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The Physiographic History of Western Montana and Northwestern Idaho

John R. Kavanagh

THE PHYSIOGRAPHIC HISTORY OF WESTERN MONTANA AND NORTHERN IDAHO

by
JOHN R. KAVANAGH

A Thesis
Submitted to the Department of Geology
in partial fulfillment of the
Requirements for the degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
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INTRODUCTION

General Statement

Millions of years of physiographic changes have conditioned us to the fact that our present drainage is a temporary feature. Rivers once flowing opposite to their present direction is not an unusual condition for physiographers to suggest. It is less common that they propose the existence of a former major drainage system trending across that of the present time. Both of these conditions are suggested by the writer as having been in existence during early Tertiary time in northwestern Montana.

The purposes of this thesis are two-fold. First, a review was made, and is here presented, of the previous physiographic work that has been done on an area including: (1) The region in Montana west of Butte and west of the front ranges of the Rocky Mountains in northern Montana, (2) Idaho, north of the Snake River. Secondly, some possible drainage modifications in northwestern Montana, which have heretofore not been suggested, are proposed. Particular emphasis will be placed on the Clark Fork and Flathead valleys.

It should be emphasized at the outset that the drainage modifications herein suggested are presented as an hypothesis, and nothing more. No field work in regards to this problem has been done by the author, and of course it is realized that intensive field work must be done in certain areas in order to either prove or disprove the hypothesis.

The problem is an exceedingly complicated one. For one reason, very little work of this nature has been done in this area; for another, evidence is obscured by earth uplift, glacial erosion and deposition, and dense vegetation. For example, when one would desire to recommend drainage modification on the basis of a "barbed" drainage pattern, he must reckon with those streams which naturally follow fault lines. And these fault lines are in turn obscured by glacial till or by heavy vegetation, or more generally by both.

Summary of Proposed Drainage Modification

It would be proper to submit at this time a summary of the drainage changes proposed. The relationships of the various streams to the overall modification pattern might be better kept in mind if this preliminary summary is given.

Primarily on the basis of the idealized drainage pattern presented by the piecing together of the major wide valleys of the region, the following modifications are proposed: (Refer to Plate II) (1) In early Tertiary times the Upper Clark Fork flowed in opposite direction throughout most of its present valley, (2) The Kootenai River flowed southward into Clark Fork valley, (3) The Flathead River had its course the same as at present as far south as the town of Dixon. From Dixon, where it joined the old Clark Fork valley, it traveled southward through the Jocko River valley to Missoula, and then continued southward through the Bitterroot valley. It should be emphasized again that these proposals are made without the aid of field work and are therefore subject to question.

The crux of the drainage modifications here proposed hinges about the Clark Fork and Flathead rivers and their tributaries, and therefore particular emphasis will be placed on the description and analysis of these rivers. First, a general picture of the physiographic history of the larger area and a resume of previous work will be given.

ACKNOWLEDGMENTS

The writer especially wishes to thank Dr. Eugene S. Perry for the assistance he has given throughout the preparation of this thesis. Many thanks

are due also to Mr. Charles E. Erdmann of the United States Geological Survey for his assistance during early phases of preparation and orientation.

PRESENT LAND FORMS

General Statement

The area described in this report is essentially characterized by high mountains of bold and rugged relief. The eastern mountain front rises sharply from the Great Plains, and the area is marked by a series of great ranges and trenches, trending in a general northwest to southeast direction. Parallel ranges continue to near the city of Spokane, Washington, which lies on the eastern border of the Columbia Plain. The following descriptions of the major mountain ranges and systems, and of the major valleys and trenches, are largely taken from the works of Daly, Calkins, Davis, and Fennemen. (See bibliography)

As Daly has shown, the limits of the natural orographic groups of this region are certain major valleys. Because of their extent and character, Daly has designated the major surface depressions as "trenches." This term well describes their comparative uniformity of cross-section and their approximate straightness and breadth.

The Rocky Mountain Trench

The more eastern of the depressions, a structural feature which limits a long and narrow orographic zone that Daly calls the Rocky Mountain system, has been named by Daly the "Rocky Mountain trench". This extends as a "narrow and wonderfully straight depression" in a northwesterly direction for about 800 miles from the head of Flathead Lake. South of Flathead Lake the valley does not continue quite so definitely but can be traced in different character down the Flathead, Jocko, and Bitterroot valleys. It is in the

Rocky Mountain Trench that the Clark Fork and Kootenai Rivers have their head waters, and they flow in opposite directions, only to join each other far to the east. (Refer to Plate II for locations of minor and major streams, and refer to figs. 1 and 2 for locations of the major trenches and mountain ranges.)

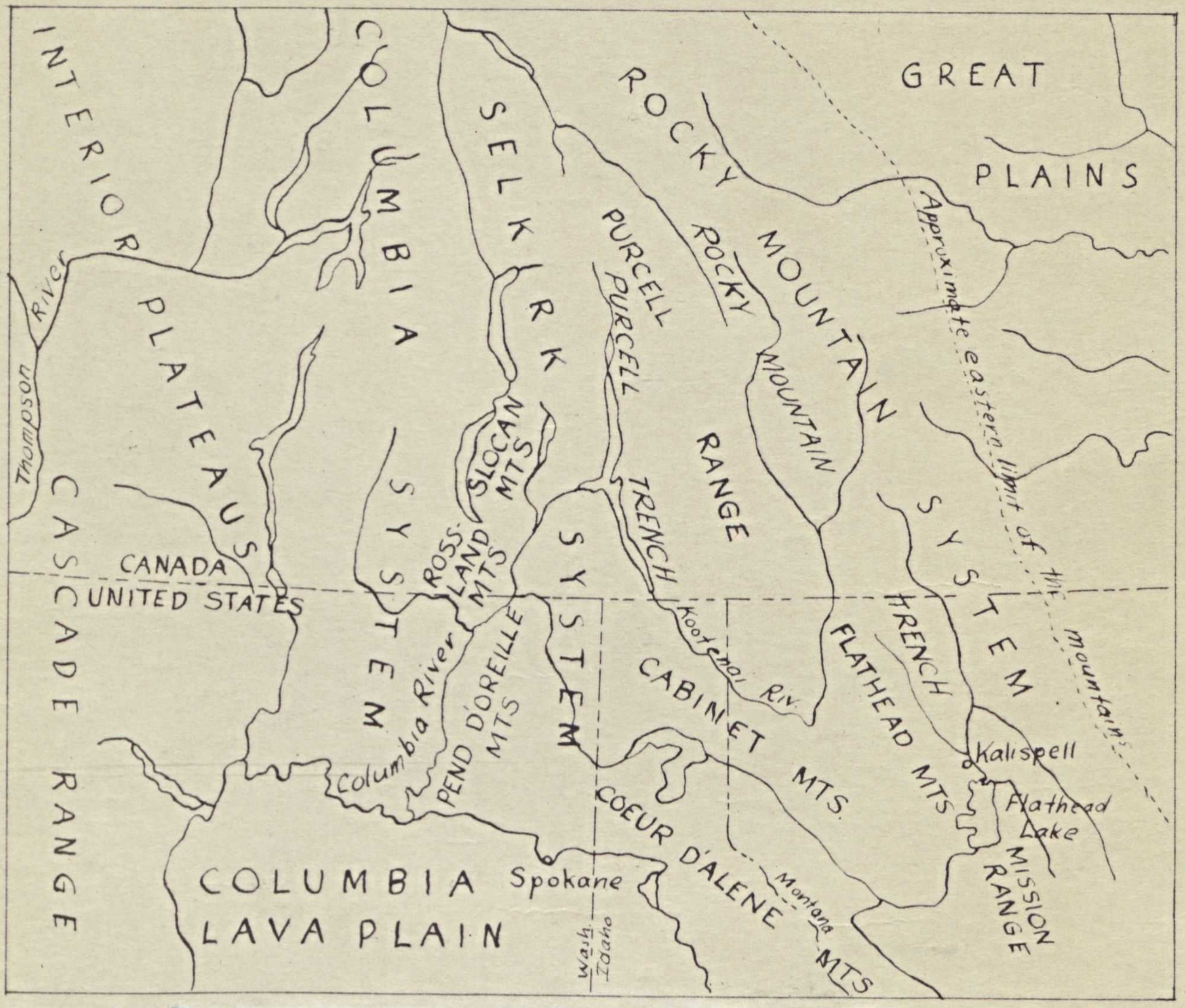

Figure 1.--Physiographic provinces between the 47th and 53rd parallels of latitude (After Daly)

The Purcell Trench

The more western depression, named by Daly the "Purcell trench", joins the Rocky Mountain trench about 200 miles north of the international boundary, and is considered by him as terminating at the south near Bonners Ferry.

But Calkins (5: p. 11) thinks it more reasonable to consider it as extending at least to the southern end of Lake Coeur d'Alene, about 80 miles south of Bonners Ferry.

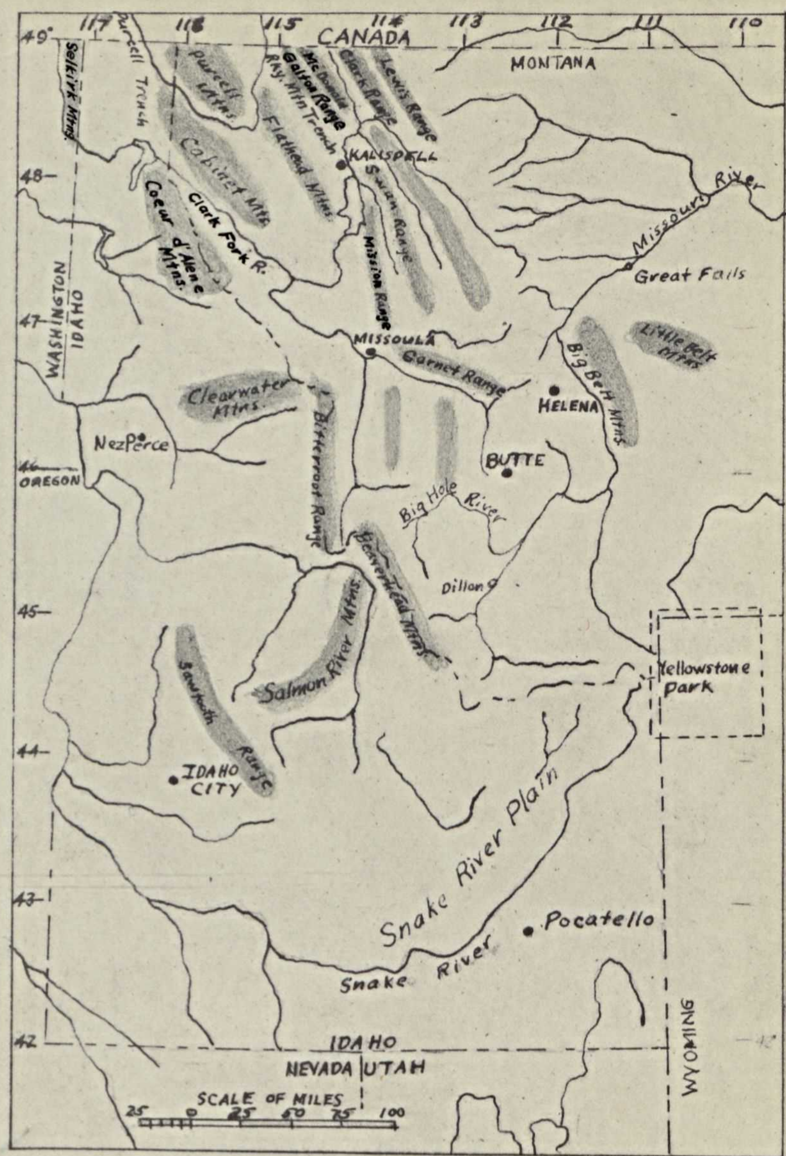

Figure 2 .--Index map of the Northern Rocky Mountains.
(After map drawn by Guy-Harold Smith)

The Mountain Systems

Each of the three orographic divisions marked off by the Purcell and Rocky Mountain trenches is distinguished by certain broad characteristics, which may be described briefly. There has been some confusion in dividing this great mountain area, and in naming the several parts. Daly's system of nomenclature has been generally followed except in the use (in the United States) of the term "Rocky Mountains."

Rocky Mountain System.- (Daly) The eastermost of these divisions is that designated by Daly as the Rocky Mountain system, and is described by him as lying between the Great Plains and the Rocky Mountain trench. The term "Rocky Mountains", however, is more generally interpreted in the United States to include the whole system of mountains from Alaska to Mexico, limited on the east by the Great Plains and on the west by the Great Basin and the Columbia Plain. At any rate, the area between the Great Plains and Daly's Rocky Mountain trench is characterized by a development of the principal streams chiefly in a longitudinal direction, which south of the forty-ninth parallel is about north-northwest. In consequence of this the belt consists of a number of overlapping ranges having the same direction, the principal ones being the Lewis, Livingston, and Galton, near the international boundary, and the Kootenai, Mission, Swan, and Flathead ranges farther south. The topography of these ranges is generally bold, and elevations of 8,500 to more than 10,000 feet are attained by many of their peaks. Daly does not include the Mission Range in the Rocky Mountain system; his map (fig. 1) shows this range as separate from the larger division on the east, although it would seem to be a part of it.

Mountains Between the Two Trenches.- The next great division to the west, lying between the Rocky Mountain and Purcell trenches and comprising the Coeur d'Alene, Cabinet, Flathead, and Purcell mountains, has a less strongly accentuated relief than Daly's "Rocky Mountain system." Except in a part of the Cabinet Range, few of its peaks surpass 7,500 feet, and on the whole only a small proportion of its summits attain 7,000 feet. The more important stream valleys, in contrast to those of the eastern zone, have an average direction of about west-northwest, and it is these streams that form the boundaries between the chief subdivisions worthy to be distinguished by separate names. (Calkins, 5: p. 12)

The Selkirk System.- The great orographic division immediately west of the Purcell trench is designated by Daly as the Selkirk system. As defined by him it is bounded on the west by a section of the Columbia River valley having a nearly north to south direction, and on the south by the Columbia Plain. Calkins believes that the latter part of Daly's definition is hardly adequate, and that it leaves one in doubt as to just how far south the Selkirk system should be considered to extend. He would consider the Selkirk system as gradually tapering to an end somewhere near the southern end of Lake Coeur d'Alene. It would thus include a group of hills lying south of Spokane River between Spokane and the lake. (5: pp. 12-13)

The topographic character of the Selkirks is in general similar to that of the mountains between the Purcell and Rocky Mountain trenches. Near the boundary they are moderately rugged and attain heights of nearly 7,000 feet, but south of Spokane River they are gently rounded and few of their summits rise higher than 5,000 feet above sea level. The major drainage lines north of the valley of Clark Fork of Columbia River trend north and south, but in the southernmost part of the system they trend nearly east and west. (5: p. 13)

For more detailed descriptions of the topographic characteristics of the major ranges and valleys, the reader is referred to F. C. Calkins' "A Geological Reconnaissance in Northern Idaho and Northwestern Montana" and to Fenneman's "Physiography of the Western United States." Some of the major valleys will be described in greater detail later in this report, but little further mention of the ranges will be made.

SUMMARY OF THE HISTORICAL GEOLOGY OF THE NORTHERN ROCKY MOUNTAIN PROVINCE

General Statement

One of the prime difficulties of a report of this sort seems to be that of giving each area its proper weight and emphasis. At one point it seems necessary to give the reader a picture of a broad, general area. At another point it seems necessary to give detailed accounts of one area and to almost completely neglect another. The former circumstance is perhaps obvious. The latter is due to the fact that much has been described about some areas and little or nothing about others, and also that the scope of this report prohibits detailed discussions of some regions which are of secondary importance, even though they may be of interest to the reader.

It seems proper that the historical geology, particularly the physiographic history, of a broad area should be given in general terms, and this discussion follows. It is largely taken from a chapter on the Northern Rocky Mountain Province in Fennemen's "Physiography of Western United States."

Fennemen states that, "In that part of the Rocky Mountain System that lies north and west of Yellowstone Park and within the United States... ... neighboring divides are in general of nearly uniform height. In a wide view so many of these crests fall into nearly the same plane that the sky line in many cases is almost horizontal though the valleys may be very steep and from 1,000 feet to a mile in depth. Recent faulting or differences in rock structure or unequal erosion may cause one divide or peak to rise above its neighbors, but the uniformity is more striking than the exceptions. The larger part of the area looks like an approximate peneplain raised to a level from 6,000 to 9,000 feet above the sea and sharply dissected almost or quite to maturity.

"Montana has a dozen or more Tertiary lake basins and its mountains are thus divided into more or less circumscribed patches sometimes loosely spoken of as ranges."

Mountains of Idaho

The Mountains of Idaho are in several ways the most typical representatives of the Rocky Mountains north of Yellowstone Park. Here the distinctive characteristics, the accordance of crest levels, deep dissection, and the lack of linear ranges are seen in their best development and over the largest area. Here also is the largest area underlain by rocks almost uniformly resistant. Moreover, much of the previous work that has been done on the area discussed has been carried out in the mountains of Idaho. (11: pp. 185-186)

The northern limit of the area to be described under this heading is arbitrarily set at the Clark Fork. Those portions further north will be discussed under the title: "Mountains of the Canadian Border".

Rocks.- Twenty thousand square miles of this area are the exposed surface of a great granite batholith, structureless except for local development of foliation (11: p. 186) The northern end of the area consists mainly of the rocks of the Belt series, very thick and almost uniformly resistant. There are minor areas of undifferentiated pre-Cambrian, and also of lavas. The rocks of the southeastern part of the area are folded and metamorphosed Paleozoics and some Mesozoics. Fennemen states that, "Erosion here has been so conditioned by structure that definite northwest-southeast ranges have resulted. Elsewhere valley cutting has been about as easy in one direction as another."

Several long troughs in Idaho and Montana are due to structural causes, though the country has since passed through at least one erosion cycle and the present valleys are mainly erosional. The origin of some others of these basins is undetermined. A few seem to be satisfactorily explained by erosion alone, but the nearly uniform character of the rocks limits the application of this explanation. (11: p. 192)

Order of Events.- The intrusion of the Boulder Batholith and the elevation both of it and of the rest of the region preceded any land forms now in existence. The main point at issue in regards to the succeeding course of events involves the question as to whether the peneplain was made before the existing basins or later. The first assumption is the older and perhaps more common. On this assumption the order of events was as follows: (11: p.193) (1) The region was uplifted before any existing land forms were made. (2) It was reduced by erosion to low relief (3) The peneplain was elevated, much as at present, and dissected by the present valleys. Whatever marginal flexures or faults now outline the mountain province were made presumably during this elevation though possibly started earlier. (4) Floods of lava built the Columbia Plateau on the west, damming the outflowing rivers, and causing lakes in which sediments were deposited. (5) In time the streams carved gorges in the lava plateau, again lowering their downstream courses. (6) Most of the deposits made in the mountain valleys during the interruptions were cleaned out, and erosion of the bedrock again started. (7) An extensive period of glaciation occurred during Pleistocene time. (8) In post-glacial time the glacial debris has been largely removed, and erosion of bedrock is again in progress.

It is primarily the Miocene age of the sediments filling the large valleys and basins which leads to the assignment of the peneplain to Eocene by this theory. This conclusion is also supported by the Miocene lavas filling the valleys of the Columbia Plateau.

The opposing hypothesis, that is, the idea that the broad valleys and basins were formed before the peneplain, is supported by Blackwelder (3:pp. 410-414) who has established the following succession of events: (1) that the broad valleys, whether formed by erosion or by faulting and folding, were formed before the peneplain, (2) that the valleys were filled with weak Tertiary sediments, (3) that the peneplain was developed on all rocks, strong and weak alike, and (4) that erosion after uplift has revealed the old valleys. Block-faulting accompanying the uplift could account for the abrupt "dead-ends" to many of these wide valleys. According to this hypothesis the age of the peneplain is probably Pliocene.

The controversy is discussed by Mansfield (14: pp.472-487). He does not make a final decision, but thinks that the latter hypothesis best fits the southeastern Idaho area.

Fennemen (10: pp.194-196) says of the two hypotheses, "....no dogmatic decision is now possible, but evidence in favor of a Pliocene peneplain, at least in the southern part of the mountain area, continues to accumulate. The disagreement would be much reduced by assuming that the divides in northern Idaho represent an older peneplain than the one recognized farther south. It is in northern Idaho that the (presumably) Miocene lavas of the Columbia Plateau invade the mountain valleys like an encroaching sea, affording the strongest evidence for the greater age of the mountain topography."

Mountains of the Canadian Border

The Tertiary Peneplain.- Evidence of an old peneplain is not obvious in the mountains of the Canadian border. In particular, the mountains near the eastern margin (Clarke and Lewis Ranges) exhibit no evidence at all of an ancient peneplain. It could be readily assumed that near the eastern margin uplift was unequal and that all vestiges of the peneplain have been destroyed. In fact, most geologists assume that such a peneplain did exist, since, "with respect to accordance of summit levels, this area is part of a vast region extending far to the south where the hypothesis of peneplaining is satisfactory and no other has been considered." (Fennemen, 10: p.204) Also, in those mountains west of the Rocky Mountain trench evidence of an old peneplain is not entirely lacking.

Alpine Glaciation.- In those mountains east of the Rocky Mountain trench, faulting and alpine glaciation have produced mountains of extremely rugged topography and high relief, while in those mountains farther to the west the features due to alpine glaciation occur only on several of the higher peaks. Those principal higher mountains west of the Rocky Mountain trench which did carry alpine glaciers are the Cabinets, the Coeur d'Alenes, and the Selkirks.

Rocks and Structure.- The strongly metamorphosed beds of the Belt series east of the Purcell Trench are moderately folded and closely faulted along north-south lines. From the Purcell Trench almost to Clark Fork (just west of the Idaho-Washington boundary) the closely compressed and highly metamorphosed Paleozoic rocks are almost vertical, and north-south faults are not evident. West of that, abundant intrusives and volcanic rocks have complicated or obscured the folding so that outcrops are in irregular patches instead of north-south belts.

Mountains of Southern Montana

The mountains of Montana south of latitude 47 degrees (south of Missoula) are divided into relatively small masses, mainly by large Tertiary basins. The rocks lack the uniformity observed farther north and west, being of all ages from pre-Cambrian to Tertiary. In practically all of these ranges accordance of summit levels is prominent, although some carry peaks or ridges that were never reduced. (11: p. 213)

Tertiary Basins

Tertiary lake beds exist throughout the Northern Rocky Mountains. Located among mountains with an average height of 6,500 to 7,500 feet, the floors of these valleys are generally from 3,000 to 5,000 feet in elevation. In width they range from a mile up to 10 or 15 miles. The lower parts of all contain Tertiary sediments, frequently Oligocene at the bottom. Miocene is generally represented, with some Pliocene. In general these beds are either horizontal or dip but slightly. They are often covered with Recent stream gravels or Pleistocene glacial till. In particular, those valleys north of the Clark Fork have thick glacial covering, and Tertiary outcrops are rare. Their origin dates from that last great period of block-faulting and lava flows, supposedly beginning in late Eocene time, when rivers were blocked, and interior drainage was widely developed.

PREVIOUS WORK REGARDING DRAINAGE MODIFICATION

The following paragraphs will include, first of all, brief discussions of those papers by other writers who have described drainage modification in Montana and Idaho. This resume includes, so far as is known, all those areas which have been described to date. It appears that only three major regions have been described in regards to drainage modification. These are: The Salmon River area, Southwestern Montana, and Northern Idaho.

The Controversy of the Salmon River Area

Shenon (18: pp. 4-5), in a review of previous work by Umpleby, Atwood, and Kirkham states his belief that, "An ancient drainage once existed, and that an old stream occupying Lemhi Valley flowed southward by way of Birch Creek to join the Snake River near Idaho Falls." This idea is in accordance with those of Umpleby and Atwood, and is in discordance with the views of Kirkham and Anderson. Umpleby (19: p. 30) suggested the southward course of the old drainage, and Atwood (2: pp. 706-721), after making a particular study of this drainage in Western Montana and eastern Idaho, reached the same conclusion. Kirkham (13: p. 11) has studied the problem in southeastern Idaho, and believes part of the ancient drainage flowed northward. On Birch Creek he advocates a drainage divide just south of Kaufman. Shenon states that after careful review of the literature pertaining to the subject he favors the view of Umpleby and Atwood. Shenon further says:

"There is, however, some contradictory evidence against a southward flowing drainage system. Several re-entrant valleys in Little Lost River and Pahsimeroi Valleys have a decided northward trend. Kirkham has used this as evidence of an old northward flowing drainage. Broader evidence apparently fails to support this conception. The gravels of Pahsimeroi Valley have not been traced farther north than the Salmon River, and there is no evidence of a channel to the northward. A southward drainage, as postulated by Atwood, seems to be in accordance with the distribution of the ancient gravels, and also more satisfactorily explains the peculiar course of the Big Hole River of Montana." Umpleby believes the ancient valleys, such as the one through which Birch Creek now flows, were developed in a peneplain of Eocene age by stream erosion. Atwood assumes the same age for the peneplain, but stresses warping and faulting in explaining the development of these valleys.

In a more recent report, Anderson (1: pp. 61-75), on the evidence of headwater trends, aligned wind gaps, and the distribution pattern of Tertiary volcanics across block mountains, reasoned that the Salmon River drainage extended far to the northeast, probably to the Missouri River, in ancient times. He believes that that portion of the Salmon River now flowing westward had an eastward flowing history. In regards to the northward flowing portion, he supports the view of Kirkham and states, "Diversion of Salmon River to the west side of the state apparently resulted from capture by headward erosion of a vigorous stream from the west as a consequence of crustal disturbances during late Tertiary and early Quaternary time. Diversion of other streams into northwest-southeast structural basins between block-faulted mountains probably took place at about the same time. By reason of these diversions the Continental Divide has been shifted about 100 miles east of its location in late Tertiary time."

No attempt will be made here to give an opinion on this controversy, the object being merely to present all known opinions on drainage modifications within the area being discussed, and to point out that differences of opinions are commonplace.

Southwestern Montana

In southwestern Montana Perry discusses two ancient drainage systems. (17: pp. 6-8) The first of these "has been so obscured by uplift, valley cutting, and valley filling, that little is known about it."

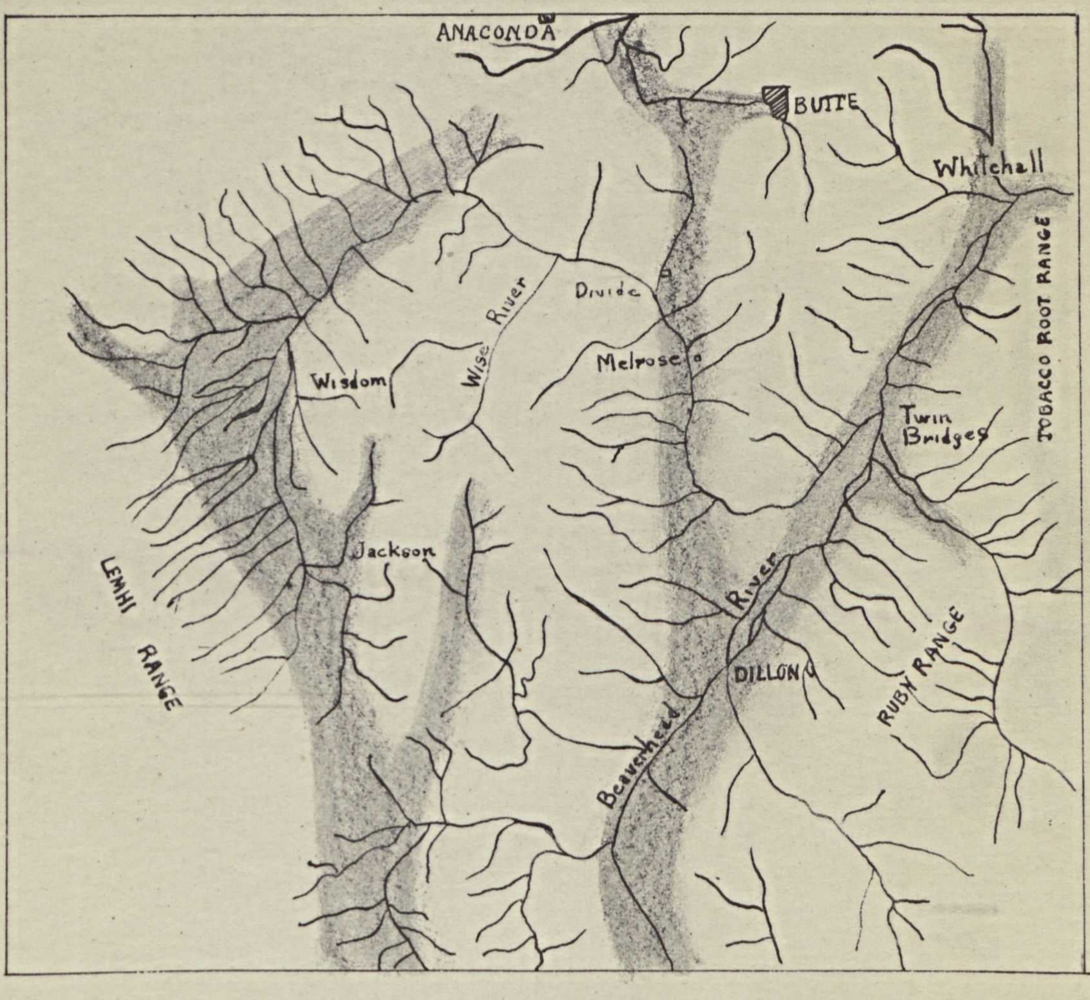

Figure 3.-- Map showing relation of Big Hole River to ancient valleys the trends of which are shown by shading. (After Perry)

The principal evidence of the older drainage "is the presence of ancient river gravels in many places on high mountain ridges 7,000 feet or more in elevation."

Perry further states: "The second river system is better known.

The general pattern is shown (1) by the trends of certain wide valleys, (2) by many high well-developed remnants of old erosional surfaces which merge into the surrounding mountains with broad sweeping curves, and (3) by extensive areas of lake beds which were laid down in parts of the valleys after damming." Perry proposes a southward drainage, as shown on Figure 3., during much of early Tertiary time.

Northern Idaho

Anderson (la.: pp. 1-29) describes changes in drainage that were produced in Northern Idaho, and the immediately adjoining area in eastern Washington, by flows of basalt in Miocene time and by glacial advances in the Pleistocene. "A restoration of the pre-basalt surface features evidences that the whole drainage of the area was southward and westward--that Priest River, Clark Fork, and St. Joe River followed the Spokane Valley until obstruction by the advancing flows of Columbia basalt from the west caused the deposition of the clays and shales of the Latah Formation in eastern Washington and the deflection of these three rivers northward through the Purcell Trench."

Essentially, the effects of Pleistocene glaciation were to produce the drainage features which exist today. A more detailed description of the effects of glaciation follows.

GLACIATION

General Statement

The traces of the two great Canadian glaciers, which Davis has called the Kootenai-Flathead and the Kootenai-Pend Oreille glaciers are easily followed southward from Canada along the Purcell and Rocky Mountain trenches into the Flathead and Pend Oreille troughs. The paths of tributary glaciers may be traced back into the higher mountains adjoining the great depressions.

The eastern depression is associated with the strong glacial features of Glacier National Park.

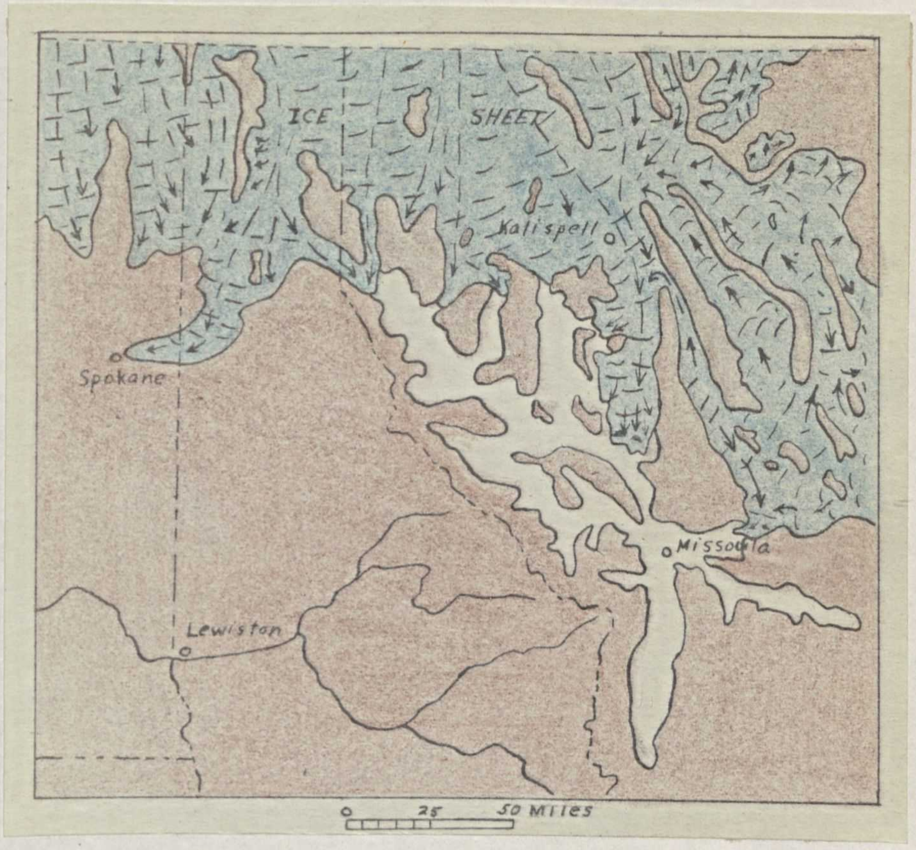

Figure 4.--Glacial Lake Missoula hemmed in by a barrier of ice to the north. (After Pardee)

The traces of the eastern or Kootenai-Flathdad glacier cover a greater breadth and also extend somewhat farther south than the Kootenai-Pend Oreille glacier.

Northern Idaho

Anderson presents evidence of an early ice advance in Pleistocene time, coming from the north and passing down the Rathdrum (between lakes Coeur d'Alene and Pend Oreille) and Spokane valleys. As temporary features of the ice advance, which is believed to be of Spokane age, were Lake Spokane, with outlet through the Mica Spillway, and Greater Lake Coeur d'Alene, a great body of impounded water with a maximum depth of about 700 feet, and extending several dozens of miles into the mountains. This glacier, which Anderson calls the Rathdrum lobe, left an immense thickness of glacial fill and outwash on its retreat and caused the drowned-valley lakes which border Spokane and Rathdrum valleys. At the same time, Anderson believes, the St. Joe system was restored to its pre-basalt course through the Spokane valley and that Spokane Falls and Post Falls are results of this readjustment. The Clark Fork likewise became established in its present course across the State.

Evidence of a much later ice advance from the north, less extensive than the earlier advance and of the valley-glacier type, is also presented. This advance is possibly of Wisconsin age and explains the origin of Pend Oreille and Priest Lakes.

Two advances of the ice are recorded in the region, one an older extensive lobe from the north which joined the Spangle lobe described by Bretz (4: pp. 573-649, 1a: pp. 646-7), who assigned the ice to Spokane age, and another much younger but less extensive advance assigned to the Wisconsin epoch by Anderson.

The Spangle lobe of the Spokane advance, as described by Bretz, moved from the north along the west side of the Selkirks, blocking the Spokane Valley a few miles east of Spokane, crossing the valley of Latah Creek, and leaving its terminal moraine on the basaltic plateau near the towns of Spangle and Medical Lake.

Anderson describes the Rathdrum Lobe as coming from the north, following the Purcell through the Rathdrum and Spokane valleys to its junction with the Spangle lobe a short distance east of Spokane. "All the topography in the upper Purcell Trench north of Sandpoint, with the exception of the highest peaks, bears evidence of ice erosion. The ice must have had a maximum thickness in places of more than 4500 feet." Coeur d'Alene Lake owes its origin to a glacial gravel and sand dam deposited across the mouth of the valley at Coeur d'Alene city during this earlier advance. The configuration of the lake bears every resemblance to a drowned river valley, and shows that it was never occupied by an ice lobe.

A long interval of time existed between the Spokane ice advance and retreat, and the later advance in Wisconsin time. The later advance was not extensive and did not pass far southward. The south end of Pend Oreille marks the beginning of its terminal moraine and represents the fartherest advance.

The Rocky Mountain Trench

A great lobe of the Canadian ice sheet extended down the Rocky Mountain trench. Two advances are recorded by Davis, who has called this lobe the Kootenai-Flathead glacier. (9: pp. 75-147) The southern limits of this glacier are marked by two great terminal moraines, "one strong and fresh looking--the other farther south and of softer contours, in the southern part of the Flathead trough." Inside the younger moraine, called by Davis the "Polson moraine", lies the existing Flathead Lake. The older and more southern moraine has been called by Danis the "Mission moraine". The distance between the Polson and Mission moraines is about 20 miles. In an earlier report Davis (9a.: pp. 267-288) has described the evidences of glaciation on the western face of the Mission Range. He tells of a "middle Belt" characterized by a normal erosion surface, a low normal belt showing evidence of severe scouring by a "great glacier of Canadian origin", and a high southern belt exhibiting effects of normal stream erosion together with mountain glaciation.

Elrod (10) says that the moraine at the foot of Flathead Lake is 450 feet above the lake. It extends from the Mission mountains on the east to the Cabinets on the west. At the time this moraine was formed the outlet of the lake was through the arm at Wild Horse bay, and through the present Little Bitterroot river.

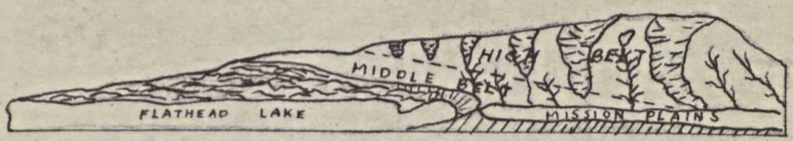

Figure 5 .-- Diagram of Mission Range, Montana, looking east. (After Davis)

A large amount of water caused the lake to rise unusually high until it overflowed the moraine. The cutting was rapid, resulting in a lower lake level and a new outlet.

The Clark Fork Valley

Davis describes an invasion of at least part of the Upper Clark Fork valley by a distributary of the Kootenai-Pend Oreille glacier. (9: pp. 75-147)

For the first 60 miles southeast of Lake Pend Oreille, the valley of the Clark Fork has a width of from two to five miles; its floor is heavily covered with drift deposits which are frequently trenched and terraced by the river. Davis says that a short stretch of valley upstream from Pend Oreille lake has been glaciated by the Kootenai-Pend Oreille glacier. A longer stretah of 30 or 40 miles upstream was not examined closely enough by him to determine whether or not this arm of the great glacier projected farther upstream. Indisputable evidence of glaciation is in the form of a broad moraine that occupies the valley at Thompson Falls, and Davis observed that no open entrance from the north exists.

Near Plains some low hills were interpreted by Davis as being moraines. The valley here opens to the north and suggests to him a probable source for the glacier which deposited this moraine, and also those moraines at Thompson Falls and Camas Creek. In a statement regarding the basin-like expansions of the valleys at and above Thompson Falls and Plains, Davis says that he "had no means of determining whether....they are normally eroded excavations in areas of less resistant rock, or small fault troughs...."

At Camas Creek, 13 miles above Paradise, a lateral moraine forms a well-defined embankment several hundred yards in length and 500 to 600 feet high. This moraine surmounts a low ridge of inclined and scoured ledges on the north side of the valley opposite Perma. According to Davis this moraine did not come from the north, but rather from the direction of Plains.

Glacial Lake Missoula

Horizontal beach terraces are well shown at Missoula, in the Jocko Valley at Plains, below Trout Creek, in the valley of Clark Fork, and also in the Bitterroot valley. These terraces give evidence that a large continuous body of water occupied these valleys in the recent geologic past. Because of the excellent development of the beaches on this lake at Missoula, it has been named Lake Missoula.

When the beaches are traced northward and westward, they are found to terminate just in front of the southernmost extent of the great glacier that came down from the north. As the beaches thus show a definite relation to the ice front, and as they seem to correspond in time with the glacial epoch, it seems probable, if not certain, that Lake Missoula was due to the damming of Clark Fork by the ice. All evidence points to the conclusion that the main valley of the Clark Fork in the vicinity of Pend Oreille Lake was effectively blockaded by the ice, and that the low valleys to the north were shut off as avenues of escape for the waters of the upper valleys. (6: pp. 134-135)

THE MAJOR VALLEYS OF NORTHWESTERN MONTANA AND NORTHERN IDAHO

Flathead Valley

The Rocky Mountain Trench extends 800 miles northwestward from Flathead Lake, and is drained by eight different streams. Alternate streams flow northwest and the others southeast. The depression can be followed, not so continuously, down the Flathead River valley, through the Jocko River valley, and into the Bitterroot valley. The Kootenai River in its southward course occupies the trench at the international Boundary.

The valley of Flathead River is an extensive trough, measuring from 12 to 30 miles in width and is evenly filled over most of its extent. South of Flathead Lake it continues as a wide, flat valley as far south as St. Ignatius. The valley narrows here where the river makes a sharp bend to the west.

Following the Flathead downstream, near Perma the river turns left and cuts a narrow canyon through the ridge which bounds the valley on the left. In this part of its course the Belt series is cut by many dikes and sheets of igneous rock (diorite), showing that at one time there was considerable disturbance in the region.

Below Perma the canyon is deep and narrow, and its walls are very precipitous. The walls rise 1,500 to 2,500 feet above the valley floor.

The Jocko River Valley

The Jocko River valley, with its mouth at the elbow of Flathead River, follows a wide valley throughout most of its length. Between its mouth and Ravalli the valley is narrow, but the hills are smooth and comparatively low. Upstream from Ravalli, towards Missoula, the valley is broad and flat, and the mountains to the east, though not as high as the Mission Range, are steep and rugged, towering above the valley to the height of several thousand feet. (6: pp. 137-140)

Following the Northern Pacific route between Evaro and DeSmet, near Missoula, the valley is gulch-like in character. The summit of the pass near Evaro has an elevation of nearly 4,000 feet, as compared to an elevation at Dixon (the mouth of Jocko River) of 2,531 feet.

The Clark Fork Valley

One of the most striking features of the valley of Clark Fork is the fairly regular succession of narrow canyons and broad valleys. For several miles east of Pend Oreille Lake the bottom lands are broad, and terraces at various levels up to about a thousand feet above the river are extensively developed as far east as Smeads Crossing. There the valley is somewhat constricted, but broadens eastward and becomes several miles wide at Thompson Falls. Between this expansion and another known as Plains there is an imposing gorge, with cliff-like walls on either side. Above Plains, also, the sides of the valley are rugged, steep, and close together, until they subside and separate in the gently rolling country of the Flathead Reservation. (5: p. 18)

The Kootenai-Pend Oreille Depression

If Calkins' extension of the Purcell Trench is used (5: p.2), then the terms Purcell Trench and Kootenai-Pend Oreille Depression could be used interchangeably within the area described. However, the latter term, used by Davis (9), is more restrictive and will be used here.

The Kootenai-Pend Oreille Depression is from three to five miles wide at the Canadian border and decreases to a narrow valley about a mile wide a few miles south of Bonners Ferry, but widens to ten miles near the town of Sandpoint. South of Sandpoint the depression is neither so regular nor so definitely bounded as it is northward. Hills on either side are lower than to the north, and are broken by several valleys. Three valleys exist to the south of Sandpoint, each of which merges with Rathdrum Valley still farther south.

No large streams occupy the Purcell Trench between Bonners Ferry and Sandpoint, though the present Valley would indicate a large stream. Chamberlain (7: pp. 7-8) states that at one time a major stream did occupy the valley. Deep Creek and Pack River are separated by a low divide of glacial debris at 2,253 feet elevation, and Davis (9: pp. 103-4) suggests that a glacier stood for a considerable time near the Elmira divide.

Kootenai Lake, beginning 18 miles north of the international boundary and lying in the Purcell trench, occupies the deepest part of one of several almost mature glacial troughs, overdeepened by the great trunk glaciers of a number of recently extinct glacial systems. The troughs follow the main valleys of the Selkirk mountains. The lake is 65 miles long and two to three miles wide. It is said to have been sounded to a depth of 800 feet, and its surface stands 1,760 feet above sea level, while the adjoining mountainous highland has summits that reach elevations of 8,000 feet and more. After Kootenai river enters the trough from the east, it turns sharply to the north and flows to the lake over a delta plain some 30 miles in length.

The Kootenai River Valley

The Kootenai river, following the Rocky Mountain trench southward, turns southwestward just after crossing the international boundary. Dividing the Purcell Mountains to the north from the Cabinet and Flathead Mountains to the south, it flows into the Purcell Trench and eventually into the Columbia some distance beyond the Canadian border.

The valley of Kootenai River east of Bonners Ferry, Idaho is markedly different in character from that in the Purcell trench. The part lying within the United States is nearly all narrow as compared with the Purcell trench, and for most of the distance between Gateway and Bonners Ferry the waters of the stream flow swiftly between steep rocky banks. The canyon walls do not rise everywhere to a great height, for a broad terrace, partly cut in rocks and partly built of gravel and sand, is generally developed at a height of several hundred feet above the river. From Libby to the east side of Lake Creek valley, however, the slopes rise steeply from the water's edge to a height of several thousand feet, and near the middle of the gorge thus formed there is a low cataract in the river. Where the broad valleys of Lake Creek and Libby Creek enter from the south, there are expansions which afford room for the towns of Troy and Libby. (5: pp. 17-18)

THE RECONSTRUCTED DRAINAGE PATTERN

General Statement

When the study of this problem was begun, it was believed likely that a normal or nearly normal drainage pattern was developed on the extensive peneplain formed after the Laramide orogeny and before the more recent period of block-faulting. The age of this peneplain is somewhat in dispute (see pp. 6 and 7), and therefore the age of this proposed drainage pattern would be in dispute.

Furthermore, it may be presumed that some of the major river valleys were able to cut through obstructions, and therefore persist during the period of renewed mountain building during late Tertiary time.

With these facts in mind, all the major valleys and tributaries in the area were indicated by outlining on a map all known, exposed, Tertiary and Quaternary sedimentary deposits of western Montana, Idaho, southeastern British Columbia, and southwestern Alberta. (Refer to Plate I). These major valleys and tributary valleys were then integrated into what seemed to be the most logical, ideal drainage pattern.

Most of those valleys tributary to the Upper Clark Fork River present a normal barbed pattern, and if the direction of flow of this river should be reversed and projected southward through the valley of either Ninemile Creek or Jocko River, it would unite with the southward flowing portion of Flathead River in a normal manner.

It would not be unreasonable to assume a southward drainage on the peneplained surface of this area; it is a well-known fact that the northern part of Montana has witnessed a greater magnitude of uplift than the southern portion. This is evidenced by complete stripping of all Paleozoic rocks in northern Montana, and the incomplete stripping in southern Montana, coupled with the fact that the thickness of Paleozoic rocks was at least as great in th e northern part as in the southern. This, of course, is not held to be conclusive evidence that the northern section actually was higher in elevation than the southern during Tertiary time, but is rather submitted as being suggestive.

Further and more direct evidence that greater uplift occurred in southern Montana is described by Fennemen. (11: pp. 197-198)

"Anywhere in this great area (the mountains of Idaho, excluding the Bitterroot Range) the major crests within a single broad view are of sub-equal height, indicating that before the cutting of the valleys the whole region was one of small relief. With proper reservations, this former surface may be called an upraised peneplain.

"Despite the accordance of neighboring crests, the restored surface, i.e., approximately the level of the ridge tops, is not level but warped. The altitude of the crests is greatest in the southeastern part near the Montana boundary in latitude about 44 degrees 30 minutes. The greatest up-warp is along an east-west axis continuous at the east with the Centennial Range (the east-west portion of the Idaho-Montana boundary) and extending westward into Oregon, crossing the Snake River at the place where the Columbia Plateau is highest and the canyon deepest.

"From southeastern Idaho where the crest level is 10,500 ft., the level declines both north and south. In 50 miles to the north it falls 2,000 ft., the altitude being 8,500 ft. in the vicinity of Salmon near where the Salmon River turns westward from its northerly course. It continues to decline northward in the Clearwater Mountains where it is little above 7,000 ft. even on the east side." Elevations of the old erosion surface also decline towards the west.

This brief outline is the basis on which the drainage modifications are here proposed. As mentioned before this idea is presented only as an hypothesis. Those areas which the author believes will require extensive field work in order to prove or disprove the hypothesis will be discussed in later paragraphs.

Proposed Modifications

The Eocene (?) drainage suggested here (Refer to Plate II) in many places traverses several areas of which little or nothing is known by the writer. It would be desirable always to trace the old drainage only through areas where wide terraces or valleys are known to exist. Unfortunately this cannot be done for this report, and therefore in some cases streams will be projected in one direction while they might better have been projected in another.

The Kootenai River.- In Canada the Kootenai River is carried southward through its present valley and in its present direction. At the confluence of the Tobacco and Kootenai rivers there are two possible courses. It could be continued further down its present valley; or it could be projected southeastward up the valleys of Tobacco River, Fortine Creek and across divides into Wolf Creek, Fisher River, and Lynch Creek, and then into the Clark Fork. The topographic character of none of these divides is known, and would have to be examined in the field. The latter course of the Kootenai was selected by the writer, rather indefinitely, because of the existence of the wide valley of Fortine Creek which would be discordant to the other possible direction of the Kootenai, and which is, incidentally, discordant to its present course. The wide valley near Plains is directed toward the valley of Fishtrap Creek and could be a possible point of junction of the Clark Fork and "old" Kootenai rivers.

The Clark Fork River.- When the major valleys connecting with Clark Fork (as indicated by the beds of Quaternary sediments, PlateI) are examined, it will be seen that they make a barbed drainage pattern with the present northwestward flowing Clark Fork. Also, that small portion of the Clark Fork now flowing eastward just below the mouth of the St. Regis River, together with the St. Regis River itself, make a barbed pattern with the present day westward flowing portion of the Flathead River. And further, the sharp bend of the Flathead River at Dixon does not present the type of pattern which would be developed by an adjusted river. This almost complete absence of adjustment of the major tributaries of the Clark Fork gives some evidence, at least, of a former southeastward-flowing course of the Clark Fork.

Near Paradise, where the Clark Fork and Flathead rivers join, the old drainage is continued on to Dixon and then southward through the Jocko River valley. It is possible, however, that it flowed into the Broad valley of Ninemile Creek. The divide between Ninemile Creek and the Kootenai River should be examined in the field for terraces or wind gap, which, if found, might indicate a drainage in this direction.

An essential condition for the suggested southward flow of the several rivers so far mentioned involves the topographic character of that divide separating the Jocko and Clark Fork Rivers, that is, the divide between Evaro and Missoula. The volume of water which would have flowed over this area would necessitate the former existence of a wide valley through here. Possibly field evidence could prove the former existence of such a valley. The description of the Jocko River valley given earlier (see p. 15) shows that a wide valley does exist throughout most of the length of the Jocko River, but more should be known about the divide between Evaro and Missoula.

With the elevation of Evaro being 3,971 feet, and the elevation of Cabinet just west of the Idaho-Montana boundary on the Clark Fork being 2,173 feet, a differential uplift of the Evaro area in the magnitude of 1,800 to 2,000 feet would be required to produce a reversal of drainage of the Clark Fork since Eocene(?) time. There is suggestive but inconclusive evidence that this occurred.

Campbell mentions some facts in regards to the shore lines of Glacial Lake Missoula. (6: pp. 135-136)

"A number of facts now known indicate that many modifications may be necessary when the final history of the lake is written. The most difficult to harmonize with the theory given (p. 16) is the difference in the height of the beach lines in the several valleys. Thus at Stevensville, in the Bitterroot Valley (about 25 miles south of Missoula), they extend up the valley wall to an altitude of 4,200 feet; north of Dixon beach lines are well developed up to 3, 950 feet; at Plains they can be traced up to an altitude of 3,100 feet, but above that level the hills break away and it seems certain that the uppermost terraces are not represented; near Trout Creek they apparently cease at 3,500 feet; and on St. Regis River no beach lines have been found, but extensive terraces that probably record the height of the water and should be correlated with the uppermost beach lines in other valleys, are well developed at Haugan and Saltese, at an altitude of 3,450 feet. It is true that some of these altitudes have not been accurately determined, but there seems to be a gradual decrease in the altitude of the terraces toward the northwest that indicates a depression of the earth's crust in that direction since the beaches were formed, or a rise in the surface toward the southeast. Such a movement is also indicated by the recent canyon cut by Clark Fork between Missoula and the Mouth of the St. Regis River". In regards to the Trout Creek area, Campbell says: "Beach lines can be identified up the slopes to a height of 1,200 feet above the river, or 3,500 feet above sea level, but beyond that height no trace of such markings has been found. The uppermost beach line here probably corresponds with the highest oen observed near Missoula and Dixon and as these beach lines were formed by the same body of water, it is almost certain that the crust of the earth has been tilted since the disappearance of the lake, the surface about Missoula having been raised 1,000 feet above that at Trout Creek."

If it is true that the area near Missoula has been uplifted 1,000 feet more than the area near Trout Creek, since Pleistocene time, it would not be unreasonable to expect a differential uplift of 2,000 feet or more since Eocene time.

The Bitterroot River.- The Eocene(?) drainage is continued southward through the Bitterroot valley, principally because of the more ideal pattern presented by this course, and because this valley is wide enough to support it. Such a direction of flow would mean that the drainage passes over an area which now has an altitude of 7000 feet. That a considerable amount of recent faulting has occurred is indicated by Fennemen. (11: p. 199)

"It is generally agreed that the foot of the range (Bitterroot Range, eastern slope) marks the position of a great fault, and that the mountain front corresponds more or less closely with the fault plane. If the scarp be in its first cycle of erosion, the down-throw is necessarily on the east, the last movement being so recent that the lower part of the slope is almost untouched by erosion. If it be assumed that the fault scarp is in its second cycle the fault may have been a thrust, by means of which weak Tertiary beds on the east were brought into contact with the strong gneiss on the west. It must be assumed that the weak beds were eroded, and the gneissic block stripped, so rapidly that the lower part of the slope is not yet altered by erosion." Fennemen gives reference here to the works of Lindgren and Flint. (References in Bibliography)

Perry has described an abrupt square end to the wide Bitterroot valley just south of Hamilton which strongly suggests rather recent faulting transversely across the valley. (Personal communication)

A southward flowing river in the Bitterroot valley might have drained into the former southward flowing Big Hole River described by Perry (see p. 11), or it may have continued directly southward into Salmon River valley.

<u>The Flathead River</u>.- The Flathead River is carried southward through its present valley as far as Dixon. Here the Flathead would join with the proposed eastward flowing Clark Fork River and would enter the Jocko River valley.

<u>The Rivers East of the Flathead and Bitterroot Rivers</u>.- No description of those rivers and valleys east of the Flathead and Bitterroot Rivers will be given here. A southward-flowing system is indicated by the writer (Plate II), but descriptions of the various river valleys has been restricted to those so far mentioned.

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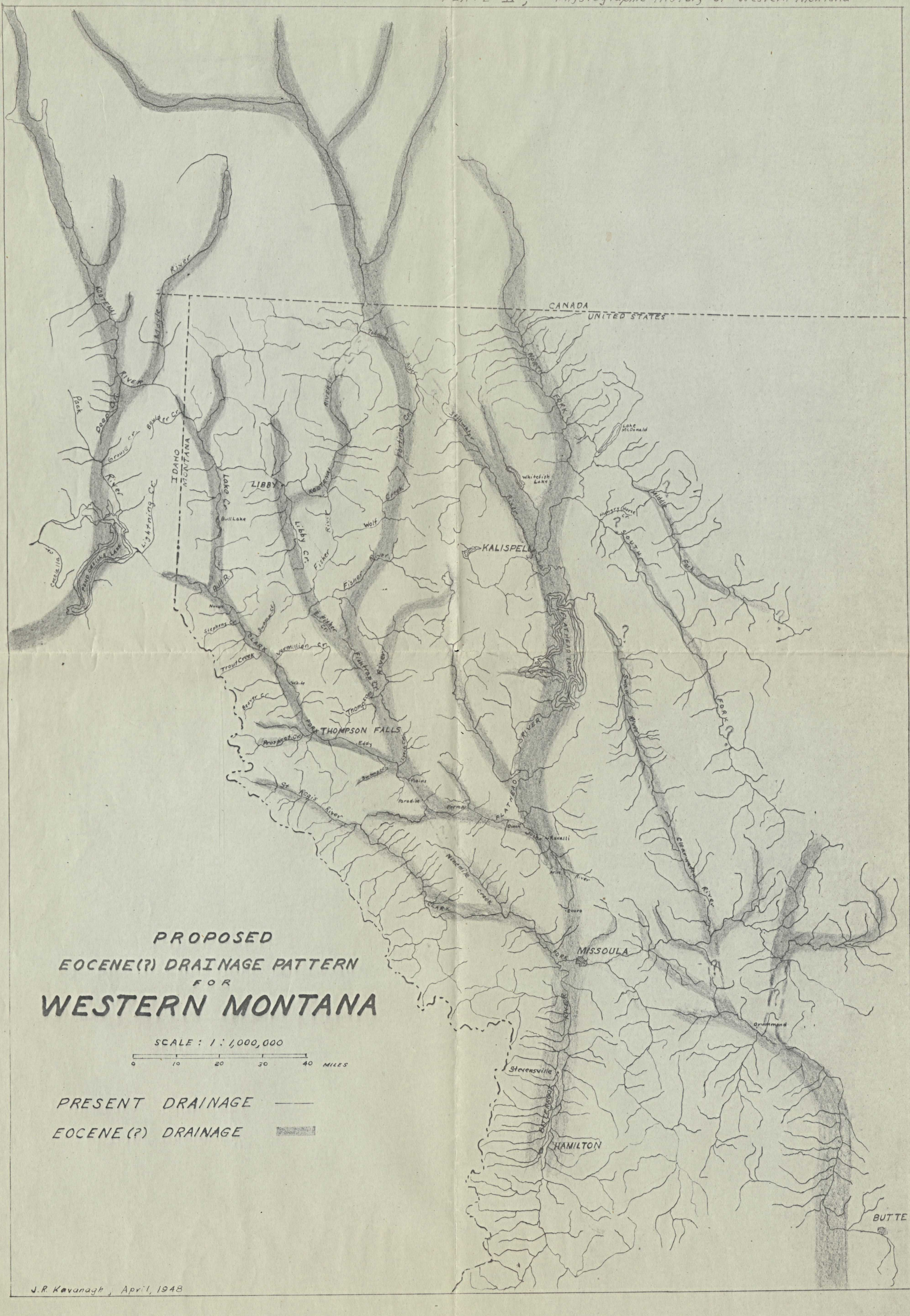
TERTIARY and QUATERNARY SEDIMENTS
OF
WESTERN MONTANA
AND
IDAHO
SCALE : 1 : 1,000,000
APRIL, 1948
QUATERNARY
TERTIARY
IGNEOUS
KOOTENAI LAKE
KOOTENAI
RIVER
BULL LAKE
PEND OREILLE LAKE
CLARK
FORK
NORTH FORK
FLATHEAD
FLATHEAD
RIVER
KALISPELL
SOUTH FORK FLATHEAD
FLATHEAD LAKE
FLATHEAD
RIVER
ST. REGIS
RIVER
CLARK
FORK
CLEARWATER
RIVER


ST. REGIS
RIVER
CLARK
FORK
CLEARWATER
RIVER
BITTERROOT RIVER
BUTTE
BIG HOLE RIVER
BIG HOLE RIVER
SALMON
RIVER
SNAKE
RIVER
PAYETTE RIVER
SALMON
RIVER


PROPOSED
EOCENE(?) DRAINAGE PATTERN
FOR
WESTERN MONTANA
SCALE : 1 : 1,000,000
0 10 20 30 40 MILES
PRESENT DRAINAGE
EOCENE(?) DRAINAGE
J.R. Kavanagh, April, 1948
CANADA
UNITED STATES
IDAHO
MONTANA
KOOTENAI
Moyie River
Deep Cr.
Pack
Boulder Cr.
Grouse Cr.
Lightning Cr.
LIBBY
Lake Cr.
Bull Lake
Bull R.
Libby Cr.
Fisher River
Wolf Creek
Fortine Cr.
Stillwater
Whitefish Lake
Lake McDonald
KALISPELL
NORTH FORK
Middle Fork
SOUTH
Hungry Horse Cr.
FLATHEAD LAKE
FLATHEAD
RIVER
Swan River
Thompson River
THOMPSON FALLS
Prospect Cr.
Trout Creek
Vermillion Cr.
Eddy
Plains
Paradise
Perma
St Regis River
Ninemile Creek
Dixon
Ravalli
Evaro
MISSOULA
Clearwater River
Drummond
Stevensville
HAMILTON
BUTTE