Mansfield, 1923; Lindgren, 1904, 1918; and Blackwelder, 1912). Early workers disagreed about whether one or two "peneplains" developed and whether the valleys were filled with Tertiary sediments and then re-eroded in the same sites. Ross (1959) could find no evidence of peneplanation in the Flathead region, hence he believed that no plains topography extended westward into the area after the Lewis thrust and related tectonic activity (Laramide orogeny) elevated the area. This idea of a single post-Cretaceous uplift seems logical. The accordant summit levels that were presumed to indicate peneplanation are readily explained as the expectable result of erosion of similar rocks under similar climatic conditions throughout the area.

The foregoing comments are not meant to imply that tectonic activity ceased completely at the end of the Laramide orogeny. Subsequent folding and faulting may have been sufficient to produce some drainage changes, and may in fact be continuing at present, but only on a comparatively small scale. Numerous minor earthquakes have shaken the area, and these may indicate tectonic movement, although they may also indicate elastic rebound of the area after removal of the load of glacial ice that covered the region only a few thousand years ago.

GLACIATION

In the Kootenai-Flathead area, only the ice of the last stage of glaciation (Wisconsin) left positive evidence of its advance and retreat. Indications of earlier glacial action, if any, were removed by the ice during its last advance or were buried under the mass of material deposited by the ice and by its meltwaters. Alpine glaciers descending from the high ranges merged with and augmented the Cordilleran ice sheet, which advanced generally southeastward along the major valleys. Both the advance and the retreat were somewhat irregular, being interrupted by relatively brief reversals.

The Cordilleran ice sheet entered Montana from the north as individual lobes that filled the valleys, but at its maximum stage of development it probably covered most of the map area west of the Rocky Mountain Trench (Fig. 3). At the International Boundary the ice reached a maximum altitude of 7,300 feet (Daly, 1912). Northwest of Lakeside, near the north end of Flathead Lake, a moraine that dams a small lake indicates that the ice there reached a minimum altitude of 5,100 feet. Only a few miles farther south, the Lake Mary Ronan lobe scoured the Dayton bench at an altitude of about 4,200 feet, and the altitude of the top of the terminal moraine south of Polson averages about 3,400 feet. Greatest thickness of the ice ranged from about 4,000 feet at the International Boundary to at least 2,000 feet near Kalispell, then decreased more rapidly to the margin near Polson.

Striations and fluting of rock outcrops are the principal indicators of the direction of ice movement (Fig. 3). These markings are prominent on the more resistant quartzite of the Ravalli Group. Only a few scattered striae were observed on the softer beds of the Piegan Group. Distribution of drift and till, erratics, and moraines shows the extent of glaciation. Cirques and U-shaped and dissected hanging valleys characterize alpine glaciers, which originated on many of the high peaks and extended a short distance down the mountain valleys. At the same time, the Cordilleran sheet advancing along the major valleys sent prongs up the tributary valleys. Thus it is impractical to attempt to draw a "contact" between sheet and alpine glaciers.

The westernmost lobe of the Cordilleran ice in Montana followed up the West Fork of the Yaak and also down the main Yaak Valley but eventually overrode the divides to merge with adjacent lobes. On "The Scout" Mountain west of the headwaters of the West Fork of Yaak River, glacial striae at an altitude of 6,000 feet trend southwest, showing that the Yaak lobe penetrated into Idaho.

The main lobe entered Montana north of Eureka, crossed the Tobacco Plains to Black Butte, and at first it there split in two. One branch moved down the Kootenai Valley, the other up the Tobacco Valley. Subsequently, however, the intervening Salish Mountains were overridden at least as far south as Elk Mountain, where the thickened ice sheet was again split in two.

The branch that moved up the Tobacco Valley, then down the Stillwater and the lower part of the Flathead Valley seems to have been the largest and longest tongue, probably because it was moving in the largest and deepest valley, and for the greater part downgradient. Its terminal moraines lie south of Flathead Lake, at Polson,

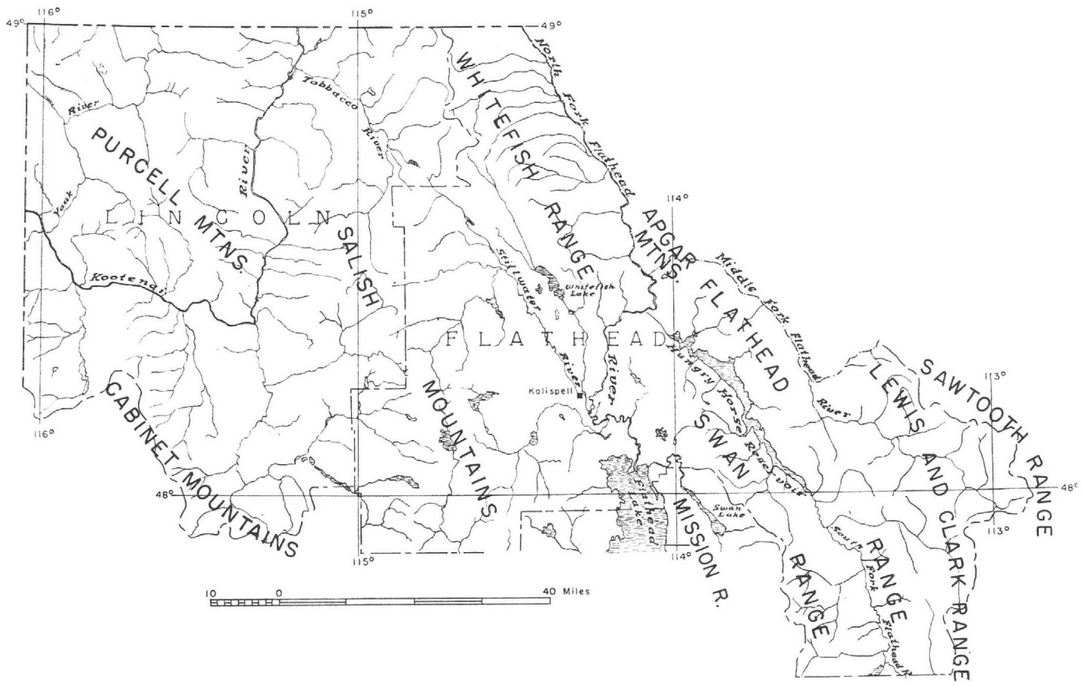


Figure 2.—Index map of northwest Montana showing mountain ranges.

PHYSIOGRAPHY

The area is in the Northern Rocky Mountain province (Fenneman, 1931), which here is characterized by successive heavily forested ranges trending north to northwest and separated by long straight valleys that show mature drainage patterns. Between the Idaho boundary and the Great Plains are a dozen linear ranges, eight of which are in the area described in this report. The intervening parallel or subparallel depressions are the valleys of the Kootenai, Thompson, and Flathead Rivers, and their nine tributaries, forming in Montana the upper Columbia River drainage system. The largest of the rivers are the Flathead and Kootenai, contributing average discharges near Polson and at Leonia, respectively, of 11,610 and 13,850 cubic feet per second.

Tectonic forces elevated the entire Rocky Mountain area in a broad upwarp and also caused the differential uplift of the individual mountain ranges by faulting. The Hope fault, which has a vertical component of 1,500 feet (Gibson, 1948, p. 65), borders the southwest flank of the Cabinet Mountains. The Swan fault, which has a stratigraphic displacement of 11,000 feet, borders the west flank of the Swan and Whitefish Ranges. A vertical component of several thousand feet for the Lewis thrust undoubtedly contributed to the elevation of the ranges that stand east of the Rocky Mountain Trench, especially in Glacier National Park and north of the International Boundary (Fig. 2).

Most of the ranges stand 5,000 to 7,000 feet above sea level, and the highest peaks reach altitudes of 7,500 to 9,000 feet. The highest point is Swan Peak, in the Swan Range, 9,255 feet. Other scenic peaks are Silvertip Mountain (8,890) in the Flathead Range, Pentagon Mountain (8,877) in the Lewis and Clark Range, Snowshoe Peak (8,712) in the Cabinet Mountains, Green Mountain (7,830) in the Whitefish Range, and Mt. Robinson (7,700) and Northwest Peak (7,518) in the Purcell Mountains.

In the western part of Lincoln County the valley of the Kootenai is locally 2 to 5 miles wide, as at Troy and at Libby, but throughout most of its length it is much narrower. Lowest point in the area is at Leonia (1,822 feet), where the Kootenai crosses the boundary into Idaho. The valleys farther east are wider; the Flathead Valley is as much as 16 miles wide within the study area, and

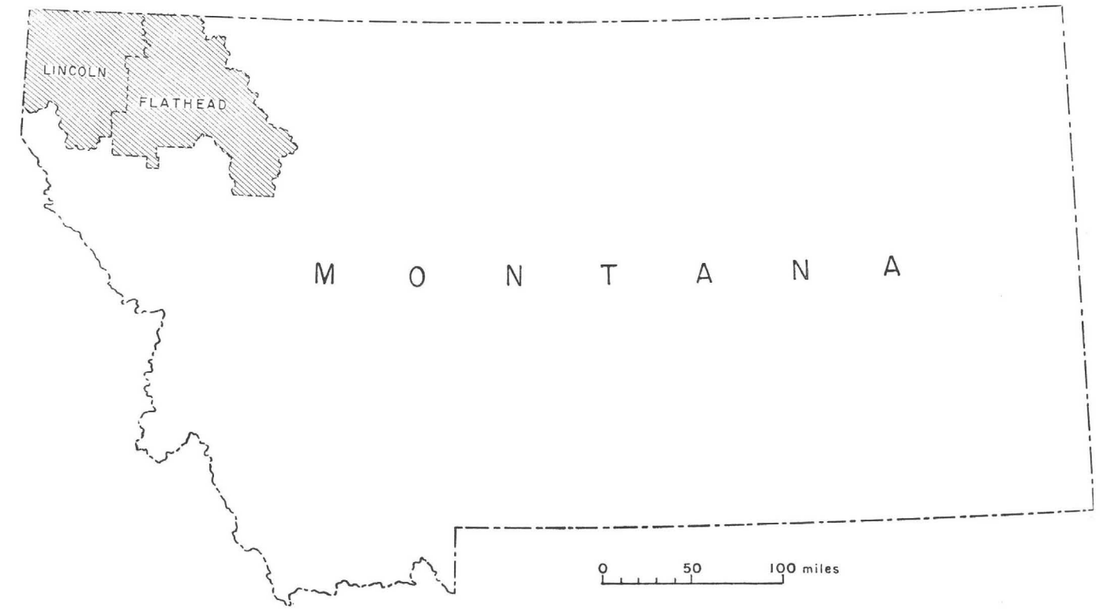


Figure 1.—Index map showing location of Lincoln and Flathead Counties.

sive study of Belt rocks (Precambrian) in the Lewis and Livingstone Ranges of Glacier National Park. Walcott (1906) described measured Belt sections in the Mission and Swan Ranges and published the first correlations of Belt rocks in northwestern Montana and northern Idaho.

G. S. Lambert, A. C. Bevan, R. A. Wilson, E. B. Young, and C. H. Clapp mapped the Salish Mountains and adjacent areas in western Flathead County between 1921 and 1924; their results were published in part (Wilson and others, 1924; Bevan, 1929). Their work was later incorporated in the Geologic Map of Montana (Ross and others, 1955). Over a period of years C. H. Clapp (1932) mapped a considerable area extending northwestward from the Missoula-Drummond-Helena area to the southern Whitefish Range. A detailed stratigraphic study (C. L. and M. A. Fenton, 1937) was concerned with subdivision of the Belt Series in Glacier National Park. C. P. Ross (1949, 1959, 1963), in regional studies throughout Montana, contributed in large measure to the present knowledge of Belt Series stratigraphy and structure and was co-author of the report of an investigation (Ross and Rezak, 1959) of rocks and fossils in Glacier National Park. Rezak (1957) classified the Precambrian stromatolites of Glacier National Park.

C. F. Deiss (1933, 1935, 1938, 1941, 1943a, 1943b) mapped the Silvertip quadrangle (including southeastern Flathead County) and parts of the adjacent Saypo, Ovando, and Coopers Lake quadrangles, and studied the stratigraphy of Precambrian and Paleozoic rocks in these areas. Sloss and Laird (1945, 1947) prepared reports on Devonian and Mississippian stratigraphy in northwest Montana in connection with oil and gas investigations. Mudge and others (1962) subdivided Mississippian strata in the Sawtooth Range. Studies in the Sawtooth Range by Mudge (1965, 1966a, b, c) and in the southern part of the Lewis and Clark Range by McGill and Sommers (1967) have been published.

The Rocky Mountain Trench of southern British Columbia and northwest Montana has been the subject of papers by Flint (1924), Shepard (1922, 1926), and Leech (1959). Other contributors to the geology of the region are Pardee (1950), who postulated block faulting in intermontane valleys, Childers (1963), who mapped an area south of Glacier National Park, and Sweeney (1955) and Bentzin (1960), who reported on parts of the Whitefish Range.

Within western Lincoln County, Gibson (1948) and associates studied the geology and ore deposits of the Libby quadrangle. Publications by Gale (1934), Gibson (1934), and Gibson and Jenks (1938) are indirectly related to this study. Gibson and others (1938) presented studies of the igneous rocks in the Libby quadrangle.

Mines and mineral deposits were examined by MacDonald during a reconnaissance survey of the general economic geology of the Cabinet and Purcell Mountains (Calkins and MacDonald, 1909). Schrader (1911) also reported on early mining activity and placer operations in the Libby district and adjacent areas. Billingsley (1915) prepared an unpublished report on mineral deposits in parts of Lincoln County. Pardee and Larsen (1929) and Perry (1948) described the occurrence of vermiculite in the Rainy Creek pyroxenite stock in the Rainy Creek district northeast of Libby. Boettcher (1963) reported on the geology, petrography, and geochemistry of the Rainy Creek pluton. Geology and ore deposits of the Hog Heaven district, including the Flathead mine, are subjects of a paper by Shenon and Taylor (1936). Sandvig (1947) listed mines and placers in the Libby, Troy, West Fisher, and Hog Heaven districts, and Crowley (1963) published a report on mining properties in Sanders County, several of which are described in this report.

Geologic studies of Belt rocks outside of Montana but peripheral to Lincoln County were made by Daly (1912) along the 49th parallel and these were followed by some revision of Daly's mapping and stratigraphic nomenclature by Schofield (1914a, 1915). Leech (1958, 1960) mapped the Cranbrook-Fernie area in southeastern British Columbia. Kirkham and Ellis (1926) published a reconnaissance map of Boundary County, Idaho, and Harrison and Jobin (1963) discussed the stratigraphy and structure of the Clark Fork area of northern Idaho. Price (1962) mapped Precambrian, Paleozoic, Mesozoic, and Cenozoic rocks in southeast British Columbia and southwest Alberta.

Glaciation of parts of northwest Montana was studied by Davis (1916, 1921), who made observations relative to the steep west fronts of the Mission and Swan Ranges. Alden (1953) reported on glaciation in the Kootenai, Tobacco, Stillwater, and Flathead Valleys. Erdmann (1944, 1945, 1947) published detailed studies of possible damsites along Kootenai River west of Libby, and on structure, economic geology, and glaciation of the Hungry Horse damsite and reservoir area and other proposed damsites on the Flathead River and its tributaries.

ACKNOWLEDGMENTS

The Kootenai-Flathead mapping project owes its inception to a planning meeting held in Butte on March 5, 1958. Present were Al Haley and Ralph Watson of the Great Northern Railway Company, Lew Growney and Garth Duell of the Pacific Power & Light Company, and Edwin G. Koch, Walter S. March, Jr., and Uuno M. Sahinen of the Montana Bureau of Mines and Geology. An operations committee consisting of Watson, Duell, and Sahinen was appointed to supervise the project. Willis M. Johns was selected as project geologist. In later years the operations committee was assisted by alternates Henry E. Reed of the Great Northern Railway Company and Winston M. Sahinen of Pacific Power & Light Company.

Graduate assistants who aided in field mapping were D. H. Dahlem (Montana College of Mineral Science and Technology), L. P. Beer (University of Massachusetts), A. W. Shelden (Montana State University), D. A. Sommers (University of Rochester), F. V. Latuszynski (University of Montana), W. D. Page (University of Colorado), W. C. Barnes (Princeton University), A. G. Smith (Princeton University), F. W. Hall (University of Montana), and E. H. Gilmour (University of Montana).

Assistant geologists who contributed significantly to the field mapping were D. M. Hutchinson, K. T. Bondurant, A. L. Boettcher, and W. L. Newell.

Appreciation is expressed to Mr. U. M. Sahinen, Director of the Montana Bureau of Mines and Geology, for his many helpful suggestions and critical revision of the manuscript and for his assistance throughout the entire course of the project, to Dr. J. C. Maxwell of Princeton University for additional data on the Pinkham fault in the Rexford area, and to Dr. R. B. Berg of the Montana Bureau of Mines and Geology for checking and extending the thin-section study. Dr. W. C. Barnes graciously permitted the use of his report and map of the northeast Whitefish Range done under the direction of the Geology Department of Princeton University.

Mr. Don C. Lawson, mineral technician, Montana Bureau of Mines and Geology, assisted in preliminary soil-sampling work during the final phases of the program. Mineral and rock analyses were performed by Mr. F. P. Jones and the late Mr. C. J. Bartzen, Bureau analysts. Mr. R. B. Holmes, Bureau draftsman, assembled tables and drafted maps and illustrations for this report.

The writer thanks the many individuals who graciously contributed services and information on location, history, and production of mining properties throughout the area. These include Mr. A. M. Bartlett, Mr. Dan Garrison, Mr. Jack Garrison, Mr. Allen Goodgame, Mr. Jim Lyle, Mr. W. A. Rankin, Mr. Ernest Williams, Mr. L. W. Bolyard, Mr. Blaze Echo, Mr. Clive Roark, Mr. W. C. Zollars, Mr. G. G. Kenelty, Mr. C. Tallmadge, and the late Mrs. Elizabeth Powers, Mr. Leslie W. Leigh, Mr. Henry P. Reinshagen, Jr., and Mr. J. K. Potter, all of the Libby-Troy area; Mr. H. K. Waylett, Mr. O. V. Miller, Mr. D. Larue, Mr. J. D. Daniel, Mr. W. L. Fewkes, Mr. Oscar Moen, Mr. B. Hansen, and the late Mr. Albert Thayer of the Fisher River-Rexford-Eureka area; Mr. Marion Fishel, Mr. Guy Maycumber, Mr. Carl Luke, Mr. A. E. Lewis, Mr. U. L. Poston, Mr. H. L. Poston, Mr. W. C. Kirkpatrick, Mr. Vern Strodtbeck, Mr. A. Darling, Mr. A. M. Johnson, Mr. Glen Bauska, Mr. Frank Bauer, Mr. Ben Trosper, Mr. Barry Adkins, Mr. Al Harvey, Mr. H. E. Bear, Mr. R. L. Bear, Mr. O. G. Tiegan, Mr. Barton Pettit, Mr. Thain White, Mr. Waino Lindbom, Mr. Oscar Oftedahl, Mr. Levi Gaustad, Mr. John Jense, Mr. Paul Jense, Mr. Norman Stringfellow, Mr. Ray Hough, Mr. Bill Adams, and the late Mr. F. A. Stahl, Mr. Harold Luke, and Mr. Jim Whilt of the Kalispell-Dayton area; and Mr. Ted Ross, Mr. Tom Crum, Mr. Earl Scott, Mr. Ed Smith, Mr. Walter Bissell, and the late Mr. Vance Williford of the Whitefish-Olney-Polebridge area.

The late Mr. E. J. Strasburger graciously supplied maps and other information on the Independence group of claims; Mr. Fred Sproul of Star Meadow, Mr. Manuel Bauska of Kalispell, and Mr. Lee Rost of Perma supplied equipment and horses during the 1963 field season. The writer is indebted to John Hall, Dick Strong, Theodore Paullin, and Arnold Dillard of the U. S. Forest Service for assistance and cooperation during mapping in the Flathead National Forest.

GEOGRAPHY

GENERAL STATEMENT

Flathead County was created in 1893. A portion of the county was segregated in 1909 to form Lincoln County. Lake County was created August 10, 1923. Flathead County is the largest, 5,294 square miles, and has a population of 32,965 (1960 census). Lincoln and Lake Counties have populations of 12,357 and 13,104 respectively, and areas of 3,666 and 1,564 square miles. Federal ownership of land exceeds 73 percent in Lincoln and Flathead Counties, most of which is national forest. In Lake County 52.1 percent of the area is under federal control, part of the acreage being included in the Flathead Indian Reservation.

Lumbering, ranching, and farming are the essential industries in the area. Flathead Valley north of Flathead Lake contains rich farming land; cherries noted for size and flavor are grown on the shores of Flathead Lake and shipped to eastern seaboard cities. Many tourists visit the area, as Glacier National Park and Flathead Lake are among the leading vacation attractions in the state. Flathead County acquired a basic industry when The Anaconda Company erected an aluminum reduction plant near Columbia Falls.

Kalispell, a city of 10,000, is at the crossroads of U. S. Highways 2 and 93. Eureka (population 1,229), near the Canadian border, and Polson (2,314) at the south end of Flathead Lake, are along U. S. Highway 93. Other centers of population are Whitefish (2,965) and Columbia Falls (2,132) in Flathead County, and Libby (2,828) and Troy (855) in western Lincoln County.

Climatic conditions within the map area, as within the western mountainous part of the state, are affected by the Rocky Mountains, which act as a barrier to south-moving arctic and central Canadian storms, while restricting the eastward passage of moisture-bearing prevailing westerly winds from the Pacific Coast. The mountain barriers tend to make winters more moderate and summers cooler and to produce an increased amount of rain and snow; the Libby area lies within the snowbelt of western Montana and northern Idaho.

Average annual precipitation amounts to 16.5 inches in the eastern part and 18 inches in the western part of the map area. Annual mean temperatures range between 42.8°F and 44.5°F. At Kalispell, for the period 1956-61, the average maximum temperature was 54.2°F and the average minimum 31.3°F. Annual snowfall amounts to about 68 inches, although snowfall in the mountains may exceed 100 inches a year. The highest temperature recorded for Kalispell since 1920 was 104°F in 1960; the lowest was -38°F in 1950. The greatest amount of rain falls during May and June; July and August are relatively dry.

Thick stands of second-growth evergreens cover slopes and ridges, but both evergreens and deciduous trees grow in the valleys. Western yellow pine (ponderosa), western larch (tamarack), and Douglas fir make up the bulk of merchantable timber; white pine, lodgepole pine, white fir, cedar, and Engelmann spruce also are commercially important, but juniper and hemlock are not. Deciduous trees include cottonwood, quaking aspen, birch, alder, and willow. Common shrubs and flowers are huckleberry, serviceberry, beargrass, and Indian paintbrush. Native grasses, including timothy, white clover, quack grass, and fescue, thrive in valleys, high parks, and open south-facing slopes.

mud cracks and some mud-chip breccia. Roosville strata also contain mud-chip breccia.

Mud cracks in the Wallace Formation of western Lincoln County are ¼ inch or less in depth. Undoubtedly the feature had been subsequently compacted by the weight of overlying rocks, but the short downward extension of the cracks may indicate that intervals of exposure to the atmosphere were very short before subsequent re-inundation.

Current ripple marks and oscillation ripples occur in the quartzite and argillaceous quartzite of the Ravalli, in the argillaceous beds of the Wallace and Piegan units, and in argillite and quartzite of the Striped Peak. In Ravalli rocks north of Elk Mountain west of the Rocky Mountain Trench, Gilmour (1964, p. 37) noted current ripple marks trending northwest. Near the Rocky Mountain Trench north of Olney, symmetrical and asymmetrical ripple marks in the P_1 formation range in trend from N. 30° W. to N. 10° E., the most commonly observed direction being about N. 15° W. A grid-type ripple mark consisting of one set of ripples superimposed on another set, the two sets intersecting at right angles, was observed in outcrop near Loon Lake north of Libby.

Crossbedding was best developed in the quartzite of the Ravalli and Striped Peak rocks. Graded bedding was rarely observed in outcrop. Scour-and-fill channels are sparse, and most were observed in the Ravalli Group. Mud-chip breccia is most abundant in the Piegan and Missoula Groups. A few load casts were observed in red argillite of the Striped Peak Formation. Barnes (1963, p. 42) described cross-lamination, load casts, mud-chip breccia, conglomerate, mud-crack casts, and sparse current ripples in the Roosville Formation in the eastern part of the Whitefish Range.

Previous to the development of radiometric age dating, the minimum age of Belt rocks was determinable only by stratigraphic and structural relationships with other rocks. In parts of western Montana the Flathead Quartzite (Middle Cambrian) overlies the youngest Belt rocks, thus fixing their minimum age.

Radiometric age dating of ore deposits in Belt rocks in the Coeur d'Alene district, in the Sullivan mine in British Columbia, and other ore deposits in the northern Rocky Mountains provide figures for the age of Belt strata. In the Coeur d'Alene district, Eckelmann and Kulp (1957, p. 1129) analyzed specimens of pitchblende containing lead; they calculated the time of deposition as being between 1,100 and 1,200 m. y. ago. Long and others (1960, p. 653) determined a lead-isotope age of approximately 1,400 m. y. for certain Coeur d'Alene ores; Leech and Wanless (1962, p. 270) determined that lead in ores from the Sullivan mine in the Kimberly district left their source 1,250 m. y. ago; and Cannon and others (1962, p. 128) reported lead-isotope dates as old as 1,350 m. y. in the Coeur d'Alene district of northern Idaho and the East Kootenay district of British Columbia. Cannon believed that the wide range of ages from 1,350 m. y. to "future model ages" implies that the lead-zinc deposits of the Wallace Formation may have a geologic history different than that of the deposits in older Belt rocks (Prichard and Ravalli).

Glauconite from the upper part of the Belt, that is, within a few thousand feet below the Flathead Quartzite (Middle Cambrian), near Marias Pass in southeastern Flathead County, gave K-Ar and Rb-Sr ages averaging 1,070 m. y. (Gulbrandsen and others, 1963, p. 390). The age is regarded as a minimum for these Missoula Group strata. Wampler and Kulp (1964, p. 1443) determined that a sample from the Siyeh Formation that contains cubic pyrite enriched in lead corresponded to a Northern Pacific type lead of 1,250 m. y. Wampler (personal communication) expressed the opinion that this analysis indicates that the rocks cannot be much younger than 1,200 m. y. but that his isotopic data do not set a maximum age for the strata.

Barnes (1963, p. 48) interpreted certain radiometric age data as follows:

> "During the later [earlier?] stages of Belt deposition, about 1,400 to 1,500 m. y. ago, sills were emplaced and the Purcell Lavas [Basalt] were extruded. Later, about 1,250 to 1,400 m. y. ago, the Hellroaring Creek and associated granodiorite stocks [in British Columbia] were intruded and the Sullivan and Coeur d'Alene ore bodies were emplaced. Folding and faulting of the Belt strata probably took place at this time . . . and deposition of the Windermere System may also have begun. Later muscovites and biotites of the region lost argon, possibly as a result of increased pressure and temperature caused by burial beneath thick Paleozoic and Mesozoic sequences."

According to radiometric data, therefore, Prichard strata were deposited before 1,350 or 1,400 m. y. ago. The Siyeh Formation was deposited at least 1,200 m. y. ago, and strata in the upper part of the Missoula Group 1,150 or 1,170 m. y. ago. If these figures are correct, they indicate a long period of deposition and a subsequent long period of erosion during the time intervening between deposition of the uppermost Belt rocks now exposed and deposition of the Flathead Quart-

Whereas the Flathead lobe of the Cordilleran ice sheet moved almost if not quite continuously downgrade, being restricted only laterally, the western lobes were forced to move upgrade after reaching the Libby area. In moving up the valleys of Lake Creek, Libby Creek, Fisher River, and smaller drainages, their effectiveness as erosive agents decreased, their rate of advance was retarded, and the amount of debris deposited in the terminal moraines was relatively scant.

In the northwestern part of the area, early encroachment of the Cordilleran ice sheet restricted the extent and intensity of action by the alpine glaciers. In the Purcell and Salish Mountains, only those few peaks more than 6,500 feet high stood as nunataks. Farther southeast, the greater height of the mountains and the lower surface of the ice sheet permitted more extensive activity by alpine glaciers, which also persisted for a longer period of time here. In fact, one small remnant of a mountain glacier still remains on the northeast slope of Swan Peak, in the Swan Range, at an altitude slightly above 9,000 feet.

GLACIAL TOPOGRAPHIC FEATURES

Long stretches of the valley of the Kootenai River north of Warland and of the Yaak River valley were carved to a U-shaped cross section by the advancing lobes of the Cordilleran ice sheet. The lobe that followed the Tobacco-Stillwater-Flathead Valleys in the Rocky Mountain Trench probably eroded such a valley there, but subsequent filling with moraine, outwash, and alluvium produced a virtually flat valley bottom. Sublobes of this eastern lobe moved up the valleys of Good Creek, northwest of Kalispell, and of Ashley Creek, southwest of Kalispell, producing U-shaped valleys in their lower reaches.

Alpine glaciers produced many U-shaped valleys near the headwaters of small drainages. They are especially prominent in the Swan Range and the Lewis and Clark Range, where they started well above the present timber line. On the northeast flank of the Swan Range, good examples can be seen at Sand Creek, Fawn Creek, Sullivan Creek, Bunker Creek and its Middle Fork, Gorge Creek, and Little Salmon Creek. On the southwest flank of the Swan Range, the North Fork of Lost Creek, Bond Creek, and Hall Creek occupy U-shaped valleys.

An unusual feature on the North Fork of Lost Creek seems to be related to the erosion of U-shaped valleys. Ice moving down from Thunderbolt Mountain scoured a narrow terracelike surface high on the south side of the valley, at an altitude of about 5,500 feet. The flat area averages about 50 feet in width and extends for 2 miles or more. On the state geologic map a northwest-trending fault is shown in this position, but no evidence of a fault is apparent along the North Fork, on the divide north of Thunderbolt Mountain, or along Bunker Creek east of the divide.

The sublobe of the Flathead lobe that diverged northwestward at Dayton produced the narrow uniform sloping Dayton Bench. This flat surface trends west-northwest for a distance of 1½ miles. Waterworn and striated pebbles and cobbles, glacial erratics, and small mounds of drift are scattered over the surface. Curiously, the outcrops above the bench show no evidence of ice movement.

Cirques, like U-shaped valleys, are more numerous and more fully developed in the Swan Range and other high ranges in the southeastern part of the area than in the northwestern part. In the Salish Mountains, as far north as the latitude of Whitefish and Libby, however, cirques that developed at the head of Listle Creek and on other nearby drainages whittled Dunsire Point to a sharp horn. Even the peaks nearest the Canadian border are sculptured by cirques; Northwest Peak is surrounded by cirques, several of which contain lakes. The 7½-minute topographic maps published by the U. S. Geological Survey after our field work was completed show these features clearly. In fact, erosional features that are below the present timber line are more readily identifiable on the topographic maps than in the field.

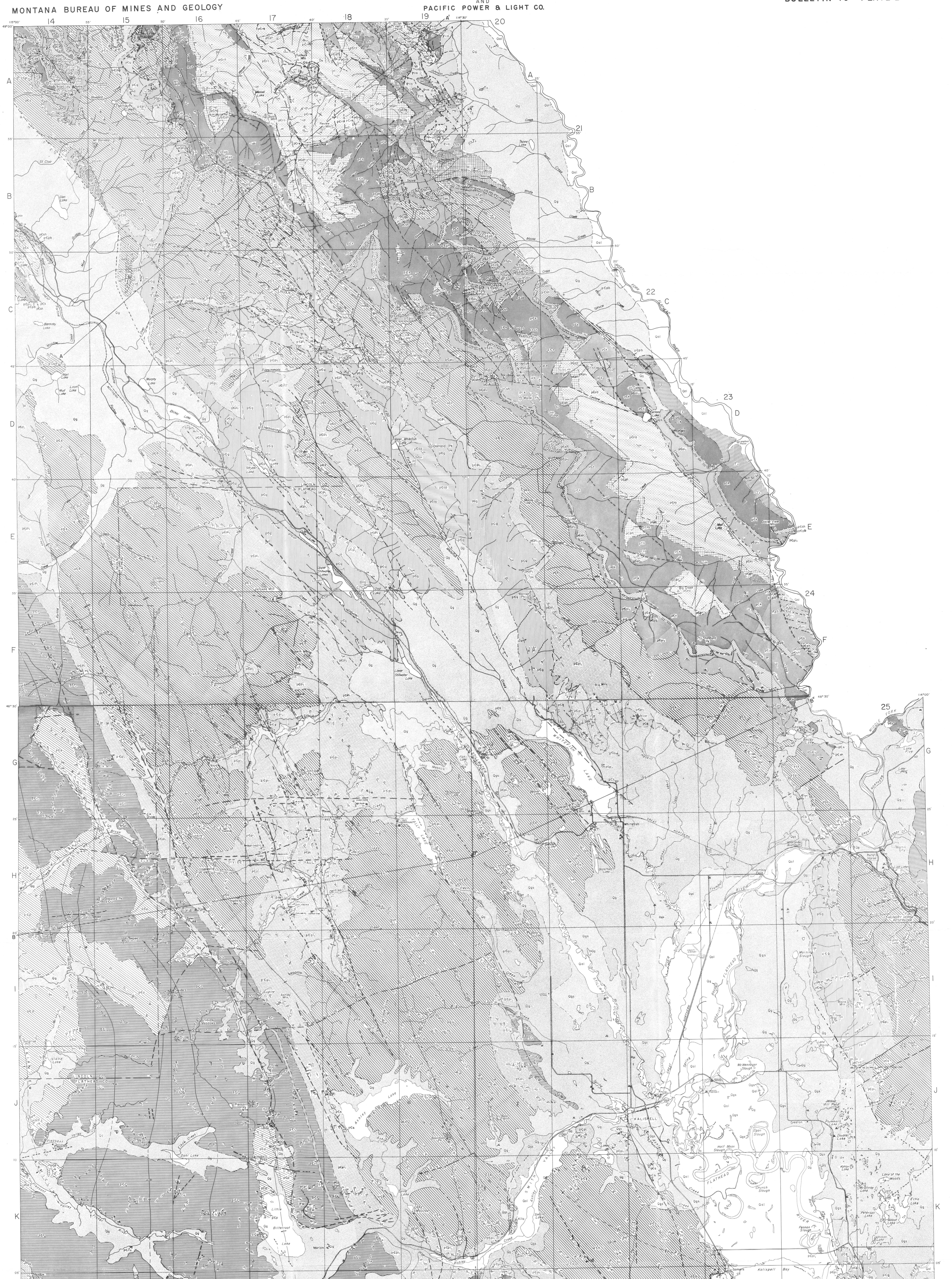
The most conspicuous glacial constructional features are the moraines, especially those that block drainageways and impound lakes. By far the largest lake is Flathead Lake, but the moraines that retain it are outside the study area, at Polson and west of Big Arm. A sublobe of the Flathead lobe left a terminal moraine that confines the water in Lake Mary Ronan, and the city of Whitefish is built on a low recessional moraine that impounds Whitefish Lake.

Numerous mountain lakes lie behind moraines left by the valley glaciers or by the Cordilleran ice sheet, but not all mountain lakes originated in this way. Many are contained in cirques or in overdeepened stretches of the valleys. A moraine fills a low area on the divide at the northwest end of the Cabinet Mountains; Bull River flows southward to the Clark Fork but it no longer drains Bull Lake, which lies north of the moraine. Instead, the water from Bull Lake flows northward down Lake Creek to the Kootenai, near Troy. Similarly the site of Tally Lake seems to have once been the valley of Lost Creek, before a moraine was deposited at the southeast end of the present

MONTANA BUREAU OF MINES AND GEOLOGY

PREPARED WITH THE COOPERATION OF
BURLINGTON NORTHERN, INC.
AND
PACIFIC POWER & LIGHT CO.

BULLETIN 79 PLATE 2



GEOLOGIC MAP AND SECTIONS OF EASTERN LINCOLN COUNTY AND WESTERN AND NORTHEASTERN FLATHEAD COUNTY, MONTANA

0 1 2 3 4 5 miles

PREPARED WITH THE COOPERATION OF
BURLINGTON NORTHERN, INC.
AND
PACIFIC POWER & LIGHT CO.

IGNEOUS ROCKS

Porphyritic latite to andesite flows and intrusive bodies

Diorite dikes

Syenite stocks

Quartz latite porphyry dikes

Granitic rocks including granodiorite, quartz monzonite, and alaskite occurring as stocks

Basic stock composed of pyroxenite

Metadiorite—dark-green-gray and gray-black dikes, sills, and stocks mapped by others as gabbro, hornblende gabbro, amphibolite, and metadiorite

pЄm — Metagabbro—sills and dikes of dark rocks of diabasic texture (Pl. 3)

SEDIMENTARY ROCKS

PRECAMBRIAN — BELT SUPER GROUP

Missoula Group

Libby Formation
Light-gray, dark-gray, green-gray, yellow, and yellow-green argillite; some calcareous argillite; a few thin beds of yellow and yellow-brown limestone and stromatolitic limestone.

Roosville Formation
Green-gray, red-brown, grayish-orange, and red-purple coarse-grained argillite. Some gray quartzite in lower part. Dolomitic stromatolites in lower 1,000 feet.

McNamara Formation
Gray, green, and greenish-gray feldspathic sandstone and quartzite. Uppermost strata are green thin-bedded and sericitic argillite interbedded with grayish-red thin-bedded quartzite and argillite. Minor amounts of stromatolitic limestone and calcareous argillite present.

Phillips Formation
Grayish-red and red feldspathic sandstone, quartzite, and argillite; some gray-pink and green-gray sandstone. Cross-bedding, ripple marks, and mud-crack casts common.

Bonner Formation
Grayish-red, light-gray, and white quartzite, interbedded with some grayish-red and gray sandstone near top.

Upper Missoula Group
Grayish-red to pale-red argillite and interbedded light- and moderate-red quartzite; massive pink quartzite unit near the center; above is greenish-gray and medium-gray feldspathic sandstone and quartzite. Corresponds to Ahorn and Hoadley Formations of Deiss.

Kintla Formation
Greenish-gray, grayish-red, and brown fine-grained argillite, sandstone, and quartzite. Dolomitic stromatolites interbedded with quartzite in lower part.

Shepard Formation
Finely crystalline light-gray and green-gray magnesian limestone interbedded with gray argillite. In the Rexford area (Pl. 2) the formation consists of gray quartzitic sandstone and green-gray and blue-gray argillite grading upward to dolomite.

Shields Formation
Pale-red argillite, light-gray quartzite, and purple-gray laminated and mud-cracked argillite.

The "main body" pЄm is argillite, quartzitic argillite, and quartzite, in which reddish tones predominate. Locally the top unit, pЄga, is grayish-green argillite. One mass, pЄig, of pale-pink quartzite is mapped. Limestone, pЄlm, similar to the Siyeh Formation is plentiful and is believed to be Siyeh that was misidentified.

Middle Missoula Group
Medium-gray limestone and dolomite and banded green-gray calcareous argillite weathering grayish orange and yellow brown. Corresponds to Cayuse Limestone of Deiss.

Striped Peak Formation
Gray and grayish-red sericitic quartzite and gray-red-purple argillite. Some interbedded gray-green laminated argillite near center. Ripple-marked and mud-cracked strata common; some casts of salt crystals.

Snowslip Formation
Grayish-red and red argillite and sandstone interlayered with laminated pale-green and gray-green argillite, some slightly calcareous. Contains mud cracks, ripple marks, and mud-chip breccia.

Lower Missoula Group
Grayish-red and pale-red mud-cracked and ripple-marked argillite and quartzite interbedded with pale-green and gray argillite, calcareous argillite; grayish-red and pale-red argillite near base. Corresponds to Miller Peak Argillite of Deiss.

Purcell Lava
Dark-gray-green porphyritic and amygdaloidal lava. Two flows near Robinson Mountain separated by 100 to 150 feet of gray and green calcareous argillite and argillite.

Piegan Group

Upper Piegan Unit
Thin-bedded and banded pale-green to grayish-green argillite, calcareous argillite, and minor limestone, equivalent to basal greenish calcareous argillite of Missoula Group, pЄCa of Ross.

Wallace Formation
Gray, green-gray, and yellow calcareous and dolomitic sandy argillite; discontinuous dolomite and magnesian limestone beds are common near the middle of the formation. Grayish-red shale and minor quartzite locally present near the top. Mud cracks and ripple marks common.

Siyeh Formation
Thick-bedded to massive medium-gray and bluegray crystalline stromatolitic molar-tooth limestone and dolomite. Weathers orange, brown, and yellow. Pyrite cubes common.

Lower Piegan Unit
Pale-blue-green to pale-green and gray argillite and calcareous and siliceous argillite. Locally contains light-gray limestone lenses, white quartzite, and several thin gray-red discontinuous argillite beds in the Swan Lake area.

Ravalli Group

Ravalli undifferentiated
Magnetite-bearing medium- to light-gray quartzite, quartzitic argillite, and argillite; some interbedded and laminated green-gray quartzitic argillite weathering gray. In the Flathead Lake region grayish-red-purple, grayish-red, and grayish-green argillite and locally calcareous quartzitic greenish-gray argillite. Upper Ravalli marker bed of calcareous argillite mapped as pЄr₁.

Grinnell Formation
Green-gray, purple, and red-purple siliceous argillite, locally some calcareous argillite.

Pre-Ravalli Group

Appekunny Formation
Green and gray-purple argillite, some black argillite, and greenish-gray quartzite.

Prichard Formation
Lowest strata exposed are gray-brown and white sericitic quartzite and some grayish-brown sandstone. Locally schistose, containing garnet, sericite, and biotite. Upper strata are biotite-bearing gray and blue-gray argillite, weathering rusty brown.

CENOZOIC — Quaternary

Alluvium
Recent gravel, sand, and silt. Some Pleistocene glacial outwash.

Glacial silt
Lacustrine silt and clay.

Glacial moraine
Drift, gravel, and some alluvial-fan material.

Quaternary glacial deposits
Undifferentiated lacustrine silt, clay, drift, gravel, and alluvial-fan material.

Tertiary

Kishenehn Formation
Light-gray sandstone and silty sandstone, some brown sandstone and red-brown calcareous claystone; some carbonaceous shale, lignite, and twigs and wood fragments. Locally, indurated conglomerate is exposed. Fresh-water mollusks and mammal remains.

MESOZOIC — Cretaceous

Kootenai Formation
Gray, green, red, and red-purple sandstone and sandy shale; local lenses of gray limestone and calcareous sandstone. If Morrison strata are present, they are included with Kootenai beds.

Jurassic

Fernie Formation
Gray-black and brown-black fissile shale, light-gray dolomitic sandstone, and dark-gray siltstone with intercalated beds and discontinuous blocks of medium- and dark-gray limestone. Belemnite phragmocones locally abundant in carbonate rocks.

Ellis Formation
Fissile black shale interbedded with sandy limestone; yellow sandstone at base locally. Sawtooth, Rierdon, and Swift Formations present, but not distinguished separately on map.

PALEOZOIC — Permo-Pennsylvanian

Rocky Mountain Formation
Light-gray and yellow-gray fine-grained quartzite and quartzitic sandstone weathering grayish yellow and grayish pink; cross bedding and ripple marks. Upper beds contain some cherty and sandy dolomite.

Mississippian

Etherington Formation
Gray limestone and dolomite containing nodular masses of chert. Crinoid plates and columnals, bryozoan debris, and corals common.

Mount Head Formation
Gray and brown-gray cherty limestone and dolomite; the formation commonly is a cliff former; productids and corals near top.

Hannan Limestone
Light-brownish-gray thin- and medium-bedded limestone containing chert layers; weathers light gray. Very fossiliferous zones contain crinoid stems, horn corals, brachiopods, and bryozoans. Thirty-foot brecciated limestone (Silvertip Conglomerate) at base.

Livingstone Formation
Gray, blocky, massive cherty limestone. Crinoid and bryozoan fragments common.

Banff (and Exshaw?) Formation
Brownish-gray and gray cherty limestone, more shaly in basal part. Brachiopods common, especially in the finely crystalline limestone.

Devonian

Devonian undifferentiated
Yellow-gray, yellow-brown, medium-dark-gray and light-olive-gray fine- to medium-crystalline commonly fetid dolomite and limestone. Some zones contain crinoid stems, brachiopods, and local irregular calcite blebs. Weathers light gray and yellow gray. In Deiss' map area includes Devonian rocks above White Ridge Limestone but in Barnes' and Ross' map area includes all Devonian strata.

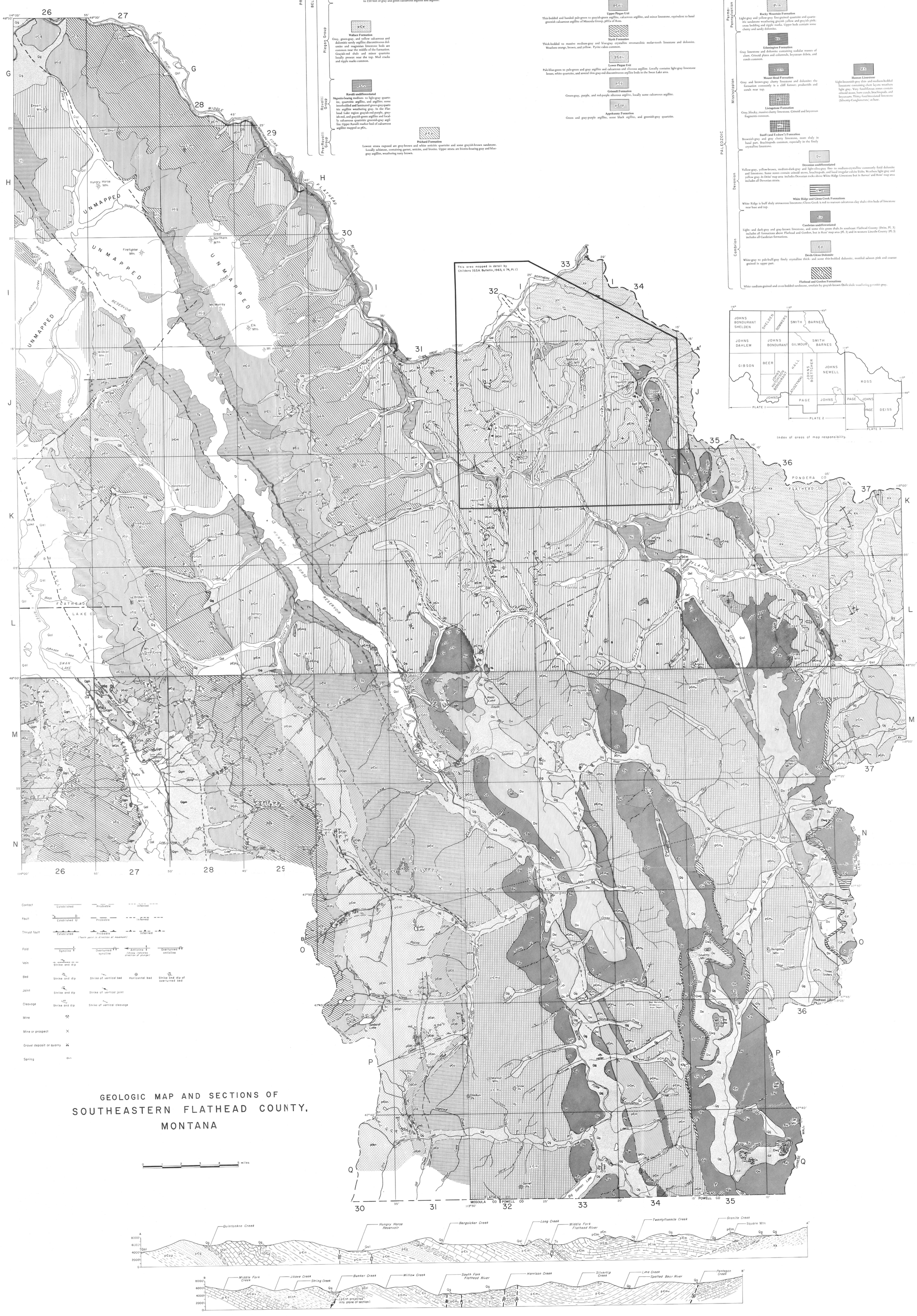
White Ridge and Glenn Creek Formations
White Ridge is buff shaly arenaceous limestone; Glenn Creek is red to maroon calcareous clay shale; thin beds of limestone near base and top.

Cambrian

Cambrian undifferentiated
Light- and dark-gray and gray-brown limestone, and some thin green shale. In southeast Flathead County (Deiss, Pl. 3) includes all formations above Flathead and Gordon, but in Ross' map area (Pl. 3) and in western Lincoln County (Pl. 3) includes all Cambrian formations.

Devils Glenn Dolomite
White-gray to pale-buff-gray finely crystalline thick- and some thin-bedded dolomite, mottled salmon pink and coarser grained in upper part.

Flathead and Gordon Formations
White medium-grained and cross-bedded sandstone, overlain by grayish-brown fissile shale weathering greenish gray.



Contact — Established / Probable / Inferred

Fault — Established / Probable / Inferred

Thrust fault — Established / Probable / Inferred (Teeth point in direction of movement)

Fold — Syncline / Overturned syncline / Anticline (Arrow indicates direction of plunge) / Overturned anticline

Vein — Strike and dip

Bed — Strike and dip / Strike of vertical bed / Horizontal bed / Strike and dip of overturned bed

Joint — Strike and dip / Strike of vertical joint

Cleavage — Strike and dip / Strike of vertical cleavage

Mine

Mine or prospect

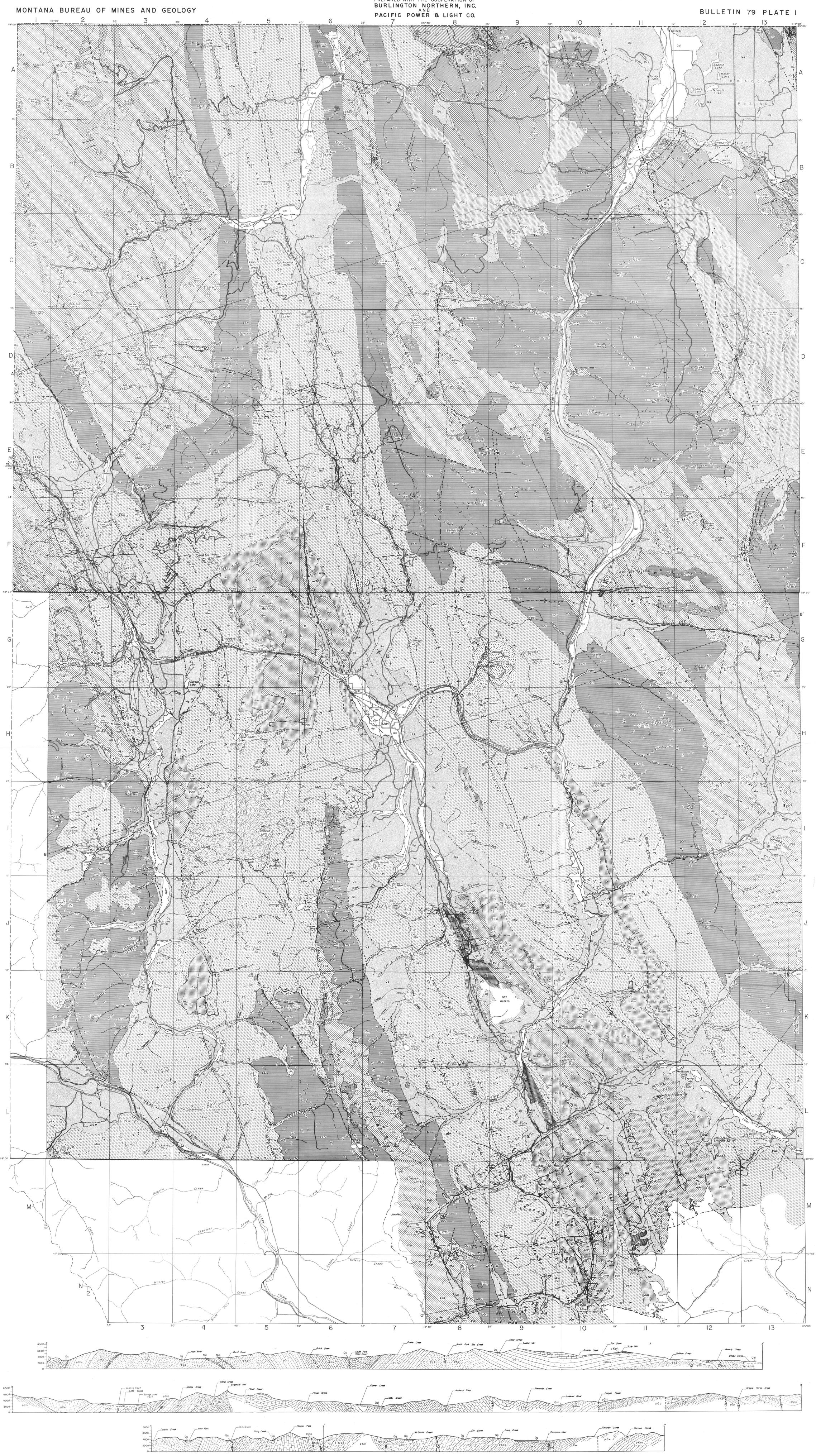
Gravel deposit or quarry

Spring

GEOLOGIC MAP AND SECTIONS OF SOUTHEASTERN FLATHEAD COUNTY, MONTANA

0 1 2 3 4 5 miles

PREPARED WITH THE COOPERATION OF
BURLINGTON NORTHERN, INC.
AND
PACIFIC POWER & LIGHT CO.



GEOLOGIC MAP AND SECTIONS OF
WESTERN LINCOLN COUNTY AND PART OF
NORTHERN SANDERS COUNTY, MONTANA

0 1 2 3 4 5 miles