DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 384

A GEOLOGICAL RECONNAISSANCE

IN

NORTHERN IDAHO AND NORTHWESTERN MONTANA

BY

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WITH

NOTES ON THE ECONOMIC GEOLOGY

BY

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WASHINGTON

GOVERNMENT PRINTING OFFICE

1909

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A GEOLOGICAL RECONNAISSANCE IN NORTHERN IDAHO AND NORTHWESTERN MONTANA.

By F. C. Calkins.

INTRODUCTION.

During the field seasons of 1903 and 1904, I was engaged, under the supervision of Mr. F. L. Ransome, in mapping the areal geology of the Cœur d'Alene district in Montana. The rocks of that district consist mainly of a thick series of old sediments, in which no fossils were found and which are presumably of pre-Cambrian age. On all sides of this known territory lie extensive tracts of land which were then almost unknown, geologically, but were supposed, from the fragmentary information available, to be also occupied in the main by pre-Cambrian sediments. It was believed, indeed, that the Cœur d'Alene district lay in the same great zone of pre-Cambrian sedimentation in which lie certain areas in the Rocky Mountains where stratigraphic studies had previously been made by Messrs. Walcott,[a] Weed,[b] and Willis.[c] It was primarily with the object of correlating the Cœur d'Alene section with the ones, not obviously resembling it, which have been described by those authors, and of observing the changes undergone by the formations of the Cœur d'Alene district in their extension to the north and east, that, at the suggestion of Mr. Ransome, the reconnaissance of which this paper is to give an account was undertaken.

The field work was begun early in July, 1905, and carried on continuously until October 1. During this period the exploring party and its camp equipage were transported by means of saddle horses and a pack train. In October this work was supplemented by foot traverses along the main line of the Northern Pacific Railway between Thompson Falls and Dixon, and in Missoula Valley and the

[a] Walcott, C. D., Pre-Cambrian fossiliferous formations: Bull. Geol. Soc. America, vol. 10, 1899, pp. 199–244; Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, pp. 1–28.

[b] Weed, W. H., Description of Little Belt Mountains, folio (No. 56): Geol. Atlas U. S., U. S. Geol. Survey, 1899; Fort Benton, folio (No. 55): Geol. Atlas U. S., U. S. Geol. Survey, 1899; Geology and ore deposits of Little Belt Mountains: Twentieth Ann. Rept. U. S. Geol. Survey, pt. 3, 1900, p. 257 et seq.

[c] Willis, Bailey, Stratigraphy and structure, Lewis and Livingston ranges, Montana: Bull. Geol. Soc. America, vol. 13, 1902, pp. 305–352.

hills north of it. An idea of the extent and location of the area studied may be gained from the index map (fig. 1), and the amount of observation upon which this report is based may be roughly estimated from an inspection of the main routes of exploration, which are shown on Plate I. It will be evident from a comparison of the time employed with the area surveyed that the work was necessarily of a relatively hurried nature, and this must serve to explain the lack of completeness and finish in the results obtained.

The purposes formulated at the inception of the undertaking were substantially accomplished. The stratigraphic divisions of the

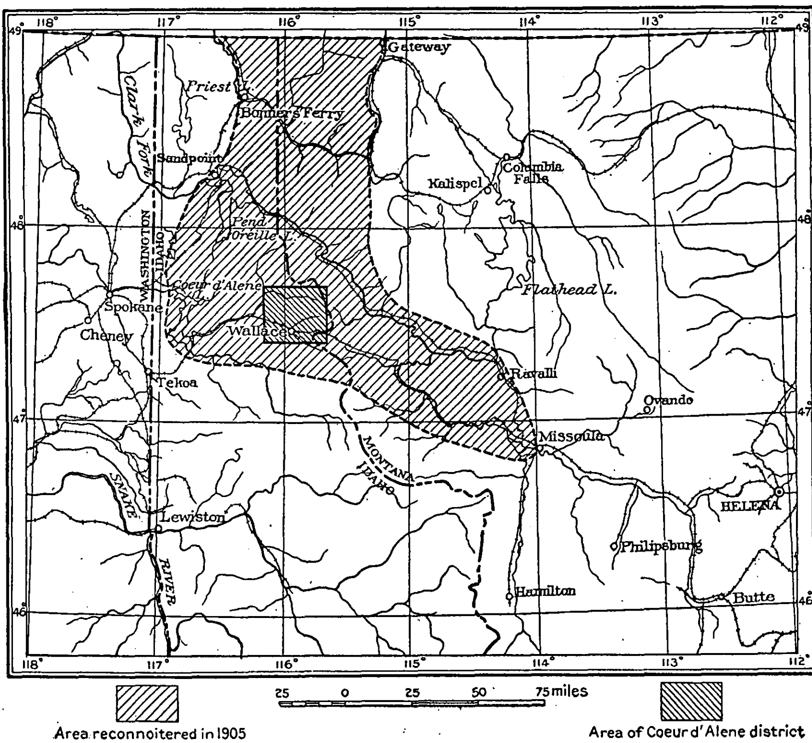

FIGURE 1.—Index map showing location of area described.

Cœur d'Alene section were traced northward and eastward, most of them to the boundaries of the area covered, and others to gradual disappearance. On the north, connection was made with a zone studied during the season of 1904 by Dr. R. A. Daly,[a] of the Canadian Survey, and on the east a junction was practically attained with an area studied simultaneously by Mr. Walcott. Correlation of the Cœur d'Alene section with sections worked out by Mr. Walcott was made, thus fixing certain horizons in the stratigraphic column over a very extensive area. The season's work of Mr. Walcott, fortunately

[a] See geology of the western part of the international boundary: Summary Rept. Geol. Survey of Canada for 1904, 1905, pp. 91–100.

providing a connecting link between the Cœur d'Alene section and those farther eastward previously described, enabled him to make correlations between the different Algonkian sections of a vast area in Montana, Idaho, and British Columbia, and to show the applicability throughout this region of the term Belt "terrane," applied to the Algonkian in that part of the region first carefully studied.

In both field and office I was efficiently assisted by Mr. D. F. MacDonald, and the work of examining mines and prospects was delegated in greater part to him. The brief account of the region's mineral resources appended to this report is substantially similar to one prepared for Bulletin 315, with the addition of some information concerning recent developments, and of some details which it was deemed advisable to omit from the sketch that appeared in that bulletin.

The report has profited by the criticisms of Mr. Ransome, who carefully read the manuscript, and to whom my thanks are offered for many helpful suggestions.

Acknowledgments are due to many owners and managers of mines and prospects in the region examined, who, without exception, freely offered facilities for inspection of the properties in their charge.

Mr. Leiberg, the owner of much land on the southwest shore of Lake Pend Oreille and of prospects on Little North Fork of Cœur d'Alene River, devoted a day to guiding us about the vicinity of Chilco Mountain and supplied considerable information concerning the geology in the vicinity of the lake. For his assistance cordial thanks are tendered.

Acknowledgments are due also to the courtesy of Mr. F. J. Whitney, passenger traffic manager of the Great Northern Railway, and of Mr. A. M. Cleland, general passenger agent of the Northern Pacific Railway, who most obligingly furnished detailed maps of the portions of their respective lines which cross the region surveyed.

CHAPTER I.

GEOGRAPHY.

GENERAL PHYSIOGRAPHIC RELATIONS.

The traveler who crosses the continent on the Great Northern Railway is continually surrounded by mountains from the time he enters a breach in the wall of the eastern front of the Rockies, which looks out over the ocean-like expanse of the Great Plains, until, near the city of Spokane, he reaches the eastern border of that arid and monotonous tract known as the Columbia Plain, which he must cross before entering the forest-covered Cascade Range. In this part of his journey he will have traversed a relatively narrow section of the main chain of a mountain system which extends almost unbroken from the extremity of the Alaska Peninsula to Cape Horn. South of his line of travel this essentially mountainous zone gradually broadens. It is limited on the east by the Great Plains and is separated on the west from the continuous chain of the Cascade and Sierra Nevada ranges by a region in which well-defined and comparatively short ridges divide broad stretches of barren plain. Almost immediately north of his route it expands abruptly on the west. The northern boundary of the Columbia Plain is a sinuous line, the average direction of which is nearly east and west, and which does not depart greatly from the forty-eighth parallel of latitude. It marks the southern limit of a tract occupied by mountain ridges of moderate and approximately uniform elevation. North of this boundary the western mountains of the North American continent form a zone divided into subordinate groups by some great valleys but interrupted by no areas of level ground at all comparable in magnitude with the Columbia Plain.

The attention of the reader may now be narrowed to the area bounded on the north and south by the forty-ninth and forty-seventh parallels of latitude, on the east by the Great Plains, and on the west by the meridian of Spokane. This area includes the field of this reconnaissance and contains, in addition, parts of the great physiographic divisions that border it.

The mountains of this area are divisible into groups of at least two orders of magnitude. For most of the region the task of outlining these groups and of putting their nomenclature, which was long confused and illogical, into orderly form has been admirably accomplished by Daly.[a] Daly's paper appeared after my return from the field, but, having recognized in the area which I had explored essentially the same major physiographic units that Daly has pointed out, I was prepared to accept his conclusions in all essential particulars. He has placed under material obligation all who are interested in the geography of the northwestern part of the continent.

As Daly has shown, the limits of the natural orographic groups of this region are certain major valleys. The mountains comprised within the area outlined above are divided into groups of the first order by two linear depressions of remarkable length. As each is occupied not solely by one stream but by numerous streams and lakes, they can not be designated, as are most topographic features resembling them in form, by the term "valley" coupled with the name of a river. Daly applies to them the term "trench," which well connotes their comparative uniformity of cross section and their approximate straightness.

The more eastern of these depressions, which limits a long and narrow orographic zone that Daly calls the Rocky Mountain system, he has named 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 this lake the depression does not continue with so characteristic and regular a form, but it seems best to consider, for reasons which will presently be discussed, that its rôle as a boundary between mountain groups of the first rank is taken up by a zone of low land occupied by Flathead Lake, part of Flathead River and Jocko Creek, and, south of the region here considered, by Bitterroot River.

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 it seems more reasonable to consider it as extending at least to the southern end of Lake Cœur d'Alene, about 80 miles south of Bonners Ferry. It is true that the southern part of the "Purcell trench," if the application of the term be so extended, has not the striking regularity of the more northern part, but it is none the less a definite and persistent zone of depression, remarkable for the discordance of its direction with the prevailing trend of the major streams.

Each of the three orographic divisions marked off by the Purcell and Rocky Mountain trenches is distinguished by certain broad characteristics, which may be indicated briefly before proceeding to a more detailed description of the area in which the geologic reconnaissance of 1905 was carried on.

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[a] Daly, R. A., The nomenclature of the North American Cordillera between the forty-seventh and fifty-third parallels of latitude: Geog. Jour., vol. 27, No. 6, June, 1906, p. 586.

The easternmost of these divisions is that designated by Daly the Rocky Mountain system,[a] and is comprehended between the Great Plains and the Rocky Mountain trench. It 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, and Swan 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[b] shows this range as separate from the grander division on the east. But, as has been suggested on a preceding page, it is to some extent a matter of choice whether we shall consider the Rocky Mountain trench as continued southward by the depression containing Flathead Lake and part of Jocko Creek or by the valley of Swan River. To me, who have not had the advantage of actual observation in the critical area, there seem to be two reasons for preferring the former alternative. In the first place, the first-named depression, so far as can be judged from available maps, continues much farther south than the second, and is therefore of more practical use. In the second place, the Mission Range is closely allied to the mountains east of it by proximity, by identity of trend, and by being strongly contrasted in the last-named respect with the far less rugged elevations west of the main Flathead River.

The next great division west, lying between the Rocky Mountain and Purcell trenches and comprising the Cœur 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 notably 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.

The great orographic division immediately west of the Purcell trench is designated by Daly the Selkirk system. As defined by him, it is bounded on the west by a section of the Columbia River valley having a nearly meridional direction, and on the south by the Colum-

[a] Daly's definition of that system is at variance with the usage prevailing in the United States and embodied in a recent decision of the United States Geographic Board. This makes the term embrace the whole of the mountainous region north of the Colorado Plateaus, which is limited on the east by the Great Plains and on the west by the Great Basin and the Columbia Plain.

[b] Daly, R. A., The nomenclature of the North American Cordillera between the forty-seventh and fifty-third parallels of latitude: Geog. Jour., vol. 27, No. 6, June, 1906, p. 588.

bia Plain. But the latter part of the definition is hardly adequate and leaves one in doubt as to just how far south the Selkirk system should be considered to extend. East of longitude 117° 30′ the border of the Columbia Plain, although rather sinuous, has a general direction more nearly north-south than east-west. It therefore approaches the line of the Purcell trench. But so far as I am aware these two great natural boundaries do not quite meet. Still, as the height of the hills between them diminishes southward at the same time that their breadth decreases, it is perhaps sufficiently definite to consider the Selkirk system as gradually tapering to an end somewhere near the southern end of Lake Cœur d'Alene. It would thus include a group of hills lying south of Spokane River between Spokane and the lake.

The topographic character of so much of the Selkirks as was seen during the work on which this paper is based 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 to 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.

PRINCIPAL TOPOGRAPHIC FEATURES.

GENERAL STATEMENT.

The field covered by this reconnaissance lies, as the map forming Plate I shows, almost entirely within the great zone comprised between the Purcell and Rocky Mountain trenches. It slightly overlaps the Purcell trench at the west, but does not, on the other hand, comprise the "Flathead Mountains" of Daly, which lie east of the Cabinet Range and west of the Rocky Mountain trench. The main physical features of this field will now be enumerated and described. The limits and character of the mountain ranges will first be set forth, and then some of the principal features of the drainage will be considered.

MOUNTAIN RANGES.

CŒUR D'ALENE RANGE.

Definition.—The Cœur d'Alene Range is the southernmost in this region. The definition of its limits has not been generally agreed upon, so that the one put forth here may be considered as provisional. The use of the term here adopted is that suggested by Lindgren,[a] who defines the range as extending from Lake Pend Oreille at the

[a] A geological reconnaissance across the Bitterroot and Clearwater mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1907, p. 23.

northwest to the vicinity of Lolo Pass, beyond the southern limit of the area shown on Plate I. Its form is rudely triangular. Its southern boundary is rather vague, but should probably be considered as formed in greater part by the rim of the drainage basin of Clearwater River. For a short distance near its southwest corner it adjoins the Columbia Plain, but most of its western boundary is constituted by the Purcell trench. Its northeastern border is considered as being formed by the valleys of Clark Fork, Flathead River, and Jocko Creek.

The watershed of the range, as thus defined, forms a divide between Clark Fork of Columbia River and the main trunk of that stream. Its two versants are extremely unequal in area, the northeastern being drained by short creeks that flow directly into Clark Fork and Flathead River, and the southwestern by several long and much ramified streams whose waters are gathered into Spokane and Snake rivers.

Character.—As a whole the Cœur d'Alene Range has a less diversified relief than the ranges north of it. Viewed from high stations it shows a rather monotonous expanse of ridges that are nearly equal in height and have nearly level crests without markedly prominent summits. Its general aspect is therefore similar to that of a maturely dissected plateau. The general level of this upland, in its central and highest part, is a little above 6,000 feet, although a few of its peaks rise nearly 7,000 feet above the sea. To the west the general equality of summit levels is not so marked, for the valleys have been more extensively cut out, so as to destroy any regularity of level that the ridges may once have had. About Pend Oreille and Cœur d'Alene lakes few of the summits are more than 5,000 feet high.

CABINET RANGE.

Definition.—The Cabinet Range is here considered as extending from Bonners Ferry southeastward to the junction of Jocko Creek with Flathead River. Its boundaries, in the part with which a relatively thorough acquaintance was gained during this reconnaissance, are quite definite. Its west side is bordered by the Purcell trench, and its southwest side by the nearly straight valley occupied mainly by Clark Fork of Columbia River and partly by Flathead River. The character of its most eastern part was not so thoroughly learned and its boundary on that side is apparently less definite. It seems reasonable to follow Daly in considering the southern part of its eastern boundary as constituted by the valley of Little Bitterroot River with a short portion of Flathead River, and the northern part by the valley of Fisher Creek.

Character.—The Cabinet Range as a whole is somewhat loftier than the Cœur d'Alene Mountains, and far more diversified in character. It is divided into two fairly distinct portions by a north-south valley or trench, near whose center lies Bull Lake. The portion of the range west of this trench is of the dissected plateau type, but because of the hardness of the rocks from which it has been carved and the intense alpine glaciation to which it has been subjected the details of its sculpture are highly picturesque. The most rugged scenery in this section of the range is found about Scotchman Peak and to the east of it, where the country rock is quartzite. The northern, eastern, and western faces of the peaks in this vicinity overlook great amphitheaters, from many of which the summits are not directly accessible.

The valley that divides the range affords an easy-graded wagon route from Smeads Crossing to Troy. It is broad compared with its length, except along the lower part of Bull River, and its highest part is only about 700 feet above Clark Fork of the Columbia. The pass is in an area of moraines, south of which are extensive meadows whence the waters of the united forks of Bull River flow southward. Just north of the divide lies Bull Lake, draining through Lake Creek northward, although erroneously shown on most maps as draining to the south. The depth to which the range has been channeled by this transverse valley is emphasized by the fact that some of its highest and most jagged peaks overlook the valley on the east.

It is in the portion of the Cabinet Range extending about 25 miles southeastward from Bull Lake that one finds the most impressive alpine scenery of the region. Even in distant views from the heights of the Cœur d'Alene Mountains or of the Purcell Range the superior elevation and deeply serrate sky lines of the mountains in this vicinity set it in striking contrast with the surrounding expanse of lower and more even-crested ridges. What is believed to be the highest summit of the range, its elevation being estimated barometrically as between 8,500 and 9,000 feet, is Bear Peak, which rises at the head of Bull River. Toward this stream it presents a smooth and moderate slope, but its northern and eastern faces are deep cirques with precipitous sides. In the northern cirque is a small glacier, a remnant of those which once flanked all the higher peaks of the region.

A number of lofty and rugged peaks are aligned to the south of Bear Peak, and it is rivaled in height—possibly surpassed—by Great Northern Mountain, near the southern end of the column, which also seems to carry a glacier. Near the head of Fisher River the average level of the crests diminishes abruptly by about a thousand feet, and a topography of pyramids and spires gives way to monotonously level and gently rounded ridges like those characteristic of the Cœur d'Alene Mountains. Southeastward from this pass the range was not explored, but, to judge from maps and distant views, it seems that the mountains diminish further in height and become more and more dissected by low-grade valleys.

PURCELL RANGE.

Definition.—The Purcell Range, as defined by Daly, trends about north-northwest. It is for the most part bounded on the east by the Rocky Mountain trench and on the west by the Purcell trench, the remainder of its boundary being defined by the valley of Kootenai River from Gateway, where it leaves the former trench, to Bonners Ferry, where it enters the latter. That minor portion of it which lies in the United States is embraced by the great bend of Kootenai River between the points where it crosses the boundary.

Character.—This southern portion of the Purcell Mountains is divided into three subdivisions by Mooyie and Yaak rivers.

West of Mooyie River, between its valley and that of the Kootenai, is a range trending almost due north and south and having comparatively simple topography. About 5 miles south of the international boundary this range is crossed by one of the remarkable flat-bottomed low-grade valleys so numerous in the region. The crests of its ridges are comparatively even in height and bear no conspicuous peaks.

The mountains dividing the Mooyie from the Yaak drainage are in greater part of a gentle character and are heavily wooded where they have not been swept by forest fires. The main divide, however, from a short distance south of the international boundary to Mount Ewing, several miles farther south, is a somewhat more elevated, rocky ridge, and at the south end of the chain is also a group of jagged summits. The maximum elevation of the range is about 7,500 feet.

The mountains east of Yaak River have the same general character as those west of it. The divide, surrounding the broad basin of Yaak River, comprises most of the higher points, of which at least one exceeds 7,500 feet in height.

MAJOR DEPRESSIONS AND DRAINAGE FEATURES.

PURCELL TRENCH.

The ground plan of that portion of the Purcell trench which lies south of the forty-ninth parallel is rudely indicated on Plate I by the tint appropriate to the Quaternary deposits that cover most of its bottom. This part of the depression varies considerably in width and topographic character. On the basis of these variations it may be considered as comprising four sections, which, in order from north to south, extend respectively (1) from the forty-ninth parallel to Bonners Ferry, (2) from Bonners Ferry to Lake Pend

Oreille, (3) from Lake Pend Oreille to Spokane River, (4) from Spokane River to the south end of Lake Cœur d'Alene.

The northernmost section, between the forty-ninth parallel and Bonners Ferry, where Kootenai River enters the trench, has a flat, marshy bottom 2 or 3 miles wide, bounded on either side by mountains. Those on the west rise abruptly, while those on the east slope more gently at the south but precipitously at the north. In the flat bottom Kootenai River ordinarily meanders between reedy banks, with broad windings and glassy surface, but in time of freshet it floods the entire valley from one mountain wall to the other.

From Bonners Ferry to Lake Pend Oreille the trench has the same topographic character as to the north, but is not occupied by any master stream. The northern part is drained by a small tributary of Kootenai River, the southern part drains into the lake by way of Sand Creek, and the middle part is drained by Pack River. This stream, remarkably enough, flows directly across Purcell trench and, making its way eastward to Lake Pend Oreille through another low-grade valley, cuts off from the main Cabinet Range a triangular mass of hills.

South of the lake the trench is neither so regular nor so definitely bounded as it is northward. The hills on either side are lower than to the north and are broken by several broad, level-bottomed valleys. The width of Rathdrum Valley diminishes near Cocolalla Lake to about a mile, then expands to about 9 miles in the gravelly plain that embraces what are locally known as Rathdrum and Eightmile prairies.[a] This "prairie" section has no surface drainage except Clark Fork. In several canyons that open into it are small lakes, the waters of which seep into the great sheet of gravel that holds them back, and doubtless finally make their way into Spokane River, whose valley forms a broad avenue into the great plain of the Columbia.

South of Spokane River the Purcell trench, somewhat constricted, is occupied by the main body of Cœur d'Alene Lake, on either side of which rise rounded hills, with high terraces of basalt on their flanks.

KOOTENAI VALLEY.

The valley of Kootenai River east of Bonners Ferry is markedly different in character from the Purcell trench. The part lying within the field of this reconnaissance is nearly all narrow as compared with the Purcell trench, and for most of the distance between Gateway and Bonners Ferry the turbid pale-green waters of the stream flow swiftly between steep rocky banks. Not everywhere do

[a] See Sandpoint and Rathdrum sheets, Topographic Atlas U. S., U. S. Geol. Survey.

the canyon walls rise 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 are expansions which afford room for the towns of Troy and Libby.

CLARK FORK–FLATHEAD VALLEY.

The boundary between the Cabinet and Cœur d'Alene ranges is the nearly straight depression extending from Lake Pend Oreille southeastward to the mouth of Jocko Creek. The greater part of this depression is occupied by Clark Fork of Columbia River, but the portion east of the mouth of the stream locally known as Missoula River, which joins the Flathead at a right angle, is occupied by Flathead River. The depression between the two ranges mentioned may therefore be referred to as the Clark Fork–Flathead Valley.[a] This valley is somewhat similar in character to that of Kootenai River, but its sides have on the whole rather gentler slopes. For some miles east of Pend Oreille Lake the bottom lands are broad and are often flooded in time of freshet, and terraces at various levels up to about a thousand feet above the river are very 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 Horse Plains there is an imposing gorge, with cliff-like walls on either hand. Above Horse 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.

CŒUR D'ALENE VALLEY.

The valley occupied by the main trunk of Cœur d'Alene River and its South Fork is a remarkably straight depression, whose position was probably determined by easy erosion along a zone characterized by extensive faulting. At Kingston the North Fork, which is considerably larger than the South Fork, enters this depression. Below the junction the valley becomes on the whole gradually broader down to its mouth at Cœur d'Alene Lake, and its floor, in this lower portion, is one great expanse of meadow land, which is annually flooded by the river. At the mouths of many of the ravines that enter

[a] The United States Geographic Board, in a recent decision, has made the name of Clark Fork of Columbia River applicable to the streams now known as Missoula River, Hellgate River, Deer Lodge Creek, and Silver Bow Creek.

it there are small lakes, precisely similar in character and origin to those about the borders of Rathdrum Prairie. (See p. 17.) The valley of the South Fork is for the most part rather broad, although it passes through a gorge between Mullan and Wallace, while the valley of the North Fork is of canyon-like dimensions through most of its course, but contains some expanded parts about half a mile wide. It is far more tortuous than the South Fork Valley, probably owing to the lack of the directive influence of great faults.

MISSOULA RIVER VALLEY.

The valley of the stream known as Missoula River is one of the larger depressions of the region. That portion which lies between the mouth of St. Regis River and the basin in which the town of Missoula is situated is as a whole relatively broad and open.

The present channel of the river, however, is a steep-sided and tortuous canyon intrenched in the bottom of a wider valley floor developed in an earlier stage of topographic history. Near the mouth of St. Regis River the Missoula, turning sharply to the right, enters a profound and steep-sided gorge, by which it crosses the northern part of the Cœur d'Alene Mountains and joins Flathead River.

The principal tributary of Missoula River in this region is St. Regis River, which heads near Sohon Pass and flows in a rather narrow and relatively straight canyon. This stream is followed to its head by the Cœur d'Alene branch of the Northern Pacific Railway, which, after crossing a high and difficult pass, descends to the valley of the South Fork of Cœur d'Alene River.

LAKES.

The region has innumerable lakes, of which the great majority are small glacial tarns in high amphitheaters. Only the two large lakes of the western part of the mountains deserve especial notice.

Both Lake Cœur d'Alene and Lake Pend Oreille have the topographic character of drowned valleys with several ramifications. Both are held in on the west by gravel dams. Their shores are constituted in part by cliffs of rock that plunge as precipitously beneath the water as they rise above it (Pl. II, *A* and *B*); in part by more gentle rock slopes or shelving beaches of shingle. The principal streams entering them are forming deltas, which indeed constitute the valley bottoms for some miles upstream from the lakes. All these features are well illustrated in Pend Oreille Lake. The southern arm has a somewhat fiordlike character, although its walls are broken by many canyons with gently sloping sides. The south shore of the eastern arm is precipitous, but much of the western portion of the lake is bordered by gravel beaches. The meadow lands at the head of the lake have all the characteristics of a true delta, which the river, divided into three branches, overflows when swollen by melting snow.

CLIMATE AND VEGETATION.

The climate of northern Idaho and northwestern Montana is similar in general character to that of the other northwestern interior States. The year is divided into a dry and a wet season, the former beginning near October 1 and the latter about June 15, but they are not sharply marked off from each other. Thunder showers were frequent in July, 1905, and occasional rains may be expected in any of the summer months. The summers are exceptionally mild and agreeable, the days being never oppressively warm and the nights always cool. Conditions are favorable for efficient field work from about July 1 to October 1, after which considerable snow is likely to fall on the hills, while in November it may begin to lie in the valleys. Snow does not persist throughout the year upon any slopes much exposed to the direct rays of the sun, but on the steep northern faces of many of the higher peaks it forms perennial banks, and, as already mentioned, one or two small glaciers yet linger in the Cabinet Range. This fact is somewhat remarkable inasmuch as far higher peaks in west-central Montana have long been free from glaciers. There is little difference of latitude or of temperature in the two regions, and the longer persistence of glaciers in the Cabinet Range is probably due to its receiving a larger amount of precipitation.

The region was once heavily clothed with coniferous forest, but is now devastated by fires, which yearly throw a veil of smoke over the land during the summer months.

The character of the primeval forest varies according to latitude, altitude, and conditions of exposure. The size of the trees decreases toward the north, and while on the slopes of the Cœur d'Alene Mountains trees 2 or 3 feet in diameter are not uncommon, along the international boundary the lancelike trunks of tamarack, spruce, and lodgepole pine, few of which are more than a foot in diameter, constitute most of the forest.

The terrace lands of the principal river valleys support great open groves of yellow pine and tamarack, almost devoid of underbrush, that have a stately, parklike beauty. The adjacent mountain slopes bear a denser cover of fir, spruce, and tamarack, which with increasing elevation gives way to open growth of small, regularly formed spruces underlain by an often luxuriant carpet of grass.

The fires have perhaps made their most severe ravages in the western part of the area. Some decades ago the hills about Lake Pend Oreille were extensively burned and the forests have here been replaced in great measure by a cumbrous growth of brush. The valley of Mooyie River from the boundary to its mouth has suffered more recently. At the time my party passed through it in 1905 there were to be seen only a few forlorn remnants of a once continuous forest, and even these were in course of destruction. To the east of this valley, however, in the drainage of its tributaries and those of the Yaak, is one of the largest areas of virgin forest in the region. From the higher points of the Yaak-Kootenai divide a broad expanse of forest-clothed ridges extends on every side. The timber of this area, however, is the least marketable in the entire region, and its greatest value to future generations must probably consist in the shelter it affords to game and fur-bearing animals and its efficiency in conserving the rainfall of a great part of the Kootenai drainage basin. At the present time it constitutes part of the Kootenai National Forest.

INDUSTRIES.

In spite of comparatively good railway facilities, the mountainous region with which this report is concerned has but a sparse population. The people are occupied with agriculture, lumbering, and mining, but none of these industries is being pursued very extensively or systematically.

Lumbering supports large sawmills at Sandpoint, Bonners Ferry, and other points on Clark Fork, but an abandoned mill, once operated by power from Thompson Falls, bears witness to a decline in this line of activity.

Agriculture is pursued to some extent on the terraces of the larger valleys. The most desirable farm sites seem to be on old delta fans at the mouths of tributary canyons, where the soil is richer than on the sands and gravels of the rivers. The crops consist chiefly of hay and apples, but in places grains and small fruits thrive.

The mining industry of this region, regarded as a whole, is probably not at present self-supporting. The profits from the one mine steadily producing at the time of this reconnaissance are presumably far overbalanced by the labor being spent by prospectors with no immediate, and in many cases no prospective, results. But the fortunes of the mining population are doubtless taking an upward turn. The high hopes generated years ago by the finding of rich oxidized ores near the surface gave way, when these bonanzas were exhausted and there remained only lean sulphides, to a state of discouragement, from which a healthy reaction is now setting in. The renewal of activity, guided by conservative principles, which is now taking place, gives reason to hope that mining in this region will before many years be put on a firm and profitable basis.

A brief discussion of the mineral resources and mining development will be found in a subsequent part of this report (pp. 92–108).

ROUTES OF TRAVEL.

Taking advantage of the relatively small width of the mountain zone at the north, and of the existence of a number of low-grade valleys whose course is more or less transverse to the trend of this zone, three important railways, uniting at Spokane, cross the region here described within about a hundred miles of the international boundary. The northernmost of these is the Great Northern Railway, the one next south the main line of the Northern Pacific, and the southernmost one the route connecting the Cœur d'Alene district with Spokane on the west and with Missoula on the east. The portion of the last-named route that extends from Wallace to Missoula is owned by the Northern Pacific Railway Company, and the portion west of Wallace by the Oregon Railroad and Navigation Company.[a] Between this route and the Oregon Short Line, some 250 miles farther south, there lies a broad expanse of wooded mountains dissected by profound and narrow valleys which do not appear to afford any practicable passage for a transcontinental railway. Two subsidiary railway lines, joining the Great Northern at Bonners Ferry, extend into Canadian territory, one following the Purcell trench, and the other the valley of Mooyie River. It helps one to realize the geographic importance of the Purcell trench to note that it is continuously occupied by railroads from Rathdrum Prairie northward beyond the international boundary.

These numerous railways make the sparsely settled Idaho "panhandle" and the neighboring portion of Montana comparatively easy of access. Most of the principal wagon roads follow the railway lines. The Northern Pacific is paralleled by tolerable roads for the entire length of its course across the region. The main line of the Great Northern, however, can not be followed with a wagon. A road extends from Bonners Ferry to Troy, making a long detour toward Sylvanite to avoid the ravines that notch the edge of the high terrace north of the river. The gorge between Troy and Libby, however, is traversed only by the railroad and a very precarious trail on the north side of the river. East of Libby, also, there is no wagon road along this railway. A wagon road follows the Cœur d'Alene route from Missoula to Mission, in Cœur d'Alene Valley, but there it diverges to the north and reaches the town of Cœur d'Alene by way of Fourth of July Canyon. This portion of the route is so rugged as to be almost impracticable for heavy vehicles. The portion of the road

[a] Since the writing of this report the last-mentioned route has been adopted for the transcontinental line of the Chicago, Milwaukee and St. Paul Railway, now under construction. The Northern Pacific Railway Company, abandoning the tracks between Missoula and the mouth of Flathead River, which formerly were part of its main line, has constructed a roadway through the gorge of Missoula River from St. Regis to its mouth, and will henceforth send its transcontinental traffic along that stream, thus avoiding the steep grades that formerly had to be traversed between Missoula and Jocko.

near St. Regis Pass is likewise difficult of passage for any but a very light wagon. The Purcell trench is followed by good roads from Lake Cœur d'Alene to the international boundary.

In addition to these main wagon routes there are subsidiary ones which cross or penetrate the mountain ranges. The Mooyie Valley Railway is to be followed by a wagon road, which was in course of construction at the time of our visit. The Cabinet Range is crossed by a fairly good road over the low Bull Lake Pass. This route, however, is debarred by Clark Fork from approach by wagons from the south. A second route across the range follows a wagon road up Vermilion Creek and its west fork to the Silver Butte mine, and thence by a very poor trail which connects with other wagon roads among the eastern foothills of the range. After crossing the divide on this trail, one reaches wagon roads within a few miles which lead to Libby by way of Swamp Creek and the lower part of the well-made road to the Snowshoe mine. The Cœur d'Alene Range may be crossed by a wagon road from Thompson Falls which follows Prospect Creek to its headwaters and then gives a choice between two routes into the Cœur d'Alene district—the one a very rough and steep-graded route by way of Glidden Pass and Burke, the other a longer but easier route by way of Thompson Pass and Mullan.

The wilder parts of this region are not to be reached by wagon roads. Numerous pack trails traverse it, however, and almost any portion of it may be reached by a day's walk from a point accessible to horses. It is impossible to enumerate all the minor trails in this region that lead to active or abandoned mining properties, but some of the more important routes that are practicable for pack horses may be mentioned.

The international boundary between Porthill and Gateway may be followed in a general way, though not closely, by the route used by the boundary commission in setting the monuments that mark the position of the forty-ninth parallel. The route from the Purcell trench to Round Prairie, at the edge of Mooyie Valley, is a wagon road that follows a short flat-bottomed trench that cuts through the mountain ridge between the two meridional valleys. By this time this wagon road will doubtless have been extended to Spokane Junction, on the Canadian Pacific Railway. Thence a trail leads up Hawkins or Meadow Creek and over a very low pass into the basin of Yaak River, following the west fork of that stream to the point where it bends abruptly southward and crosses the boundary. From this portion of the main trail, which lies a few miles north of the forty-ninth parallel, there are several short branch trails to boundary monuments. The portion of the trail east of the west fork of Yaak River was made for the boundary commission, and follows the boundary as closely as the conformation of the ground permits.

The basin of Yaak River is reached from the south by a trail from Libby, which follows Pipe Creek to the head of the south fork, whose valley it follows down to the main stream. The trunk of the river is followed by trails from the boundary route to Sylvanite. The route upstream from the South Fork we found to be confused by frequent branchings, and in places obstructed by windfalls of lodgepole pine, and the downstream trail, not followed by my party, has an ill name among the few inhabitants of the region.

The mountains between Mooyie and Yaak rivers are probably more accessible from the south than from the north, although the party did not attack them from that direction. But the road to the Buckhorn mine leads to their crest, and the late R. U. Goode[a] states that Mount Ewing, about 10 miles south of the boundary, was reached by pack horses from that mine.

The Cabinet Range has few trails of importance, but its western part is penetrated by some prospectors' trails, and many of its level and sparsely wooded ridges might be followed on horseback for considerable distances, so that there would be no serious obstacles to thorough exploration of that portion of the range. The rugged area east of Bull Lake Valley would offer more serious difficulties, but by means of trails extending up several of the creeks on the east side a large part of its crest could be examined without often resorting to man power for carrying camp equipage. The journey to Bear Peak and return was accomplished in a day from a camp several miles north of the Snowshoe mine, notwithstanding that several hours were spent beside the Lake of Shadows in waiting for fog to lift from the summit.

The northern part of the Cœur d'Alene Mountains is traversed by several trails in more or less imperfect states of repair. The best of these is the Leiberg trail, named for its maker, Mr. John A. Leiberg, who has prospected extensively in the basin of the Little North Fork. It follows the Little North Fork of Cœur d'Alene River to its head, then after crossing Chilco Mountain descends to the plain near the southwest end of Lake Pend Oreille. This trail, originally made with great care, is still occasionally used, although not kept clear of windfalls. The crest south of Lakeview, a little farther east, is reached by wagon road, and thence another trail leads over the hills to the main North Fork of Cœur d'Alene River. Its condition, except for its northernmost part, is not known, and its usefulness is limited by the necessity of ferrying from Lakeview to the opposite shores of the lake. The Cœur d'Alene district, in the early days when the placers on Eagle and Prichard creeks were its main

[a] Survey of the boundary line between Idaho and Montana from the international boundary to the crest of the Bitterroot Mountains; Bull. U. S. Geol. Survey No. 170, 1900, p. 38.

attraction, was reached by a trail from Clark Fork which followed Trout Creek and the ridge between the forks of Eagle Creek, but this route has fallen almost entirely out of use. Passage from the Clark Fork–Flathead Valley to the valley of the stream generally known as Missoula River may be effected in two ways. The more direct route is a trail, whose condition is not known, that leads from Plains to St. Regis. The other is by way of Paradise Springs and the Iron Mountain mine. This route, which I traversed, follows a wagon road from Plains to the springs. The passage of this portion necessitates ferrying first Clark Fork below the Flathead and then the river known locally as the Missoula. From Paradise Springs one follows a trail until it reaches, a short distance north of the divide, the road formerly used for hauling the ores of the Iron Mountain mine to a point on Missoula River some miles above the springs. This road leads to the town of Superior, on the Cœur d'Alene branch of the Northern Pacific Railway. The gorge of Missoula River between the mouths of Flathead and St. Regis rivers is too narrow to have been adopted as a route of travel even by Indians.

SETTLEMENTS.

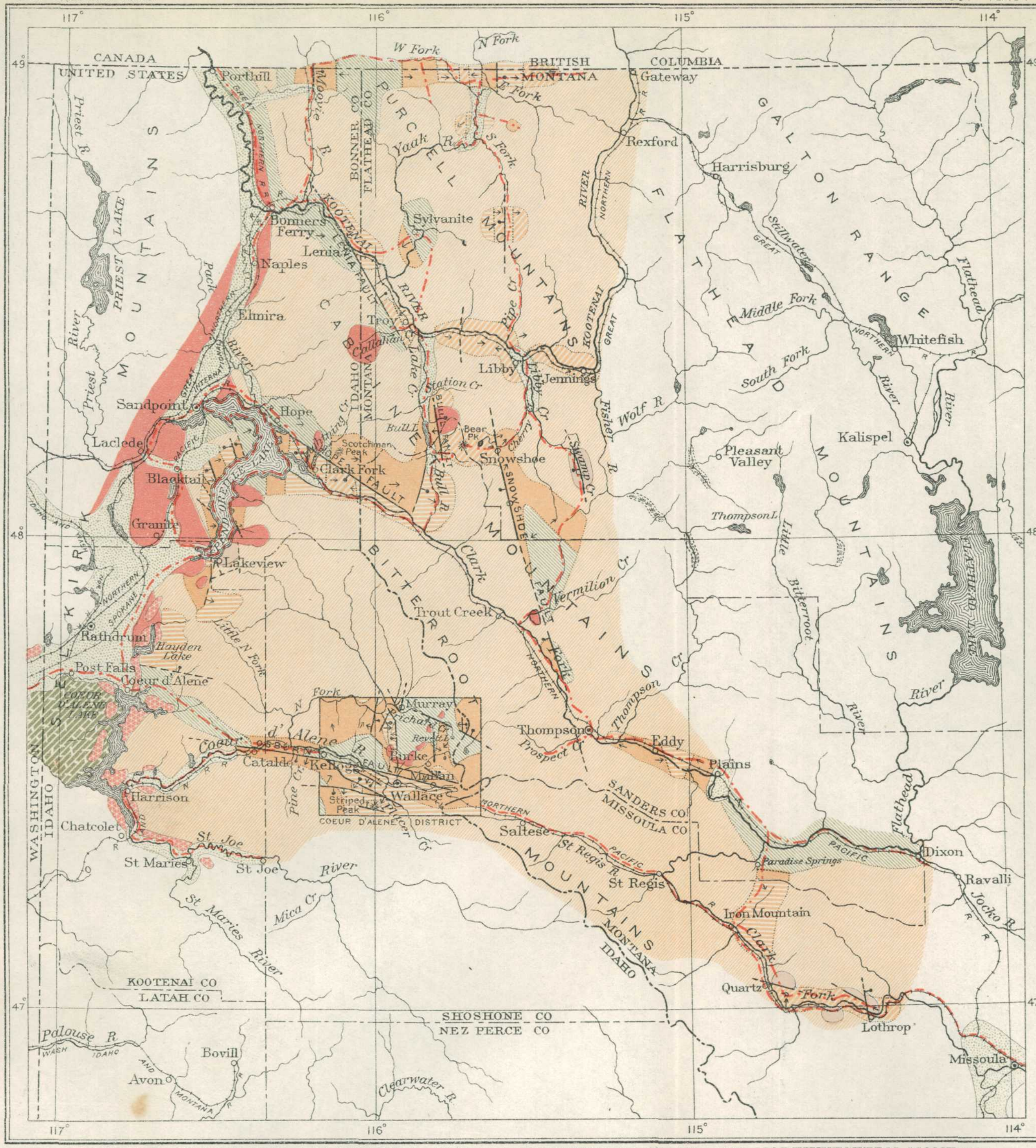
Except in the immediate vicinity of the railroads, the population of the region is extremely sparse. Some families make their homes on small ranches in the valleys; at the few producing mines there are groups of buildings occupied by those engaged in the work of exploitation, and there are several lumber camps among the wooded hills; but the less accessible parts of the mountains contain only the scattered habitations of lonely prospectors and of the fewer and still more solitary hunters that find subsistence in the wilderness. The greater part of the inhabitants of the region are gathered into settlements on the railways, and of these settlements only a few are worthy of especial mention.

On the Great Northern Railway the only considerable towns that lie within our field are Bonners Ferry, Troy, and Libby. Bonners Ferry, with a present population of about 700, bids fair to increase in importance with the completion of the Mooyie Valley Railroad, which will make it a junction point of some importance. Both Troy and Libby, which are farther east, have suffered considerable loss of population in late years, having reached their maximum prosperity at the time the railroad was in course of construction. Their future development must depend chiefly on the development of the mines in their vicinity. In the valley of Yaak River Sylvanite, a town once occupied by several hundred inhabitants, presents a scene of desolation that is typical of abandoned mining camps.

Of the towns on the main line of the Northern Pacific, Sandpoint, which also has a station on the Great Northern, is the most flourishing and gives most promise of future growth. Its population is about 1,500. Its most substantial industry at present is lumbering. If, however, the recent establishment of a smelter in the neighborhood has the stimulating effect upon ore production about the shores of Lake Pend Oreille that may reasonably be hoped, a considerable accession to the wealth and population of this town may be expected. The agricultural possibilities of the vicinity are doubtless capable of considerable development, for its loamy soil appears well adapted to those fruits and vegetables for which the climate is not too cold. The nearest important settlement to the east is Hope, until recently a division point on the railroad, but now supplanted in that function by Trout Creek. Still farther east lies Thompson Falls, a small town dependent on agriculture and undeveloped mines, apparently not actively progressing in importance, and Plains, whose prosperity, evidenced by many new buildings and an appearance of activity, depends chiefly upon stock raising.

South of the main line of the Northern Pacific the most important town in the region, exclusive of the Cœur d'Alene mining district, is Cœur d'Alene. Like Sandpoint, it derives its chief support from lumbering, but this source of revenue is largely supplemented by agriculture and by the numerous seekers after rest and recreation who resort to it in summer.

East of the Cœur d'Alene district the valleys of the St. Regis and the Missoula contain several small towns of no great importance at the present time. Their dependence is chiefly on the lumbering industry, and to a less extent on mining.



GEOLOGIC RECONNAISSANCE MAP OF A PORTION OF NORTHERN IDAHO AND NORTHWESTERN MONTANA

Scale
10 0 10 20 30 40 50 Miles
1909

ANDREW. B. GRAHAM CO., PHOTO-LITHOGRAPHERS, WASHINGTON, D. C.

CHAPTER II.

GENERAL SUMMARY OF THE GEOLOGY.

PRELIMINARY OUTLINE.

That mountainous portion of northern Idaho and northwestern Montana described in the preceding pages which lies east of the Purcell trench is now known to form part of one of the largest areas of Algonkian rocks in North America. Along the forty-ninth parallel these ancient sediments occupy the surface almost continuously from the eastern front of the Rockies to the Purcell trench, which for a great part of its length forms the boundary between these distinctly bedded and but slightly altered strata and an assemblage of schistose and massive rocks strikingly contrasted with them in appearance. The extent of the Algonkian tract northward is not yet known very definitely. In its eastern part, at least, it becomes largely interspersed with areas of later rocks within a relatively short distance from the international boundary. At the south it narrows abruptly near the forty-seventh parallel, where it is deeply cut into at the west by a great body of granular intrusive rock. Its southward continuation at the east becomes more and more broken and it is finally quite replaced by younger sediments and igneous intrusives. The region here described lies therefore almost entirely within an extensive tract occupied mainly by Algonkian sediments, but it includes areas of other rocks of several widely differing kinds.

The rocks west of the Purcell trench consist chiefly of granites, schists, and gneisses, in complex association. They comprise rocks that are partly of sedimentary origin, but mostly produced from intrusive igneous magmas, which have been rendered more or less schistose by pressure. The intrusive rocks in all probability represent several different periods of igneous activity. There are reasons, which will be detailed on subsequent pages, for believing that most of the gneiss and granite occurring on the west side of the Purcell trench, north of Clark Fork at least, was intruded after the accumulation of the Belt series. But south of that stream, and especially in the vicinity of the town of Cœur d'Alene, there are exposures of rocks far more intensely deformed, which may be of Archean age, although the evidence on that point is not conclusive.

The Belt series, whose areal distribution is limited on the west by the Purcell trench along the greater part of the course of that depression through the region here considered, consists of an enormous thickness of distinctly bedded sediments, which, in strong contrast to the rocks mentioned above, do not in general betray conspicuous evidence of alteration. The Belt rocks are chiefly sandstone and shale, or their slightly altered equivalents, quartzites, and hard argillites, but they include also a moderate amount of impure limestone and dolomite containing considerable iron carbonate and silica. The striking characteristics of the series as a whole are its enormous thickness of more than 30,000 feet, its essential conformability throughout, the abundant evidence that the greater part of it was laid down in extremely shallow water, and the fine texture of its constituent materials, which comprise almost no conglomerates.

Folded and faulted into these pre-Cambrian sediments, and very subordinate to them in aggregate surficial area, are several masses of supposedly Paleozoic rocks. The belief that they are Paleozoic rests partly on the finding of a few obscure fossils on Swamp Creek and near Lothrop, and partly on the following lithologic evidence. All these masses consist in large part of relatively pure and thick-bedded limestone. Such material makes up the greater part of the well-known Paleozoic sections of central and western Montana, and differs from the limestones known to belong to the Belt series, which are generally thin bedded and largely admixed with silica and the carbonates of magnesia and iron. It is wholly on this lithologic evidence that certain limestone masses in which no fossils were found, notably those near the south end of Lake Pend Oreille, are considered as probably Paleozoic.

The Algonkian sediments, as well as the limestones near Lake Pend Oreille, have been invaded by great masses of igneous magma, which differ from one another in composition and mode of occurrence. The most extensive of these intrusions are irregular batholithic masses of acidic igneous rocks, which occur for the most part in the western part of the region, and with these it is believed that a large part of the great mass of granitoid rock west of the Purcell trench is contemporaneous. In addition to these batholiths there are masses of more basic rocks, injected for the most part between the strata, but partly into fissures transverse to the bedding.

These intrusions were probably in part contemporaneous with the extensive deformation which the region has undergone. In general, the rocks do not show intense folding except in the southern part of the region, where the structure is more complex than in the northern part. The most conspicuous tectonic features of the region are a number of great faults, some of which are remarkable for their persistence and the magnitude of their throw.

Owing to the almost complete absence from this region of stratified rocks younger than the early Paleozoic, a great part of the geologic record is missing. One can only conjecture whether these rocks were never deposited there, or whether they were deposited and later removed by erosion. The date of the intrusion and deformation which the region has suffered is likewise a matter of conjecture, which may range unchecked by definite facts through a great stretch of geologic time. Nor can we attempt to judge closely at what period the region was finally exposed to those erosional activities which gave the land surface its present form.

It is certain, however, that the origin of some of its topographic features must be referred back to the early Tertiary. The most definite reason for so doing is the relation of the basalt of the Columbia Plain to the older formations. The Columbia Plain is underlain by basalt whose flows lie for the most part in a nearly horizontal attitude and, in the vicinity of Spokane, abut against the gentle slopes of the hills to the east, which are carved in the ancient schists and granites. In the valley of Spokane River one may see terraces of basalt at the bases of the slopes on either side, and the same features may be seen in still more conspicuous development about the shores of Lake Cœur d'Alene and in the lower part of the valley of Cœur d'Alene River. The presence of the terraces makes it clear that these depressions had attained something like their present depth before the period of basaltic eruption, which, as investigations in other regions have shown, was in Miocene time.

The inundation with basalt of the lower portions of these valleys and that of Clark Fork must have had some notable influence on their subsequent development and that of their tributaries. The effect of the retardation of the down cutting of the streams is believed to be shown in the presence of rock-cut benches several hundred feet above the present water level in all the major valleys of the region.

Another formation, probably of Neocene age, whose relation to the basalt has not been directly observed, occurs only in the eastern part of the region and was seen near Plains, in the broad part of the valley of Flathead River, and in the vicinity of Missoula. It consists of very light-colored, soft, fine-grained rocks, with obscure bedding generally in an almost horizontal attitude. The material was not collected or closely examined in this reconnaissance, but it is doubtless identical in part with that which has received much attention from Rowe[a] and Douglass[b] and which occurs very extensively in the intermontane valleys of western and central Montana. It is perhaps

[a] Rowe, J. P., Some volcanic-ash beds of Montana: Bull. Montana Univ. No. 17, 1894.

[b] Douglass, Earl, The Neocene lake beds of western Montana and descriptions of some new vertebrates from the Loup Fork: Bull. Montana Univ., 1899; New vertebrates from the Montana Tertiary: Carnegie Mus. Ann., vol. 2, pp. 145–199; Am. Jour. Sci., 4th ser., vol. 10, 1900, p. 428.

equivalent also to the Bozeman lake beds of the early Montana folios.[a] These rocks also occur and have been observed by me in the Philipsburg quadrangle. The material from the last-named vicinity proved when examined microscopically to be of volcanic ash. Rowe,[b] however, had previously shown that this was true, and that all the material which he studied, including some that occurs within the area considered in this bulletin, was of similar character. The beds near Missoula contain fine impressions of fossil leaves, figured in Rowe's paper, which prove their Neocene age.

The conditions under which these beds were laid down are imperfectly known and need not be discussed here. It is well to remark in passing that the assumption, formerly so often made, that extensive deposits of fine-grained, more or less definitely stratified clastic material must necessarily be of lacustrine origin, is especially lacking in justification when the deposits consist of volcanic ash. It is probable that in general volcanic-ash beds accumulate in great part on dry land, but that as their accumulation is relatively rapid, they may readily cause the rapid shifting of streams and the ponding of drainage. The latter effect is likely to be produced also by eruptions of lava closer to the volcanic centers.

The interpretation of the land forms produced by post-Neocene erosive and depositional agencies constitutes by no means the least interesting of the problems to be solved when the region is subjected to thorough geologic study. These problems were apart from the principal objects of the reconnaissance and received but little attention during its progress, but brief mention of some of the more striking features of the physiography and surface geology may serve to bring into notice a most attractive field for investigation by students of such matters.

The general approximation to a common level exhibited by the mountain ridges of large portions of this region has been remarked by Lindgren[c] and by Daly.[d] This condition still awaits a thoroughly worked out and satisfactory explanation. Lindgren inclines to the belief that the southern part of the region is a dissected peneplain, while Daly, on the basis of observations in this and other regions, has constructed an argument against the too broad application of the peneplain theory by showing that the topography generally thought characteristic of an elevated and maturely dissected peneplain can be formed in other ways; that in fact it tends to be formed in any mountain region at no very advanced stage of topographic development.

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[a] Peale, A. C., Three Forks folio (No. 24), Geol. Atlas U. S., U. S. Geol. Survey, 1896; Weed, W. H., Livingston folio (No. 1), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

[b] Op. cit.

[c] Prof. Paper U. S. Geol. Survey No. 27, 1904, p. 59.

[d] Geol. Survey Canada, Summary rept. for 1904, p. 94; Jour. Geology, vol. 13, 1905, p. 105.

Very high rock-cut terraces, observed in particular along Clark Fork, west of Bull River, may aid in the interpretation of the early drainage history. The possible connection of one with the Tertiary basalt floods has already been mentioned.

The more striking of the younger physiographic features are those due to ice action. As shown by Chamberlin,[a] though without indication of the basis of his conclusions, the northern part of the region was mantled by the Cordilleran ice sheet, which sent a lobe down the Purcell trench at least as far as the southwest end of Lake Pend Oreille and there attained its greatest extension toward the south. The map in Chamberlin's report should be amended to show the valley of Clark Fork as occupied by ice from north of Bull River to Lake Pend Oreille, for strong indications of glaciation by a deep ice stream appear on the valley bottom between these places and for several hundred feet up its sides.

Daly[b] has noted that the limit of general glaciation was at 7,300 feet above sea level at summits occurring in the middle of the Purcell Range on the forty-ninth parallel. On the slope north of Hope glaciation has been effective up to a level of about 2,500 feet above the lake, or about 3,500 feet above sea level. The striæ run nearly north and south. At the mouth of Bull River erratic bowlders were noted at a level of 2,000 feet above Clark Fork.

The hills lying south of the outlet of Lake Pend Oreille exhibit a highly typical effect of ice erosion. They are carved from sandstones and shales of the oldest portion of the Belt series with a regular strike not far from north-south. Viewed from a distance, their sides appear to have a rude horizontal fluting on a huge scale, owing to the projection of the more resistant strata, whose edges are gently rounded off. While these projecting ledges are almost barren, the intervening terraces which mark the position of the softer beds are covered more or less thickly with brush. The impossibility of such features being produced by water erosion is obvious. Similar sculpture was noted in other places, notably along Swamp Creek, and others were seen along Clark Fork southeast of Hope and elsewhere. "Roches moutonnées" in the trench west of these hills have been figured by Chamberlin.[c]

As already hinted, a noteworthy physiographic peculiarity of the region is the existence of numerous flat-bottomed valleys, long in proportion to their width, many of which are divided by very low watersheds, whence the streams draining the depressions flow in opposite directions. The Purcell trench exemplifies these features typically and on a grand scale; other examples are the Bull Lake trench and

[a] Chamberlin, T. C., Seventh Ann. Rept. U. S. Geol. Survey, 1888, Pl. VIII, pp. 178–179, and fig. 15.

[b] Geol. Survey Canada, Summary rept. for 1904, p. 95.

[c] Op. cit., fig. 15.

the one that cuts so deeply into the ridge dividing the Mooyie from Kootenai River. Another seems to lie across the head of the Cabinet Range at the head of Thompson River. It is probable that these depressions, even though their location may have been determined primarily in many cases by fault lines, have been brought to their present form by the long-continued erosion of great valley glaciers, powerful enough to override the divides between the heads of some of the larger streams and to grind them down nearly to the general base-level. The conditions indicated especially characterized the period following the retreat of the continuous ice mantle and are those now prevailing over large portions of Alaska.

Typical morainal deposits are not so abundant in this region as the great extent of its glaciation might lead one to expect. Indeed, a comparison with certain parts of west-central Montana, where, possibly because the postglacial climate has been more arid, moraines are far more abundant and better preserved, indicates that in the area with which we are here concerned the glacial deposits have been very largely rearranged by water. No continuous lateral moraines were noted. The terminal moraine of the ice lobe that came down the Purcell trench is not a conspicuous topographic feature. The dam of the southwestern arm of Lake Pend Oreille has a steep slope toward the water and is composed of material which may be perceived to be of glacial origin from an examination of the good exposures on the wave-worn sides of the little cape at Steamboat Landing. Here may be seen an ill-assorted mixture of subangular bowlders as much as 3 feet in diameter with material grading downward in size to fine sand. The surface to the westward, however, although not without many shallow undrained hollows, appears as if smoothed over to a certain extent by flowing water.

Great quantities of glacio-fluviatile gravels composed of products of ice abrasion have evidently been spread out by voluminous heavy-laden streams beyond the area of ice invasion. Such gravels form the dam of Lake Cœur d'Alene and of many other lakes already mentioned which are similarly retained in small valleys just above their junction with much larger ones.

In the vicinity of Bonners Ferry there were seen exposures of a very extensive deposit of fine-grained light-colored sands and silts, which form a high and broad terrace. These could hardly have been precipitated from suspension except in still water or a very sluggishly moving current. It seems probable, therefore, that they were accumulated in a lake formed in the Purcell trench during the recession of the ice, held in at the south by the terminal moraine and on the north by the glacier front. Abundant fine sediment would have been rapidly supplied by the milky waters that flowed from the dwindling glaciers.

In the following section of this paper a description of the bedrock formations, with the exception of the ash beds, will be given. Further consideration of the physiography and surficial deposits will be omitted, for although the region offers a most attractive field for special students of such features the cursory nature of my observations relating to them makes it unjustifiable to enter into a full discussion of the surface geology, some of whose more noteworthy features have just been indicated.

The geologic sketch map which forms Plate I exhibits rudely the areal distribution of the principal geologic terranes of the region and the larger features of the structure, so far as these have been ascertained. Its purpose is to aid in the understanding of the descriptive text, and it makes no claim to detailed accuracy. In particular the boundaries of the small areas of intrusive rocks, of Paleozoic strata, and of Miocene basalt have only diagrammatic value, being intended to show the approximate position of the masses actually seen.

STRATIGRAPHY.

ANCIENT SCHISTS AND GNEISSES.

The highly altered rocks, which are considered as probably older than the Belt series, have been observed chiefly about the northwest arm of Cœur d'Alene Lake and along the valley of Spokane River. A few minor occurrences of rocks more doubtfully referable to the Archean were noted along Clark Fork. These metamorphic rocks comprise a variety of schists and gneisses which are in part certainly of igneous origin, while a part have the appearance of metamorphosed sediments. As these rocks have not been sufficiently studied to render possible a satisfactory general description of them, only a brief indication of their general character in the principal outcrops observed will be given. After this has been done an attempt will be made to summarize the evidence that has been gathered in our field regarding their age.

One of the best exposures is found in a cutting for the electric railway at Post Falls, on Spokane River. This displays greatly sheared granular igneous rocks, varying somewhat in texture and composition, cut by dikes of aplite and pegmatite. The granular rocks are composed essentially of plagioclase and orthoclase, abundant quartz, and considerable biotite and muscovite. The two feldspars are present in amounts not far from equal, except in a local phase in which plagioclase predominates over orthoclase. Farther east along Spokane Valley and south of the river there are exposures of granite and of a gneiss thought to be of sedimentary origin, but cut by dikes and sheets of clearly intrusive granitic rock. The supposedly sedimentary gneiss is fine grained and of a light-gray color, is composed essentially of quartz, feldspar, and mica, and has a distinct foliation, brought out by parallel arrangement of the biotite flakes. The laminæ, though somewhat crumpled, have a low general dip. The gneiss is cut by numerous dikes and sheets of pegmatite and medium-grained granitic rock. Examined microscopically the foliated rock is found to have quartz as its chief constituent, but it contains a large proportion of feldspar, chiefly orthoclase. The micas are not very abundant.

Just south of the town of Cœur d'Alene is a small hill of fine-grained highly schistose gneiss, rich in muscovite, cut by dikes of pegmatite, which have also been sheared.

Excellent exposures of the ancient-looking crystallines are found in a quarry at Threemile Point, about 3 miles south of Cœur d'Alene, on the western shore of the lake. The rock here consists mainly of fine-grained, light-gray banded gneiss, like the supposedly sedimentary gneiss of Spokane Valley. It has a remarkably regular cleavage, which dips gently south and breaks readily into smooth, flat slabs. This is cut by many dikes of pegmatite which have evidently suffered considerable shearing, and a narrow dike of fine-grained granitic rock which is not distinctly laminated. Some greenish-black hornblende schist containing garnets was found here, but its relations to the other rocks were not made out. From its composition, as seen under the microscope, it may have been derived from diabase or a related rock.

On Clark Fork a short distance above Laclede there was seen some banded schist intruded by a porphyritic granite or monzonite, and on the south side in the same vicinity is exposed an augen gneiss rich in hornblende, which is probably a sheared diorite.

The problem of the age of these rocks is far from being definitely solved. Daly,[a] from evidence still to be given in detail, believes that on the forty-ninth parallel west of the Purcell trench there are rocks much older than the Belt series. The evidence to be presented here relates solely to the rocks west of Lake Cœur d'Alene, with which I am acquainted. That these are partly Archean and much older than the Belt series is the suggestion that is most naturally brought to mind by the salient features of their character and occurrence. The fact that the schistose parts of the complex everywhere display far greater metamorphism than the Belt rocks east of the Purcell trench show, except, perhaps, very locally and in immediate proximity to large batholiths; the sharp discontinuity between this complex and the relatively little altered sediments; the fact that the Belt rocks more commonly than otherwise dip away from the boundary be-

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[a] Geol. Survey Canada, Summary Rept. for 1903, p. 97.

tween the two terranes—all are consonant with the supposition that the highly schistose rocks form a basement upon which the Belt sediments once rested with strong unconformity.

But the alternative possibilities pointed out by Ransome[a] are worthy of consideration. It is possible that these rocks are Algonkian or post-Algonkian; that their high degree of metamorphism is due to igneous intrusions by which they have been so thoroughly penetrated; and that their present position is due to faulting along the line of the Purcell trench, either contemporaneous with or subsequent to the intrusion, with downthrow to the west. In some degree confirmatory of this hypothesis is the fact that obscure traces of what appear to be Paleozoic corals have been found in crystalline limestone apparently forming part of this complex not far north of Spokane.[b] Again, some of the intrusive rocks entering into the crystalline complex are certainly younger than the Belt series. The coarsely porphyritic granite (see p. 44), extensively developed west of the Purcell trench near Sandpoint and to the north, occurs also on the east side, where it is in irruptive contact with the Belt rocks.

Personally I am inclined to the belief that some of the rocks described in the preceding paragraphs are older than the Belt, but the contrary belief is certainly not excluded by the evidence now available. The problem is doubtless capable of solution, but it will be solved only by patient and thorough work.

ALGONKIAN ROCKS.

GENERAL STATEMENT.

It is proposed to give here a brief generalized description of the Algonkian section, which will apply to the whole region. Many details, especially regarding the upper, less-known strata, will be left for description in Chapter III, which will be devoted to the areal geology of the region reconnoitered in 1905; and in the report on the geology of the Cœur d'Alene district[c] a detailed description of the formations that occur in that district may be found.

PRICHARD FORMATION.

The lowest portion of the Belt series in this region consists of an assemblage of bluish argillites, grayish quartzite, and rock intermediate in character between these. For the purposes of this paper this assemblage of strata is considered as a stratigraphic unit. It will be

[a] Geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908, p. 18.

[b] Shedd, Solon, Building and ornamental stones of Washington: Rept. Washington Geol. Survey, vol. 2, 1903, pp. 84–85.

[c] Ransome, F. L., and Calkins, F. C., Geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908.

referred to as the Prichard formation, because it is considered essentially equivalent to the Prichard slate, whose type locality is the basin of Prichard Creek in the Cœur d'Alene district. It may include beds contemporaneous with part of the Neihart quartzite. The base of the Prichard has not been seen in the area of this reconnaissance. Its upper limit is fairly well defined and is marked by a lithologic change from the blue argillites that everywhere form the uppermost part of the Prichard to the greenish-gray, flaggy, siliceous sediments that form the base of the overlying Ravalli group.

The Prichard formation varies considerably within the limits of the region. In the Cœur d'Alene district it consists chiefly of dark gray-blue, regularly banded argillite or slate, with a subordinate amount of interbedded gray sandstone, which is apparently not more abundant in the lower than in the upper part. In the extensive exposures near Plains, Paradise Spring, and Dixon, east of the Cœur d'Alene district, the lithologic character of the formation is essentially the same as at the type locality. The same may be said of the area crossed by Vermilion Creek, northeast of the Cœur d'Alene district, but here it is probable that erosion has not cut so far down into the formation. However, in going westward from Wallace to the town of Cœur d'Alene, a gradual change in the prevailing character of the Prichard rocks was observed. They become, on the average, a little more silicious and coarser toward the west. Subsequent study of the sections about Lake Pend Oreille, along Kootenai and Yaak rivers, east of Bonners Ferry, and in the vicinity of the forty-ninth parallel showed that a similar change proceeds to a still more marked degree toward the north. In the western part of the Cabinet Range the formation consists in greater part of gray quartzitic sandstone, with which, however, considerable argillaceous material is interbedded. Along the international boundary the siliceous character of the formation is even more marked, and it is there represented, wholly or in large part, by Daly's Creston quartzite. But, as I have already indicated, the uppermost part of the formation is everywhere argillaceous. In the excellent exposures just west of Scotchman Peak, in the Cabinet Range, the Ravalli group is immediately underlain by about 2.000 feet of rock which closely resembles the typical Prichard slate of the Cœur d'Alene district. On Callahan Creek, on Kootenai River near Lenia, and near Sylvanite on Yaak River, similar rocks were seen at the same horizon, developed to a thickness amounting at least to several hundred feet, although nowhere closely estimated. Near Spokane Junction, a few miles east-northeast of the point where Mooyie River crosses the boundary, similar rocks were seen, underlying greenish and purplish beds supposedly belonging to the Ravalli group.

It will be understood from what has been said that the correlation of all the strata below the Ravalli with the Prichard involves the hypothesis that all but the uppermost part of the formation gradually changes in character along the strike, so as to become more and more siliceous toward the west and north. The alternative hypotheses would be (1) that there is an upper argillaceous formation overlapping unconformably a lower siliceous formation and gradually thinning toward the northwest, and (2) that there is an unconformity of the base of the Ravalli. Neither of these hypotheses is supported by the field evidence, which appears rather to indicate that the Belt rocks of this area are conformable throughout.

The thickness of the group is roughly estimated at 10,000 to 15,000 feet. In the Cœur d'Alene district the Prichard slate is about 8,000 feet thick. The thickness of the beds exposed in the Cabinet Range would appear to be considerably greater, but they could not be reliably measured unless the structure were well worked out.

RAVALLI GROUP.

Overlying the Prichard formation is an assemblage of light-colored siliceous rocks varying from very pure white quartzite to siliceous shale. Much of the material is tinted in rather subdued tones of gray, green, purple, and red. In the Cœur d'Alene district this group comprises three distinct formations. These are, in ascending order, the Burke formation, consisting of grayish siliceous shales and sericitic quartzites; the Revett, of hard, white quartzite, and the St. Regis formation, consisting of purple and green siliceous shales and quartzitic sandstones. In the region north and east of the Cœur d'Alene district, however, the Revett quartzite is not everywhere present as a definite formation distinct in character from underlying and overlying portions of the group. It is typically developed in the Cabinet Range north of Heron, but over much of the region it is not distinctly recognizable, and, as the Burke and the St. Regis formations are not sharply differentiated from each other, the group can not be subdivided consistently on lithologic grounds. For this reason it is necessary to use a name that shall apply to all the rocks equivalent to the Burke, Revett, and St. Regis formations collectively. Ravalli group, Walcott's term for these rocks in the Swan Range section, appears the most suitable. The names of the subdivisions will be applied in the following pages to rocks that can be definitely referred to one or another of the formations recognized in the Cœur d'Alene district. The total thickness of the Ravalli group in the Cœur d'Alene district is about 4,200 feet. It increases, however, to the north and east. Daly estimates the thickness of the Kitchener quartzite of the section on the forty-ninth parallel, which may be equivalent to the Ravalli group, is about 7,000 feet, and Walcott gives about 8,000 feet as the minimum thickness of the Ravalli "series" in the Mission Range where its base is not exposed. In the Cabinet Range, near Scotchman Peak, its thickness seems to be even greater.

NEWLAND FORMATION.

The quartzitic group is succeeded by a thick formation, distinguished from all those beneath by being in great part calcareous or dolomitic. This was called in the report on the Cœur d'Alene district the "Wallace" formation. In Walcott's Mission Range section its equivalent is the "Blackfoot limestone," and it is possibly to be correlated with Daly's Mooyie argillite. It is equivalent beyond reasonable doubt with the Newland limestone of the original Belt section, so that on grounds of priority it will be called Newland in the following pages. The formation is composed throughout of fine-grained thin-bedded rocks, which comprise green, more or less calcareous or dolomitic, sericitic slate, blue and white banded argillite, impure bluish or greenish ferruginous and dolomitic limestone, and light-gray white-weathering calcareous quartzite. All these types are connected with one another by gradations. The entire accumulation is characterized by sun cracks and ripple marks. In the Cœur d'Alene district the lowest part of this formation consists of green slate, overlain by a great thickness of thin-bedded argillite, impure limestones, and calcareous quartzites, in rapidly alternating succession. Higher in the formation the quartzitic beds are absent and the strata consist of impure limestones and argillites, the latter being partly made up of shale in very thin blue-gray and white layers and partly of gray-green, fairly homogeneous, somewhat calcareous argillite. Between these divisions the transitions are gradual, so that they are not mappable as distinct formations. The Newland formation was supposedly recognized throughout the region. Its general character is everywhere about the same as in the Cœur d'Alene district, but it apparently grows somewhat more calcareous eastward.

STRIPED PEAK FORMATION.

In the Cœur d'Alene district the Newland ("Wallace") formation is overlain by an accumulation of red and green argillite and quartzite with mud cracks and all other signs of shallow-water deposition. Its thickness is at least 1,000 feet in its best exposure on Striped Peak, from which the formation is named. The Striped Peak formation corresponds in lithologic character and position to the lowest part of the Camp Creek "series" in Walcott's Mission Range section. Beds similar to the typical Striped Peak and in the same relation to calcareous beds like the Newland ("Wallace") are found at intervals from the Cœur d'Alene district northward to the international boundary, and would be correlated unhesitatingly with the Striped Peak if it were not that such a correlation would conflict with Daly's conclusions. As will be shown on a later page, he considers certain beds in the eastern part of the Purcell Range, which I believe equivalent to the Newland, as representing a calcareous phase of his Kitchener quartzite.

STRATA ABOVE STRIPED PEAK FORMATION.

Beds supposedly Algonkian and younger than the Striped Peak formation were found at various places in the northeastern part of the region, but their stratigraphy has not been thoroughly worked out, nor has their relation to the Striped Peak been absolutely demonstrated. These strata comprise a great thickness of dark greenish-gray argillites, with some thin beds of limestone, developed about Bear Peak in the Cabinet Range; green and purple argillites and quartzites, with a little limestone, of which a section is displayed in the gorge of Kootenai River between Troy and Libby; and gray and red argillites and limestones, with some quartzitic beds exposed in the Yaak drainage basin.

The Algonkian beds above the Newland, including those referred to the Striped Peak and those supposed to be younger, are probably roughly equivalent to Walcott's Camp Creek "series," although a definite correlation is hardly justifiable as yet.

These supposedly later Algonkian beds whose position in the stratigraphic column is not yet certain can not be treated systematically, but their local occurrences will be described in the section on "Areal geology" (see pp. 58 et seq.), with a view to aiding future work.

REGIONAL CORRELATION.

The accompanying table, based largely on that prepared by Walcott,[a] shows what seem to be the most probable correlations between the more complete sections of the Belt series that have been described. For some of the sections the correlation is based chiefly on a general similarity in the sequence of rocks. It is greatly strengthened in some cases by the presence of the characteristic fossil *Beltina danai* at a horizon near the top of the Newland formation, but even were this paleontologic evidence wanting, the lithologic evidence, discussed more fully in the report on the Cœur d'Alene district,[b] is, I believe, such as to leave little room for doubt concerning the essential correctness of most of the correlations. Those relating to the sections in the Mission Range, the Lewis and Livingston

[a] Bull. Geol. Soc. America, vol. 17, 1906, p. 18.

[b] Ransome, F. L., and Calkins, F. C., op. cit., pp. 25–28.

Probable correlation of principal sections of

Belt Mountains (Walcott).[a]	Lewis and Livingston ranges (Willis).[b]	Philipsburg district (Calkins).[c]	Mission Range (Walcott).[d]
Cambrian. ——Unconformity.—— *Marsh.* Shale, red, 800 feet.	Top not seen. *Kintla.* Shale, maroon red; ripple marks, etc.; some quartzitic and calcareous beds. 800 feet. *Sheppard.* Quartzite, yellow, ferruginous. 700 feet.	Cambrian. ——Unconformity.——	Cambrian. ——Unconformity.—— *Camp Creek.* Sandstones, gray, rather thin bedded. 1,762 feet.
Helena. Limestone, with some shale. 2,400 feet. *Empire.* Shales, greenish gray. 600 feet. *Spokane.* Shales, with thin beds of sandstone; deep red. 1,500 feet. *Greyson.* Shales, mostly dark gray. 3,000 feet.	*Siyeh.* Limestone, dark blue or gray, weathering buff, with shale interbedded. 4,000 feet. *Grinnell.* Shale, partly arenaceous; dark red; ripple-marked and sun cracked. 1,800 feet. *Appekunny.* Shale, gray, black, and greenish, interbedded with white quartzite. 2,000± feet.	*Camp Creek.* Shale and sandstone, the latter prevailing in upper portion. Color chiefly red. 5,000+feet to 0 feet.	Shales, sandstones, and limestones. 1,560 feet. Sandstones, mostly reddish. 4,491 feet. Sandstones, largely shaly, colors red and gray, with 198 feet of limestone 700 feet below top. 3,887 feet.
Newland. Limestone, impure, weathering buff, with interbedded shale. 2,200 feet. *Beltina danai.*	*Altyn.* Limestone, upper part thin bedded and ferruginous; lower part grayish blue, massive, siliceous. 1,400 feet. *Beltina danai.* Base not exposed.	*Newland.* Limestone, thin bedded, more or less siliceous and ferruginous, passing into shale; generally buff on weathered surface. 4,000 feet.	*Blackfoot.* Limestone, thin bedded, more or less siliceous; siliceous layers, weathering buff, interbedded with calcareo-arenaceous shales. 4,805 feet. *Beltina danai.*
Chamberlain. Shale, mostly black, with some sandstone. 1,500 feet.		*Ravalli.* Quartzite, gray, with some dark bluish and greenish shale. 2,000 feet. *Prichard.* Shales, dark bluish, interbedded with sandstone; rusty brown on weathered surface. 5,000± feet.	*Ravalli.* Sandstones, quartzitic, fine grained, grayish purple and gray. 2,550 feet. Sandstones, compact, gray. 1,060 feet. Sandstones, greenish gray, fine grained, in layers 4 inches to 2 feet thick. 4,645 feet. Base not seen. Total Ravalli, 8,255 feet.
Neihart. Quartzite, with some shale in upper part. 700 feet.		Quartzite, light colored. Base not exposed. 1,000± feet.	
Archean.			

[a] Walcott, C. D., Pre-Cambrian fossiliferous formations: Bull. Geol. Soc. America, vol. 10, 1899, pp. 199–244.
[b] Willis, Bailey, Stratigraphy and structure, Lewis and Livingston ranges, Montana: Bull. Geol. Soc. America, vol. 13, 1902, pp. 305–352.
[c] Report in preparation.

Algonkian sediments in Montana and Idaho.

Cœur d'Alene district (Calkins).[e]	Cabinet Range, western and central parts (Calkins).	Forty-ninth parallel, between crossings of Kootenai River (Daly).[f]
Upper part of section eroded.	Shales and sandstones, medium to thin bedded; color prevailingly greenish gray, but in part red and purple. Shales partly calcareous and weathering buff. A little white crystalline limestone, weathering yellow, at several horizons. Base not seen. 10,000± feet.	Upper part of section eroded.
Striped Peak. Shales and sandstone, red and green. 1,000+ feet.	*Striped Peak.* Shales and shaly sandstones, prevailingly dark red; ripple marks, etc. 2,000+ feet.	*Yaak.* Quartzite. 500 feet.
Wallace. Shales, more or less calcareous, interbedded with thin layers of siliceous and ferruginous limestone and calcareous sandstone. Limestones and calcareous shales weather buff. 4,000 feet.	*Newland.* Limestones, thin bedded, siliceous and ferruginous, interbedded with more or less calcareous shales. 5,000± feet.	*Mooyie.* Argillite. 3,400 feet.
St. Regis. Shales and sandstones, purple and green. 1,000 feet. *Revett.* White quartzite, partly sericitic. 1,200 feet. *Burke.* Indurated siliceous shales, with sandstones and quartzites, prevailingly gray-green. 2,000 feet.	*Ravalli.* Quartzites, siliceous shales, and shaly sandstones; upper part green and purple; lower part gray, mostly greenish, locally with faint purple tinge; middle part thickest bedded, and most quartzitic, consisting locally of fairly pure white quartzite. 8,000± feet.	*Kitchener.* Ferruginous quartzite. 7,400 feet.
Prichard. Argillite, blue-gray to black, with distinct and regular banding, interbedded with a subordinate amount of gray sandstone. Uppermost part arenaceous and marked with shallow-water features. Base not exposed. 8,000+ feet.	*Prichard formation.* Argillite, dark bluish, banded. 2,000 feet. Sandstones, gray, thick bedded to shaly, interbedded with more or less sandy bluish shales. The rocks become more argillaceous toward the southeast. 10,000± feet. Base not exposed.	*Creston.* Quartzitic sandstones, thick-platy, gray, interbedded with a subordinate amount of bluish argillaceous material. Base not exposed. 9,500+ feet.

[d] Walcott, C. D., Algonkian formations of northwestern Montana: Bull. Geol. Soc. America, vol. 17, 1906, pp. 1–28.
[e] Ransome, F. L., and Calkins, F. C., Geology and ore deposits of the Cœur d'Alene district, Idaho: Prof. Paper U. S. Geol. Survey No. 62, 1908.
[f] Daly, R. A., Summary Rept. Geol. Survey Canada for 1904, 1905, pp. 91–100.

ranges, and the Belt Mountains, are supported by the weight of Walcott's authority, and the ground covered in my work in the Cœur d'Alene district and the Cabinet Range virtually joins with that covered by him. Although the Philipsburg work has not been joined with that of others, any correlation of the Philipsburg section essentially different from that shown in the table would involve the assumption that the formations change in character along the strike far more rapidly than they have yet been proved to do.

The correlation of the formations studied by Daly along the forty-ninth parallel is, however, distinctly tentative, and may be erroneous. Up to the present time only a very brief description of these formations has been published. The section given in the table is that which apparently indicates Daly's conception of the sequence in the western part only of the Purcell Mountains. Toward the east, according to him, the Creston and Kitchener quartzites become distinctly finer grained and are interleaved with calcareous material. It were hardly fitting that the impressions gathered in my hasty reconnaissance in the Purcell Mountains along the forty-ninth parallel should be opposed too positively to Daly's interpretation of the stratigraphy in the same area, based as it is upon more thorough work and perhaps fully supported by the detailed evidence which could not be presented in his brief preliminary report. But failing such evidence I find it difficult to believe that this marked change takes place within the distance of a few dozen miles, in view of what I have myself observed and in view of the resemblance between the different sections studied by others at widely separated points, especially when it is taken into account that several of these sections have been correlated on paleontologic evidence. My own belief, implied both in the preceding account of the stratigraphy and in the account of the areal geology that is to follow, is that the stratigraphic sequence in its larger features is essentially the same across the entire width of the area with which the present paper deals. The Newland formation, not recognized by Daly on the forty-ninth parallel except as a calcareous modification of strata that are not calcareous to the westward, is typically developed on the west side of Lake Pend Oreille, about 50 miles south of the international boundary.

SUPPOSED PALEOZOIC ROCKS.

Limestones are exposed on the southern shores of Lake Pend Oreille near Lakeview and on the north side of Squaw Bay. The conjecture that they are Paleozoic is suggested by their great lithologic difference from any calcareous rocks forming thick beds in any of the known Algonkian of this region. The limestone is gray to white in color. It is partly thin bedded, alternating in layers about an inch thick with thin laminæ of blue argillite, partly thick bedded;

and north of Squaw Bay, where it was doubtless affected by the neighboring intrusive granodiorite, it is massive and coarsely crystalline. The maximum thickness exposed in any one section is approximately 500 feet. In thickness and in lithologic character these limestones differ from the limy beds in the Newland formation as usually developed; the latter are generally to be measured in inches and are darker, harder, finer grained, and much less pure than the limestones on Lake Pend Oreille. In the northern part of the region limestone with some resemblance to those on Lake Pend Oreille occurs, but in beds only a few feet thick.

A heavy stratum of limestone is also exposed on Swamp Creek south of Libby. This rock is gray and thick bedded and contains forms that suggest worm borings. In the same vicinity is a series of gray and red shales with thin beds of pink limestone which contain a few imperfect molluscan fossils that to Dr. G. H. Girty, of the Geological Survey, had an Ordovician aspect.

Great bodies of gray limestones were also seen at various localities in the valley of Missoula River. This rock and its relations are best exposed in a hill on the north side of the river near Lothrop, where the thickness developed is about 1,500 feet. Its relations and character, in the opinion of Doctor Walcott, indicate that it is middle Cambrian.

IGNEOUS ROCKS.

GENERAL STATEMENT.

The igneous rocks comprise (1) acidic intrusives, which belong to the species quartz monzonite, granodiorite, and syenite; (2) basic intrusives, in dikes and sills, which comprise lamprophyre and diorite, the latter perhaps derived from the alteration of diabase and gabbro; and (3) volcanic rocks, including the altered basic lava interbedded with the Algonkian rocks east of Yaak River and the Miocene basalt.

ACIDIC INTRUSIVES.

QUARTZ MONZONITES.

General distribution.—Quartz monzonite occurs (1) north and east of Hayden Lake, (2) on Chilco Mountain at the head of the Little North Fork of Cœur d'Alene River, and (3) along the Purcell trench from Sandpoint northward.

Hayden Lake area.—The mass near Hayden Lake is of medium-grained, evenly granular, light-gray rock, whose essential constituents are quartz, plagioclase, orthoclase, microcline, and biotite. The plagioclase, belonging mostly to andesine, is about equal in amount to the alkali feldspar. Quartz is rather abundant, and biotite is present in moderate quantity.

Chilco Mountain area.—The rock forming the small area at the head of Little North Fork has the same essential constituents as the rock last described, but is more acidic. Biotite is rather scarce, and quartz in comparatively large anhedra is abundant. The most conspicuous megascopic feature is the porphyritic development of orthoclase, which forms phenocrysts not very thickly distributed that attain a length of about 1 inch. On microscopic examination the feldspars of the groundmass are found to be oligoclase and orthoclase, with the former in decided predominance. On the whole the two kinds of feldspar are apparently not very far from equal.

Areas along Purcell trench.—Along Clark Fork, from a short distance north of Laclede to Sandpoint, the country rock is a conspicuously porphyritic granolite. It shows rather abundant phenocrysts of orthoclase, mostly from one-half inch to 1½ inches long, in a groundmass that consists essentially of feldspar, quartz, and considerable biotite, which makes the rock somewhat darker than the one just described. Locally this rock exhibits a somewhat schistose structure, but this is far less pronounced than in the supposed Archean gneisses of Cœur d'Alene Lake and Spokane Valley.

Rock similar to this is found at Bonners Ferry, where it is strongly schistose. It crops out along the east side of the valley northward from that place for many miles, and in these outcrops the schistosity is not always marked. About 18 miles north of Bonners Ferry it was seen, from the train, in irruptive contact with siliceous sediments belonging to the Prichard formation. Near Naples, a small station on the Great Northern Railway about 12 miles south of Bonners Ferry, it is also found intrusive in the Algonkian. It is concluded, therefore, that the coarsely porphyritic granular rock exposed along the Purcell trench from Sandpoint to the vicinity of the forty-ninth parallel belongs to a great mass of post-Algonkian age.

Microscopic study of the groundmass of this rock shows an apparent predominance of plagioclase. Much of the feldspar shows faint zonal banding and very faint striation or none at all, so that there is some difficulty in distinguishing between the two feldspars. The classification of the rock as monzonite is made tentatively, but more thorough study might show it to be allied rather to the granites.

A related rock, probably of the same mass, forms a small knob that projects through the alluvium near Boyer, a small station east of Sandpoint. It contains not very abundant pinkish phenocrysts of orthoclase, having rather imperfect form and numerous inclusions, in a medium-grained granular groundmass which consists of plagioclase, orthoclase, considerable quartz, and some biotite and hornblende. In the groundmass the plagioclase predominates markedly over the orthoclase, but owing to the presence of the orthoclase phenocrysts the amounts of the two feldspars probably do not differ very greatly.

GRANODIORITE.

General distribution.—Granodiorite of a type that is widely distributed in the Pacific States, and familiar to students of the geology of the Sierra Nevada and the Cascade Range, forms a rather large intrusive mass that is exposed about the southern shores of Lake Pend Oreille, and there is an extensive area of granodiorite porphyry east of the lake.

Rocks differing from this widespread type of granodiorite, but coming within the class as originally defined by Lindgren, were observed at the west base of the Cabinet Mountains on the Northern Pacific Railway, on Lightning Creek, and east of Bull Lake. They are composed essentially of plagioclase, markedly subordinate alkali feldspar, quartz, and biotite.

Areas on Lake Pend Oreille.—The granodiorite in the areas about the southern shore of Lake Pend Oreille is clearly intrusive in the Newland rocks on Bernard Peak, and in the St. Regis formation just north of Cape Horn. The more northern of the igneous masses exposed on the eastern shore of the southern arm also is formed of the same rock.

The granodiorite of this vicinity is a rather light-gray medium-grained rock composed essentially of plagioclase, orthoclase, hornblende, biotite, and quartz, all of which may be distinguished by the unaided eye. It has no schistosity. The plagioclase, which forms crystals that are generally much clouded, belongs chiefly to oligoclase and andesine. It is much more abundant than the orthoclase, which is allotriomorphic against plagioclase and the ferromagnesian constituents. The hornblende, biotite, and quartz are present in moderate and nearly equal amount. Marginally, dark phases are developed in which the ferromagnesian constituents are more abundant than in the great bulk of the mass, which is highly uniform.

Closely related in mineralogical composition to this rock is a coarse-grained holocrystalline granodiorite porphyry, exposed for a short distance along the south shore of Pend Oreille Lake, and said to form Packsaddle Mountain, some miles eastward. Its outcrop at the lake shore is limited on both sides by faults, but it is not sheared, and is probably post-Algonkian.

Megascopically, the rock shows prominent and abundant phenocrysts of plagioclase, small ones of hornblende and biotite, and a few rather large rounded ones of quartz, in a fine-grained dark-gray groundmass. With the aid of the microscope it is found that the plagioclase is mostly andesine and that the groundmass consists of plagioclase, hornblende, biotite, much quartz, and a large proportion of orthoclase, which forms irregular poikilitic individuals. On the whole the plagioclase is markedly more abundant than the orthoclase, and the rock probably does not differ much in composition from the granodiorite already described.

Area at west base of Cabinet Range.—On the Northern Pacific Railway between Sandpoint and Hope, near the west base of the mountains, there is a small outcrop of granodiorite which is intrusive in sediments corresponding to the Prichard. The igneous rock is evenly granular and is composed of greenish-white feldspar, smoky quartz, and small bright foils of biotite. The feldspar is found microscopically to be mainly plagioclase, and interstitial perthitic orthoclase is seen to occur in rather small amount.

Lightning Creek area.—A mass of granodiorite is seen cutting the old quartzites and argillites on the walls of Lightning Creek canyon a short distance above its junction with the Clark Fork valley. It shows roundish phenocrysts of quartz embedded in a fine-grained base, consisting of dull white feldspar and considerable biotite. Under the microscope the greater part of the feldspar is found to be plagioclase with marked zonal banding.

Area east of Bull Lake.—The mass east of Bull Lake was observed on a fault contact at the border of the valley, and on the ridge above is seen in clearly irruptive relation to the partly calcareous Algonkian strata, in which it has produced striking contact metamorphism. In composition it is similar to the two rocks last described, but richer in biotite. It is chiefly remarkable for a marked schistosity, supposedly induced by powerful drag along the fault that limits the mass on the west.

The existence of a mass of granitoid rock in the basin of Callahan Creek, as rudely indicated on the map, is known only from hearsay and from the presence of float in the lower reaches of the stream. Nothing is definitely known regarding the size and form of its superficial outcrop.

SYENITE.

Occurrence.—Syenite forms a small mass, intrusive in the Prichard formation, on Vermilion Creek near its junction with Clark Fork.

Petrography.—The mass is somewhat variable in composition. Some of it appears megascopically to be almost wholly of feldspar, while other parts contain a considerable amount of a dark prismatic mineral. A specimen illustrating the more feldspathic phase is found on microscopic examination to have perthitic orthoclase for its principal constituent, but to contain also a few small individuals of sodic plagioclase, a very little interstitial quartz, and some deep-green ægirine-augite. Titanite is an abundant accessory. Another specimen representing the more femic phase contains a fairly large proportion of deeply altered plagioclase, which is still, however, subordinate to the orthoclase. It contains more quartz than the first specimen, and prismatic masses of hornblende and biotite which are thought to be pseudomorphic after pyroxene.

This rock, so distinctly different from that of the intrusive masses to the west, shows marked affinity with the masses of monzonite and syenite exposed to the southwest in the Cœur d'Alene district, which are described in the report on that district.[a] The distinct linear arrangement of all these masses of alkaline rocks, which are the only ones known in this region, is noteworthy and doubtless significant.

BASIC INTRUSIVES.

LAMPROPHYRE.

Occurrence.—In the vicinity of Lake Pend Oreille were seen many dikes of fine-grained, holocrystalline, dark-colored rocks, whose chief constituents are plagioclase, hornblende, and biotite. The last two minerals, especially the biotite, are generally prominent megascopically. These rocks occur in the Cœur d'Alene district, and description of them will be found in the report on that district.[b]

These dikes were seen in greatest abundance on the south shore of the peninsula in Lake Pend Oreille, southwest of Hope. A large number of them, with a north-northwesterly direction and steep dip to the west, there cut the east-dipping rocks of the Prichard formation. Their attitude is about parallel to that of two great faults located farther southwest, and they are probably connected in origin with the faulting. Other dikes of the same character were noted on the railroad west of Hope, and on the east shore of the southern arm of the lake, north of Granite Creek. One at the latter place dips 70° W. and strikes N. 30° W.

Petrography.—The lamprophyres of this region are mostly rather fine grained and very dark, but some of the larger masses have a coarser texture and a lighter hue. The constituents megascopically visible are feldspar, hornblende, and biotite. The dark minerals exhibit notably well-developed crystal form, the biotite occurring in hexagonal tablets and the hornblende in elongated prisms. The feldspar is not conspicuous in the darker and finer grained specimens. By the aid of the microscope it is seen that the feldspar is mainly plagioclase of moderate basicity, the biotite of a deep-brown variety, and the hornblende variable in color, passing from green to brown in the same individual. Some interstitial orthoclase and quartz, usually intergrown, occur in all specimens, and some contain augite.

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[a] Ransome, F. L., and Calkins, F. C., Geology and ore deposits of the Cœur d'Alene district: Prof. Paper U. S. Geol. Survey No. 62, 1908, pp. 45–48.

[b] Idem, pp. 53–54.

DIORITE.

Occurrence.—The name diorite is applied provisionally to a dark, medium to fine-grained rock, rich in hornblende, which in this region forms very numerous tabular intrusive masses in the Algonkian, being confined chiefly to its lower portion. Where their relations are clear they are found to be sills, injected between the strata. These intrusive bodies are most numerous in the northwestern part of the region, and are best displayed along the Great Northern Railway between Bonners Ferry and Lenia. Here they are approximately parallel to the steeply inclined east-dipping strata of quartzite and argillite, but may occasionally be seen cutting the planes of stratification at a small angle. In all cases where this was observed they are steeper than the strata. The thickness of these bodies in this locality varies from a few feet up to several hundred feet. Other masses of the diorite, splendidly exposed on the steep sides of glacial amphitheaters, were seen along the divide between Mooyie and Yaak rivers from the boundary to Mount Ewing, about 6 miles south. The gray Prichard quartzite here dips gently to the east, and the intrusive masses, although they occasionally break across the strata, are clearly seen to be essentially sills. Half a dozen were observed in this vicinity, and some are 300 feet or more in thickness. These rocks were seen at other localities where their relations are not so clearly displayed. They are abundant in the Prichard formation on Yaak River near Sylvanite, on Vermilion Creek, and in the area south of Sandpoint and west of Pend Oreille Lake. Large intrusions of the same character form some of the peaks of the Cabinet Range northeast of Hope. At these places it was not determined whether they were dikes or sills. Similar intrusive masses were observed again, chiefly by Mr. MacDonald, in the Prichard rocks east of Plains. There they were thought by him to be dikes, but they show a trend approximately parallel to the general strike of the rocks—about east and west—and may prove to be sills. Some of the masses here are as much as 600 feet in thickness.

Petrography.—These intrusive bodies consist for the most part of a very dark, somewhat greenish, hypidiomorphic-granular, medium-coarse to fine-grained rock. The most conspicuous mineral, megascopically, is greenish-black hornblende, usually somewhat fibrous, but feldspar and quartz are easily recognizable in all but the finest-grained specimens.

Examined in thin section, this rock is found to be composed chiefly of hornblende, plagioclase, and quartz, with variable but generally small amounts of orthoclase and biotite. The common accessories are iron ore and apatite. The plagioclase crystals generally show far larger extinction angles at the center than on the periphery, but the more basic grades into the more acidic feldspar, so that distinct zones are not recognizable. The species represented range from labradorite to oligoclase. The orthoclase commonly is intergrown with quartz, which in some specimens is very abundant. The hornblende is the most interesting of the minerals because of its problematic origin. In thin section it usually shows a rather pale green color, irregular boundaries, and splintery terminations. In some specimens it is deeper green and more massive. Although its form is commonly prismoidal, it is, as a whole, of later crystallization than the plagioclase; yet in only one of the slides examined does it show an ophitic relation to the feldspar. While the usual character of the amphibole is similar to that of uralitic hornblende, in none of the many specimens examined was any augite detected. It may be pertinent to note that diabase dikes trending about north-northwest are found in the Cœur d'Alene district, and that the rock forming these is composed essentially of plagioclase, a little quartz and feldspar, and augite that is commonly much uralitized. The rock now under consideration is, on the whole, richer in quartz than the diabase of the Cœur d'Alene district, but otherwise similar except in the absence of augite; and this may be accounted for by the probably lesser age of the latter rock, which cuts across beds as late as Striped Peak, while the diorite sills here described were not seen in contact with rocks younger than the St. Regis. These considerations, together with the character of the hornblende, suggest that dioritic rocks of this region are uralitized diabases and gabbros, and although complete proof is wanting, I am inclined to believe that such is the case.

The feldspar shows abundant evidence of alteration, which has probably taken place under deep-seated conditions. It usually contains numerous well-individualized inclusions, chiefly of hornblende, epidote, and zoisite. The iron ore is commonly replaced by a cloudy "leucoxene," which appears to be chiefly titanite.

A remarkable phenomenon connected with these intrusions has been described in detail and discussed by Daly.[a] He has observed that near the upper surfaces of the great sills the rock changes gradually from hornblende gabbro to granite, and he ascribes this change to assimilation of part of the overlying siliceous sandstone by the magma. Similar observations were made in the region described in this report. I formulated no explanation of them in the field, but read Daly's paper after the season closed, and believe the conclusions therein stated to be essentially correct.

[a] Daly, R. A., The secondary origin of certain granites: Am. Jour. Sci., 4th ser., vol. 20, 1905, p. 185.

The two most striking cases of this marginal variation that were observed have been selected for brief description here.

The first occurs a little west of the mouth of Mooyie River, in a great sill about 800 feet thick, which dips steeply east with the inclosing strata. Most of the mass is composed of medium-grained, dark-gray, hornblendic rock, which becomes darker and finer grained near its western or lower side. For a few yards from its eastern or upper side, however, it is variable, but lighter colored on the whole and in part coarser grained. A typical specimen appears, megascopically, as an aggregate of lath-shaped feldspars, abundant quartz, and a moderate amount of hornblende, which forms conspicuous, long, splintery-looking individuals. The feldspar, on microscopic examination, proves to be somewhat more than half andesine, and the remainder orthoclase, which forms laths like the plagioclase instead of occurring interstitially as in the normal diorite.

The second locality is near the junction of Flathead and Missoula rivers. Here along one margin of a large intrusive body the typical diorite passes into a fine-grained pepper-and-salt aggregate of quartz, feldspar, and biotite. With the aid of the microscope it is seen that the feldspar comprises sodic plagioclase and an approximately equal amount of orthoclase. There is a very large proportion of quartz and micropegmatite, and abundant minute particles of biotite are included in the feldspar and quartz. The texture is unlike that of an ordinary granite in that the grains are extremely irregular in form and uneven in size.

A similar rock is extensively exposed at Plains, but here its relations to the diorite were not observed.

VOLCANIC ROCKS.

ALGONKIAN VOLCANICS.

Occurrence.—The only surface volcanic rocks noted in the Algonkian were seen near the forty-ninth parallel, on the high ground between Yaak and Kootenai rivers. They are best exposed in the steep glacial cliffs on the east side of the divide, which exhibit in section about 500 feet of lava, amygdaloid, and tuff, quite clearly extrusive.

Petrography.—These rocks are of a dark-green color, and are greatly altered, but examination of the more crystalline phases of the lava gives some clue to their original composition.

They have a striking porphyritic texture, showing to the unaided eye a dark-green aphanitic groundmass in which are embedded many conspicuous, markedly tabular phenocrysts of plagioclase, with a somewhat parallel arrangement, which attain a maximum length of about one-half inch. The feldspar is colored pale green, evidently by secondary material. In thin section it is seen that plagioclase is the only original mineral present, and that it forms a second generation of microscopic crystals. The material in which it is embedded is nearly all chlorite. Though clouded considerably with chlorite and kaolin, the feldspar may be determined from its extinction angles to be chiefly andesine. The considerable proportion of iron and magnesia shown to be present by the abundant chlorite, together with the character of the feldspar, indicate that the rock belongs to the andesites or basalts. Comparatively fresh lavas of the same highly characteristic texture as these have been found in the Miocene of Washington,[a] and they contain abundant augite as the only ferromagnesian mineral; it is probable that they should be classified as augite andesites.

MIOCENE BASALT.

Occurrence.—Just northeast of Spokane the west base of the rounded hills of old crystalline rocks north of the river valley is seen to be skirted by a horizontal terrace of basalt, which connects with the great volcanic sheet that underlies the Columbia Plain of eastern Washington. This terrace is continued eastward by a line of isolated, level-topped masses of basalt on either side of Spokane Valley. Similar basalt terraces are seen all about the shores of Cœur d'Alene Lake, along the western base of the Cœur d'Alene Mountains for some 14 miles north of the lake, along St. Maries River beyond the mouth of the St. Joe, and for several miles up Cœur d'Alene River.

It is about Cœur d'Alene Lake, and especially in the vicinity of Harrison, by the mouth of Cœur d'Alene River, that these terraces are most extensive and conspicuous. Their height above the water level at Harrison is about 500 feet, but it is 200 to 300 feet more at the north end of the lake. This may be due to the initial slope of the lava away from its source to the west, but this supposition can not be established without more observation.

Character.—The basalt is a dark, heavy, black rock, more or less crystalline and rather fine grained. It shows the characteristic columnar parting in places, and the upper parts of the layers have the vesicular character of surface flows. Detailed petrographic descriptions of this lava have appeared in several publications[b] and need not be repeated here. It belongs in general to normal basalts, with or without olivine. The one specimen taken on Lake Cœur d'Alene contains none of that mineral.

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[a] Snoqualmie folio (No. 139): Geol. Atlas U. S., U. S. Geol. Survey, 1906, p. 9.

[b] See, for example, Smith, G. O., Mount Stuart folio (No. 106), Geol. Atlas U. S. U. S. Geol. Survey, 1904; Smith, G. O., and Calkins, F. C., Snoqualmie folio (No. 139), Geol. Atlas U. S., U. S. Geol. Survey, 1906; and Calkins, F. C., Bull. Dept. Geology Univ. California, vol. 3, 1902, pp. 159–166.

STRUCTURE.

GENERAL STATEMENT.

The region is characterized structurally more by faulting than by folding. Very few folds in the region can be traced for great distances, but a number of faults, some of which are of enormous throw, have been followed for many miles. The blocks between the faults are generally much tilted, and steep dips persist in places for long distances across the strike. The Cœur d'Alene district is an area of exceptionally complex deformation, this fact being probably in large measure the cause of its richness in fissure-vein deposits.

The map shows the principal faults detected in the reconnaissance and also a few of the more extensive ones in the Cœur d'Alene district. Only the greatest faults can be represented with approximate correctness on a map of such diminutive scale. For some of those indicated for only short distances the direction has not been accurately determined. The most important faults have been given names, indicated on the map, by which they will be referred to in the text. The strike and direction of dip of the strata, where they are persistent over wide areas, have also been shown on the map.

FAULTS.

GENERAL CHARACTER AND EXPRESSION IN TOPOGRAPHY.

The great faults of the region are mostly steep, and probably the majority of them are normal, although a normal character has not been actually proved in many cases. The downthrow of all the steeply inclined faults, except the great Lenia fault and the one west of Bull River, is to the west and south. The strike of all except the Hope fault is approximately that of the dislocated strata, and the downthrow to the west is generally opposed to an easterly dip; or, in other words, the prevailing kind of dislocation is step faulting. The fault just east of Bull Lake is the only overthrust clearly shown to be such that was found outside the Cœur d'Alene district.

The marked extent to which the great faults are expressed in the topography can not be appreciated fully without the aid of a contour map, yet it is illustrated by the approximate coincidence of certain stretches of Clark Fork and Kootenai River with fault lines, which the small reconnaissance map shows. The crushing that has taken place along planes of movement has tended to the formation of valleys along fault lines. The course of the Hope fault is marked by a line of depression that separates a range of hills from the main Cabinet Range; the depth of the broad pass in which Bull Lake is situated is probably due in part to easy erosion along a zone of faulting; and other instances of this kind of topographic expression will be cited when the faults are described in detail.

Of true fault scarps the region affords no proved examples. Several features, taken by themselves, might be thought to exemplify this phenomenon, and the most apt for such an explanation is perhaps the Hope fault. On the north side of this dislocation the Cabinet Range rises abruptly, with a steep and fairly regular frontal slope and the topographic character of a dissected plateau, while on the south or downthrown side lies a range of rather flat-topped hills. These facts accord with the supposition that the tops of both the mountains and the hills are remnants of a single peneplain which has been dislocated by faulting. If this be true there can be no doubt—since the hills are carved in younger rocks than the mountains—that the peneplain was developed only after a displacement of several thousand feet had occurred, and that subsequently to the development of the peneplain a smaller displacement, equal in amount to the difference of elevation between the two dissected plateaus, has taken place on the same fissure.

But the hypothesis of direct physiographic expression of faulting, as applied to this case, can hardly be considered proved, for there is an alternative which appears to me at least equally competent to explain the facts. The greater topographic elevation of the upheaved block along the Hope fault is naturally accounted for by the superior resistance of the quartzitic rocks north of the fault as compared with the calcareous shales to the south, and the flat tops of the hills in the valley may represent an old valley level.

All the other apparent instances of direct topographic expression of faults in this region that can be recalled at present may similarly be explained as the result of differential erosion. Moreover, in some places the topographic evidence is opposed to the supposition of direct expression of tectonic movements. The most striking evidence of this kind is afforded by the part of the Snowshoe fault that is near the Snowshoe mine. There the downthrown block, on the west, is topographically the more elevated.

DESCRIPTION OF PRINCIPAL FAULTS.

Lenia fault.—The Lenia fault, named for a railway station near which it passes, has a course of about north-northwest and has been traced, though not continuously followed, from the mouth of Mooyie River to a point near the junction of Keeler and Lake creeks. It has a steep dip, whose direction is not certainly known, and the downthrow is on the east. Excellent opportunity to observe the character of the fault zone is afforded by the numerous cuts along the Great Northern Railway in the vicinity of Lenia. About a mile and a half northwest from the station the track crosses the fault, which can there be located within a few feet. There is intense disturbance and crushing for some yards on either side the fissure, which seems to be nearly vertical, but within a short distance may be seen the gray Prichard quartzite on the southwest side and green shales, with purple beds and thin layers of limestone, supposedly belonging to the Newland, on the northeast side, both dipping toward the fault at angles of 50° to 60°. The throw here, being equal to about twice the thickness of the strata intervening between the horizons brought together by the fault, must be more than 15,000 feet.

The fault crosses Callahan Creek at a point not accurately located, but a few miles from its mouth. Here it seems to bring Striped Peak against Prichard. The promising "Big Eight" and "B. & B." mines on this stream, in slates and quartzitic sandstones of the Prichard formation west of the fault, are located on fissures whose course is about parallel to this great dislocation and which dip steeply to the west. The suggestion arises that the Lenia fault may be of the steep reversed type, of which many examples are found in the Cœur d'Alene district.

The fault is expressed strongly by the topography, for it has partly determined the course of Kootenai River, which flows directly along the fissure for a short distance northwest from Lenia. It also has determined the location of several saddles between the river and Lake Creek.

Snowshoe fault.—The Snowshoe fault is conspicuous in the vicinity of the Snowshoe mine, about 20 miles south of Libby, whose ore body is in the main fault fissure. In the workings of the Snowshoe mine the fissure strikes nearly north and south and is almost vertical, but dips on the whole a little to the west. This is also the side of downthrow, for the country rock east of the fault is purplish-gray quartzite, which is referred to the Burke formation, while to the west it is calcareous shaly material, very similar to the typical Newland, but referred to a horizon even higher. The throw here must be considerably more than 6,000 feet, probably fully 10,000 feet. Contrary to what might be expected in view of this great displacement, the fissure as seen underground is remarkably clean cut; the Snowshoe vein is for the most part only about 5 feet wide, and the rocks that constitute its firm, well-defined walls exhibit little disturbance. The small amount of crushing that has taken place in the fault zone accounts for the comparatively slight expression of the fault in the topography. In the vicinity of the Snowshoe mine the spurs are rather sharply notched where it crosses, but its course to the south, across a lofty portion of the Cabinet Range, is not marked by any conspicuous depression. The sharply defined character of the Snowshoe fault is probably due to its nearly vertical attitude, which allowed the movement to take place with a minimum of friction.

For some distance south of the Snowshoe mine the fault was not directly observed, but its southward continuation is thought to be indicated by a fault contact clearly exposed on the north side of Clark Fork valley about halfway between Thompson and the mouth of Vermilion Creek. There the high bluffs that overlook a bend of the river show disturbed red and green shales, probably belonging to the St. Regis and Newland formations, dipping to the east toward westward-dipping Prichard argillites. The fault has here had some influence on the location of the east wall of the valley, and it disappears to the south under the alluvium.

Hope fault.—The Hope fault has been traced approximately from Hope to Heron in the valley of Clark Fork. The course of the fissure is marked by a trench dividing the Cabinet Mountains proper from a zone of much lower hills that lie between the range front and the river. The fact of faulting is clearly established by the relations of the rocks of the hills to those of the mountains. The rocks of the Cabinet Mountains in this vicinity belong to the Prichard, Burke, and Revett formations, whose strike makes a large angle with the course of the dividing trench and whose dip is east, while the valley hills are composed chiefly of Newland rocks, with some St. Regis and Striped Peak beds, which also dip east from Hope to Clark Fork. The hill tract has therefore been carved from a block which has been greatly depressed with reference to that which forms the mountain tract. South of Scotchman Peak, for example, the base of the Burke is brought against Striped Peak rocks, involving a displacement of not less than 12,000 feet. The dip of the fissure is not known, but it is probable that, like the majority of fissures observed in this region, it dips to the southwest, and that the fault is normal.

Bull Lake fault.—The fault east of Bull Lake differs markedly in character from those described in the preceding paragraphs. It is an overthrust, dipping 45° W. The force which produced it produced also a strong and extensive schistosity in the granite east of it, and intensely sheared and crumpled the sedimentary rocks in its vicinity farther south. Its throw, although probably amounting to some thousands of feet, is not known with any definiteness, while its extent north and south from the points where it was actually located is uncertain. It is thought that it probably extends at least as far north as Station Creek and as far south as the lower forks of Bull River. The evidences that indicate the character of the fault will be described in detail later. (See p. 66.)

Evidences of faulting along Purcell trench.—Mr. Ransome, who reconnoitered the western part of this region in 1901, suggested in conversation the idea that the Purcell trench might have been determined by a great fault, with the downthrow to the east, which dropped the Algonkian down against the Archean. The existence of such a persistent and straight valley is in itself suggestive of faulting. My endeavor to verify this hypothesis did not lead to definite proof of extensive dislocation. The boundary between the Algonkian and the Archean is covered at the south by basalt and alluvium, and farther north is invaded by post-Algonkian granitic intrusions. Some evidence of faulting along this trench was found, however, and may be briefly stated.

In the railroad cuts just north of Porthill there are exposed gray quartzites and shales belonging to the lowest formation of the Algonkian, and these are cut by a basic dike. The sediments are much fissured and mineralized, and the basic dike, which is greatly altered, has a distinct vertical schistosity that strikes about north and south. These phenomena are indicative of faulting about parallel to the valley.

The gneissic banding also that is developed in the granite or quartz monzonite at Bonners Ferry and to the south may be due to shearing in a zone of faulting.

Again, although along the western base of the Purcell and Cabinet mountains the strata dip eastward and belong to the lowermost division of the series, farther south the structural trend makes a considerable angle with the line of the Purcell trench, and areas of strata so high in the series as the Newland formation extend to the western limit of the Algonkian belt. The lack of concordance in this vicinity between the course of the dominant topographic feature and that of the structural axes and faults to the east of it might have been produced by faulting.

FOLDS.

In the northern part of the region the strike of the rocks is notably uniform and is, on the average, a little west of north. In the southern part, and especially in the Cœur d'Alene district, it is far more variable, but is most commonly near west-northwest. As has already been mentioned, few extensive unbroken folds can be traced. The greatest one recognized is an anticline that runs along the northeastern side of the Cabinet Range. Its course is about north-northwest, and it makes an oblique angle with the Snowshoe fault, which cuts off a part of its western limb, so that in the vicinity of the Snowshoe mine only its eastern limb is seen. At the head of Fisher River, however, a fine section across the crest of the arch is exposed. Here in the axial portion typical Prichard slate appears, and this is flanked on either side by quartzite of the Burke formation.

A clearly synclinal structure is exhibited along the international boundary between Yaak River and the crest of the Kootenai-Yaak divide, but this syncline was not traced far along its axis.

The gorge of the Kootenai between Troy and Libby exposes several folds in section. There are a number of small folds just below the falls, and a broad syncline and anticline above.

The canyon of Clark Fork between Thompson and Plains cuts across an anticline in quartzitic rocks of the Ravalli group and a broad syncline that shows shale and limestone of the Newland formation in the axis, underlain by these quartzitic rocks on either side.

CHAPTER III.

AREAL GEOLOGY.

GENERAL STATEMENT.

The purpose of this chapter is twofold. It will present many details regarding local stratigraphy and structure which could not well be included in the general discussion that formed the last chapter, and it will enable those who for economic or scientific ends desire information concerning the geology of any particular portion of this region to find facts relating to that portion which may serve their purposes or guide them in more detailed studies.

To arrange the subject-matter of this part of the report is somewhat difficult because the examination of the region was necessarily incomplete and uneven. To discuss the geologic features of the principal mountain groups in turn would hardly be practicable, inasmuch as there are large areas in each range regarding which no details are known. It has therefore seemed best to subdivide the account of the areal geology under headings that designate sections into which the route of the party may conveniently be divided. These sections, together with the areas explored in their vicinity, will be described in the order in which they were traversed.

DETAILED DESCRIPTIONS.

CŒUR D'ALENE AND SPOKANE VALLEYS.

The Algonkian rocks along Cœur d'Alene Valley and the wagon road from the mining district to the lake belong to the Prichard and Burke formations, the former predominating. The prevailing strike is about east and west, and the prevailing dip a moderate one to the north. What is taken to be the continuation of the Osburn fault, of the Cœur d'Alene district, crosses a saddle behind a knob across the bridge from Cataldo. It brings northward-dipping Burke beds down against the shale of the Prichard formations. Two other saddles, east and west of Kingston, which were once occupied by the river, are in line with this one and with the course of the Osburn fault as traced in the Cœur d'Alene district, and they are believed to have been determined by relatively rapid erosion along the fault fissure.

The most important stratigraphic observation made in this valley was of the gradual change in the character of the Prichard formation along its strike. The change is not so marked, however, as to lead to danger of confusing the Prichard with any other formation of the region. The dark-blue fine-grained banded slate or argillite that is the dominant phase of the Prichard in the Cœur d'Alene district simply becomes on the whole more siliceous, coarser grained, and of a grayer tint, with a tinge of green in places.

The first gneiss met with along the route forms a small hill on the lake shore near Cœur d'Alene. It is separated from the nearest outcrop of Prichard by a terrace of basalt. Gneiss is exposed on both sides of the narrows where the main north-south body of the lake begins. On the east it is overlain by basalt, which presumably covers the contact between the gneiss and the Algonkian rocks. The south shore of the east arm was not examined, however, and might furnish some clue as to the relations of the two systems.

The valley of Spokane River affords other good exposures of the gneisses, already mentioned on page 33. One of the most interesting features of the geology of this section is the occurrence of basalt terraces which are remnants of tongues that projected up the pre-Miocene valley from the great basalt floods of the Columbia Plain. These are to be seen at intervals along Spokane Valley, are developed to a large extent about the shores of Cœur d'Alene Lake, and are found in the lower part of the valleys of Cœur d'Alene and St. Joseph rivers.

BETWEEN CŒUR D'ALENE AND PEND OREILLE LAKES.

The hills extending from Cœur d'Alene north-northeastward to Lake Pend Oreille are composed of Algonkian rocks. South of Canfield Butte—a hill south of Hayden Lake—these rocks resemble the Prichard formation, but that elevation seems to owe its prominence to silicification along a fault which brings the Prichard on the south against a formation on the north which resembles the Newland. This formation was also observed on Hayden Creek, where it has the aspect of typical middle Newland, also about 2 miles northwest of the head of Hayden Lake, where it is evidently metamorphosed by the neighboring monzonite and does not weather in the same yellow tints that characterize the typical Newland. The rocks of Chilco Mountain are mostly thin-bedded quartzites, of greenish hue, which in places grade into hard white quartzite or purplish siliceous argillite. They dip under Newland rocks and are supposed to correspond to the St. Regis formation. Bernard Peak is composed of white, green, and purplish-brown, fine-grained, thin-bedded rocks which weather as though calcareous and prove on microscopic examination to be composed essentially of quartz, carbonate, mica, diopside, and a pale-green amphibole. Evidently these rocks are such as might be derived from siliceous and magnesian limestones by contact metamorphism, and they strongly resemble metamorphosed phases of the Newland ("Wallace") formation in the Cœur d'Alene district. They dip southward toward the basin of the Little North Fork of Cœur d'Alene River, where the Newland formation, with its typical aspect, is well developed.

A trip into the drainage basin of the Little North Fork resulted, owing to the heavy cover of brush and forest, in little except the general observation that the rocks of this vicinity are chiefly sediments belonging to the pre-Cambrian formations that prevail in the Cœur d'Alene district. There is a vast development of Newland in the northern part of the basin, while farther south there occur white quartzites, partly pure and partly sericitic, which correspond to the Burke and Revett formations in the Cœur d'Alene district. Certain observations made during this excursion, as well as facts related in conversation by Mr. Leiberg, were interpreted as indicating that several faults crossed the river, probably with a direction approximately east and west. South of Lakeview for many miles, in both the Clark Fork and the Cœur d'Alene drainages, the prevailing rocks are typical Newland. They were found overlain and underlain by purplish quartzitic beds assigned to the Striped Peak and St. Regis formations, respectively. These two formations are apparently brought together by a fault, which was not exactly located, a few miles southeast of the head of Lake Creek.

LAKE PEND OREILLE.

The steep rocky shores of Lake Pend Oreille afford excellent exposures and were examined throughout their extent with the aid of a launch. Considerable information was thus gathered concerning the stratigraphy and structure of the vicinity. Most of the rocks were of sufficiently familiar appearance to be correlated confidently with the formations of the Cœur d'Alene district, but the place in the stratigraphic series of the pure limestones exposed about the south end of the lake (p. 42) is still problematical. In the following brief description of the shores, the southern portion, upon which the limestones are exposed, will be left until the last.

The western shore from Cape Horn northward is made up of rocks of the Newland formation, the underlying quartzitic Ravalli group, and the Prichard formation. These have prevailingly an eastward dip and are broken by step faults with downthrow to the southwest. Cape Horn is composed of a granodiorite which a few rods northward is seen in irruptive contact with metamorphosed purplish-gray shaly sandstones that correspond to the St. Regis formation. Along the crescentic curve of the shore to Blacktail Point the rocks have the typical aspect of the St. Regis and Newland formations. They generally dip toward the lake, but there is much variation in their attitude. The contacts between the two formations are not generally well exposed, but it seems probable that most of these contacts are faults. The gulch just southwest of Blacktail Mountain certainly marks the position of a great fault, with downthrow on the southwest. South of the gulch the country rock is the most typical middle Newland, dipping in general eastward, but showing much contortion and fracture and cut by several small veins. North of it is a high, steep-sided promontory carved from purplish-red and green sandy shales like typical St. Regis, also dipping eastward. Farther along the shore these beds are again conformably succeeded by calcareous shales of the Newland formation. These form the country rock of the mine east of Blacktail Mountain, along the eastern base of which runs another fault, similar in strike and direction of movement with the one mentioned just before, but exceeding it in amount of throw.

Just northeast of the little embayment at Blacktail purplish quartzite, probably corresponding to the Burke formation, much disturbed, veined, and broken, has been brought against the Newland by the Blacktail fault, and is apparently faulted again farther on against bluish thin-bedded shales, with interbedded gray impure quartzite, which are taken to correspond to the Prichard formation. These latter rocks are almost continuously exposed to the northern end of the lake. Along the shore the general dip is eastward, with some variation. It is probable, however, that this dip is offset by other lesser faults in addition to those already mentioned. One of these probably determines the location of Garfield Bay. In its vicinity the sedimentary rocks are cut by numerous basic dikes, which commonly accompany known faults in other parts of the region, and on the west side is a mine on a rather ill-defined zone of brecciation.

The north shore was examined by following the Northern Pacific Railway from the west base of the mountains to Hope, the almost continuous cuts revealing a succession of the same bluish and gray argillites and quartzites that are seen along the northwestern shore of the lake. There is much of this material that resembles the Prichard formation, but hardly any so argillaceous as the dominant phase of rock in the type localities. The most abundant species is an indurated, fine-grained, sandy shale or shaly sandstone. The sedimentary rocks are cut by a large number of dikes, both acidic and basic, and at the west base of the mountains by a batholithic mass of granodiorite. Eastward the good exposures are interrupted for a short distance, but on Mameloose Island, southeast of Hope, they are continued by outcrops of greenish-gray siliceous shales, again dipping eastward, which resemble and are probably to be correlated with the Burke. The outcrops, followed along the lake, show occasional transition to purplish beds and whitish quartzitic beds. These in turn are overlain near the east end of the lake by purple, maroon, and green beds of rather bright tint.

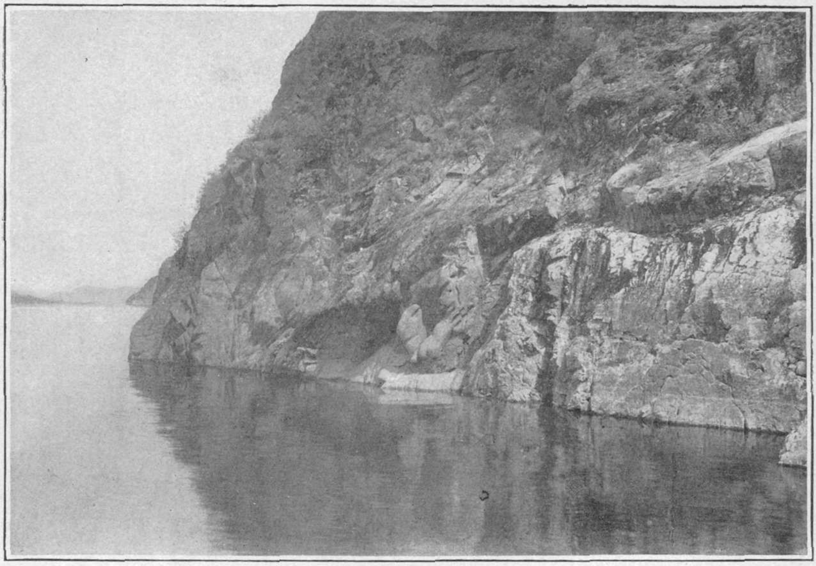
Along the south side of the eastern arm of the lake the high bluffs give excellent exposures of the Newland, underlain by purple beds like typical St. Regis, these in turn by more grayish quartzites resembling the Burke, though rather purer and thicker bedded. (See Pl. II, *B*.) There is here no distinct heavy stratum of white quartzite corresponding to the Revett quartzite of the Cœur d'Alene district. These rocks are underlain by bluish shales similar in character to those of the Prichard formation, but thinner bedded and without slaty cleavage.

Along the eastern shore of the lake to Lakewood the exposures are more diversified, and sedimentary rocks alternate with intrusive masses of granitic rocks whose occurrence is the chief feature of interest on this shore.

The limestone referred to on page 42 is exposed west of Cape Horn along the north side of Squaw Bay. It has here been rendered coarsely crystalline by the granodiorite intrusion, and in the quarry of the Washington Brick and Lime Manufacturing Company shows no recognized bedding. No clue to its stratigraphic relations can be gained at this locality, for it is not seen in contact with any other sedimentary rocks. On the southern shore, however, there is more hope of solving the problem.

The section along the shore west of Lakeview exhibits an eastward-dipping succession, in descending order, of limestone, quartzite, and bluish shale, the last-named rock probably being separated by a fault from the Newland beds that form Bernard Peak. The contact between the limestone and the quartzite is faulted, but the impression was gained that the fault is not of large throw. East of Lakeview also this main mass of limestone is cut off by a fault. A little farther northeast, however, the limestone is again seen apparently overlying bluish shale and quartzite. In the valley just southeast of Lakeview the limestone is seen faulted against quartzite on the east, but the character of its southern boundary was not made out. A little farther south the blue shale like the Prichard was seen in fault contact with typical Newland.

From these observations it appears probable that the limestone immediately overlies quartzites and shales. These latter rocks bear some resemblance to Prichard and Burke respectively, but it is a significant fact that the quartzite has in part a very coarse-grained, pebbly character, unlike that of any rocks undoubtedly belonging to the Burke or other members of the Ravalli group. The lithologic resemblance is not necessarily significant, therefore, and these shaly and quartzitic rocks may belong to a horizon above the Striped Peak. This appears the more probable because of the difficulty in account-



A

B

VIEWS ON LAKE PEND OREILLE.

ing for the development of several hundred feet of limestone at a horizon that shows no trace of calcareous material anywhere else in the district.

CLARK FORK VALLEY BELOW VERMILION CREEK.

The dominant structural feature of the valley from the lake to Heron is the Hope fault, which profoundly affects the areal distribution of the rocks. The hilly space between this fault and the river is occupied by rocks of the St. Regis, Newland, and Striped Peak formations. From Hope to Clarkfork the rocks exposed along the railway and the wagon road have an eastward dip that gradually diminishes from about 60° to almost 0°. They are chiefly Newland, but at Thornton siding, a few miles east of Hope, several hundred feet of beds like typical St. Regis, underlain by more massive purplish quartzite, are brought up by a fault with upthrow on the east, whose displacement must be at least 4,000 feet. East of Clarkfork the Newland is overlain by shaly siliceous beds, chiefly maroon in color, but with some green layers, which correspond in general character and stratigraphic position with the Striped Peak formation of the Cœur d'Alene district. Between Clarkfork and Heron the structure is in general synclinal, and to the east the Newland becomes the prevailing rock. There are some small folds and apparently some faults, both parallel to and across the strike, but these minor structural features were not worked out.

South of the river in this portion of the valley less thorough examination of the ground was made. The rocks there also are chiefly Newland and Striped Peak, the red beds of the latter being extensively developed south of Heron, where they have a thickness, according to Mr. MacDonald's observations, of more than 2,000 feet, their upper limit not having been observed.

The mountains north of the great fault were ascended northeast of Hope, in the neighborhood of Lightning Creek and north of Heron. They were found to be composed of rocks stratigraphically beneath the Newland, with a general moderate dip to the east, although there is local disturbance near Lightning Creek. From their western base to Lightning Creek they are composed of the gray quartzites and gray to bluish argillites that correspond in position to the Creston quartzite as described by Daly, and seen by me along the forty-ninth parallel, but intermediate in lithologic character between that formation in its typical aspect and the Cœur d'Alene phase of the Prichard formation. The prevailing eastward dip is somewhat variable in amount, but averages about 30° for at least 10 miles across the strike, indicating a thickness of about 26,000 feet. There is strong probability, however, that this is greatly in excess of the actual thickness of the beds, whose great width of outcrop across the strike may be due in large measure to step faulting, of which examples at Thornton and along the west side of Lake Pend Oreille have already been mentioned. North of Hope the dioritic intrusives described on page 48 are well displayed.

The ascent of Scotchman Peak, east of Lightning Creek, afforded some observations throwing light on the stratigraphy of the lower part of the Algonkian. The ascent was made by way of the first large tributary of Lightning Creek entering it on the east above its mouth, which affords an excellent section in which the general dip is about 20° E. Near the mouth of this tributary the country rocks are the impure gray quartzites with thin beds of argillite so extensively exposed farther west. These are overlain by about 2,000 feet of dark-blue banded argillite, exactly similar to the typical Prichard as developed in the Cœur d'Alene district. Overlying this material are the light-colored siliceous beds that form Scotchman Peak. These are thin-bedded, ripple-marked, and sun-cracked sericitic quartzites of a gray color, generally tinged with green and purple, almost identical in appearance with the Burke formation in its type exposures. On the north-south ridge of which Scotchman Peak forms a part, and in the profound canyon of the west fork of Blue Creek east of the ridge, these beds are most impressively displayed to a thickness estimated at about 5,000 feet, and they here exhibit no evidence of faulting.

Eastward for several miles from this locality the only observations of the Cabinet Mountains along the Clark Fork valley consisted in long-range views from the south. These showed that in the untraversed section the eastward dip persists, and that quartzites continue to be the prevailing rocks. Looking about north from Heron, however, on the east side of a deep canyon conjectured to be that of the east fork of Blue Creek, one sees a great thickness of rocks that appear darker than the quartzites, and these may be Prichard slate brought up by a fault. Without some such faulting it would be difficult to account for the very great apparent thickness of the quartzite along this section, as compared with that in the Cœur d'Alene district.

The ascent northeast of Heron gave opportunity to observe a part of the quartzitic Ravalli group, and it was found here to comprise a thick stratum of hard white quartzite similar in character and position to the Revett quartzite of the Cœur d'Alene section. Its base was not seen, but it outcrops extensively along a prominent and rugged ridge, and was estimated to be at least 1,000 feet thick. On the east the quartzite is limited by a fault, shown on the map, which has brought it against typical Newland beds.

The quartzitic group being thus cut off, the Newland formation becomes the principal country rock on both sides of the Clark Fork valley, continuing eastward on the south side nearly to Thompson and on the north side to the Snowshoe fault. The portion of this stretch extending from Bull River to Vermilion Creek was traversed only by train, because its geologic simplicity seemed to make more detailed examination needless for reconnaissance purposes. The eastward dip of the Newland west of Bull River is rather steep, but opposite the mouth of that stream the bedding is almost horizontal, and thence to Vermilion Creek it exhibits gentle undulations.

BULL LAKE VALLEY.

The trench in whose center Bull Lake is situated and which is drained by Bull River and Lake Creek is so well defined a topographic unit that its geologic features may be described together.

Observations along Bull River.—Along the lower, narrow portion of Bull River canyon the rocks are shaly argillaceous beds ascribed to the Newland formation because of their close lithologic similarity to the beds in the Cœur d'Alene district described as the "Wallace" formation. Along the lower and middle parts of Bull Lake valley these beds exhibit some folding, but their dips are prevailingly easterly and northeasterly. The Newland continues on the east side of the river nearly as far as Bull Lake, but not so far on the west side, for the fault observed northeast of Heron apparently crosses the stream, as shown on the map (Pl. I).

This fault was observed in a gulch west of a point at about the middle of Bull River valley. Here are exposed purple and green shales of the St. Regis formation, overlain by typical lower Newland beds, dipping gently to the east and abutting against brecciated white quartzite. The plane of contact appears to dip steeply west, which would imply reverse faulting, but this could not be proved without more thorough examination.

West and southwest of Bull Lake are extensive outcrops of quartzite, seemingly for the most part to be correlated with the Burke formation; and several hundred feet of greenish, more or less sericitic quartzites with some purplish bands are exposed in a remarkable defile just west of Bull Lake. This is a straight north-south ravine, bounded on both sides at the top by cliffs, from both of which descend talus slopes that merge at the bottom. The cliff on the west rises about 1,600 feet to a plateau surface, and that on the east, several hundred feet lower, joins a smooth brushy slope that descends to the lake. In the west cliff the beds are about horizontal; in the east cliff they dip gently eastward. This feature is supposed to have been formed by a huge landslide that caused the mass east of the ravine to slide downward toward the lake, toward which it became somewhat tilted. A view of it is shown in figure 2.

Bull Lake fault.—The phenomena that accompany the Bull Lake fault, already mentioned on page 55, must be described in some detail, both because it is partly from them that the character of the fault has been inferred and because they are of remarkable and unusual character.

The fault is best displayed at the side of the valley a little south of east from the north end of Bull Lake, and the relations in this vicinity are diagrammatically indicated in figure 3. On going from the road up a certain small stream that there descends from the mountains, one finds a few outcrops of unmetamorphosed shaly sedi-

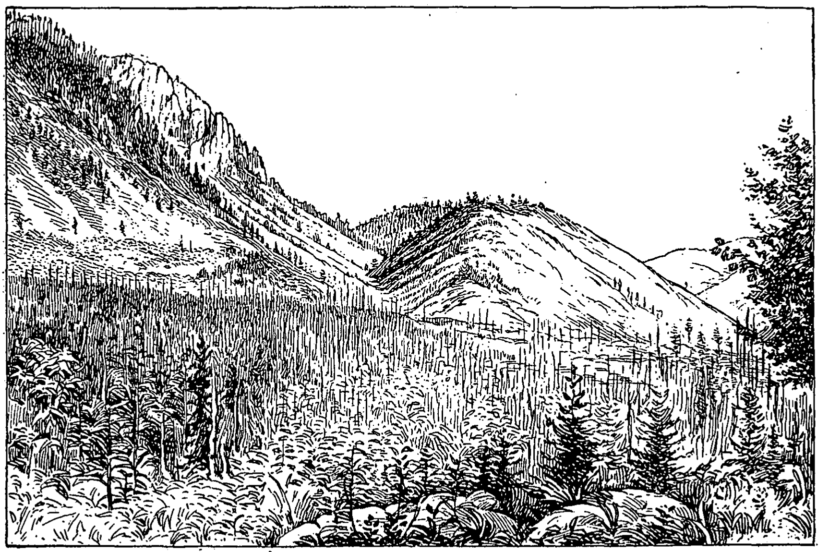


FIGURE 2.—Landslide west of Bull Lake.

mentary rock, dipping gently east, mantled by a heavy deposit of gravel. Proceeding, one comes to a place where, from the gently sloping floor of the broad valley, there rises abruptly a north-south slope, which for a few yards from the base is virtually a plane, with an inclination of 45°, but which becomes gentler and much less even above. The stream cascades down the steep incline, into which it has cut a trench.

The rock which forms this slope is a greenish-gray gneiss whose lamination is parallel to the smooth westward-dipping basal facet. Just south of the fall this regular surface is coated by a siliceous iron-stained breccia that contains extremely sheared and decomposed fragments of the gneiss. A few hundred yards farther north there is seen just west of the gneiss a mass of white siliceous sinter which is evidently a hot-spring deposit.

It is evident from these facts that this smooth rock slope is the foot wall of a fault fissure. Its freshness, relative smoothness, and regularity suggest that it may be a normal fault scarp, on which movement with relative lowering on the west side has taken place in comparatively recent time. It does not seem improbable that recent movement in this direction may have taken place, but it is believed, for reasons presently to be stated, that the main movement on the fissure has been an overthrust with relative upheaval on the west.

Some evidence for this view is given by the gneissic banding of the igneous rock. Since this is parallel to the fault fissure, it is believed to have been produced by the same force. The tremendous pressure necessary to have sheared the rock so thoroughly can hardly be accounted for by friction evolved in normal faulting on a plane of 45° dip,[a] but it might have been produced by the great tangential compressive strain involved in the production of a reversed fault.

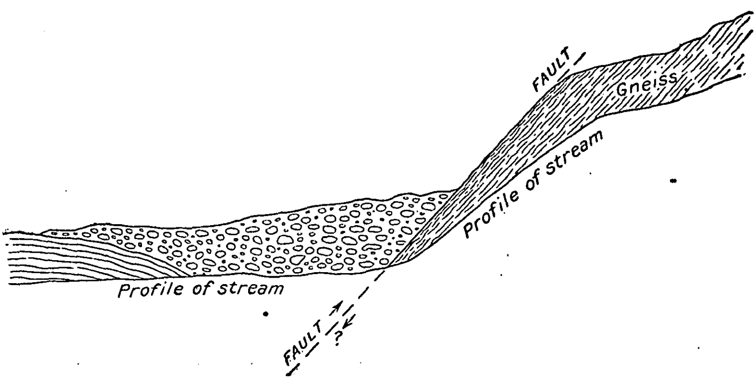


FIGURE 3.—Diagrammatic section across Bull Lake fault.

Additional evidence bearing on this matter, and striking proof of intense dynamic action, are observed in line with this fault at the forks of Bull River southeast of the lake. At the foot of the spur between the forks there are outcrops of sedimentary rock so intricately crumpled and so greatly altered that at first sight they were taken to belong to a pre-Algonkian complex. The minute folds were found to be recumbent toward the east, which should be the case if they were produced by overthrusting from the west. To the east, however, these intensely deformed rocks pass gradually into regularly dipping beds resembling the Newland, which are in turn overlain by a thick accumulation of tough, fine-grained, dark greenish-gray rocks unlike any in the Cœur d'Alene district and believed to be stratigraphically higher than the Striped Peak formation. A mile or so south of the forks there is a low saddle, west of which is a

[a] A gneissic structure induced in a granitic rock by friction on a plane of normal faulting with very low dip is described by Lindgren in Prof. Paper U. S. Geol. Survey No. 27, 1904, pp. 47–48.

hill composed of eastward-dipping Newland, which is practically continuous with the undoubted Newland of Clark Fork valley. It was inferred from these relations that the Newland on the west was thrust by this fault against similar beds on the east younger than the Striped Peak, whose characteristic red shales, though developed typically and in great thickness in Clark Fork valley, do not appear at this locality. Thus stratigraphic as well as structural evidence indicates an overthrust dipping to the west.

Sediments east of Bull Lake fault.—Observations on a great thickness of the sediments east of the Bull Lake fault constituted the chief result of a traverse from the upper forks of Bull River to the highest of the conspicuous isolated group of jagged peaks about 5 miles east. These mountains are carved from a remarkably homogeneous mass of tough, fine-grained, rather siliceous rocks of greenish-gray color. They weather in thick ledges, but show rather narrow bands parallel to the planes of stratification. They resemble some of the material in the Burke formation, but the Burke beds which are exposed in the near neighborhood are as a whole much lighter in color and are more siliceous. The thickness of these beds here exposed is about 5,000 feet, and they are underlain near the forks by partly calcareous beds resembling the Newland. At the western limit of their exposure they are vertical and strike northwest, but farther east they flatten out and show several small open folds. The steep sides of the peaks exhibit fissures along which small displacements appear to have taken place.

Farther northward a spur of the range just north of Station Creek was ascended. The rocks seen near the base of the spur are bluish and greenish shales dipping eastward, succeeded by red shales. These give way—so abruptly as to suggest faulting, possibly the continuation of the Bull Lake fault—to greenish quartzites underlain by siliceous argillites, mostly greenish gray, occasionally purplish, with some thin beds of white, yellow-weathering limestone. This aggregation of rocks differs materially from any of the formations seen in the Cœur d'Alene district, among which the Newland ("Wallace") most resembles it. These rocks differ widely, however, from the Newland exposed in Clark Fork valley within a distance far smaller than other intervals through which the formation retains its essential characters. It is therefore thought that these beds belong to a horizon above any represented in the Cœur d'Alene district.

KOOTENAI VALLEY FROM TROY TO BONNERS FERRY.

The dominant structural feature of the Kootenai Valley between Troy and Bonners Ferry is the Lenia fault, which plays a rôle similar in character and importance to that of the Hope fault in Clark Fork valley. Like the Hope fault, it brings Newland and Striped Peak beds down against the older rocks that form most of the western part of the Cabinet Range. The course and character of this fault have already been described on page 69, and we may confine most of our attention here to observations bearing on the stratigraphy of the Prichard formation as seen west of the fault and of the Striped Peak, Newland, and older rocks exposed east of the fault.

The railroad section from Bonners Ferry to Lenia affords excellent exposures of thousands of feet of impure quartzites and argillites. Their strike and dip are very constant, and do not vary much from N. 15° W. and 55° E., respectively. They show no evidences of extensive faulting, although they are cut by small slips which increase in frequency as the great Lenia fault is approached. Lithologically the rocks have a strong general resemblance to those exposed along the Northern Pacific Railway west of Hope. In the western part of the section hard, moderately thick-bedded, gray quartzites prevail. To the east bluish argillaceous beds become increasingly abundant, but without forming any thick strata free from quartzitic material.

The rocks exposed west of the fault on Callahan Creek, to the south, are believed to be stratigraphically higher than those described in the preceding paragraph, not only because the strike of the beds diverges in this direction from the course of the fissure, but also because of their lithologic character. In the vicinity of the B. & B. mine is exposed blue banded argillite showing the strongly characteristic features of the prevailing rock of the Prichard formation as developed in the Cœur d'Alene district. The thickness of this material is not determined, but amounts at least to several hundred feet. It dips southeast, apparently under the gray quartzitic rock of the Big Eight mine, which may belong to the base of the Burke. Typical Prichard slate is also exposed southward along the fault as far as the mouth of Keeler Creek, and forms the country rock of other mines in the vicinity of Grouse Mountain.

East of the fault and north of Callahan Creek is exposed a good section of the Newland formation overlain by a little Striped Peak. At the western edge of a broad gravel terrace developed near the river there are outcrops of a rock composed of thin interbedded layers of blue argillite, white sandstone, and yellow-weathering impure limestone—an assemblage of rocks which, in the Cœur d'Alene district, characterizes the middle part of the Newland. The strike here is N. 50° W. and the dip 90°; to the south the strike becomes more northerly and the dip, which is to the southwest, more gentle. Above the rocks like the middle Newland, are many hundreds of feet of bluish argillite, and of greenish shaly material the yellow color of whose weathered surface indicates its calcareous nature. Similar rocks in the Cœur d'Alenes constitute the upper part of the Newland formation. These, finally, on the top of a hill about 2,300 feet above the river, are overlain by a comparatively small thickness of green and purple beds like the typical Striped Peak.

On the east bank of the river at the ferry just below Troy there are reddish purple siliceous shales, with some thin beds of cream-colored yellow-weathering limestone. From their southwesterly dip these beds appear to be stratigraphically beneath the Newland across the river, but as their relation to any known formation was not certainly made out, their position in the sequence must be considered doubtful. To the east they show an anticlinal fold, but are separated by a broad stretch of gravel from quartzitic rocks of the Ravalli group, which are developed farther east on the road to Sylvanite.

Farther down the valley more of these calcareous shaly rocks are exposed. Some outcrops on the road a few miles west of Yaak River show greenish gray, yellow-weathering rocks with a little interbedded reddish purple shale. The strike is N. 30° W., the dip 75° SW. In the vicinity of Lenia also, east of the great fault, the rocks, which strike N. 25° W. and dip 25° W., are gray, green, and reddish-purple indurated shales, with a few beds of cream-colored limestone. It is inferred from these observations that in this vicinity the Newland may contain some beds of red shale and whitish limestone which are absent from the formation in the Cœur d'Alene district.

Near Varco's ranch, close to the Idaho-Montana boundary, are extensive exposures of typical Newland rocks dipping steeply south-southwest, and about 5 miles west some purple and green shales with a similar attitude.

Where the Kootenai Valley road crosses the Mooyie bridge gray, thick-bedded, shaly rocks, with some quartzitic bands, dipping east, were found, which doubtless belong to the Prichard formation, the Lenia fault having been crossed in an area covered with terrace gravels.

North of the valley, west of the state boundary, is a conspicuous group of high, rugged peaks of quartzite, which looks from a distance rather like the Revett than the Burke.

LOWER YAAK VALLEY.

The valley of Yaak River was examined for a few miles above and below the deserted mining town of Sylvanite, and in this portion it displays a section of some of the older formations, which in general have a southerly dip.

The country rock near Sylvanite is gray impure quartzite, thick bedded to shaly, with some argillaceous layers, dipping southeast. Up the river for at least 5 miles from the town, and an unknown distance farther, these distinctly bedded gray quartzites, with gentle dip downstream, continue. At the bridge below town the river cascades down the bedding of a blue-gray indurated sandy shale resembling the Prichard, and along the road toward Troy more typical Prichard slate is exposed. Toward Bonners Ferry no exposures are to be seen along the road until, about 3 miles from the bridge, one comes to an exposure of rock like typical Burke, striking N. 10° W. and dipping 45° W.

Anyone who visits this region for more detailed work would do well to examine the gorge of the Yaak below the falls. It should afford a good section of the Prichard, the overlying quartzites, and a part of the Newland formation.

PURCELL MOUNTAINS.

The geologic information obtained in the Purcell Mountains relates chiefly to the section along the forty-ninth parallel, which has been surveyed in detail by Daly. My observations relating to that section are stated mainly for the purpose of putting on record my conception of the correlations to be made between the strata along the boundary and the formations developed in the Cœur d'Alene district.

Mooyie Valley.—The lower part of this broad valley was traversed hastily. The slope west of the valley is apparently made up chiefly of quartzites and argillites belonging to the Prichard formation, dipping east, and interleaved with many sills of diorite. The east side of the valley is also chiefly of quartzitic rocks, including some with a purplish tinge belonging to the Ravalli group, but on this side the exposures are poor and the structure is apparently more complex than on the west side.

Vicinity of forty-ninth parallel east of Mooyie crossing.—Along the north side of Mooyie River, between the boundary and Spokane Junction, is a finely exposed section which exhibits several hundred feet of westward-dipping green and purple shales, purple and green quartzites, and argillites marked with ripple marks and sun cracks. These rocks (Daly's Kitchener quartzite?) correspond in character to the Ravalli group, but apparently comprise no white quartzite stratum corresponding to the Revett quartzite. They are underlain on the east by some very fine-grained, homogenous, blue-gray argillite, whose thickness is apparently only a few hundred feet. This is taken to belong to the stratum of blue argillite like the typical Prichard seen near Scotchman Peak, Callahan Creek, and the lower Yaak River. Below this again there are the gray quartzites, with subordinate interbedded argillite, corresponding in stratigraphic position to the lower part of the Prichard formation, which I suppose to be Daly's Creston quartzite, and these strata, with numerous dioritic sills, are exposed along the party's course to the mouth of Hawkins Creek.

From a camp in the meadows of the latter stream an excursion was made along the divide between Mooyie and Yaak rivers to Mount Ewing, several miles south of the boundary. From a point a short distance south of the boundary this ridge affords excellent exposures, but as it follows the strike it does not exhibit a great thickness of strata. It is carved from gray quartzites and argillites referred to the lower part of the Prichard formation, with heavy sills of diorite injected parallel to the bedding planes, which have produced a notable amount of contact metamorphism in the overlying sediments. These rocks all dip gently to the east.

From the longitude of this ridge eastward along Hawkins Creek and the west fork of Yaak River to the point where the latter crosses the boundary there are discontinuous exposures of rocks dipping constantly to the east, apparently in their normal sequence as laid down. These are, in order from west to east:

(1) Blue-gray argillite interbedded with gray indurated sandstone and quartzite, supposedly equivalent to the Prichard formation.

(2) Thin-bedded quartzitic rocks, whose color is light gray tinged with green and purple. These are thought to represent the lower part of the Ravalli group.

(3) Rocks like (2), but more argillaceous, and colored in rather bright tints of green and purple. These are like the typical St. Regis beds, and are presumably equivalent to them.

(4) Bluish and greenish argillaceous rocks, with abundant thin laminæ of impure limestone and calcareous argillite which weather to an ocher-yellow color. On weathered surfaces the limy layers, owing to their relative solubility, form grooves and are frequently cellular. These rocks, well exposed along the stream near where it turns across the boundary, are similar to the Newland beds and are believed to be correlative with them.

(5) Overlying these on the slope east of the bend are purple and green sun-cracked shales—some of the green material weathering yellow, as though slightly calcareous—and considerable dark blue-gray argillite. This group of strata is thought to be the equivalent of the Striped Peak formation, which it resembles in being largely constituted of purplish, sun-cracked, shaly material.

Between the west fork and the main Yaak a syncline is developed, of which a good section is afforded by an east-west ridge just south of the boundary trail. On its east limb is exposed, in reverse order, a part of the succession just described. Under the trough of supposed Striped Peak beds are some thousands of feet of thin-bedded argillaceous and calcareous rocks, comprising a bed of light-gray cellular-weathering limestone about 20 feet thick. These strata are cut by some dikes of ophitic diabase. Stratigraphically beneath them are gray-green siliceous argillites with some faintly purple bands, such as form, in the Cœur d'Alene district, the transition between Newland (" Wallace ") and St. Regis. Below, the material gradually becomes more quartzitic, and purple bands become abundant, as in the typical St. Regis beds. Rocks of this character extend down to the river, while on the opposite side and a little upstream the downward sequence is apparently continued by some purplish and greenish west-dipping quartzites resembling the Burke.

East of Yaak River observations along the boundary were continued by a traverse to the Kootenai-Yaak divide. Float and a few outcrops of noncalcareous quartzite like the Burke occur for some distance up the slope, and are succeeded by rocks like the Newland, which form the crest of the first ridge. These dip eastward, but as no considerable thickness of purple rocks seems to separate them from the Burke, they are believed to be faulted down against that formation. Along the trail for some miles they are represented by float composed largely of the ocher-yellow fragments derived from the disintegration of impure limestone. It is only on the steep slope of the second ridge crossed by the trail that thoroughly satisfactory exposures are first found. At the base of the acclivity is an outcrop of cellular-weathering, shaly, impure limestone, dipping east. About 700 feet higher, and apparently overlying this rock, are exposed about 200 feet of purple and green sun-cracked shales, also dipping east, and these are succeeded near the crest of the ridge by fine-grained, green, siliceous, banded rocks and a rather thin stratum of blue-gray argillite. Interbedded with the sediments are a few thin layers of the green porphyritic amygdaloid described on page 50. A little higher the volcanic rock, interbedded with a little green shale, forms a thick stratum, which is again overlain by fine-grained green sediments. These rocks are folded into a broad syncline, so that the stratum of green lava, tuff, and breccia, which apparently thickens somewhat from west to east, is well exposed in the cirques at the heads of the streams draining into Kootenai River.

The thickness of the green beds in the trough amounts to many hundreds of feet. Lithologically these beds are remarkably homogeneous. They are very fine grained, with a distinct lamination brought out by the differing tints of successive layers. Near the volcanic rock they have a very dark-green color, perhaps due to some admixture of chloritized volcanic material, but the bulk of them are light grayish green. In part they contain a small proportion of calcareous material in closely spaced thin laminæ, which on weathered surfaces are indicated by grooves, owing to the partial solubility of the material composing them, and are colored yellow or orange by the residual ferric oxide.

Yaak basin.—Near the ford of Yaak River below the west fork, where the main-traveled trail downstream finally crosses to the left bank, there are bold ledges of thin-bedded impure limestone weathering with a yellow color and a cellular surface, interlaminated with bluish argillite. They dip 45° W. On the west side of the valley, about a mile below, similar rocks are exposed and are overlain conformably by a little green, thin-bedded, calcareous argillite, succeeded by green and purple siliceous shaly beds, of which a thickness of 1,000 feet was actually observed. The calcareous beds are tentatively correlated with the Newland and the purple and green beds with the Striped Peak.

East of the river in this latitude an excursion was made by Mr. MacDonald to a high isolated peak that is the most conspicuous and individual landmark in this part of the region. He notes west-dipping Newland beds for some distance from the river, then some blue-gray and purplish quartzitic material, probably belonging to the Ravalli group, with the same dip. East of these are bluish and grayish argillites, probably belonging to the Prichard formation, in which an anticline is developed. The overlying rock of which the peak is formed is flaggy gray quartzite with the character of the typical Burke. It strikes N. 40° W. and dips 40° E.

Divide at head of South Fork of Yaak River.—The ridge that parts the waters between the South Fork of Yaak River and the creeks that flow directly into the Kootenai affords a good section across the structural trend, and was traversed for a few miles east and west of the point where it is crossed by the trail from Libby to the Yaak basin.

At the pass the rocks are purple and green, siliceous, flaggy sediments dipping gently east, which are presumably to be correlated with the Striped Peak. Eastward these continue to crop out, with easterly and southerly dips, as far as a saddle, about 2 miles from the trail, which seems to mark a fault with downthrow on the west. Across the saddle the dip is west and the rock is green argillite. Continuing farther eastward, one crosses a thick stratum of interlaminated yellow-weathering limestone and argillite, and one of green argillites, the whole assemblage having the lithologic character of the Newland formation and being presumably equivalent to it. These at last are underlain by purple and green beds like the typical St. Regis, which are anticlinally folded.

West of the trail the eastward-dipping purple and green Striped Peak beds are exposed for about a mile, to the brow of a slope that leads down a deep saddle in the divide. A short distance down the slope they are underlain by green argillites, which lower down are interbedded with blue argillites and impure, yellow-weathering limestones. Intruded in these is a sill of diabase. The thickness of sediments similar to the Cœur d'Alene phase of the Newland exposed from the base of the purple beds to the bottom of the saddle is about

1,500 feet. On the west side of the saddle the succession observed east of it is repeated. The slope west of the notch, nearly parallel to the east dip of the beds, is formed largely of a comparatively thin bed of bluish argillite underlain by purple and green strata which form the crest of the next ridge. Beyond and stratigraphically beneath these appear the same calcareous sediments seen east of the notch, with apparently the same intrusive diabasic sill. It is evident that the low saddle, and perhaps in large part the valley of the South Fork, is eroded on a fault that effected a downthrow on the west of about 2,000 feet. This fault is indicated on the map.

KOOTENAI VALLEY FROM TROY TO JENNINGS.

Section between Troy and Libby.—The cuts along the railroad from Troy to the eastern border of the broad valley of Lake Creek afford discontinuous exposures of red, green, and gray shaly rocks, with some thin beds of whitish, yellow-weathering limestone. Their general strike is a little west of north and their dip nearly vertical. The conspicuous outcrop of purple and green shales just east of Lake Creek is in line of strike with the beds near the Troy ferry, which are surmised to belong to a horizon well down in the Newland or to the St. Regis formation. The beds outcropping at intervals in the lower end of Lake Creek valley show much evidence of faulting, and, as extensive faulting has occurred along the valley to the south, it is impossible at present to say with confidence to what formation these beds belong, or what is their relation to those exposed in the gorge of the Kootenai east of Lake Creek.

This gorge has cut through a great thickness of folded strata in a direction almost normal to the average strike, which is about N. 10° W. The structures observed in this section are as follows: From the mouth of the gorge the beds dip steeply east for about a mile, and then form several small folds, which at Kootenai Falls, about a mile farther, give way to a very gentle east dip. Above the falls there is developed a broad syncline, of which the western limb dips gently and the eastern rather steeply, and in this syncline the highest beds of the section are developed. Beyond is a well-exposed anticline, and farther on some minor folds are seen before the broad gravel-covered valley at Libby is reached.

East of the valley of Lake Creek the first extensive exposure shows about 600 feet of fine-grained argillite, made up of thin laminæ of green, gray, and blue material, dipping steeply east. Near the upper limit of this assemblage of beds there is a 3-foot layer of white, yellow-weathering limestone, and also a small basic dike. A space of one-fourth mile separates this outcrop from the fine exposures along the gorge proper, so that it is uncertain whether the beds of the outcrop mentioned really underlie those in the gorge or whether, as the presence of the dike and the resemblance of the sediments to some developed at the top of the section to the east both suggest, they are separated from them by a fault. On the steep slopes of the gorge the first rocks encountered are light greenish gray argillites whose weathered surfaces are coated with a thin film of limonite. These are overlain by some purple and green beds, and these in turn by some beds of limestone with an aggregate thickness of about 30 feet, which are conspicuous in the gorge just below the main falls.

Above the falls the exposures are not so continuous on the track as they are below, for the valley becomes a little less steep sided. The large folds, however, can be clearly seen on the north side of the river. The gently inclined strata are gray-green, partly calcareous argillites, very much like those just mentioned as forming the westernmost part of the walls of the gorge. These are succeeded—apparently overlain—by purple and green beds, like the St. Regis and Striped Peak formations, and in the trough of the great syncline beyond are banded argillites, with gray, blue, and green tints, like those seen at the mouth of the gorge. The east limb of the syncline brings up rich-colored purple and green beds corresponding in a general way to those on the west limb, although the sections are not sufficiently continuous for detailed comparison.

A generalized summary of the section from the mouth of the gorge eastward, which was plotted on the large-scale map of the Great Northern Railway, is given in the following table. The assumption is made for the present that there is no faulting.

Summary of section (descending order) in gorge of Kootenai River between Troy and Libby.

	Feet.
Argillites, greenish gray and dark blue, finely laminated, not continuously exposed	4,300
Quartzites and indurated sandstones and shales, reddish purple and green	1,250
Argillites grading into sericitic quartzites, mainly green, but with purple strata interbedded	1,400
Argillites, siliceous, greenish gray, in part somewhat calcareous and weathering to a yellow color; dip flat, about	1,000
Cream-colored limestone weathering somewhat yellow, with some partings of green argillite, exposed near Kootenai Falls	30
Indurated shale and shaly limestones and quartzites, purple and gray-green, with some calcareous bands	600
Argillite, mostly greenish gray, weathering yellow as if calcareous, sun cracked and ripple marked	3,200
Argillite, purple	5
Argillite, gray-green	100
	11,885

The only place in this section where considerable faulting seems probable is just below the falls, where it is suggested by the complex deformation of the beds. A canyon here empties into the river on the north, and the section along the track is also interrupted for a few hundred feet, so that exposures are lacking at the critical point.

Between Libby and Jennings.—The section along the Great Northern Railway from Libby to Jennings affords fairly good exposures, but since its general course makes an acute angle with the prevailing northwesterly strike of the rocks it does not cross a very great thickness of strata. The structures observed in this section, which was examined by Mr. MacDonald, are an anticline and a syncline.

The rocks which it displays doubtless belong to the assemblage better exposed to the west. They are chiefly greenish-gray and green and bluish argillites, containing thin layers that weather to an ocher yellow and are evidently calcareous. Interstratified with this material are a few beds of purple argillite.

EAST SIDE OF CABINET RANGE.

GENERAL FEATURES OF TOPOGRAPHY AND GEOLOGY.

Topography.—South of Libby the Cabinet Range is high and rugged and has an abrupt, straight, and well-defined front trending about south-southeast. West of this line the spurs rise, at first rather steeply and then more gently, toward the jagged ice-carved peaks. East of it is a broad zone of comparatively low, rounded foothills, drained, within the area examined, chiefly by Libby Creek and its tributaries, but in part by headwater streams of the Fisher River system. It is near the point where this line intersects the Kootenai–Clark Fork divide that the rugged part of the Cabinet Range terminates.

The principal streams of the foothill area have a common trend about parallel to the front of the mountains, and between them are long ridges, or rounded elevations aligned in rows. Some of these hill ranges are more persistent than the streams. The one between Cherry and Libby creeks, for example, extends for some distance north of the confluence of those streams, being limited on the west by a line of broad saddles.

This marked parallelism of the topographic features depends primarily on the structure of the rocks. The general strike of the beds in this vicinity is a little west of north, and they are cut by at least one enormous fault of approximately this direction, accompanied in all probability by several others whose course is nearly the same. The location of the valleys has probably been determined in part by selective erosion of the softer strata, but it is probably due in greater degree to selective erosion along fault fissures. Both these causes seem to have had a share in the formation of the eastern front of the range. Southwest of Libby this seems to coincide with the Snowshoe fault, but the broad valley of Cherry Creek is underlain by softer rocks than those that form the mountains on the west, and its location and character were probably in some measure influenced by this fact. Swamp Creek also is in line with a fault, of undetermined throw, traced for only a short distance, which will be described on another page. The belief, however, that faulting has influenced the topography of this area more potently than varying resistance of strata to erosion, is based not wholly on local evidence, of which there was time to gather but little. Observations extending over a large part of the region occupied by the Belt series tend to show that in general the strata of this series do not present variations in strength sufficiently marked to determine long and persistent strike valleys in the absence of faults.

General geology.—The Snowshoe fault is the principal structural feature of this part of the Cabinet Range, and has had a great effect on the areal distribution of the rocks. The rocks west of it, where they were seen, are compact fine-grained argillites, mostly greenish gray, with some calcareous material supposed to be higher in the stratigraphic column than the Striped Peak formation. East of the fault the only rocks identified belong to the Prichard and Burke formations. They are folded into an arch which has already been referred to as the Cabinet anticline. This is complete near the Yaak-Kootenai divide at the south, where the summit peaks are carved from the quartzitic rocks on its western limb. To the north, however, its axis meets the Snowshoe fault at an acute angle, and near Snowshoe only its eastern limb, composed of Burke beds alone, is present and forms the outer parts of the spurs along the face of the range. Still farther north these quartzitic rocks disappear, being perhaps entirely cut off by the fault. Beyond the point of their disappearance the steeply rising mountains are formed, from base to top, of the greenish argillites above referred to, and here the Snowshoe fault probably separates the mountains from the foothills, in which no prominent outcrops occur.

The exposures in the foothills being in general far less satisfactory than those in the mountains, but little time was spent in examining them. They seem to be in greater part of shaly rocks in which red colors prevail. Detailed examination was made in these hills only along Swamp Creek, where some pure limestones and calcareous shaly rocks, presumably Paleozoic, were found.

SECTION SOUTHWEST OF LIBBY.

A traverse was made from Libby to one of the conspicuous high peaks southwest of that place. The low, rounded foothills crossed in order to reach the mountain slope are covered with deep soil and gravel and afford no satisfactory outcrops. The rocks composing them, judging from float, are mainly red and green shaly sediments. The lower part of the mountain slope is also covered with drift. At a height of about 6,000 feet, however, fine-grained sediments crop out, which strike N. 5° W. and dip 37° W. They have a well-developed cleavage, which strikes N. 10° E. and dips 55° W. The rock is similar to that exposed in the axis of the syncline east of Yaak River, being a light greenish gray siliceous argillite of waxy texture, whose weathered surfaces, where transverse to the bedding, exhibit closely spaced yellow stripes which are the traces of calcareous laminæ. This material is overlain by greenish-gray argillite, sun cracked, a little darker, coarser, and less slaty than that below, and not notably calcareous, which resembles the material seen east of Bull River. This forms the summit of the peak, where it dips 40° NW. Below the rock shows many minor undulations. The strata exposed on this slope are equivalent to part of the group forming Bear Peak, which is presently to be described.

SECTION EAST OF BEAR PEAK.

The ascent of Bear Peak, the most conspicuous and probably the highest summit of the Cabinet Mountains, was made by way of the canyon of Leigh Creek, which heads in the lake on the flank of the mountain. The splendid exposures encountered in this excursion made it geologically one of the most interesting, as it was scenically the most impressive, of the entire season. The section along Leigh Creek is almost identical with that seen on Snowshoe Creek, so that the first part of the following description applies equally to the vicinity of the mine.

In the lower part of the canyon the precipitous walls are of gray quartzites, which are generally more or less flaggy and sericitic, though in part fairly hard and massive. Near the mouth of the canyon they dip at a moderate angle eastward, but farther up the stream the strike becomes nearly northwest and the dip northeast, indicating approach to the crest of a northward-pitching anticline. Only the eastern half of the arch, however, is present, for about halfway up to the lake the Burke is cut off by the Snowshoe fault, whose position is marked by notches where it intersects the ridge crests on either side, and by slight gullies on the canyon walls.

Above the fault the first rocks exposed are interlaminated argillites and impure limestones, which for a short distance dip about 45° E. and then steeply to the west. A few hundred feet of rocks like those characteristic of the middle part of the Newland as developed in the Cœur d'Alenes are succeeded by rather dark gray-green siliceous argillites, finely and irregularly banded. A short distance below the lake the dip flattens rather abruptly to 25° W. For the whole mass of strata exposed on the precipitous slopes above the lake, the strike and dip, though varying slightly, are not far from north-northeast and 30° W., respectively. The rocks west of the Snowshoe fault show no evidence of appreciable faulting. They are cut, however, by some remarkably conspicuous and persistent joints, which are vertical and strike about N. 35° W. North of the lake a small stream has eroded along one of these joints a deep, narrow cleft, down which it tumbles in a succession of cascades. The rock along the fissure shows evidence of slight movement, but the close correspondence of the strata on either side shows that there has been no appreciable displacement.

The rocks exposed on the precipitous slopes above the lake do not exhibit a wide range of lithologic variation. They are in general very fine-grained, moderately hard, argillaceous rocks, whose color is prevailingly green in various tints, more rarely bluish. There is little calcareous material except at the top of the section, where there are numerous beds of whitish, somewhat crystalline limestone a few inches to a few feet thick, whose weathered surfaces are rough and stained with ocher. Some distance down the northwest slope of the peak, whose upper portion is about parallel to the dip, there are at least 1,000 feet of strata lithologically similar to those which form the summit, and stratigraphically above them.

A summary of the section observed in this traverse, with rough estimates of the thicknesses of the subdivisions that might be discriminated on lithologic grounds, is given in the following table:

Section (descending order) from northwest side of Bear Peak to Snowshoe fault.

	Feet.
Argillites, light greenish gray, somewhat calcareous, weathered surfaces covered with limonite, with thin beds of cream-colored, somewhat crystalline, yellow-weathering limestone	1, 500
Argillites, siliceous, mostly dark greenish gray but in part bluish, locally containing large crystals of pyrite	2, 500
Argillites, rather light greenish gray, with thin, yellow-weathering, somewhat calcareous layers, and a few thin beds of medium-grained white quartzite	1, 200
Dark gray-green banded argillite	1, 500
Blue argillite, intercalated with thin layers of impure yellow-weathering limestone	500
	7, 200

The correlation of these beds is problematical. The rocks that form the rugged peaks southeast of Bull Lake belong to the group described above, but the Bear Peak section exhibits some higher beds. The structure between the Snowshoe fault and the forks of Bull River is essentially synclinal, and the same horizon, namely, the top of the beds like the Newland, is exposed near by in the lowest observed part of either limb. The arguments for considering these strata to be considerably younger than the Newland formation may be found on page 68 and need not be repeated here.

OBSERVATIONS NEAR HEAD OF FISHER RIVER AND ON VERMILION CREEK.

A canyon, whose name was not learned, which heads a few miles north of the point where the Vermilion Creek road crosses the divide, affords an impressive section of the Cabinet anticline. Along the lower part of the canyon the country rock consists of indurated sandy shales made up of dark blue-gray to white laminæ, interstratified with some beds of gray quartzite. This is succeeded by a great thickness of the blue, regularly banded argillite characteristic of the Prichard formation, and the dip gradually flattens until it becomes horizontal about halfway up the gulch, then bends down gradually to the west. The argillite is overlain again on the west flank of the anticline by quartzitic rocks, which form a group of the noblest and most rugged peaks in the Cabinet Range. On the walls of the amphitheaters carved on the eastern flanks of the peaks it is estimated that fully 4,000 feet of the quartzites were seen, yet this is not their entire thickness. These beds dip down toward the valley of Clark Fork, and presumably disappear under the Newland rocks that form the valley sides for many miles below Vermilion Creek.

The lithology of the Burke and Prichard formations in this vicinity is precisely the same as in the type localities. The main body of the Prichard, of which fully 2,000 feet are exposed here, consists mainly, as in the Cœur d'Alene district, of dark-blue argillite with only occasional thin beds of quartzite, and here as there the passage to the overlying Burke is a gradual one, marked by increasing abundance of interbedded flaggy quartzite and gradual disappearance of the bluish material. The Burke, as in the type localities, is composed of flaggy sericitic quartzites marked by shallow-water features, with gray tints that are darker toward the base of the formation. In distant views toward the high peaks of this part of the range no stratum of quartzite so pure and distinctly characterized as the Revett quartzite was definitely recognized.

In the vicinity of the Silver Butte mine, near the point where the route from the Fisher River country to Thompson Falls crosses the divide, the country rock is chiefly typical Prichard, with some Burke. The locality is about in line with the crest of the Cabinet anticline, which, however, seems to be somewhat complicated in this direction by minor folds and faults and may not be traceable to the south. On a hill across the canyon south of Silver Butte a fault was seen which brings westward-dipping Burke underlain by Prichard against westward-dipping Prichard. The course of the fissure is about north-northwest; the downthrow, amounting to fully 2,000 feet, is on the east. The fault is not conspicuous, and was traced for only a short distance. The Silver Butte vein has no connection with the north-northwest faults, its strike being about N. 60° W. and its dip 30° S. In the vicinity of the mine the strike and dip of the strata are both highly variable.

On Vermilion Creek and its west fork, down which the road descends, the sedimentary rocks exposed are dark argillites with some beds of indurated sandstone, belonging to the Prichard formation and having its typical aspect. The dip is generally steep and to the west, but a steep east dip was observed a few miles below the pass. On the lower part of the creek basic dikes or sheets in the steeply inclined strata were seen, and the syenitic mass described on page 46. The sedimentary rocks near the mouth of the canyon were not examined, and the location of the Snowshoe fault, as well as its relation to the syenite, is drawn on the map by conjecture. It was expected that the fault would be found to pass west of the mouth of the stream, but observations made a little farther east along the valley and presently to be discussed (see p. 83), indicated that this was not the case.

SWAMP CREEK.

Near the middle of its course the valley of Swamp Creek, mostly rather flat bottomed, becomes constricted for a mile or so by a projection from the west side. At the northern end of this constricted portion there is a bridge, which, in order that the locality may be identified by future observers, may serve as a point of reference in the following description.

For a few miles below the bridge, limestones, forming a thicker and purer mass than any found in the known Algonkian strata of this region, are exposed along the road, chiefly on the east side of the creek, but also, for some distance below the bridge, on the west side. This heavy limestone, lithologically, is very light colored on weathered surfaces, but gray to drab on fresh fracture. It is rather fine grained and somewhat crystalline. Rubbed with a hammer it gives off a fetid odor. It is locally somewhat shaly, though without clay partings of appreciable thickness, but some of it is fairly thick bedded. The only traces of organisms found in this stratum consist of tubular bodies that suggest filled worm borings.

The most prominent exposure of this limestone occurs just west of the bridge. Here a steep spur gives a cross section of several hundred feet of the rock, striking about north-northwest and dipping steeply east. On the west the outcrop of limestone abruptly terminates at a little defile which is in line with the valley, and is succeeded by reddish-purple and green, indurated, sandy shales, with a few thin beds of yellow-weathering limestone that is pink on fresh fracture. These strata have approximately the same attitude as the thick stratum of limestone, but the abruptness with which the latter is cut off, and the depression of the surface along the contact, strongly suggest a fault, which, if it exists, probably had some influence in determining the location of the valley.

East of the bridge a traverse was made for a long distance up the slope. At the base some blue-gray and red argillite was found, and east of it a vertical bed of limestone similar to that described above, but somewhat thinner. A short distance down the stream the two beds of limestone seem to merge, perhaps through faulting, of which brecciation in the rocks gives some indication. On the slope above the limestone, and apparently deposited conformably upon it, is a great thickness of argillaceous beds, which dip east for perhaps a mile, then west. Near the base of the slope the material consists largely of a peculiar, very fine-grained, cherty shale, which is finely banded in dark blue-gray and olive-green, or in dark blue-gray and white. For some distance above the prevailing rock is green argillite, which is followed by red and green, indurated, more or less sandy shales. Near the top of the section some thin beds of the yellow-weathering limestone, interstratified with red beds as it is west of the creek, are found.

On the east side of the valley a little farther south similar beds were examined by Mr. MacDonald, who found in the limestone some imperfect fossils that could not be specifically determined but have a Paleozoic aspect.

CLARK FORK-FLATHEAD VALLEY FROM VERMILION CREEK TO DIXON.

Vermilion Creek to Thompson.—At the place where Deep Creek emerges from its canyon, whence it flows through a deep trench in the broad terraces to Clark Fork, the mountain slope is formed of Prichard slate which strikes N. 10° W. and dips 60° W. On the terrace abundant fragments of the yellow decomposed material that has often proved to be an indication of the presence of calcareous Newland rocks beneath the surface suggested that the edge of the valley was coincident with a great fault, but nothing certainly in place was seen. Within a few miles to the southeast, however, clear evidence of such a fault was found. The river above Deep Creek swings in a great bow, convex to the east, and has almost completely cut away its terraces for a little distance along the east side, so that the road has to rise far above its usual level to find safe ground. At the south end of the bow a high northwesterly facing bluff extending out from the mountain side exposes a section of fine-grained purple and green argillites, somewhat crushed and disturbed, but with a general eastward dip. These probably represent the upper part of the St. Regis formation. The slope of the valley side within a few yards of the easternmost exposures of these beds shows gray quartzite that is judged from its lithologic character and its position with reference to the beds on Deep Creek to be near the base of the Burke formation.

This fault contact was thought to represent the continuation of the Snowshoe fissure, whose course is represented on the map accordingly. The mapping, however, involves much assumption in that the fault is drawn for a long distance through country that has not been traversed. The fault along Clark Fork valley has a slightly more northwesterly course than has the Snowshoe fault, where it was first observed, and the two may intersect at the edge of the valley west of Vermilion Creek. It is also possible that the Snowshoe fault may die out before reaching the valley, but its throw is so great that it would be likely to persist across the range.

Little time was spent in detailed observations on the side of the broad valley about Thompson Falls, but some notes concerning the stratigraphy and structure in this vicinity may be worth recording.

The slopes north and east of the expanded portion of the valley in which the town is situated are carved from yellow-weathering Newland rocks which, with some underlying beds, are well exposed on the sides of a canyon that drains into the river near the railroad bridge below town. At the base of the mountain front, north of the creek, the lowest beds exposed are gray sericitic quartzites, like typical Burke, dipping north-northeast. Above them is some hard, fairly pure quartzite supposed to correspond to the Revett, but only about 200 feet thick. This is overlain by light purplish-gray and greenish-gray flaggy quartzites and siliceous argillites, like the lower St. Regis beds, which have a very distinct cleavage that strikes N. 10° W. and dips 50° W. Beyond a saddle that probably marks a small fault there are more of these beds, striking more nearly north-northwest and standing about vertical, and farther on are the Newland beds which have a decreasing eastward dip. It is believed that these beds will prove to be separated by a fault from the older, westward-dipping strata that form the valley side farther north. Indeed, the next large canyon in that direction shows near its mouth a large exposure of dark-colored west-dipping strata which appear from a distance like Prichard, and farther up the canyon is exposed a light-colored rock which forms a heavy talus and may well be quartzite of the Burke formation or the Revett quartzite that has been faulted down.

Thompson Falls probably owe their origin to Clark Fork having encountered, in sinking down through the old gravel deposits, a bench projecting from the southwest side of the valley. When the stream reached the level of the rock its down-cutting action was locally retarded, and continued rapid erosion in the gravels below the bend soon initiated a cascade, whose recession has formed a shallow gorge about a mile long. Along the east side of this gorge is exposed a succession of strata that have a gentle northerly dip. The uppermost part of the section consists of gray-green, yellow-weathering, calcareous argillite, like lower Newland, which is underlain by several hundred feet of purple and green beds having the lithologic aspect of the St. Regis formation. These are underlain in turn, without the intervention of any strata resembling the quartzite of the Burke or the Revett, by blue and white shaly argillite like the upper part of the Prichard, well exposed in the immediate vicinity of the falls. These beds probably form a lens of somewhat limited distribution, for nowhere else have similar blue argillites been found at this horizon.

Prospect Creek.—Prospect Creek, which flows in a rather broad-bottomed valley whose steep sides afford good exposures, has been reconnoitered from its mouth to the Cœur d'Alene district, where it originates. For a short distance from the river it flows through rocks resembling the Burke, which are anticlinally folded. These are succeeded by typical calcareous Newland beds, dipping east, the contact, which is marked by a line of saddles, being due to a fault. Whether or not this is a still further continuation of the Snowshoe fault, as seems quite possible, could not be proved without more detailed examination and exact mapping, if indeed the drawing of the fault across the wide alluvium-filled valley would in any case be justified.

Upstream from this fault contact a good section of rocks, dipping steeply eastward, is exposed. A considerable thickness of Newland is succeeded by purple and green St. Regis beds, which grade into hard, white Revett quartzite, exposed about 7½ miles up from the river. Farther on, these pass gradually into flaggy sericitic quartzites of the Burke formation. In the vicinity of the mines, about 9 miles above the mouth of the creek, the country rock is Burke and Prichard, showing rather complex deformation. Beyond, the Prichard, with a broadly anticlinal structure, is extensively exposed, and within a few miles from the boundary of the Cœur d'Alene district it is seen dipping westward under the Burke formation.

Gorge between Thompson and Plains.—Between the broad vales in which Thompson and Plains are situated the river flows in a steep-sided canyon, which displays an excellent transverse section of folded strata belonging to the Ravalli group and the Newland formation. The structure and general stratigraphy of this section will be described, and then a comparison will be made between the beds exposed here and the corresponding beds of the Cœur d'Alene district.

Going eastward through the canyon, whose west end is near the mouth of Thompson River, one crosses successively an anticline and a syncline. The steep spur that forms the west portal of Thompson River canyon is carved from westward-dipping rocks; these were not examined at close range, but the upper portion, which is much stained with ocher, doubtless consists of calcareous Newland beds, while the lower portion appears to be more quartzitic and presumably represents the St. Regis formation. A cut not far beyond this stream shows flaggy to rather thick-bedded, somewhat sericitic, gray quartzites, with a strike of N. 20° E. and a dip of 40° W., and these form the walls of the Clark Fork canyon for several miles eastward. In this direction the dip soon becomes lower and more northerly on the north side of the river, but is apparently southerly on the south side. About a mile west of Eddy the strata bend down rather sharply from a nearly horizontal position, and near the station dip about 45° NE. The flexure is well exposed in section on the south side of the river. On that side there is some suggestion of faulting parallel to the course of the stream, for the upper part of the slope is of soft rocks that resemble at a distance the Newland beds, and these appear to have been dropped down a little behind the quartzites.

Three miles east of Eddy a prominent spur affords a good exposure of purple and green beds, corresponding to the St. Regis formation, which strike N. 10° W. and dip steeply east, and these are succeeded by a thick accumulation of fine-grained sediments which are in large part calcareous and weather in general to a clay-yellow color. These sediments, from their character and position, evidently belong to the Newland formation. They maintain a rather steep east dip for about a mile and a quarter, then flatten rather abruptly. After continuing in an almost horizontal position for more than a mile and a half, they abruptly turn up again to an inclination of 55° W., thus completing a steep-sided, flat-bottomed syncline. The steep westward-dipping calcareous beds are exposed for half a mile farther eastward, until the exposure is interrupted by the rather wide valley of a creek that flows into the river from the north. Beyond, the sides of the canyon are lower and more gentle, but for 3 miles along the railroad track there are numerous exposures, appearing to be practically continuous on the slope to the north, of grayish quartzites, whose strike varies from N. 20° W. to N. 30° E., and which dip regularly westward at angles ranging from 20° to 55°.

The beds stratigraphically lowest in the section described in the preceding paragraphs closely resemble the Burke formation as exposed in the eastern part of the Cœur d'Alene district. They consist of more or less flaggy siliceous rocks, medium to fine grained, whose color is a light gray, slightly tinged with green or purple. They are, on the whole, rather thicker bedded than the material that represents the formation near Burke, and, as in the sections north and east of Thompson Pass, comprise a good deal of rather hard, finely banded, purple quartzite.

The Revett quartzite of the Cœur d'Alene district seems to be represented by beds of fairly pure greenish-white quartzite, rather unsatisfactorily exposed in scattered outcrops just east of Eddy. This material is not as homogeneous as the typical Revett quartzite, however, and does not constitute, as that formation does in the Cœur d'Alene district, a distinct and heavy stratum sufficiently differentiated from those above and below to be readily recognized in distant views. In this vicinity it is doubtful whether it could be mapped separately from the Burke formation.

The beds above the light-colored quartzitic rocks, closely examined only at the locality 3 miles east of Eddy before mentioned, are lithologically identical with the typical St. Regis beds as exposed in Military Gulch in the Cœur d'Alene district. They are indurated flaggy sandstones and shales, which exhibit the sun cracks and ripple marks and the bright green and purple tints characteristic of that formation.

As in other localities, these green and purple beds pass gradually into the overlying Newland formation, whose basal portion is green argillite. This phase, however, seems hardly as thick here as in the Cœur d'Alene district. The bulk of the material exposed in this section consists of grayish, more or less calcareous argillites intercalated with thin beds of impure limestone. The argillites on fresh fracture are mostly dark bluish gray and more or less distinctly banded, but as they contain ferruginous carbonates they weather in drab or yellow tints. The banded phases exhibit crumpling, and the more homogeneous phases have a cleavage that was seen in one place to strike about north-south and to dip west. The limestone is chiefly of a bluish tint and commonly weathers yellow. A rock somewhat different from any seen in the Cœur d'Alene district is exposed near the east limit of the exposure. It is a gray, drab-weathering, calcareous shale which contains numerous rudely ellipsoidal nodular bodies about one-half inch to 1 inch in diameter, of very fine-grained, nearly black limestone, which is more soluble than the matrix and weathers to a light-gray color.

The beds of this section do not comprise, so far as noted, any of the layers of calcareous quartzite that are characteristic of the middle part of the Newland ("Wallace") as developed in the Cœur d'Alene district. On the whole they are somewhat finer grained and more calcareous than the Cœur d'Alene phase of the Newland and more closely resembles the corresponding beds of the Philipsburg district in Montana.

Plains to Dixon.—From a point a few miles southeast of Plains the Clark Fork and Flathead River flow in a canyon with steep rocky sides. About 15 miles farther upstream the valley becomes very open and the hills on either side are low, but the outcrops are still fairly numerous. Throughout this distance the sedimentary rocks exposed along the railroad are dark, mostly bluish-gray, quartzitic and argillaceous sediments, correlated with the Prichard formation. They are cut by a large number of the dioritic dikes or sheets whose petrographic character is described on page 49. The sediments have suffered complex deformation. The strikes and dips along the track are very variable, and when platted indicate that the folds are pitching ones. The greatest fold noted is an anticline between Plains and Paradise Spring, indicated by the dip symbols on the map. No positive evidence of extensive faulting was observed, but in places the attitude of the beds changes so abruptly as to suggest that some faulting has occurred.

A feature of some local interest is Paradise Spring, situated on Missoula River about 3 miles from its mouth. It is a sulphur spring, with a temperature of about 100° F., which issues from the talus at the foot of a large outcrop of diorite, intrusive in the Prichard rocks.

The lithologic character of the sediments in this section is very similar to that of the Prichard formation as developed in the type locality. The beds consist of regularly banded blue-gray argillites with some gray siliceous indurated sandstone. Their weathered outcrops, like those of the typical Prichard, have a rather somber hue, and are somewhat stained with dark reddish-brown ferric oxide. On the whole, however, the beds are of a lighter gray color and slightly more siliceous than the corresponding strata in the Cœur d'Alene district, although not as arenaceous as the Prichard formation along the boundary and in the western part of the Cabinet Range.

NORTH SIDE OF MISSOULA VALLEY.

Vicinity of Lothrop.—The high, sparsely timbered hill across the river and north from the town of Lothrop shows on its upper portion a considerable thickness of light-colored beds dipping gently to the northwest. In ascending the hill from the southeast one passes over the following apparently conformable strata in order of superposition:

(1) Olive-green, more or less arenaceous shale; thickness, 1,200 feet. Base not seen.

(2) Deep-red siliceous shale, apparently grading upward into red banded quartzite, which grades into pinkish-white quartzite; total thickness, about 250 feet. A little saddle without exposures beyond.

(3) Limestone, gray, rather fine grained, distinctly bedded, containing black fragments of crustacean tests and showing vermicular bodies on weathered surfaces; thickness, about 1,500 feet. Top removed by erosion.

West of the summit these beds abut against a fault plane which, from the course of its trace on the surface for the short distance it was followed, appears to strike about north-northwest and to dip east.

Mr. Walcott, after seeing specimens of the limestone and hearing its relations described, expressed[a] the opinion that it was the middle Cambrian limestone, which forms a thick mass in the Mission Range to the east. The quartzite he considers as presumably representing the Cambrian Flathead quartzite, and the red and green shale beneath as Algonkian.

At a point a mile farther west a narrow strip of similar limestone, dipping south, is exposed on the brow of the steep slope overlooking the valley. Its stratigraphic relations, however, are here obscure, for the rock north of it is not exposed, and a fault which limits its outcrop on the southwest has given rise to a remarkably coarse limestone breccia forming conspicuous crags, whence great blocks have rolled down the slope.

Lothrop to Iron Mountain.—The rocks seen along this portion of the route are mainly argillites and quartzites, resembling the sediments of the Cœur d'Alene district in a broad way, yet sufficiently different from the formations that have been studied in detail to prevent definite correlations on lithologic grounds. Among the most abundant and conspicuous rocks developed in Missoula Valley are argillites and flaggy quartzite of a bright maroon color, which resemble the beds that immediately overlie the Newland east of Clarkfork, and may be equivalent to the Striped Peak formation. The presence of thick strata of supposedly Paleozoic limestone, of which two exposures in addition to those already described were seen, tends to indicate that the Algonkian rocks exposed in this valley belong chiefly to the upper part of the system.

The strike is prevailingly between west and north-northwest, and the dips, which are not usually higher than 45°, are in greater part to the south and west. Although little evidence of faulting was obtained, the frequency with which the boundaries between groups of strata differing in lithologic character coincide with ravines suggests that the country may be considerably faulted, and makes it impossible in many places to ascertain, without detailed examination, the relative age of masses exposed within a short distance of one another.

As a possible aid to future work the most extensive exposures will be described briefly.

Four miles northwest of Lothrop there is a good exposure of several hundred feet of deep-red shaly and quartzitic beds intercalated with some green layers, dipping very gently south. Higher

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[a] Orally.

in the succession the red material gradually disappears, while the green argillite, becoming somewhat calcareous, assumes the aspect of typical lower Newland. Some 300 feet of these green beds are overlain by dark limy slate and impure shaly limestone, very similar to some of the material in the syncline of Newland rocks east of Eddy. On lithologic grounds this assemblage of strata might well be correlated with the upper part of the St. Regis and the lower part of the Newland formation, but the fact that the deep-red color of the lower beds is decidedly different from the more subdued purple tint characteristic of the St. Regis formation wherever it has been certainly identified, together with the proximity of probable Paleozoic limestone, weakens the force of this lithologic evidence, which is not corroborated by evidence of other kinds.

About half-way between Lothrop and Quartz there is a bluff on the north side of the river, about 1,500 feet high, which exposes a very striking section of shaly beds, mostly deep red, with some green layers. They dip gently west, so that some reddish-purple quartzites, exposed a little farther down the valley and also dipping west, apparently overlie them. These quartzites dip toward a cliff composed of a light greenish gray banded, indurated argillaceous sandstone with some finer-grained layers that exhibit mud cracks. The weathered surface shows differential etching of the laminæ and is slightly stained with yellow limonite, both of which facts indicate that the rock contains carbonates. These beds are somewhat unlike any seen elsewhere in the region. They resemble certain phases of the lower Newland, but are coarser in texture. It seems most probable that they belong to Walcott's Camp Creek "series."

Opposite Quartz there are exposures of light-colored calcareous shale, dipping north, which are succeeded abruptly by red shaly quartzite, and as both rocks are brecciated the plane of contact is probably a fault. Beyond, for about one-half mile, there are shaly rocks dipping north. These are mostly red, but comprise green layers and patches, and a change from green to red in the same layer is not infrequently to be observed. North of this exposure and separated from it by a gully there appears an outcrop of gray, distinctly bedded limestone, dipping steeply south at first, then 45° N., which is somewhat brecciated and probably faulted against the red beds. Several hundred feet of this limestone is exposed; then some red quartzite, whose relation to it was not ascertained and which may be faulted up; then a steep cliff, about 500 feet high, of gray limestone, which appears to overlie some red quartzite that dips toward it near the base. This relation and the lithologic character of the limestone make it highly probable that it is the same stratum that is exposed at Lothrop.

About halfway between Quartz and Iron Mountain there are good exposures of several hundred feet of gently inclined greenish-gray, flaggy, sericitic quartzite somewhat similar to the Burke beds. Beyond, in unknown relation to this rock, is some red flaggy quartzite striking N. 40° E. and dipping 40° SE. About 3 miles southeast of Iron Mountain there is encountered the border of an extensive area of shaly calcareous rocks like the Newland beds developed east of Eddy. These show considerable folding and a variable strike. In the finer-grained material distinct cleavage is developed, whose strike and dip at one place are N. 75° E. and 75° N., and at another N. 10° W. and 75° W. These rocks continue along the valley for an unknown distance northwest of Iron Mountain.

Iron Mountain to Paradise Spring.—That the rocks at Iron Mountain belong to the Newland formation is proved by their relation to underlying strata exposed on the ridge north. The roads and trails across this ridge, built for the Iron Mountain mine (described on p. 107) afford opportunity to observe a thick, well-exposed section of all the strata included between a horizon far above the base of the Newland and one some thousands of feet below the top of the Prichard.

In the canyon below the Iron Mountain mine the rocks consist almost entirely of interbedded calcareous argillites and impure limestones that have been considerably folded. About one-half mile below the mill, however, there are some exposures of a light-greenish quartzitic rock, dipping north, which may belong to the St. Regis formation. In the vicinity of the mine there are extensive outcrops of greenish and bluish distinctly calcareous rocks. They dip northeast, first at a moderate angle, then farther on very steeply, and are almost vertical for a considerable distance along the road. A zone of complex folding succeeds the vertical dip and is followed in turn by a continuously southward dip, which persists to a point beyond Paradise Spring.

About one-half mile south of the summit the distinctly limy beds are succeeded by a small thickness of noncalcareous green argillite, which is underlain by richly colored purple and green beds, like the typical St. Regis. By gradual transition these pass over into somewhat thicker bedded and more quartzitic rocks, only faintly tinged with green and purple, exposed near the summit and a little beyond. There is here no hard white quartzite like the Revett quartzite. Many hundreds of feet of more or less flaggy beds corresponding to the Burke formation are exposed on the northern slope and are underlain by blue argillites and graywacke of the Prichard formation, of which probably some 5,000 feet are crossed before reaching Paradise Spring.

CHAPTER IV.

NOTES ON THE ECONOMIC GEOLOGY.

By D. F. MacDonald.[a]

INTRODUCTORY STATEMENT.

The examination of the mineral resources of the region traversed was but a secondary object of the reconnaissance. Only such mines and prospects therefore were visited as lay near the main route of travel, and none of these were exhaustively studied. The material thus hastily gathered could not furnish a basis for anything more than brief and general descriptions, but as virtually nothing regarding the ore deposits of this extensive tract had been published prior to our visit, even a very incomplete account has been considered worth putting on record.

The following notes are substantially a reprint of a paper published in 1907.[b] It was expected that some account of development subsequent to 1905 might be prepared from data furnished by mining men to those engaged in gathering for the Survey the statistics of mineral production, and the publication of this paper has been somewhat delayed in order that such data might be used. Unfortunately, little information of this kind has been acquired. In the time that has elapsed since our visit no production has been reported from the properties visited by us, except from one mine on Lake Pend Oreille, which has produced a small quantity of rich silver ore. Some of the most promising mines of the region seem to have lain idle because of litigation.

The metalliferous deposits observed in the course of this reconnaissance are mostly fissure veins. Not only in this respect, but also in prevailing composition and attitude, they exhibit some resemblance

[a] Since, owing to space restrictions, it was necessary that the originally published outline of this chapter be very brief, it has been somewhat expanded in the absence of Mr. MacDonald by Mr. Calkins, who is entirely responsible for the descriptions of the mines on Callahan Creek, those at the head of Fisher River, and those in Missoula Valley.—Editor.

[b] Contributions to economic geology, 1906: Bull. U. S. Geol. Survey No. 285, 1907, pp. 41–52.

to the famous deposits of the Cœur d'Alene district. As in that district, so also in the region to the north and east of it, the most important economic mineral is argentiferous galena, and although deposits of copper, gold, silver, and zinc occur, the lead-silver deposits appear to give most promise of future productivity. The trend of the veins naturally varies considerably more in this wide territory than within the relatively narrow limits of the Cœur d'Alene district, where most of the veins have a trend near west-northwest; but for the ore-bearing fissures as well as for the major faults there is a decided preponderance of northwesterly over northeasterly strikes. Dips to the north and east seem to be about as numerous as those to the south and west. The incomplete data at hand also tend to indicate that, as in the Cœur d'Alene district, galena generally occurs in steep fissures, related to, though rarely coinciding with, the major faults. This mineral appears to show, although in less marked degree than in the Cœur d'Alenes, a preference for the quartzitic sediments of the Ravalli group as country rock. The parallel is further carried out by the auriferous deposits, which, in the region as a whole, seem in general to develop chiefly in the Prichard formation, and to lie for the most part in relatively flat fissures which are more nearly parallel to the bedding than to the steep faults of large throw.

Deposits that have been prospected or exploited are more numerous in the western part of the region, where intrusive igneous rocks occupy a considerable part of the surface, than in the central and eastern parts, where igneous rocks are relatively rare, and one more instance thus appears to be afforded of that general relationship between ore deposition and igneous intrusion whose existence modern studies tend to establish more and more firmly.[a] But, on the other hand, the region contains relatively few deposits having any obvious and intimate relation to intrusive masses, and several of its more important mines, as the Snowshoe, south of Libby, and the Iron Mountain, north of Missoula River, are many miles from any extensive area of igneous rock. These facts, however, can not be considered as proving that any of the ore deposits of the region are totally independent of igneous agencies. Ransome[b] has pointed out in discussing the origin of the Cœur d'Alene ores that the lack of obvious relationship between the ore deposits and the areas where igneous rocks crop out does not prove their independence, since it is possible that the hot ascending solutions which deposited the fissure fillings may have derived their heat, if not their substance, from magma chambers lying at a relatively small dis-

[a] See Lindgren, Waldemar, Present tendencies in the study of ore deposits: Econ. Geology, vol. 2, 1907, p. 743.

[b] Ransome, F. L., and Calkins, F. C., The geology and ore deposits of the Cœur d'Alene district, Idaho; Prof. Paper U. S. Geol. Survey No. 62, 1908, pp. 135–139.

tance beneath the surface. Similar considerations may apply, although possibly with diminished force, to the broad region dealt with in this chapter. Although batholithic intrusions occupy a relatively small area in the central and eastern parts of the region, dikes and sheets of igneous rock occur there in considerable number.

A few deposits of a type allied to contact-metamorphic deposits were seen.

The only noteworthy nonmetallic mineral product of the region is lime, which is produced commercially by a single plant situated on the shore of Lake Pend Oreille.

It will be convenient to describe the mineral resources by localities, in the order in which they were visited.

DESCRIPTIONS BY LOCALITIES.

PINE CREEK DISTRICT.

General features.—Pine Creek is about 6 miles west of the Bunker Hill and Sullivan and the Last Chance mines of the Cœur d'Alene district. It flows in a northerly direction into Cœur d'Alene River and drains a large wooded basin, which lies partly within the area shown in the Cœur d'Alene special map and described in Professional Paper 62 (just cited), but mostly to the west of it.

The country rock of the mines visited on this stream is Prichard slate, and the veins are in fissures, many of which have had their walls partly replaced by vein material. The vein filling is white quartz and crushed country rock, the whole somewhat iron stained. The ore is a silver-bearing galena associated with zinc and some siderite and pyrite. The silver-lead values are low, and transportation charges are so high at present that mining for zinc, of which some of the ore contains as much as 20 or 30 per cent, is not profitable. The weathered zone of these veins was found to be fairly rich in silver and lead carbonates to a slight depth, but the base ore was soon reached and development work was then usually suspended. Although much exploration work has been done in the district and considerable bodies of low-grade silver-lead-zinc ore have been found, very little mining activity was evident at the time of visit.

Mines and prospects.—The Anderson group, 3 miles from the mouth of Pine Creek, has a few tons of rich-looking ore on the dump. The development work done there consists of a 60-foot adit and a 20-foot winze.

At the King property, a mile south of the Anderson property, a few tons of ore have been extracted from an 85-foot adit.

At the Douglas, 6 miles south of the King, a considerable amount of development work has been done. Three hundred tons of ore are on the dump and about 10,000 tons are said to be in sight. The ore, which seems to be a fine-grained galena, is peculiar in that it carries, as reported, almost 30 per cent of zinc.

The Surprise, on another branch of Pine Creek, is about 2 miles southeast of the Douglas. A 450-foot crosscut adit taps the vein at considerable depth. It is said to give an average assay of 31 per cent lead, 30 per cent zinc, and 10 ounces of silver to the ton.

The Nevada Stuart is just across the creek from the Surprise, and is on the same northwest-southeast lead. A 300-foot adit constitutes the development work.

The Nabob, on Stone Creek, a tributary of Pine Creek, expected to ship four carloads of ore in 1905.

Outlook for the district.—The mining future of Pine Creek depends on the discovery of some satisfactory treatment for saving and separating the silver, lead, and zinc values of the ores. Such treatment should enable the district to become an important producer, but under present conditions development on a large scale can hardly be expected from it as a whole. It is possible, however, that ore bodies may be discovered which contain less zinc and a greater amount of silver and lead.

LAKE PEND OREILLE DISTRICT.

VICINITY OF LAKEVIEW.

General features.—The little town of Lakeview is built on a terrace at the southeast end of Lake Pend Oreille, at the mouth of a stream that drains a mountainous basin, which is perhaps 50 square miles in area. Although extremely quiet now, it once gave promise of being a most active mining center.

In October, 1888, Messrs. Frederic A. Webber and S. P. Donnely came across from Eagle Creek, in the Cœur d'Alenes, on a prospecting trip. They made a discovery and went back for supplies. Despite their attempt to maintain secrecy a suspicion of their find got abroad, and on their return many others followed them back across the mountains. That fall and winter more than 2,000 people went into the new district and founded the town of Chloride, about 5 miles up the valley from Lakeview, of which there are now but a few tumble-down shanties remaining. The boom lasted about a year, and then the stampede element drifted away and only those who had faith in the district remained and continued systematic development of their holdings.

The country rocks of this district are chiefly of the Newland formation, but comprise some quartzites, limestones, and slates of earlier and later age. They are cut by a number of faults having various directions. A few miles to the west, and also to the north, the sediments are invaded by monzonitic intrusions.

Mines and prospects.—The Webber group of claims lies about 6 miles south of Lakeview, from which place it is reached by wagon road. The vein is in a fault fissure whose walls have been somewhat replaced by vein material. The fissure runs about east and west, and gives evidence of a considerable displacement. It is associated with a diabasic dike and cuts a country rock of shale of the Newland formation.

On the surface in the weathered zone the ore carried free silver to a reported value of about 400 ounces per ton. This led to its acquisition by a company and the installation of a complete free-milling plant. Soon, however, the lead and silver appeared in the sulphide form, and the values could not be saved by such a process. Some shipments were then made to a smelter, but the ores were not of high enough grade to return a profit, and accordingly operations at the mine and mill were suspended. It is reported to have undergone some development, however, since our visit.

The Keep Cool group adjoins the Webber property on the west and appears to be on the same vein. A section of the vein here shows a rather wide zone of breccia, gouge, and quartz carrying considerable galena and striking about N. 75° W., with a dip of 75° S.

The Conjecture property lies a mile below the Webber on the same creek. The country rock, vein, and ore are practically the same as those of the Keep Cool and Webber mines. A free-milling plant was used for the treatment of the rich surface ores.

The Hidden Treasure claim is located on a fissure in the supposedly Paleozoic limestone near a fault of considerable displacement. It is being worked by an open cut which reveals galena of good quality. The Venezuela and Silver Chord had not produced any ore at the time of visit, and have not reported any production since then.

Production.—The following table shows the estimated amount and value of ore shipped from the district:

Ore shipped from the Lakeview district.[a]

Name.	Tons shipped.	Value per ton.	Remarks.
Webber group	Concentrates, 2,000; crude ore, 11,000; now on dump, 6,000.	Lead, $2; gold, $1.50; silver, 24 to 50 ounces.	Idle for some time; hope to resume work when new smelter is built at Sandpoint.
Keep Cool	To the value of about $15,000.		Not working.
Conjecture	To the value of about $70,000.		Do.
Vulcan	50		Do.
Hidden Treasure	50; on dump, 50	Average assay, $40	One man getting out ore.

[a] This table is based on data kindly furnished by Mr. F. A. Webber.

Outlook.—This district has been proved to contain considerable low-grade silver-lead ore. Under present conditions the operation of the many small properties of the district would be expensive. Cheap production is the problem to be solved in this field. Consolidation of interests and work on a large scale would seem to be the best means of attaining that result, and would very probably produce some good dividend-paying properties. The new smelter at Sandpoint should ultimately furnish a better market for the ores than has hitherto been available, and materially encourage further work.

LIME PLANT AT SQUAW BAY.

A plant of four kilns at Squaw Bay, a few miles from Lakeview, is operated by the Washington Brick and Lime Company, of Spokane. It had been running fifteen months at the time of our visit and was turning out about 75 barrels of lime a day. This product is shipped on scows to Hope, on the Northern Pacific, and thence to its destination by rail.

A large mass of fairly pure crystalline limestone of uncertain age (see p. 62) occurs close by, and a quarry in this deposit now furnishes all the rock burned in the kilns. This deposit, together with others of the same nature which are found on the shores near Lakeview, will probably answer all demands made upon them for an indefinitely long period.

WESTERN SHORE.

There has been considerable prospecting and some productive mining on the western shore of Lake Pend Oreille. The most promising developments are in the vicinity of Blacktail Point.

The rocks of the western shore are pre-Cambrian sediments of the Belt series. Monzonitic rocks intrusive into them lie to the south and west, and the older sedimentary formations, which are exposed along the northern part of the shore, are cut by many basic dikes and sills. Structurally this vicinity is characterized by the presence of several large faults which have a northwestwardly trend and a downthrow on the southwest side.

The most important property is apparently that near Blacktail Point, owned in 1905 by J. A. Browne. The development work done on this property in 1905 consisted of a tunnel over 1,000 feet long and some short drifts. Extensive improvements, including an electric generating plant to be run by steam power, and several substantial buildings, had also been made.

The mine is situated on the west slope of a valley having a trend of about N. 30° W. This valley is evidently situated on a fault line, for although the Newland rocks west of it, which form the country rock of the mine, have a general easterly dip, the rocks east of it are the older quartzitic sediments belonging to the Ravalli group, and at the shore line, where they are exposed within a few rods of the Newland formation, they exhibit considerable fracture and contortion.

The tunnel crosscuts the strata, which, although their general dip is eastward, are affected by some minor folds. Several small faults which throw veins parallel to the bedding were noted, the largest dislocation observed being about 4 feet. About 850 feet in from the portal there is a strong fault fissure whose course is N. 10° W. and whose dip is 80° E. Two slips with a direction N. 30° W. were also noted. The principal vein of the mine, near the end of the tunnel, strikes a little east of north and dips steeply east.

The valuable minerals in the vein are galena and tetrahedrite, the latter being present in unusually large proportion. Associated with these are quartz, pyrite, and siderite. Some specimens clearly exhibit a replacement of wall rock by vein matter.

No shipments of ore had been made for some time previous to our visit. The ore was said to be rich in silver, but no assay figures were obtainable.

The Blackbird mine, owned by the Blacktail Mountain Mining Company, reported the production of some rich silver ore in 1906, but the amount is not indicated.

EASTERN SHORE.

General conditions.—As the Lakeview district began to decline the many prospectors it had attracted gradually scattered over the surrounding mountains. The result was that a great number of claims were staked on the eastern shore of Lake Pend Oreille. Many of these were abandoned, but a few are still being developed for their gold content; others are held as future producers of silver and lead. Perhaps the most promising, however, are those which are being developed for their copper values. In spite of the lack of concentrated development work, the district gives some promise as a prospecting field and may yet develop shipping properties.

Prospects.—The Green Monarch, developed by a tunnel driven into the steep, rocky bluff which forms the southern shore of the east arm of the lake, shows a vein of low-grade copper ore consisting chiefly of chalcopyrite with a little copper carbonate in a gangue of quartz. The country rock is impure quartzite of the Ravalli group; the vein strikes N. 30° W. and dips 65° W. The rocks are cut by other fissures, some striking about north-south, others about N. 65° W. No production has been reported from this property.

The June Bug lies farther east, on the same part of the shore. The country rock is green and purple siliceous shale and sandstone of the Ravalli group. The vein, which consists mainly of white quartz, runs N. 75° W. and dips 80° S. It shows considerable specular hematite, a little bornite, and some chalcopyrite. Not enough development work has been done to disclose any mineralization of commercial importance.

The Pend Oreille copper properties are located near the Northern Pacific Railway, a few miles east of Hope. The country rock is a bluish-gray shale belonging to the Newland formation. The main lead is about 11 feet wide, and its walls are fairly well defined. It seems to trend about N. 55° W. and to dip 80° NE. The croppings show cupriferous pyrite, but the vein has not been sufficiently opened to reveal its extent and value.

TROY DISTRICT.

Troy is a small town on the Great Northern Railway near the western boundary of Montana. It is the natural distributing point for the mining properties on Callahan Creek and Grouse Mountain, which hold out considerable promise of becoming active producers.

MINES ON CALLAHAN CREEK.

On Callahan Creek, about 8 miles from Troy, are two lead-zinc mines, which are among the most promising in the region with which this paper deals. Some 8 miles farther up the creek there is a prospect in an ore body which is said to be a contact deposit. This prospect was not visited, but a few hours were devoted to an examination of the other properties, which are known as the Big Eight and the B. & B. mines.

In their general features these two mines are very similar. The ore bodies are in a fissure cutting argillitic and quartzitic sediments of the Prichard and Burke formations. The sediments strike about north-northeast and dip eastward. The veins strike about N. 30° W. and dip steeply westward; their strike is about parallel to that of the great Lenia fault, described on page 53, which lies not far to the east, and brings the red and green siliceous shales of the Striped Peak formation against the much older rocks in which the mines are situated. In both the mines an altered basic dike accompanies the vein, occupying, at least in part, the same fissure with the ore body. The ores are galena and sphalerite, in a gangue of very remarkable composition, which consists chiefly of silicates such as are generally formed by contact metamorphism.

The Big Eight mine is located on a narrow promontory between two forks of the stream and near their junction. The workings in 1905 consisted of an adit, a drift which is continued north of the northern branch of the stream, and a shaft of slight depth near the junction of the adit and the drift. The principal vein, well exposed on the abrupt rocky banks of the stream, strikes N. 30° W. and dips 80° W. It is about 8 feet wide, and here has well-defined walls. A dike of a rather fine-grained dark-gray rock, which proves on microscopic examination to be much decomposed, but which is probably of diabasic or dioritic character, cuts the sediments here a few feet east of the vein. The ore is rather irregularly distributed, in places forming most of the vein, but being locally mixed with a large proportion of the silicate gangue and with fragments of country rock. It consists chiefly of sphalerite, which forms some large masses of great purity; it also comprises a variable, but, on the whole, subordinate amount of galena. A little pyrite occurs locally.

About 200 feet east of the principal vein the adit crosses a smaller one, which consists of nearly pure galena. Its strike is N. 30° W.; its dip, 65° W. Its width at the lowest point exposed is about 20 inches, but it narrows upward and pinches out near the roof of the tunnel.

The B. & B. mine is located on the rather steep slope south of the creek. The development work done there is more extensive than in the Big Eight mine, and the vein has been tapped by means of several tunnels. This mine was examined very hastily. The country rock is a gray-blue banded argillite, very similar to the typical Prichard slate of the Cœur d'Alene district. A dike rock similar to that in the Big Eight occurs here also, but its relation to the vein was not observed. The course of the vein is about the same as in the Big Eight. The ore is of the same peculiar character as in the other mine, but seems to contain a relatively larger amount of galena as compared with sphalerite.

Although both these mines had previously made considerable shipments of ore, neither was shipping at the time they were visited. The idleness of the B. & B. was said to be due to litigation. The Big Eight was being worked under a lease by Batchelder Brothers, of Spokane, and had about 150 tons of high-grade ore on the dump.

The remarkable mineral composition of the ore bodies exposed in these two mines makes the question of their genesis a problem of peculiar interest. The detailed description of the material has been deferred, therefore, to this point in order that it might be given in connection with the discussion of this problem.

The sphalerite and galena of the principal veins are associated with actinolite, chlorite, biotite, garnet, and magnetite, whose relative amounts vary widely in different specimens. Perhaps the most abundant constituent of the gangue is a dark-green, finely divided chlorite. This forms a sort of groundmass in which the other minerals are embedded. The amphibole, which appears in the hand specimen to be grayish green in color, but is nearly colorless in thin section, occurs in splintery crystals, which locally make up the greater part of the gangue and show a tendency to form radiate groups. Garnet, of a brownish-red color, forms crystals which are penetrated by splinters of the amphibole. Greenish-brown biotite, forming small tablets embedded in the chloritic base—which, however, does not appear to have been derived from it—is locally abundant. Calcite, evidently not derived from the decomposition of the silicates, but essentially contemporaneous with them, is moderately abundant in some specimens.

Some thin sections show galena and amphibole intimately associated and apparently almost contemporaneous, for while the larger areas of galena are crossed by needles of actinolite showing automorphic development of the prism faces, the sulphide locally forms irregular veinlike masses within the amphibole. It is possible, however, that these are secondary, and the first-named relation appears the more significant one.

This combination of minerals would not be remarkable under certain geologic conditions. It is in a general way similar to that existing in many deposits which occur at the contact of calcareous sediments with intrusive igneous rocks. It is plain, however, that this deposit is not the result of the thermal action of the basic dike associated with it upon the noncalcareous sedimentary rocks into which this dike is intruded. In other parts of the region basic intrusions of similar petrographic character have been observed in contact with sedimentary rocks like those at this locality, but even where the mass of the intrusive rock is much greater its metamorphic effect has been small, amounting merely to a moderate degree of recrystallization. Furthermore, it involves no notable change in chemical composition; but the gangue of the Callahan Creek deposits is rich in magnesia, which is virtually absent from the adjacent sediments. Evidently, therefore, it consists of material brought from a distance.

That the deposit is in the nature of an emanation occluded from the dike itself is improbable because such deposits have not been observed in genetic relation with similar dikes, either in this region or, so far as I am aware, in others.

Another possibility worth consideration is that a metalliferous vein with a gangue composed largely of quartz and of carbonates of lime and magnesia may have been formed, and subsequently metamorphosed upon the reopening of the fissure and the injection of the dike. Unfortunately, no definite evidence regarding the relative age of the vein and the dike was observed in the field, but certain considerations tend to indicate that the dike is the older. In the first place, it does not seem likely that the intrusion of a rather small basic dike was adequate to produce the intense effect implied in the character of the coarsely crystalline aggregate of silicates that is found in the vein. In the second place, the highly altered condition of the dike rock suggests that it has been subjected to the action of hot circulating waters, which may well have been the same that deposited the vein matter from solution. A third fact of similar tendency though of less weight is that at the Grouse Mountain prospects, presently to be described, the vein lies within, and is clearly older than, a basic dike similar in trend and character to that on Callahan Creek. There, however, the vein material differs from that of the Callahan Creek mines.

All the hypotheses thus far suggested being open to serious objection, we are forced to seek some other; and the character of the deposit is such that it must have been formed essentially by igneous agencies. The large body of granitic rock occurring farther up the stream, as attested by hearsay evidence and by the presence of abundant granite bowlders in the stream bed, may be considered, in accordance with the modern theories of ore deposition, as a likely source of the minerals in this vein. It is readily conceivable that the batholithic mass extends beneath the mines, and that the ores were deposited in a fault fissure by emanations from the granitic magma.

GROUSE MOUNTAIN PROPERTIES.

Grouse Mountain is a spur of the Cabinet Range, lying between the headwaters of Callahan and Lake creeks.

The Great Northwestern property is situated on the southwestern slope of the mountain. The country rock is grayish siliceous shale, probably of the Prichard formation, which is cut by a large diabase dike trending northwest and southeast. A fracture zone parallel to and lying within this dike forms the vein. It is filled with white quartz, calcite, and iron-stained breccia, is from 2 to 6 feet wide, and carries galena, some iron pyrite, marcasite, siderite, sphalerite, and a little chalcopyrite. The ore is said to carry from 18 to 50 ounces of silver per ton, and seems to occur in irregular bunches. The vein appears to be richer where it is cut by a porphyry dike of later origin. About 60 tons of ore are on the dump, awaiting the construction of a wagon road to Troy, 12 miles distant.

The Iron Cap claim adjoins the Great Northern, and seems to be on the same fissure, which here cuts typical Prichard slate. It has been opened up by a shallow open cut, exposing a large amount of iron capping and crushed vein material. Some pieces of galena are found in the less weathered parts.

SYLVANITE.

Location.—Sylvanite is situated in the Purcell Mountains, on Yaak River, about 12 miles from its mouth. It may be reached by a wagon road from either Troy or Bonners Ferry, between which points there is no means of taking horses across Kootenai River.

Mines.—The principal mining properties near Sylvanite are the Keystone and Goldflint, which are located on the same lode. Their country rock is gray sandstone with some shaly beds, and represents typically the quartzite phase of the Prichard as developed in the northwestern part of the region. The general strike is about north-south, and the dips are eastward at low or moderate angles. The sediments are cut by basic dikes of dioritic aspect.

The vein, which is generally about 1 or 2 feet in thickness, appears to be nearly parallel to the bedding planes, and its dip is variable, averaging about 40° E. The ore consists of deeply weathered auriferous pyrite in a gangue of quartz, which includes many iron-stained fragments of the crushed country rock.

The extent of the workings would indicate that the mine had produced considerable free-milling gold ore. This ore was concentrated in a 10-stamp mill. The properties were idle at the time of our visit, owing, it was reported, to litigation. It is possible that base ore which could not be treated by the free-milling process had been found in depth. No production has been reported since our visit.

SNOWSHOE MINE.

General statement.—The Snowshoe mine, owned by the Rustler Mining and Milling Company of Pittsburg, comprises three patented claims, the Snowshoe, Rustler, and Porcupine. Information regarding the output, values, etc., of the mine was courteously afforded by the manager.

Location.—The Snowshoe mine is situated in the most rugged part of the Cabinet Range. It is on a branch of Libby Creek and just across the divide from Bull Lake.

A good wagon road down Libby Creek connects the mine with the Northern Pacific Railway at Libby, about 22 miles to the north. Several four and six horse teams haul out ore and bring in supplies over this road.

Character of vein.—The Snowshoe vein occupies the fissure of the Snowshoe fault, described on page 54. The country rock on the east side of the fault consists of grayish-green to dark-gray indurated arenaceous shales and flaggy sandstones of the Burke formation; that on the west side is a calcareous shale resembling that of the Newland formation, but probably younger. This shows that a throw of several thousand feet has occurred, but owing perhaps to the fact that the fissure is here almost perpendicular, there has been a minimum of friction and the movement has not caused extensive crushing of the wall rocks. This principal vein trends almost exactly north-south.

One section of the vein as exposed in the mine shows a thickness of 5 feet. Next to one of the walls is about 2 feet of dark gouge mingled with slickensided fragments of wall rock; the remaining 3 feet consists chiefly of quartz mingled with a little siderite and inclosing irregular masses of galena. Near the other wall, which has little gouge, this material is banded and sheared. Another section, on the third level, shows about 6 feet of good ore. The gangue is chiefly quartz, with which siderite, pyrite, and galena are somewhat intimately mingled. The galena forms some streaks as much as 6 inches wide, and is slightly more abundant near the western wall than elsewhere. At this place the dip of the vein is a little toward the west; the walls are well defined, and there is but a few inches of gouge on either side.

Another smaller vein lies about 75 feet east of the main fissure and almost parallel to it. The filling material is principally white quartz and crushed rock, with a few inches of shiny black gouge on the east and a little greenish-blue gouge on the west wall.

Development work has opened up 300 or 400 feet of depth on the vein, showing lenticular masses of galena and an average width of about 7 feet.

Ores.—The values in the ore are derived chiefly from argentiferous galena, but it carries a gold value of about $1.50 per ton, which is said to increase with depth. An average assay shows about 10 per cent of lead and 5 ounces of silver per ton. This ore, concentrated, approximately, 6 to 7 into 1, yields about 50 per cent of lead, 25 ounces of silver, and $5 to $10 in gold. In view of the long wagon haul, it is very desirable that the concentration be carried as far as possible. This results in the loss of a large proportion of the gold values, probably as high as $400 a day. The mine was said, at the time of our visit, to have shipped in all about $850,000 worth of ore, mainly to the smelter at Everett, Wash.

Plant.—The concentrating plant is driven by water power, except the compressor and electric-light plant, which during the dry season are driven by steam.

The water power is now obtained by damming water in glacial cirques above the mine. This storage could be greatly increased and a considerable saving on steam be thus effected by improving the position and increasing the size of the dams.

Future prospects.—This property at the time of our visit was the leading producer in the region north of the Cœur d'Alene district, and gave strong indications that before long the output would be considerably increased. It reported no production, however, in 1906, and is said to have been involved in litigation. The great lode on which it is located is traceable for some miles, and is being explored in several of the numerous claims staked along its course. Handsome specimens of coarsely crystalline galena were shown us, which were said to come from the Alpine prospect on Leigh Creek, south of the Snowshoe mine, but probably on the same lode. If the present development continues, a branch from the main line of the Great Northern Railway may soon be warranted. Such a branch line could be built easily and cheaply up the gentle grade of Libby Creek. It would pass through excellent timber land and would greatly encourage mining in the district.

CABINET DISTRICT.

Location.—The name Cabinet district is here applied to an area lying in the Cabinet Mountains, about 20 miles southeast of the Snowshoe mine. It comprises the properties on Silver Butte Mountain and those on the headwaters of Fisher River. The former are reached from Trout Creek, on the Northern Pacific Railway, by a wagon road, about 15 miles long, up Vermilion Creek. Entrance into the Fisher River country is made by wagon road from Libby, 25 miles to the northwest, its nearest railway point.

Silver Butte mine.—The Silver Butte property is located on a vein which strikes N. 60° W. and dips 30° S., and cuts across Silver Butte. The country rock is the blue Prichard slate, associated with some beds of grayish arenaceous shale. The vein averages 10 feet in width, but an outcrop on top of the mountain shows white quartz to the width of 30 feet, which can be traced for about half a mile. The ore is composed of galena, which is scattered through lenses of white quartz. Some sections of the vein show only barren white quartz, crushed country rock, and gouge.

In a concentrating plant erected at a reported cost of $150,000 some ore has been milled. Some years previous to 1905, while temporarily closed down, this plant was burned to the ground, and the mine had since been idle.

The exploration work has exposed values enough to indicate that systematic development might open up sufficient low-grade silver-lead ore to make the property a regular producer. Several other locations are on what appears to be the same vein, but as yet little work has been done on them.

Mines at head of Fisher River.—Just across the divide of the Cabinet Range, in the Fisher River drainage, about north of Silver Butte, is a group of properties upon which a large amount of work has been done. They were once sufficiently productive to lead to the construction of three stamp mills, but they are now almost completely abandoned. None of them were entered in the course of this reconnaissance, but their general character was evident from the outcrops of the veins and the distribution and form of the workings. The lodes are situated near the crest of the Cabinet anticline, and are blanket veins parallel to the stratification, which dips at low angles. The country rock is typical Prichard slate. The vein material is chiefly quartz, with pyrite and gold, forming a rather low-grade ore which has apparently failed to yield profits below the zone of oxidation.

PROSPECT CREEK DISTRICT.

Location.—Prospect Creek heads in the Cœur d'Alene Mountains, near Thompson Pass. It flows into Clark Fork, near Thompson Falls, and is just across the divide to the northeast of the Coeur d'Alene mining district. A wagon road, which connects Thompson Falls with Murray and Wallace in the Cœur d'Alene district, follows the valley of Prospect Creek, and furnishes convenient access to the properties located in its drainage basin.

Mines and properties.—The Rosebud Mining Company is exploring several claims near the mouth of Rosebud Creek, a small tributary which enters Prospect Creek about 9 miles above its mouth. A vein of white quartz has been found by this company in the upper part of the Prichard formation. One of the owners reports that it carries some silver chloride and over $100 per ton in gold in the weathered zone at the surface.

The Montana Standard group of four claims is on Prospect Creek about 11 miles above its mouth. The vein is associated with a massive basic dike which cuts a country rock of the Burke formation. An adit driven on the east contact of this dike shows irregular masses of white quartz carrying galena. About 400 feet from the mouth of this tunnel a fairly well-defined cross lead runs N. 20° E. and dips 70° E. It shows some evidence of shearing and carries galena and siderite. On the west side of the dike a flat vein outcrops. It is 3 to 4 feet thick, strikes about N. 15° E., and dips 15° W. No connection between this vein and the ore deposit on the east side of the dike was apparent. The ore seems to lie in irregular bunches and cross fissures along the east contact of the dike. The examination of this property was very hurried, but it would seem advisable in the course of the present active development work to explore the east contact of the dike.

A few miles farther up Prospect Creek is an antimony vein from which a considerable amount of ore is said to have been shipped some years ago. This vein is not now being worked. Other claims in addition to those mentioned have been located on this creek, but they have been very little developed.

MISSOULA VALLEY.

General statement.—The valley of Missoula River below Missoula has been the scene of considerable mining development, but here, as in many other parts of the region, the industry is less active now than formerly. Large amounts of gold have been taken from placers on the streams which enter the valley from the south. Copper deposits are being developed in the mountains south of the river, but their future value can not as yet be predicted with confidence. The values shown in prospects north of the river are chiefly in galena, but few of the veins in this area have been developed to the point of actual production. The only property in the Missoula Valley region that was visited was the Iron Mountain mine, situated about 5 miles north of Iron Mountain station on the Northern Pacific Railway.

Iron Mountain mine.—This property, once the most important in the district, is now idle. It began to produce about fourteen years ago and was worked for eight years, during which period it yielded about half a million dollars in dividends besides paying the expenses of mine development, the building of a 200-ton mill, and the construction of 15 miles of mountain road. This road, which was used before the Cœur d'Alene branch of the Northern Pacific Railway was constructed, crosses the divide north of the mine and leads down to a point on Missoula River a few miles from its mouth, whence the ore was floated down on barges to the main line of the Northern Pacific. The closing of the mine was due to the enactment of a state law which requires that every mine shall have two openings. It has now been determined to comply with this law by the construction on the 1,500-foot level of a tunnel which will be over a mile in length. The surveys for the tunnel have been completed and its construction has been begun, so that in the near future the mine will probably resume its place as a producer.[a]

The country rock is a somewhat calcareous, light-green argillite of the Newland formation. The ore body is in a fissure vein about 5 feet in average width, striking nearly northwest-southeast and dipping steeply to the northeast. The ore, which occurs in a quartz gangue mingled with fragments of country rock, is argentiferous galena with a little sphalerite, carrying about 6 ounces of silver to the ton. The concentrates form about 45 per cent of the ore as mined.

MINING PROPERTIES NOT VISITED.

The region contains a large number of prospects concerning which we obtained no information at either first or second hand. A few of the properties that we did not visit seem to deserve mention.

The Buckhorn mines, situated in the rugged mountains east of Mooyie River and about 10 miles north of Kootenai River, have produced some good-looking ore containing both gold and galena. So far as development had gone at the time of our visit, the ore was said to be free milling. The development work reported in 1906 consisted of the driving of 2,000 feet of tunnel and the erection of a 5-stamp

[a] The completion of this tunnel has since been reported.

mill. It has been connected by wagon road with the main highway along Kootenai River.

About the headwaters of the tributaries which enter Bull River from the west there are a number of copper prospects, but, so far as could be learned, they have not been very extensively developed.

At Libby we were shown some fairly good samples of galena, said to have been taken from a contact deposit on Rainy Creek, which enters Kootenai River on the north, about 6 miles upstream from Libby.

OUTLOOK FOR THE REGION.

In regard to the region as a whole, the similarity of its rocks to those of the Cœur d'Alene district, together with its position between that district and the great producing mines of southern British Columbia, mark it as a promising field for the prospector. Moreover, large faults and their accompanying smaller fractures afford channels of circulation for underground waters and fulfill one of the conditions for the deposition of ore. Intrusive igneous rocks, which in other mining regions have also been recognized as favorable to mineralization, are developed in considerable abundance.

In general, the reconnaissance has left a strong impression that systematic and wisely directed development might considerably increase the mineral production of northern Idaho and adjacent portions of Montana.

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