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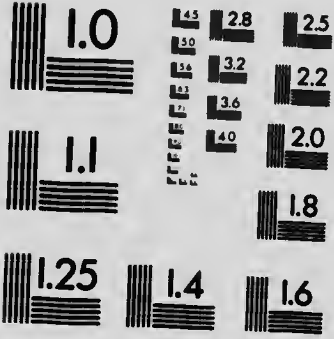

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Museum Bulletin No. 11

GEOLOGICAL SERIES, No. 23 APRIL 30, 1915

PHYSIOGRAPHY OF THE BEAVERDELL MAP-AREA AND THE SOUTHERN PART OF THE INTERIOR PLATEAUS OF BRITISH COLUMBIA

by

Leopold Reinecke

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

No. 1508

EXPLANATION OF PLATE I.

Portion of the U-shaped glacial valley of Otter river, Tulameen map sheet, looking north. The knee-shaped topographic break in slope at the junction of upland and valley side is shown in the view; also the slope of the upland toward the valley.

CONTENTS.

ILLUSTRATIONS.

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Physiography of the Beaverdell Map-Area and the Southern Part of the Interior Plateaus of British Columbia.

By Leopold Reinecke.

INTRODUCTION.

This bulletin is based on a detailed study of the physiography of the Beaverdell map-area in southern British Columbia. The Beaverdell area forms part of the Interior plateaus of British Columbia, a physiographic unit about 500 miles long by 100 wide lying in the central portion of the Canadian Cordillera. A comparison of several mapped areas in the southern part of the Plateaus with the Beaverdell area proves that they are essentially similar to it in their topographic forms and physiographic development. The study of the physiography of the Beaverdell area is of value chiefly because this area may be considered to typify a much more extensive region.

Field Work and Location.

The writer spent the autumn of 1909 and the summer of 1910 in topographical work in the Beaverdell area, and the summer of 1911 in geological work upon the same area. Previous seasons had been spent in topographical mapping of a district at the headwaters of the Tulameen river and of a much smaller area at Hedley on the Similkameen river. All three areas lie in the southern part of the Interior plateaus: Beaverdell in the southeastern corner, the Tulameen sheet at the southwestern edge, and Hedley about midway between the other two (see Figure 1).

The Beaverdell map embraces an area of about 163 square miles between north latitudes 49° 25′ and 49° 37·5′ and west longitudes 118° 55′ and 119° 10′. It takes in a part of the valley of the West Fork river and its eastern edge lies within a mile or two of the trough of the main Kettle river. This trough divides the Midway mountains of the Columbia system from the Interior plateaus. The southern edge of the map lies less than 30 miles from the International Boundary between Canada and the United States.

The Tulameen map covers an area about 170 square miles in extent, the western side of which touches the foothills of the Hozameen range on the southwest side of the Interior plateaus. The southern edge of the area is 31 miles north of the International Boundary. Thirty-two miles north of the Tulameen map-area is the southern boundary of the Kamloops area and directly east of it lies the Shuswap area. The map sheets of the two latter areas, which were also used in this work, together cover 12,800 square miles, about 9,000 of which lies within the Interior plateaus (Figure 1).

Methods of Study and Conclusions.

In extending the conclusions arrived at in the Beaverdell district to cover a wider area, advantage was taken of the Tulameen map and of the knowledge, gained in its preparation, of the topographical forms in that part of the Plateaus. The Kamloops and Shuswap maps furnished a means for studying a large section of the region lying farther to the north. Between these areas no extensive portions of the country have been topographically mapped; but descriptions of the topography by G. M. Dawson have served to some extent to bridge the gaps.

The Plateaus consist of an old land surface dissected by deep valleys. It is the apparent flatness of this old surface that has given rise to the name "Plateaus" and it is to the character of that surface that the most attention is paid in this bulletin. In determining the stage to which the old land surface had pro-

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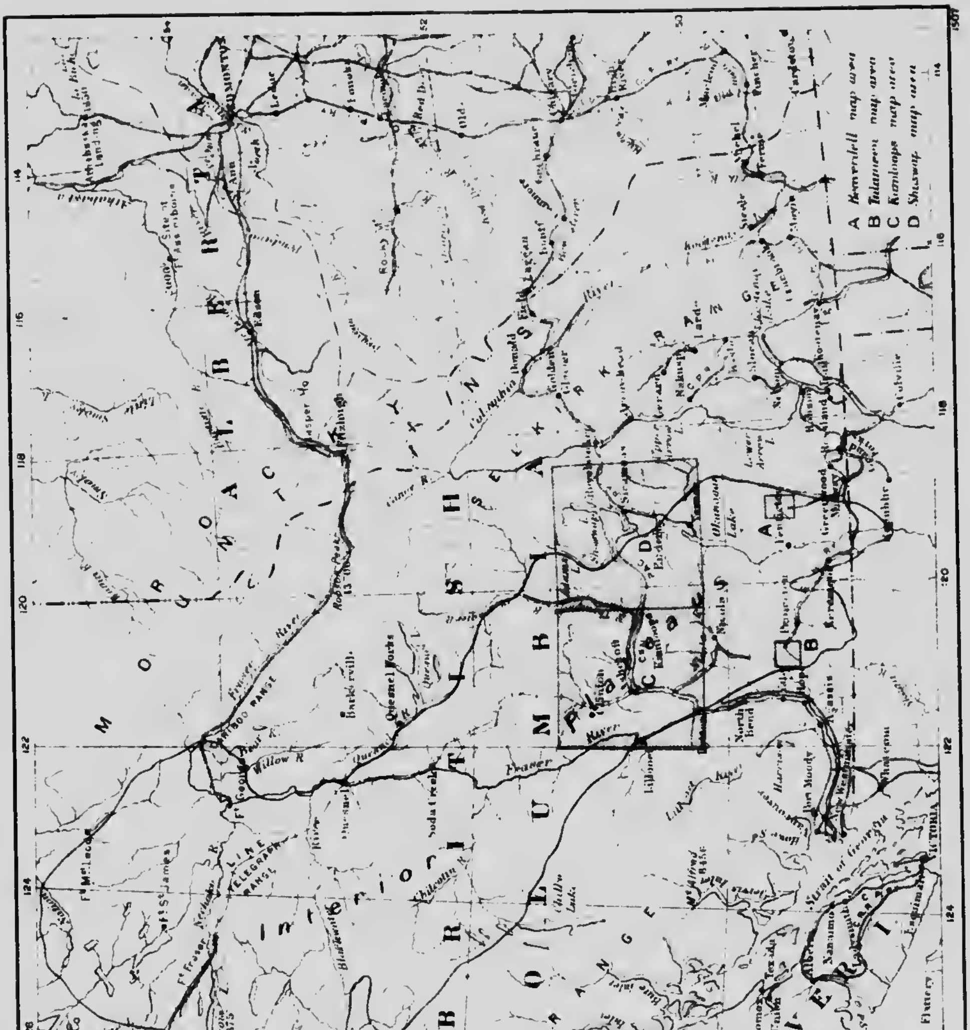

Geological Survey, Canada

Fig 1. Index Map

To accompany Bulletin by L Reinecke

gressed in the geographic cycle, the greatest stress was laid upon regional slopes within the upland. Other criteria were used in a supplementary way but were not given as much weight.

The measurements of slopes and detailed study over all the upland in the Beaverdell area gave an opportunity for testing the value of certain criteria commonly used in determining the stage to which a land form had progressed in the geographic cycle. Characteristic forms commonly used as criteria of the peneplanation of a land surface were found developed in places on the Beaverdell upland, a surface with regional slopes of from 100 to 300 feet per mile. By depending on these criteria, therefore, and neglecting the regional slopes, one would class a surface with that degree of slope with existing peneplain surfaces on which the slope is not over 10 feet to the mile. The danger of the application of such criteria to isolated remnants of an old surface, in cases where there are no means of measuring the average regional slopes, lies in the fact that these remnants are in some cases assumed to be the remains of a land form at one time nearly flat and, on that assumption, are used to measure earth warping by. The criterion of regional slopes is, therefore, suggested as a quantitative method for subdividing old land forms.

This investigation has shown that the uplands have the same topographical forms over the southern part of the Interior plateaus and that their physiographic development has been along the same lines; that there are no true peneplain remnants in them and that the present upland surface is that of late maturity. The development of the deep valleys and the terraces on their bottoms, as well as the effects of glaciation, are also discussed, but are of minor interest.

Arrangement.

This bulletin consists of four parts exclusive of the introductory section. The first contains a short description of the Canadian Cordillera and the second a more extended description of the Interior plateaus. In the third the topography of the Beaverdell map-area is described in detail. It begins with a summary description of the area, and in reading this section the more detailed part following, which is intended for reference only, may with advantage be omitted. The last part is concerned with the genesis of the Plateau topography. The discussion of the physiographic development of the Plateaus in this portion is preceded by a statement of the hypothesis of the "Geographic Cycle" and of the value of the criterion of regional slopes in classifying old land surfaces. A summary of the conclusions reached regarding the physiography of the Plateaus is given at the end of the bulletin.

Geological Formations and Structures.

The following is a short description of the rock basement upon which the action of water and ice has carved and moulded the present topography of the Beaverdell area.

The oldest rocks in the area are the Wallace group, which occupy about one-third of it, and generally outcrop on the upland. They consist of limestone, argillites, andesites, tuffs, schists, and basic plutonic rocks; the andesites and tuffs forming perhaps 80 per cent in bulk of the whole. The sediments, andesites, and tuffs are bedded and in some cases have been thrown into open folds. The andesites and tuffs occur also in irregular masses in which bedding planes are not apparent. The coarser igneous rocks are in dykes, sheets, or irregular masses. The group is provisionally classed as of Triassic-Jurassic age.

Into this group there is intruded an extremely irregular batholith, the West Fork quartz diorite, which is thought to be of Jurassic age. In the Eocene, another batholith, the Beaverdell quartz monzonite came into place. Each of the two batholiths occupies nearly one-third of the area of the sheet.

After a period of erosion in which parts of the Beaverdell batholith were exposed at the surface, a series of thick-bedded coarse conglomerates overlain by thin-bedded, fine-grained tuff were laid down, probably in local basins. They are of Oligocene age and have been called the Curry Creek series. A series of lavas, the Nipple Mountain series, follows the Curry Creek and are of Miocene, perhaps partly of Oligocene age.

The oldest group, the Wallace, has been very extensively faulted, brecciated, and metamorphosed; but only locally foliated. The metamorphism varies in character and intensity from place to place and is largely the result of later, batholithic intrusion. The West Fork batholith is also faulted, brecciated, and locally foliated but in less degree than the Wallace group. The Beaverdell batholith of the Eocene is nowhere foliated, seldom brecciated, and, except very locally, is unmetamorphosed. Both this batholith and the Curry series are faulted, and the Curry and Nipple Mountain series have been thrown into open folds. The folds in this area trend north and east of north; the major faults and zones of brecciation are in groups striking from about north by west to northeast with a subordinate set trending east and west. Although there is a slight indication of regional foliation trending northwest, the areas underlain by rocks affected by it form a very small fraction of the whole. In all other areas of foliation the direction of strike corresponds to the line of contact of neighbouring intrusive masses.

THE CANADIAN CORDILLERA.

Between the forty-ninth and fifty-fifth parallels of latitude the Canadian Cordillera can be separated into three main divisions: a broad belt of mountains on the east, a more compact mountainous unit along the Pacific ocean on the west, and a lower and relatively flatter region between. The belt to the east consists of the Rocky Mountain system, the Purcell, the Selkirk, and the Columbia systems. The Rocky Mountain system trends north-northwest to northwest for about 1,000 miles. It is bounded on the east by the great plains and on the west by the Rocky Mountain trench, a narrow but persistent depression occupied in turn by many different streams. West of the Rocky Mountain system lie the Purcell range, the Selkirk system, and Columbia system.[1]

[1]Names and boundaries as given by R. A. Daly in "The nomenclature of the North American Cordillera between the 47th and 53rd parallels of latitude," The Geographic Journal, vol. 27, No. 6, June 1906, pp. 586-606, 1 map.

Each of these is separated by a narrow valley which open into the Rocky Mountain trench to the north, so that that de pression bounds each of the three mountain areas in turn at thei northern ends. The more or less continuous systems forming thi eastern belt are prolonged southward across the United State border, where they are succeeded by ranges of less regularity an persistence to the southeast and end abruptly to the southwes in the great Columbia lava plateau.

The western part of the Cordillera consists of the Coas range, a persistent system extending from near the Internationa Boundary to Alaska. A subordinate group, the mountains o Vancouver island and the Queen Charlotte islands, lies to th west of it. Its southern end is separated by the canyon of Frase river from the Hozameen and Skagit ranges of the Cascad system.

Between the mountains of the eastern belt and the Coas range lies a tract with less rugged relief, known as the Interio plateaus. At the United States boundary on the 69th paralle the width of the Cordillera, exclusive of the mountains on Van couver island, is about 400 miles. The eastern belt is ove 200 miles wide, the Coast range and Interior plateaus abou 100 miles each. Farther to the north the Cordillera narrow somewhat.

THE INTERIOR PLATEAUS.

GENERAL FEATURES.

The region of Interior plateaus is about 500 miles long by 100 wide and trends northwest from the International Boundary to about the 56th parallel (Figure I). It consists essentially of areas of rolling upland separated from each other by deep valley trenches. Unlike other units of the Cordillera its boundaries are not always well defined, and in places the uplands seem to rise to meet the mountains.[1] To the west of it lie the Cascade

[1] "The geology and ore deposits of the Hedley mining district, British Columbia," by Chas. Camsell. Geol. Surv., Canada, Memoir No. 2, p. 30; see also p. 9.

and Coast ranges; to the east the Columbia system; on the north it is bounded by a group of irregular ranges, which lie between the Coast range and the Rocky Mountain system and begin near the 56th parallel of latitude; on the south it ends in wedge-shaped form against the Hozameen, Skagit, and Okanagan ranges of the Cascade system, and the Colville mountains of the Columbia system.[1]

In the southern part of the Plateaus the uplands lie from 4,000 to 6,000 feet above sea-level. They decrease in general elevation to the north. The main valleys lie from a few hundred to over 4,000 feet below the upland, and a few rugged hills rise several hundred feet above the surface. The total relief within areas of a few hundred square miles is probably nowhere over 5,000 feet, and is generally less than 4,000.

The greater part of the Interior plateaus drains south and west into the Pacific by way of the Fraser and its tributary, the Thompson. A portion at its northern end drains into the Skeena river. The southern and southwestern end is drained by the Similkameen, Okanagan, and Kettle rivers, whose waters all flow into the Columbia.

The deep valleys which separate the Interior plateaus into irregular blocks have walls upon which the slopes are much steeper than those prevailing on the uplands between them. The junction of upland and valley wall is generally abrupt, and the plateaus are thus divided into *upland* and *valley* portions which are topographically distinct (Plate I). By valleys we mean those valleys which have steep sides and whose bottoms lie below the general upland surface. Shallow valleys occur upon the upland; but are here considered as forming a part of that surface. The areal ratio of upland to valley is about three to one.

The following more detailed description of the Interior Plateaus region applies particularly to that part south of the 52nd parallel of latitude. A conception was gained of the general character of the topography by a comparison of the topographic

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[1] "The nomenclature of the North American Cordillera between the 47th and 53d parallels of latitude," by R. A. Daly. The Geographic Journal, vol. 27, No. 6, June 1906, pp. 586-606, 1 map.

maps of three widely separated areas[1] supplemented by descrip tions of the topography by Dawson[2]. The topographic ma are those of the Beaverdell area; of the Tulameen area; a of the Kamloops and Shuswap areas, whose location is shown Figure 1.

THE UPLANDS.

A study of the upland surface was made along the followi lines: (1) the degree of regional slope and relief upon its surfac the variation of such slope in the different areas and the presen or absence of a relation between general slope and drainage line (2) the presence or absence of local irregularities of slope, cliff flat areas, and steep hillsides differing widely from the gener slope; (3) the nature of the soil covering; (4) the drainage upo the upland and its relation to the drainage along the deep valley (5) finally, the presence or absence of a relation between th upland surface and the structure of the underlying rocks. Th data so obtained were used later to determine to what stage th upland surface had progressed in its evolution through th geographic cycle.

Regional Slopes.

The deep valleys divide the upland into broad, rather irregu lar ridges. If one were to project the upland surface across th main valleys and imagine the valleys filled up to the base of th shallow trough thus formed, the resultant all-upland surfac would show marked relief. Measurements made upon the thre topographic maps show that the average regional slopes from th

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[1] "Kamloops and Shuswap sheets, British Columbia; Tulameen sheet Yale district, British Columbia; map 36A, Beaverdell, Yale district, Britis Columbia," Geol. Surv., Canada.

[2] "On the later physiographical geology of the Rocky Mountain regio in Canada, with special reference to changes in elevation and to the histor of the Glacial Period," by G. M. Dawson. Trans. Roy. Soc. Can., vol. 8, sec 4, 1890, pp. 3-74.

"Report on the area of the Kamloops map sheet, British Columbia," by George M. Dawson, Geol. Surv., Canada, No. 573, pp. 3B-6B, 1896.

higher hills to the lower valleys run from 160 to 300 feet to the mile, and differences of elevation from 1,500 to 2,000 feet occur constantly within 10 miles of each other, but seldom exceed those figures. The regional slope both along and across ridges varies considerably from place to place within the same area; but slopes measured upon interfluves which are not much cut up by canyons show a general uniformity. Thus slopes measured from hilltop to hilltop across a system of parallel ridges in the Beaverdell area generally run from 200 to 300 feet to the mile, although upon the Niople Mountain interfluve the slopes go 800 feet to the mile (Figure 2, profiles 1 and 2). Slopes measured along ridges show about the same grade and variation (Figure 2, profiles 3 and 4). The regional slope in the Tulameen area averages over 300 feet to the mile (Plate II). In the Kamloops map-area the regional slope is about 160 feet to the mile, though here as elsewhere there are many local slopes which differ from the average. In the western half of the Shuswap area they are somewhat higher and vary more widely. This section of the upland is in general flatter than in the other two southern areas examined (Figure 2, profile 7), and this corresponds to Dawson's statement that the plateaus decrease in ruggedness to the north. A study of profiles drawn from three of the topographic maps, Figure 2, shows that there is generally a regional slope upon the upland down toward the deep valleys which now separate the ridge-like upland blocks. In the Tulameen area the profiles do not everywhere show the same degree of accordance between regional upland slope and main drainage lines (compare profiles 5 and 6 in Figure 2). Here parts of the upland surface appear to be tilted to the east away from the mountains, as can be seen in profile 6.

Local Irregularities in Slope.

Many local slope irregularities occur upon the upland surface in all three regions under discussion. In the Beaverdell quadrangle such irregularities are chiefly connected with the Tertiary volcanics, although found developed upon any type of underlying rock. They are not as dominant features as the gentler slopes.

Soil Covering.

The soil covering upon the upland does not as a rule grac into weathered rock below, but seems to have been transporte there from its original source. That it is transported materi is confirmed by the foreign boulders scattered through it. Th covering, which consists of sand, clay, and boulders only rarel stratified, is irregular in thickness but is in general thin. It ha been ascribed to deposition from a continental ice sheet whic at one time covered the country and which scoured soil and rock off one part of the plateaus and deposited them on anothe Large terraces found to elevations of over 5,000 feet above sea level are supposed to be sediments laid down in lakes forme during the retreat of the ice sheet.[1]

Drainage upon the Upland.

The drainage upon the upland is by means of wide shallov valleys which show a certain amount of rectilinearity in plan and parallelism between adjacent valley stretches. In thi respect they resemble the deep valleys which lie below them, an we shall discuss their relations more fully under the heading o "Valleys", p. 13. Many small lakes and swamps are foun within these shallow troughs. Some of them are rock basin and others seem to be partly held up by dams of glacial debri at their lower ends.

Relations between Topography and Structure.

The relations of topography to structure are of particula interest from a theoretical standpoint since they form one of the more delicate criteria by which one may judge to what stage a landform has progressed in its gradual evolution through the geo- graphic cycle. We found a partial accordance of the upland

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[1] "On the later physiographical geology of the Rocky Mountain region in Canada, with special reference to changes in elevation and to the history of the Glacial Period," by G. M. Dawson. Trans. Roy. Soc. Canada, vol. 8, No. 4, 1890, pp. 3-74.

surface to structure, but not a marked one, and very often no apparent relation between rock structure and topography. Accordance between topography and rock structure is strongly indicated by the relations between certain upland valleys and fault zones in the rocks beneath them. Accordance seems proven also in certain areas where there is a marked difference in the topographic character of surfaces underlain by Miocene lavas and surfaces underlain by rocks of different texture which occur near the lavas (Plates III and IV). On the other hand, the general upland surface often passes over the contacts of rocks of different hardness and texture without apparent change in character.

The relations between valleys on the upland and zones of fracture in the nearby rocks were studied more particularly in the Beaverdell area. Here it was seen that the valleys, both below and on the upland, are generally made up of straight stretches; that sets of these stretches were roughly parallel; and that any particular set might include both upland and deep valleys. Certain valleys below the upland were found to be actually following zones of fracture in the rocks, and certain valleys on the upland were lying in directions parallel to the strike of zones of fracture in the nearby rocks. Moreover, by plotting all the fractures observed by us on a protractor diagram, it was shown that they lie in roughly parallel sets and that the great majority of them trend from north to northeast. This is the trend of the larger number of parallel valley stretches. The general correspondence in trend between parallel valleys and parallel fractures, coupled with the fact that certain individuals of a set of parallel valley stretches are actually known to follow zones of fracture in the underlying rocks, strongly indicates that the valleys both on and below the upland largely follow zones of weakness in the underlying rocks. In the Kamloops area, and on other parts of the Plateaus, the same parallelism between valley stretches may be observed, and this suggests that the same conditions hold throughout the Plateaus.

Changes in topographic form to correspond to changes in the texture and hardness of the underlying rocks were seen in the Beaverdell quadrangle. Certain lavas of Tertiary age occur here in connexion with older granitoid and metamorphic rocks of different physical character. The topography of the lava areas differs in the abundance of cliffs, steep slopes, and flat tops, from the more gently rolling character of the areas underlain by the other rocks. In the Kamloops area north of Highland valley certain lavas of upper Miocene age lie upon granitic rocks. The contact between the two apparently follows the sides of the hills, and from an examination of the map one gains the impression that the lava acts as a hard cap which protects the lower rock from erosion.

Evidences of disregard for the underlying structure are plentiful. Schists and granites lie side by side upon many of the rather flat topped hills in the Beaverdell area. In the Tulameen area the upland surface planes across a centroclinal basin of sandstones, conglomerates, and shales without apparent regard to the structure (Plate V and Figure 2, profile 6). In the Kamloops area nearly flat parts of the upland surface were seen to plane across lavas and agglomerates dipping up to angles of 25 degrees.[1] In all three areas the topography shows less of a relation to structure than a disregard for it, but a partial relation evidently does exist.

To sum up: the character of the upland is very similar in the areas studied. It contains average regional slopes which vary from 3 to 6 per cent, with differences of elevation upon it of from 1,500 to 2,000 feet within 10 miles. It seems to grow slightly flatter toward the north. The regional slopes are generally related to present drainage lines, although such drainage lines may be occupied by valleys lying far below the upland surface. This is not always true in the case of areas upon the border of the Plateaus, for here the surface is sometimes tilted away from the surrounding mountains. Cliffs, steep hillsides, and flat tops occur in many places as local variations from the regional slope. The soil covering upon the upland is variable in thickness, and generally of glacial origin. The drainage is by wide valleys, and lakes and swamps are not uncommon. Fin-

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[1]Oral communication from Mr. Bruce Rose of the Geological Survey of Canada.

ally, the topographic surface of the present upland shows a partial relation to the structure of the rocks below, both in the drainage pattern, and in the differences in the topography developed upon the oldest rocks.

These characteristics indicate that the upland surface has reached the stage of late maturity, or the beginning of old age in the geographic cycle. We shall discuss its physiographic development in more detail later on.

THE VALLEYS.

From wide and shallow valleys upon the uplands the streams flow through narrow canyons to the floors of the large flat-bottomed steep-sided valleys. There is, therefore, an upland type, a V-shaped canyon type, and a U-shaped, deep trench type of valley. The last two types have walls upon which the percentages of slopes are five to ten times that found upon the sides of the upland valleys (Figure 2, profiles 1 to 6, and the topographic map in pocket). They form breaks on the upland surface and their floors are often hundreds or even several thousand feet below it (Plate I).

Drainage Pattern.

The valleys have in certain parts of the Plateaus a marked rectilinearity in plan; that is, they are made up of straight stretches and the streams turn sharply from one to the other of these stretches. A number of such intersecting straight stretches will trend in one direction for a long distance, and then the valley will turn at nearly right angles into the next series of "straights." Thus the North Thompson, which occupies a southerly trending valley for over 100 miles, joins the South Thompson where its valley is trending to the west. Forty miles below their junction the South Thompson makes a big turn and trends southerly with minor deviations until it joins the Fraser. In detail the longer valley stretches of these two rivers are made up of a series of straight reaches from a few miles to 20 miles long.[1]

[1]Kamloops map-sheet, British Columbia. Geol. Surv., Canada.

The valley of Okanagan lake and river is another example of a south-trending trench made up of short intersecting straight stretches. The Otter river in the Tulameen district occupies a remarkably straight valley and the streams in the Beaverdell quadrangle illustrate the rectilinearity in stream plan in great detail. This fact applies to streams upon upland surfaces as well as those occupying deep valleys.

Straight stretches in adjacent valleys often show a marked parallelism which is only brought out in a topographic map. This parallel trend is the more striking when one of the valleys is deep and the others are on the high uplands on both sides of it. As an example from the Kamloops area one may cite the valley at the headwaters of Highland creek, which is paralleled by three troughs upon the upland north and south of it, and by a section of the South Thompson valley. A number of such parallel stream courses are cited in the detailed description of the Beaverdell area, where they are found to be related to zones of weakness in the underlying rocks. Rectilinearity or parallelism of the valley courses is not the invariable rule for all streams or sets of streams within the plateaus, but the tendency is marked enough to make a noticeable feature of the drainage plan over at least the southern part of the plateaus. From a theoretical point of view, the parallelism of upland valleys and the troughs below the upland is of interest, because it suggests that the same conditions, namely zones of weakness in the underlying rocks, controlled the formation of both.

Valley Bottoms.

The valleys of the larger streams have flat bottoms which are sometimes from 1 to 2 miles wide. They are made up of series of flat terraces and often lie far below the upland surface. Stream grades are low, the fall of the Thompson for instance being about 10 feet to the mile at its lower end. Railways use these broad valleys because they offer more constant and lower grades. Because of their comparatively low altitudes fruit ranching is becoming an important industry upon the larger valley floors, although upon the higher uplands fruit trees do not grow. Lakes large and small occur upon the valley floors as well as upon the uplands. Two of the larger ones are Okanagan lake, which is about 70 miles long by 2 wide, and Kamloops lake, which lies in the valley of the South Thompson. These lakes are partly caused by damming of the valleys by glacial debris.

TOPOGRAPHIC FORMS DUE TO GLACIERS.

In conclusion we may refer to certain special types of topography which occur upon the plateaus and are generally thought to be due to glacial action.

In certain places in the valley bottoms which for some reason are protected from erosion, one sometimes finds long low ridges lying along the sides of the valleys. These often have a narrow smoothly rounded top with the sides sloping evenly from it, and a small draw between it and the hillside proper. The ridges are made up of unconsolidated rounded boulders and sand. Similar ridges may lie across a valley and with them may occur rounded depressions without outlet, and irregular mounds, the whole making up an irregular hummocky surface. These ridges, depressions, and mounds, are similar to deposits laid down by valley glaciers in mountain regions to-day, and are called moraines. The greater part of the blanket of round boulders, sand, and clay which is spread over the upland to-day is thought to have been laid down by a continental ice sheet which covered all of the Interior plateaus at one time. A number of high terraces which have been found up to elevations of over 5,000 feet have been described as the remnants of deposits laid down in lakes which were formed during the melting of this ice sheet. Finally the steep sides and flat bottoms of the large valleys all over the plateaus resemble known glaciated valleys very closely. The steep smooth valley walls which are perhaps the most striking features of the Plateaus topography are without doubt the work of the glaciers.

DESCRIPTION OF THE BEAVERDELL MAP-AREA

Summary.

That part of the Interior plateaus included within the Beaverdell map-area consists of a rolling upland with a relative relief of 2,000 feet. It is drained for the greater part by the West Fork river whose bottom lies from 1,000 to 1,500 feet below the surface of the upland, increasing the total relief to about 3,250 feet. The West Fork flows southerly and joins the main Kettle river which is roughly parallel to it, and 12 miles east, about 16 miles south of the area. The Kettle flows south along the eastern foot of the Midway mountains near the International Boundary where it turns east and finally enters the Columbia south of the Rossland mountains. In its north-south course the deep valley of the Kettle forms the eastern border of the Interior plateaus which wedge out a few miles south of the International Boundary. The Beaverdell map-area, therefore, whose eastern boundary is nearly on the edge of the trench of the Kettle, lies in the southeastern corner of the Interior plateaus.

The rolling surface of the high country is diversified by buttes and mesas of Miocene lavas, often surrounded by high cliffs which lend a rugged element to the scenery. It consists of broad ridge areas trending north to northeast, each of which is a composite of a number of small, parallel ridges. These major ridges slope gently down to more or less steep bounding valleys. Their crest lines are sometimes nearly flat for several miles, but often pitch strongly toward some valley, or from some lava-covered butte (Plate III). The average elevation of individual flat topped ridges ranges from about 4,000 feet near the deep West Fork valley to 4,700 feet in most of the country east of it, and over 5,700 feet near the large volcano-covered area of Nipple mountain. Nipple mountain, the highest point on the map, is 5,758 feet high. Nipple mesa, north of it, and Red mountain, 3½ miles to the southwest, both outside the quadrangle, are at about the same elevation. Goat peak, a volcanic plug on Wallace mountain, is 5,675 feet high, while lava mesas to the northeast of it are over 5,500 feet.

Many local irregularities in slope occur within the uplands; small parallel steep sided ridges are common within areas underlain by plutonic batholiths; contrasts of flat hilltops and sheer cliffs are often seen within the lava areas, some of the cliffs, as in the Goat Peak region, reach a height of several hundred feet. The soil covering is irregular in thickness and everywhere characterized by the presence of rounded pebbles foreign to the rock formation below. These erratics are found upon the highest points within the quadrangle. The upland surface cuts across contact surfaces between the formations older than the Tertiary lavas at all angles. Tertiary lavas, however, generally occupy higher ground than the adjacent older rock formations; very often the contact is at the base of a lava cliff, such cliffs being the rule rather than the exception. To the west the upland surface appears to rise gradually to the watershed between the Okanagan and Kettle rivers; on the east of the quadrangle it ends at the canyon of the Kettle river; northward it appears to become less rugged; but about 20 miles north of the quadrangle the flat surface is interrupted by a high ridge coming from the northeast, known as the Black ridge, with Ptarmigan mountain apparently near its southwest end; to the southwest the upland is rugged and apparently much broken by canyons; to the southeast the plateau surface ends or merges into the Midway mountains.

The West Fork river occupies a steep sided, flat bottomed valley which crosses the western half of the quadrangle in a north-south direction. It falls from an elevation of over 3,000 feet on the northern to about 2,500 feet at the southern end of the quadrangle. Its tributary, Beaver creek, drains a large part of the quadrangle to the east and occupies the same type of valley in the lower 5 miles of its course. Numerous streams coming from the broad troughs on the upland surface flow through V-shaped canyons into the larger valley bottoms of the West Fork and the Beaver. The upland draws resemble a flattened V, in cross section, and are a part of the upland surface. The change from valley side to upland slope is abrupt and forms a distinct knee, convex upward, in profile (Plate IV and Figure

2, profile 1). Corresponding to this there is a steepening of stream grade upon going from upland to canyon bottom.

The West Fork valley floor is made up of a series of terraces which occur in irregular patches upon its bottom, or as fragments often far up the valley sides; similar terraces occur in the side stream valleys. The terraces are sometimes complicated or obscured by alluvial fans, where side streams enter the valley, by rock outcrops, by morainal deposits, and kettle holes. Unmodified glacial deposits are rarely met with. A number of lakes occur upon the upland and in the valley bottoms. They are small and generally quite shallow. Some of them occupy rock basins, but in many cases their lower ends appear to be held up merely by local deposits of loose glacial detritus or by beaver dams.

Detailed Description.

The walls of the larger valleys within the quadrangle have in general much steeper slopes than the uplands lying between them, and this contrast in slope varies as the size and depth of the valley. The larger valleys also differ in the shape of their cross sections from the shallow troughs upon the uplands. These facts have furnished a basis for the division of the topography into an upland and valley type. The topography is described under the headings of uplands, valleys, lakes and swamps, and glacial forms.

THE UPLANDS.

The deeper valleys in this quadrangle divide the upland surface into a number of blocks. These blocks have the form of broad flat topped ridges trending parallel to their bounding valleys, and whose surfaces as a whole slope down toward the valleys. Since valley trenches grow shallower toward their sources, the upland areas tend to merge into each other at such places, and again at other places an area between two large valleys will be incised by smaller canyons. We may divide the quadrangle into six principle interfluves, naming them after their dominating ridges: the St. John block lying between Trapper creek and the West Fork river on the west, and Maloney and Beaver creeks and Wallace draw on the east and south; the Lake Ridge block which lies east of Cedar, Beaver, and Maloney creeks, and west of the Kettle River canyon; the Crystal Mountain block, including Crystal mountain and Crystal butte; the Wallace Mountain block, including Wallace and Curry mountain; King Solomon Mountain block; and finally, the Nipple Mountain area, which includes Red mountain, Ferroux mountain, Nipple mountain and mesa, and Arlington mountain. One or two of these blocks are largely covered by Tertiary lavas; the others have very little or no lavas on them. The St. John, Lake Ridge, Crystal Mountain, and King Solomon Mountain blocks are not capped by areas of lava of any size; the Nipple Mountain area is largely covered by volcanic rocks, and the Wallace Mountain block partly so. The two types of interfluve differ somewhat in average elevation above sea-level, in the parallelism of their component ridges, the degree and character of their slopes, and in the relation which exists upon them between topography and rock structure.

Parallel Ridges.

The St. John block, which is not much incised, may be taken as a type of an interfluve with little or no Tertiary lava. It is a broad composite ridge consisting of parallel ridges with a high ridge line generally near to the middle.

There is a rough parallelism between major and minor ridges with their longer axes trending north-south, north by east, south by west, and less often, northeast-southwest. This seems to hold in great detail in certain areas where the surface is underlain for a distance of several square miles by a batholithic intrusion of quartz-monzonite. Such areas are the top of the broad hill about one mile west of Clark lake, which is made up of ridges and draws with crests 50 feet or more above their troughs, lying roughly parallel; the country to the south of Cup lake, or the ridges across Maloney creek to the west of it, where in travelling across country in an east-west direction, one is continually climbing up one ridge and down into the next trough, the miniature valleys being often 50 to 100 feet across, and from 20 to 50 feet high; another such area is on Crystal mountain to the east and northeast of Goat peak. In some places a parallel set of ridges will trend across a major crest line at a low angle. Such a case occurs upon Lake and Kloof ridges, where minor north-south ridges cross a major northeast crest line. The lava capped Nipple Mountain block is more irregular.

Relative Relief.

The highest points in the Nipple and Wallace Mountain blocks ascend to elevations of 5,675 and about 5,758 feet respectively, the high ridges of St. John, Lake ridge, and Crystal mountain vary from 4,600 to over 4,800 feet, maintaining even skylines. Another set of flat ridges occurs in nearly all the blocks close to the West Fork and on King Solomon mountain; these have an elevation of from 3,300 to about 4,100 feet.

Regional Slopes.

Along the ridges free from the lavas even crest lines are the rule.

Figure 2, profile 3, is drawn along the high crest of the Wallace Mountain and St. John blocks. It shows the up-land surface dipping toward Beaver creek from both sides and also into the east-west depression occupied by Joan lake. For about 5 miles on the top of St. John ridge the slope is not much over 100 feet to the mile, and in places the ridge is practically flat, but where it dips north into the Joan Lake basin, and south into the Beaver, the slope varies from 250 feet to 300 feet to the mile. Below the valley wall the profile is, of course, much steeper, but does not represent a part of the upland surface. The profile on Wallace mountain is not very regular, the slope from the top of the volcanic mesas at 5,500 feet being very abrupt, and the general slope for the first mile about 900 feet, then for a distance of 2 miles the ridge top is much flatter, varying from about 4,650 to just over 4,900 feet in elevation. On Crystal mountain the ridge profile slopes about 200 feet to the mile from 4,900 to 4,500 feet, and is interrupted by the Tertiary intrusive butte of Crystal mountain. On Kloof and Lake ridges there are many irregularities in profile, the high line varying between 4,500 and 4,800 feet. On Cranberry ridge the elevation varies from 4,300 to 4,000 feet with a slope of 200 to 300 feet to the mile. Series of lower ridges show the same evenness of crest, but a slope which is always more than 100 feet to the mile. For instance, a profile of the flat topped ridge east of the West Fork valley from Trapper creek to Wallace lake, if continued on to the southeast ridge of King Solomon mountain, would show somewhat tabular surfaces at an elevation of between 3,800 and 4,100 feet. By shifting his position the observer can see two sets of even skylines in the same interfluve, one of which is actually 700 feet above the other and from 1½ to 3 miles away. The la· capped Nipple Mountain block has an irregular ridgeline consisting of flat topped areas separated by wide draws. There is a gradual slope of ridgeline from the top of Ferroux mountain on this block south to the West Fork river. This is shown in Figure 2, profile 4.

Across the ridges there is a general slope down to the bounding valleys, either from one dominating ridge or from two parallel ridges at nearly the same elevation. This is especially well brought out on the St. John interfluve, where the borders of the interfluve have not been much cut up by canyons (Figure 2, profiles 1 and 2). The high ridges here are the broad top of St. John ridge, and the upper end of China ridge which range from 4,500 to over 4,800 feet in elevation. On the northern end of this interfluve the eastward slope is from 200 to 250 feet to the mile. The bounding valley of Maloney Creek trough here merges into the upland surface. On the southern end of the block the slope measured to the wall of the bounding valley is about 300 feet to the mile. The slope to the west is not uniform, but averages about 150 to 200 feet to the mile. The gentler slope to the west is toward the more distant but deeper valley. Upon the Lake Ridge, Crystal Mountain, the Wallace-Curry Mountain interfluves there are dominating central ridges from 4,500 to 4,900 feet high, and cross slopes. But the upland surface is much more irregular, being broken by volcanic intrusions and flows, and cut into by canyons. On King Solomon mountain there is a high spot on the northwest side ranging from 4,000 to 4,200 feet, and a ridge on the southeast, 200 feet below (Plate III). The slope from Nipple and Ferroux mountains to the walls of Hall creek is from 750 to 1,000 feet to the mile.

Local Steep Slopes and Flat Areas.

In detail the upland is broken up and contains local slopes which have no relation to the average interstream slopes given above. Although the average slopes are not steep, and wide stream troughs and basins like those of Lassie lake exist which are nearly flat, one is constantly coming upon hillsides from 50 to 100 feet high which are steep enough to make climbing difficult. These are not often shown on the topographic map unless the particular slope is more than 100 feet high. Such sharp slopes are found within all parts of what is here called the upland, not only far away from the canyons which fret the borders of an interfluve, but also close to them. For instance, one-half mile west of the lower end of Clark lake there is a hill face of Wallace limestone, most of it bare rock, about 40 feet high, the slope on which must be very nearly 30 degrees. Within the quartz-diorite and quartz monzonite areas such hill slopes are common. It is, however, within the Tertiary lavas that the most marked cliff faces are seen. Goat peak is surrounded by a sheer cliff wall over 275 feet high at its lowest point on the north side, and probably about 400 feet on the southwest. Sheer cliffs exist within every large patch of Tertiary extrusive on the map, whether such an extrusive patch lies in the middle of a flat upland basin like the one between Lassie and Joan lakes or near the edge of a deep valley trough like that of Red Mountain valley. They lie near the contact of the extrusives with the older formations, as in the case of Goat peak, and the mesas to the northwest of it, or away from it, as does the cliff surrounding Nipple mountain. They vary in height from 20 to 200 or 400 feet.

A comparatively flat area lies partly within the quadrangle at its northeastern corner; it is about 4 miles wide, and covers about 6 square miles. It contains a number of lakes and swamps, including Joan and Lassie lakes. South of Joan lake the end of St. John ridge slopes into it at the rate of 600 feet to the mile. On both sides of Lassie lake olivine basalt rises from the basin surface forming cliffs 40 feet high in places, from one of which one may look far over the plateau area to the north.

Ridge tops are often quite flat and smooth. These are from a few hundred to over 1,000 feet across, with gentle slopes in the direction of the ridge. They are as well developed upon a low ridge like the part of King Solomon mountain overlooking Beaver creek, as upon St. John ridge which lies in the centre of a large upland area and is about 900 feet higher. The tops of hills within the Tertiary lava areas are often comparatively flat. Such is often the case in areas partly or wholly surrounded by cliff faces such as the mesas northwest of Goat peak and the larger mesa north of Nipple mountain, which lies just outside the quadrangle.

Drainage Upon the Upland.

What has been said about the parallelism of the hills upon the upland and their slopes, applies also to the valleys between them, since valley bottom and hill top are roughly parallel and the hillsides are the valley walls. Cross valley profiles are in general much gentler than those of the main trenches into which these upland valleys drain. Stream bed profiles steepen very abruptly at the head of the canyons by which the upland valley is connected with the ma' valleys, forming a break in profile corresponding to that between upland surface and valley wall. The upland drainage will be treated in more detail in discussing the valleys.

Soil Covering.

The amount of bare rock varies from place to place upon the upland. Rock outcrops seem to be more abundant upon the ridge tops than in the troughs which separate them. The tops of ridges within Tertiary volcanics are especially bare of soil. Parts of the tops of Cranberry and other rather flat topped ridges are, however, often covered with loose material for long distances. Rounded pebbles and boulders differing in character from the underlying rock are invariably found mixed in the loose soil. There is probably very little loose detritus within the quadrangle which does not contain foreign pebbles. What proportion of it is residual soil in place we do not know, but the rock outcrops are very seldom much weathered, and one can generally obtain fresh rock within a few inches of the surface, which would indicate that most of the loose detritus is transported material. This blanket of detritus is with some exceptions probably nowhere more than a few feet thick. It is ascribed to deposition from a large ice sheet.

Relation of the Rock Structure to the Upland Surface.

Among rocks of pre-Oligocene age there is no very evident relation of the upland topographic surface to rock structure. Contacts between the formations cross the slopes at all angles, and sometimes one and then another will occupy the higher ground. There is, however, some parallelism between the direction of valleys or dry troughs upon the upland and the strike of planes or zones of fracture in the rocks, which indicates that the valleys are located upon zones of weakness in the rocks. There is also a definite relation between topography and rock structure in the areas underlain by Tertiary sediments and lavas.

That the courses of the streams are largely determined by fracture zones in the underlying rocks is indicated by the following facts: the valleys in plan are generally made up of straight stretches. Straight stretches in adjacent valleys are often parallel to each other, and to parts of valleys lying below the upland surface. When the strikes of all the fracture zones and fault planes determined within the quadrangle are plotted on a projector chart it is found that they are bunched in four or five zones, and that these lie between N. 8° W. and N. 55° E., with a subordinate group which strike N. 85° E. If the directions of the straight stretches in the valley bottoms lying within the quadrangle be measured they are found to be divisible into groups which trend roughly parallel and strike from N. 6° W. to N. 45°

E. with subordinate groups striking east-west and north N. 20° W. The groups of faults, however, do not agree in strike very closely, nor can their direction be compared in detail with that of the trends of the groups of parallel valley stretches. This may be due to the fact that strikes were determined upon short surfaces of the fracture planes only and that 75 per cent of the faults and fracture zones were determined within a small area of quartz diorite on Wallace mountain. The rough parallelism of valley stretches and fault zones, and their general accordance in direction is, however, significant. Moreover, fault planes were actually found outcropping along the bottoms of certain small draws on the side of the West Fork valley, and in the bottom of Hall Creek valley, and valleys upon the upland were found to lie parallel to the trend of fracture zones in the adjacent rocks.

A relationship between topography and structure upon the areas underlain by Tertiary rocks is brought out by the topographic change which occurs in passing from one Tertiary rock formation to another, and from the Tertiary rocks to the older. It is suggested further by the finding of evidences of undeveloped drainage in the Tertiary.

On Wallace mountain the white, fine-grained tuffs of the Tertiary overlie conglomerates of the same age; the tuffs at this place lie nearly flat, and form a terrace about 30 feet high, with a steep front upon the conglomerates. There is thus a change in topography at the contact between conglomerates and tuffs.

The Tertiary lavas, which overlie the sediments here, and the older formations elsewhere in the quadrangle, generally stand out from the surface immediately surrounding them to form rugged buttes or mesas. The flat top and cliff topography developed upon them differs from the gentler slopes on the older formations (Plate IV). Their contact with the older formations is also quite often marked by a cliff in the lava, although the cliff is not always immediately at the contact, but may lie some distance back of the contact. In places the lava surfaces suggest evidences of undeveloped drainage. On the northern of the two China buttes, for instance, there is a semicircular depression

70 feet in diameter, and about 10 feet deep, in olivine basalt, with a rock rim of [illegible]t high which, except for 15 feet on the north side, completely surrounds it. Such a depression might be formed by the collapse of a gas chamber in the lava after it has partially cooled. The depression would have to be filled up at least 3 feet before water could flow out of it, and it is difficult to explain as an erosion phenomenon. Nearby lavas in the same mass are amygdaloidal, and the writer believes this to have been formed near the surface of the original flow and to be as yet practically unaffected by erosion. The patch of lava at upper Collier lake lies in a trough between hills of older rocks. It lies higher than the adjacent valley floor to the west, and has a cliff 20 feet high facing the lake. Its flat rock surface does not appear to have been very much modified by water action. In the two cases cited the topography seems to be very largely dependent upon the original rock structure.

THE VALLEYS.

The West Fork river and its tributary, Beaver creek, drain all of the quadrangle except that part which flows into the Kettle river by way of Cedar and Cañon creeks. The West Fork flows southerly and joins the main Kettle, which is roughly parallel to it here and 12 miles to the east, about 16 miles south of the quadrangle. The principal streams entering the West Fork are Curry, Beaver, China, and Trapper creeks on the east, and Carmi, Wilkinson, and Hall creeks on the west side. Beaver, Wilkinson, and Trapper are the largest of these. Beaver creek drains the larger part of the east and south of the area, while only the lower part of Trapper and Wilkinson lie within the map-area. Trapper creek drains an area of unknown extent north of the quadrangle, the Wilkinson basin lies west and northwest of it. As seen from Nipple or Red mountain the basin of Wilkinson creek appears to cover about 100 square miles.

To the south of the quadrangle the wedge-shaped area between the Kettle and West Fork canyons drains into them by Dominion, Deep, and Cedar creeks; Cranberry creek drains the rather high upland directly to the southwest of the quadrangle.

Rectilinearity and Parallelism.

The trend of the valleys within the quadrangle varies from north-south to northeast-southwest, with minor stretches trending nearly east-west. In detail they seem to be made up of a number of intersecting straight stretches. A stream will follow one course for distances up to 6 miles, and then turn more or less abruptly into the next. In general a number of these will trend in somewhat the same direction for a long distance, and then there will be a turn nearly at right angles. The Beaver, for instance, flows southerly for about [illegible] miles, and then turns west for 3½, then south 35 degrees west for 5 miles.

The characteristic of intersecting straight stretches is more marked where the streams are incised in narrow rock canyons as are Cedar, Crystal, and Hall creeks, than where they flow over thick unconsolidated material in broad valleys, as in the case of parts of the headwaters of Beaver and Maloney creeks.

Straight stretches in adjacent valleys often exhibit a rough parallelism, for instance Trapper creek, the upper 1½ miles of China creek, and the valley lying directly southeast of China buttes, are almost exactly parallel to each other with a trend of about 35 degrees east of north. The upper part of Weird creek, 3½ miles of Hall creek, and 2 miles of the West Fork just above where Trapper creek joins it, are parallel, trending 2 degrees east of north. The upper 3½ miles of Maloney creek is paralleled to the west by the Beaver between Joan and Clark lakes, and by a short stream lying between these two; this system trends nearly due north. Another good example is the lower 5 miles of the Beaver, and the shallow trough on King Solomon mountain about 1½ miles to the northwest of the Beaver. In the areas underlain by quartz diorite and quartz monzonite batholiths, one sometimes finds series of small parallel valleys and draws such as described under local slopes in the uplands.

Along the valley of Hall creek a number of small dry draws are to be seen upon the valley sides, trending in a direction parallel to that of the main valley. They are bounded by cliffs and look as if they had been partly sliced out of the valley side and left hanging in the air. Such parallel draws are seen all along Hall creek, and one especially well developed is to be seen in the West Fork bottom on the northern edge of the map. Here there is a dry canyon about 80 feet deep paralleling the river, and on the west side of it.

Relation of Shatter Belts to Stream Courses.

The bottom or side of a stream course is often the outcrop of a belt of shattering which trends in the same direction as its valley trench at that point. This has been more especially seen in the case of small valleys within the quartz diorite and quartz monzonite batholiths. On Wallace mountain the outcrops of belts of shattering and of strong faulting occur along the bottom of small gullies on the mountain side. The faulting and shattering was in this case seen in mine tunnels under the gullies. In two cases dykes were seen to be displaced along planes following the bottom of small gullies, one in quartz monzonite and the other in quartz diorite. The relation between fault lines and valley courses has been discussed on page 24 in describing the accordance between topography and structure upon the uplands.

Shapes of the Valleys in Cross Section.

According to the shape of their cross sections one may classify the valleys into three types. There is a U-shaped or glacial type, a canyon type with a typical V-shape, and an upland draw type which resembles a very much flattened V in cross section.

The U-shaped valleys have steep sides and a broad flat terraced bottom (Figure 2, profile 4). As one looks up or down some of the straight stretches of these U-shaped valleys their two sides appear as two planes steeply inclined to the floor like the two sides of a gigantic flume. The continuity of these planes is broken by the gaps made by side streams, but between these gaps the side spurs end abruptly in one of the planes, and look as if their front ends had been neatly sawed off. The West Fork occupies such a flume-like valley, and so do the last 5 miles of Beaver creek, and the lower ends of Trapper and Wilkinson creeks. The characteristic shape of these valleys is especially well brought out where side streams are small and scarce, as in the lower stretches of the Beaver. The planate sides are steep, and sinc· the larger valleys are of this type, their valley walls together with the walls of certain of the deeper canyons are the most conspicuous feature in the relief of the region.

The canyon type is exemplified by the canyon occupied by Cedar and Larsen creeks, steep sides running down to a narrow bottom. Canyons are found at the lower ends of almost all the smaller streams draining from the upland into the larger valleys of the West Fork and Beaver creeks. Upland draws have gently sloping hillsides and rounded rather than flat bottoms. Such is the valley of Beaver creek between Joan and Clark lakes (Figure 2, profile 1) and the draw crossing King Solomon mountain on its southeastern end (Figure 2, profile 4). An examination of the side hill slopes of valleys of the U and canyon types shows that there is an abrupt change in practically all cases, somewhere upon the hillside, from the steep grades peculiar to these types below to a gentle slope which is more nearly that of the upland draw (Figure 2, profiles 1, 2, and 4). Upon climbing out of the West Fork valley for instance, one ascends a slope of from 1,800 to 2,500 feet to the mile for an elevation varying from 800 to 1,500 feet, according to the locality, and then suddenly the grade flattens so that one appears to be upon a flat tc [illegible] ·ill. As a matter of fact, however, there is generally an upv [illegible] e of 600 feet to the mile or less to the ridge top which m. [illegible] a mile or more away. As one ascends a side stream the gentle slopes descend farther toward the valley bottom and the canyon becomes shallower until it becomes a narrow trench within a wide uplanddraw. Cañon Creek valley is an example of such a change from canyon to broad draw.

Stream Grades.

Stream grades along the [illegible] shaped valley bottoms are usually quite low. The West Fork averages about 30 feet to the mile from the southern limit of the quadrangle to Trapper creek, and 40 feet to the mile for some distance above that point. The profiles of the side streams show stretches of steep grade followed by long flats which are in turn succeeded by steeper grades. Upon such stretches lakes and swamps often occur, while the steeper bed grades are usually in canyons. The smaller tributaries of the West Fork, like China and Curry creeks and St. John and Crystal creeks which flow into the Beaver, generally have steep gradients within the canyons through which they enter the valley of their master stream, and flatter grades in the upper upland troughs. Beaver creek has a very variable gradient and falls in a series of three steps from the source at Joan lake to its junction with the West Fork at Beaverdell. The flats or treads of these steps lie in U-shaped or upland valleys, the raises in canyons sunk in such valleys. The grade varies from 40 to 80 feet per mile in the flats and 100 to over 200 feet per mile in the raises.

Discordance between Valley Size and Stream Volume.

Comparison of the stream volumes of two confluent creeks sometimes shows that the larger volume of water is being carried by the smaller valley. Such is the case where Trapper creek enters the West Fork, the valley of Trapper creek being about twice the size of the corresponding part of the West Fork and carrying less water. Another instance is seen at the junction of Beaver and Maloney creeks.

An extreme case is that of Wallace draw, a broad valley connecting the West Fork and Beaver creek. Its highest point is about 40 feet over Wallace lake, which lies on the surface of an extensive terrace on the floor of the West Fork valley and the slope from this point to the Beaver is much less, while its valley is wider than that of the Beaver above the point where they come together. Nevertheless the Beaver carries a fair sized stream while Wallace draw is practically dry. The reasons for this are discussed under the heading of "Stream Piracy," page 45.

Terraces.

The floor of a broad U-shaped valley like the West Fork is made up of a series of terraces becoming successively higher as one moves from stream trench to valley side. In valleys of the canyon type, they are often found in remnants above the steep V of the canyon. Typical upland draws which have no canyon trenches in their floors do not show terraces. Figure 3 is a cross section of the West Fork above China creek showing the terraced floor.

In following a particular terrace up or down the valley, one finds it occupying the greater part of the floor in one place and in another existing only as a narrow ledge upon the side hill or as an isolated flat topped remnant within the valley bottom, while there the major part of the floor is taken up by a higher or lower member of the terrace series. Fragments of terraces sometimes exist several hundred feet above the valley. The terraced character of these large valleys is obscured in places by alluvial fans, kettle holes, dry channels, and outcrops of bedrock, but it is the dominant feature of the bottoms of the larger valleys.

LAKES AND SWAMPS.

A number of small lakes are scattered through the upland country, most of them being found in the northeastern parts of the quadrangle, and one or two occur on the floors of the deeper valleys. The largest one, Joan lake, does not cover more than about 200 acres, the smallest ones are mere ponds. They vary in depth but are probably for the most part shallow. The upper of the three Arlington lakes in the valley of Hall creek measured 24 feet at its deepest point. Some of them occupy rock basins, as in the case of Joan and Cup lakes, others seem to be merely dammed up by loose debris assisted by the work of beavers. In some cases the lake is a sheet of water in the middle of a swamp, but a number of them have rocky or sandy shores and clear water, and when surrounded by an unburnt forest, as is the case with Clark and Joan lakes, are very picturesque.

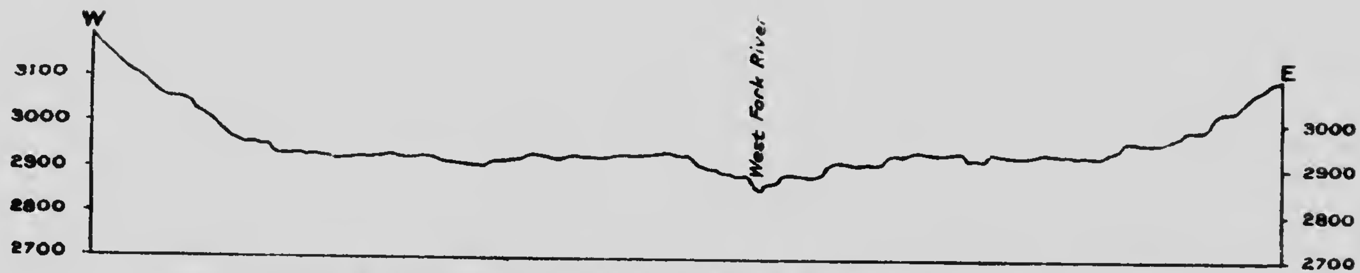

Fig. 3. Profile of the West Fork valley floor, north of China creek, showing series of terraces. (Diagrammatic).
Horizontal scale, 800 feet to 1 inch; Vertical scale 400 feet to 1 inch.

GLACIAL FORMS.

A few topographic forms occur in sheltered parts of the valleys which are typical of glacial deposits, and some irregular mounds and ridges are found which have the appearance of somewhat modified glacial deposits. In Wallace draw both lateral and end moraines occur. Here a long narrow ridge follows for some distance along the foot of the Knob Hill side of the draw, and another, below it, lies two-thirds of the way across the valley. These ridges are about 30 feet wide on top and slope smoothly away to both sides at angles of about 20 degrees. The top of the lateral moraine along the hill side is about 60 feet above the adjacent valley floor and pitches with some irregularities down the valley. Between it and the foot of the hill is a draw about 20 feet deep. The slopes along this ridge top are remarkably smooth. Below the cross ridge there is a jumble of irregular mounds and depressions in which drainage lines are absent or only feebly developed. The cross ridge and the mounds below it form the end moraine. Such glacial forms are comparatively rare in the Beaverdell quadrangle and can be looked upon more as accessories than essential parts of the topographic surface.

GENESIS OF THE PLATEAU TOPOGRAPHY.

In order to obtain a basis upon which to classify the land forms found in the southern Interior plateaus we shall begin this section by a discussion of the theory of the geographic cycle, and will give reasons for believing that a classification of land forms according to their average regional slopes is desirable and necessary. The discussion is followed by an account of the physiographic development of the plateaus.

The Geographic Cycle.

According to the prevailing theory of physiographic development, if a portion of the earth's crust be raised a certain amount above sea-level the atmospheric agencies of disintegration, decay, and erosion which act on its surface will be greatly stimulated. Following a definite course these agencies will proceed to dissect such a land mass. The larger streams will first deeply trench it with canyons; side cutting from the streams will skeletonize the interstream areas, that is, carve them into a number of peaks and narrow ridges which would slope down to the stream beds; and these ridges by decay and decrease of slopes will have slowly reduced their relief relative to the stream beds. This process will continue until the hills between streams have been cut down very low. As they sink lower and lower the forces of erosion, which vary greatly with the slopes upon which they work, will become very weak and finally a stage will be reached at which erosion is hardly perceptible and the land mass resembles a rolling plain with a few low residual hills upon it. The period of time in which this series of changes takes place is known as a geographic cycle[1] and has been divided into the stages of youth, maturity, and old age, while the final land form is called a peneplain. Youth is that stage in which the greater part of the down cutting of streams takes place. Maturity may be divided into two parts: early maturity in which the interstream areas are being skeletonized and the relief is greatest, the country being then decidedly mountainous; and late maturity, in which the reduction of relief is very rapid and the country is cut down from the rugged mountains to rounded hills. After that comes old age, in which further cutting down is slow. If old age be allowed to continue long enough without disturbance of the crust by either warping or change in level, a peneplain will finally result. During each of these stages certain characteristic forms appear, which are distinctive. Thus in youth the streams are ungraded, waterfalls and lakes often occur along their courses, and the slopes upon interstream areas are apt to be very different from those upon the main stream valley sides. In maturity stream beds assume smooth profiles, divides become ridges, the relief is most accentuated and then rapidly diminished, and differences in rock structures are brought out,

[1] "The Geographic Cycle," by W. M. Davis, The Geographic Journal, vol. 14, 1899, pp. 481-504.

soft rock being carved into valleys, and hard rocks standing out as ridges. Old age is characterized by the comparative absence of cliffs upon the hill sides, by the fact that differences in rock structures are no longer brought out by the topography, and by relatively low relief. Thus one may, by determining which of these characteristics a land form possesses, determine to what stage it has progressed in the Geographic Cycle.

Land forms are, however, very seldom the product of one cycle of erosion, and mountainous regions especially are often made up of the remnants of land forms produced in several distinct cycles; the earlier cycle existing as the smaller remnants upon the higher points. In trying to determine where a composite form is to be placed, in which different parts have different characteristics, one is led into more speculation than seems warranted; hypotheses upon the origin of composite land forms can generally be verified only by detailed studies over large areas with the aid of topographic maps. The one thing, however, which can be determined for any given region with satisfaction, is the relative relief and the average regional slopes. By average regional slopes we mean here such as are obtained by taking differences of elevation upon the higher interstream areas and in the lower valleys that lie between them, thus indicating the average fall of the waters which aid in denuding and degrading the land. It is fairly well established that there is a definite diminution of average slope after a region has passed the stage of early maturity, that such diminution is very rapid during maturity and becomes very slow during the later stages of old age. It would, therefore, seem possible to classify land forms according to their average regional slopes into a system which would not violate the accepted theories of the origin of such forms, and would place definite limits to the various stages.

The necessity of such definition of land forms can be especially illustrated by the use of the term peneplain. This term is continually being applied to land forms having a mature appearance irrespective of their actual relief. Thus the uplands of the Interior plateaus of British Columbia, with regional slopes of 160 to 300 feet to the mile (3 to 6 per cent), have been referred to as peneplains.[1] The same name is applied to the Laurentian plateau[2] and the Great plains of western Canada[3] which have average slopes of less than 10 feet per mile, and are really plain-like in appearance. Not only do the uplands not resemble plains, but, according to the idea of extreme slowness in the later stages of the degradation of the land forms,[4] they are further removed in time from land surfaces with slopes of 10 feet to the mile than from rugged mountains with slopes of from 800 to 2,500 feet to the mile. The necessity of defining the relief of various land forms becomes more apparent when remnants of an old land surface are used to measure earth-warping by. Here the accuracy of measurement is directly related to the amount of original relief, and that relief is often disregarded.[5] For instance, if the original surface has a relief of 1,000 feet, the measurements of warping upon isolated remnants of that surface are, of course, apt to be out by 1,000 feet.

We may conclude then, that a classification of this type is desirable and necessary, and that it would not be contrary to the existing theories of the development of land forms. In the following account of the physiographic development of the Interior plateaus the criterion of regional slopes, or relative relief, is used as the chief basis for classifying the land forms found therein.

Physiographic Development.

In the following account of the physiographic development conclusions are largely drawn from a study of the Beaverdell map-area. Since, however, the topography of this area is very similar in drainage pattern and relief to mapped areas in the

[1] "Report on the area of the Kamloops map-sheet, British Columbia," by G. M. Dawson, Geol. Surv., Can. Ann. Rep., Vol. VII, part B, pp. 4-5.

[2] "The Laurentian Peneplain," by A. W. G. Wilson, Jour. Geol., Vol. XI, 1903, pp. 628-629.

[3] "Forest Physiography" by Isaiah Bowman, pp. 410-411, New York, 1911.

[4] "The Geographic Cycle," by W. M. Davis, Geographic Journal, Vol. XIV, 1899, p. 48.

[5] "An old erosion surface in Idaho: a criticism," by Eliot Blackwelder, Jour. Geol., Vol. XX, No. 5, July-August, 1912, pp. 410-414.

southwestern and south-central part of the plateaus, we shall extend our conclusions to cover all of the southern portion of the Interior plateaus.[1]

The development of the physiography may be conveniently divided into three periods which are separated by two rather obvious changes in topographic form. The first is the period preceding the laying down of the Tertiary lavas; the second period begins at the time the lavas were erupted and ends at the beginning of the great uplift which caused the cutting of the present deep valleys; the last period is concerned with the physiographic development following the uplift. The first and second periods are separated by the eruption of the lavas. A break in the geographic cycle is suggested there, because of the difference in the topography upon, and off, lava areas. The second and third are separated by the uplift which formed the valleys. We shall for convenience refer to this as the "great uplift." The forms developed in the second and third periods are generally easily separable by difference of slopes.

THE PERIOD PRECEDING THE ERUPTION OF TERTIARY LAVAS.

The evidence relating to the land forms existing in this period is rather fragmentary. We have some evidence, however, which indicates the type of land surface that existed in the Beaverdell area at the beginning of Oligocene time, and also just before the eruption of the lavas.

Deposits of conglomerates, agglomerates, sandstones, and fine-grained tuffs occur in the southern part of the Beaverdell quadrangle. They are of Oligocene age, and have the character-
structure and make up of a continental deposit of the Piedmont type. The association of coarse conglomerates and fine-grained, thin bedded tuffs suggests the presence of steep mountain valleys, lakes, and nearby volcanic cones. We may, therefore, infer that the topography at that time was mountainous.

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[1]A comparison of the Beaverdell, Tulameen, Kamloops and Shuswap map-areas has been made in the regional description of the Interior plateaus, pp. 6 to 15. According to all available information the portions of the plateau lying between these widely scattered areas do not differ essentially from them.

The period following was evidently one of degradation of the land, for at the time the lavas were laid down a mature surface had been developed. The relative relief within the Beaverdell area was more than 1,500 feet, and the drainage lines occupied approximately the same position as they do to-day. The evidence of the relief is furnished by the actual contacts of the lavas with the underlying rocks. Thus in Nipple mountain this contact varies from 3,500 to 4,800 feet above sea-level. On Cranberry ridge it is 4,500 feet, and on Wallace mountain about 5 miles to the southeast between 5,000 and 5,400 feet. At Lassie lake it is 4,300 feet, and 3 or 4 miles to the northeast in the bottom of Kettle valley it lies between 2,500 and 2,800 feet. Although there has been folding of the lavas since, it is not probable that they have shifted very greatly in a vertical direction. It may, therefore, be supposed that the relative relief within the quadrangle was at least 1,500 feet. The tilting of the contact surfaces from the Nipple and the China buttes toward the West Fork valley suggests a depression in that direction, and the finding of lavas upon the present bottom of the Kettle river near Copper creek suggests an old valley there. Such is the evidence in regard to the former drainage. The evidence for the maturity of the topography is that the topography developed upon rocks older than the lavas seems much further advanced than that developed on the lavas themselves, and suggests that they were laid down upon a surface already well truncated.

Having established the probable land form upon which the lavas were laid down, in the Beaverdell area, we may pass on to the next period.

THE PERIOD ENDING AT THE GREAT UPLIFT.

From the difference in composition of the lavas seen in the Beaverdell quadrangle, it is inferred that there at least they were local in their distribution; that is, the material derived from one particular centre of disturbance did not cover a very extensive area. One may suppose that when the disturbances were over, certain valleys were filled up and hills of lava existed in other places. It is quite possible that parts of the original surface were never covered with lava. The present uplands were developed from the partly or wholly lava covered land surface. The method of that development must be deduced from what we know of the uplands to-day. It is here assumed that, except where dissected by streams, they have changed very slightly in character since the "great uplift."

Two alternative hypotheses are advanced here to account for the present form of the uplands. The first is that it is a peneplain which may or may not have been somewhat dissected before the great uplift took place; the second hypothesis is to the effect that the uplands represent a land form in the stage of late maturity and that there are no evidences of the interruption of the cycle between the laying down of the lavas and the great uplift.

The Presence or Absence of Peneplain Remnants.

The tenability of the first hypothesis depends upon the finding of peneplain remnants which were formed after the deposition of the lavas and before the great uplift. The arguments for peneplanation are first of all the general evenness of skyline to be observed in all parts of the plateaus, and in the second place the fact that the greater part of the upland surface cuts indiscriminately across rocks of different formations.

Flatness of skylines would indicate that upon the higher ridges remnants were left of what was once a fairly flat surface. This argument is strengthened if a number of ridge tops lie at an elevation close to that of some of these flat crestlines. In the Beaverdell quadrangle there are a number of such ridge tops lying at elevations of between 4,500 and 4,800 feet, and some of them have apparently quite flat skylines. That flatness of skyline is not a very safe criterion for the determination of plain or peneplain remnants, is indicated by the fact that such even crestlines occur at elevations 700 feet apart and only 2 or 3 miles away from each other in several places in the Beaverdell quadrangle. Thus the observer by climbing up the side of the West Fork valley near Hall creek and looking east would first see a flat skyline on the east of the West Fork valley at about 4,000 feet above sea-level, and if he ascended higher, he would presently see the flat crestline of St. John ridge, 3½ miles farther east and 700 feet higher than the first.

It is even possible to assume a position in which the angle of vision would blend the two crestlines and make them appear as one flat top. Moreover, if one actually measures the slopes along ridges it is seen that although they may locally seem flat they pitch at grades comparable to the average regional slope of the region. A comparatively flat skyline is shown in Plate V in the Tulameen area. In the Beaverdell area the number of ridge tops which lie between 4,500 and 4,800 feet are practically lava free and their mature slopes are best ascribed to the cycle previous to the deposition of the lavas, for where lavas are developed to any extent the ridge tops rise to 5,500 and 5,700 feet.

The cutting of a rather flat surface across different formations is another criterion which must be used with caution. In the Beaverdell quadrangle the three formations older than the Tertiary are the Wallace complex and the quartz diorite and quartz monzonite batholiths. The two batholiths resemble each other in texture and there is no reason why they should exhibit great differences in topographic expression. The softer members of the Wallace complex often lie in wedgelike form within a surface of plutonic rock, and are thus protected. These three formations cover the larger part of the area, but the passing of a flat surface from one to the other of them cannot be taken as of any great significance. Moreover, such a planing of flat surfaces over rocks of markedly different texture occurs upon King Solomon mountain which is relatively far below the other ridges and is obviously not a peneplain remnant (Figure 2, profile 4, and Plate III).

We conclude, therefore, that in the Beaverdell quadrangle at least we have no evidence that remnants exist which would indicate peneplanation after the deposition of the lavas. The topographic maps of Kamloops and Tulameen do not reveal such remnants if any exist there.

The Uplands in the Stage of Late Maturity.

The evidence given above, coupled with a study of a number of profiles in the Beaverdell and Tulameen area (see Figure 2, profiles 1 to 6), have led us to believe that no interruption of the cycle took place between the laying down of the lavas and the great uplift. It still remains to prove that at the uplift the uplands had reached the stage of late maturity. Late maturity is the stage between early maturity and old age. In early maturity the topography is rugged, cliffs are plentiful on the hill sides, and there is a definite relation between topography and rock structure. In old age the relative relief is very low, cliffs are scarce or wanting, the soil covering is heavy, and there is no relation between the topography and the structure of the underlying rocks.

The hypothesis that the cycle had attained the stage of late maturity is based upon the presence of cliffs and other local irregularities of slope, the partial accordance which exists between topography and structure, and the degree of average regional slope and relative relief which exists on the uplands.

Local Inequalities of Slope.—On pages 22 and 23 we have given evidences of the presence of cliffs and flat areas upon the uplands in the Beaverdell area, which vary markedly from the average regional slope. Some of them occur far away from the present deep canyons, and could not have been formed from erosion subsequent to the uplift. They occur at all angles to the prevailing southeasterly movement of the continental ice sheet, and many of them could not have been formed by glacial plucking. A good many cliffs, short, steep slopes, and also flat areas must, therefore, have existed upon the uplands at the time of the great uplift.

Partial Accordance between Structure and Relief.—In the description of the Beaverdell map-area, and of the Interior plateaus as a whole, we have discussed at some length the relationships between the upland topography and the rocks underlying it. Near Beaverdell the river valleys consist of straight stretches, and straight stretches in adjacent valleys are parallel. A relationship evidently exists between the direction of sets of fault zones and sets of parallel valley stretches. The indication is that the valley bottoms follow the fault zones. The peculiar drainage pattern of the Beaverdell area is repeated over the rest of the plateaus, and it suggests that the same conditions hold for the plateaus as a whole.

The difference in the topographic forms developed upon different rock formations of the Tertiary in the Beaverdell area proves a definite relationship between topography and structure upon those areas. In the Kamloops area such a relationship is indicated by the manner in which Miocene lavas, on the uplands near Highland valley, overlie granite.[1] It looks as if the lava were acting as a protective cap to the granite. Evidences of the disregard of the topography of the uplands for rock structure are plentiful. Pre-Tertiary rocks of the Beaverdell area are planed across, irrespective of their structure. In the Kamloops area the upland cuts across Miocene lavas with a dip of 25 degrees, and at Tulameen across a centroclinal basin of Tertiary sediments (Figure 2, profile 6, and Plate V). The disregard of topography for the structure is, therefore, the more prominent feature, but in some respects topographic form is evidently still controlled by rock structure.

Average Regional Slope and Relative Relief.—We have pointed out in the regional description of the Plateaus that in their southern portion the average regional slopes of the uplands measure between 160 and 300 feet to the mile and that differences of elevation of 2,000 feet are of constant occurrence within 10 miles of each other. In discussing the theory of the geographic cycle we have shown that land surfaces with such slopes and relief are more closely related to rugged mountains than to plain-like forms; on the basis of that theory, therefore, the uplands of the Interior plateaus represent a stage closer to early maturity than to old age.

To Sum Up:—The number of local irregularities of slope, that is, cliffs and flat areas which are to be found on the upland together with the partial accordance which exists between its topographic form and rock structure, proves that it represents a stage of development between early maturity and old age. The average grade of its slopes and general relief show that the upland is more closely related to mountains than to peneplains. We, therefore, place it as a land form at the stage of late maturity. It may be of interest to note here that since in the Beaverdell, Tulameen, and Kamloops map-areas there seems to be no evidence of the existence of more than one land form above the deep valleys, one may in those areas apply the term upland to that form with more propriety than uplands. On the same grounds the term Interior Plateau, first applied to this region by Dawson, is, as far as our evidence goes, more appropriate than Interior plateaus.

THE PF ᵕ. FOLLOWING THE GREAT UPLIFT.

Consequences ᵕj . . . ;ft.—At the beginning of the third and last period of physiographic development a change occurred in the intensity and manner of attack of the erosive agencies upon the land. Instead of the mere wearing down of a mature landscape the main streams began cutting canyons in their beds. These canyons moved gradually up stream, and sideways along tributary streams, and started to destroy the old surface (Plate II). The reason for this change in the intensity and manner of erosion is ascribed to uplift of the land and the consequent change in base level of the streams, which caused them to cut down and form canyons. A measure of the extent of the uplift was obtained in the following manner: the slope of the old surface toward the deep valleys of to-day indicates that the deep valleys are situated upon the sites of large valleys in the upland surface. By projecting these old slopes to meet over the present deep valleys it appears that in certain places their present bottoms lie 1,000 feet below the bottoms of the old valleys. This was the case in the Beaverdell area, and indicates that that part of the plateaus was raised up at least 1,000 feet. While the period we are treating of is chiefly concerned with the development of the deep valleys, it must not be forgotten that away from the deep canyons and valleys the upland was also being worn down. Here erosion acted upon it at about the same rate as just before the uplift. But the changes brought about on a mature surface like the upland are insignificant in comparison with the results effected in valley cutting during the same period of time.

After the beginning of the uplift there was a period of glaciation, and after glaciation ceased, a period of adjustment of the drainage disorganized during glacial time, and of modification of the topographic forms left by the glaciers. The adjustment and modification have continued until the present time.

Glaciation.

Glaciation occurred first by means of a continental ice sheet which moved southerly over the Interior plateaus and east of south in the Beaverdell area; and later, after the ice sheet had disappeared, by valley glaciers which moved down the larger valleys.

Evidence of the continental ice sheet consists of striæ, with a constant general trend to the southeast, which occur upon the higher ridges, and of the blanket of drift which is found all over the uplands. From the evidence of transported boulders sometimes striated and generally smooth, which are found on points like Nipple mountain at an elevation of 5,758 feet, and on King Solomon mountain at 3,800 feet, we may conclude that the ice sheet was quite thick, probably at least 2,000 feet.

The ice sheet carved out rock basins in which lakes now exist, and probably scraped away most of the residual soil from the rock surfaces. It deposited drift, which dammed up streams and often diverted their waters. A great number of the swampy areas on the Beaverdell uplands are undoubtedly the result of glacial damming of streams. Some of the lakes are also due to this, while others are partly or wholly hollow basins carved by the glaciers in bedrock. Evidences of alterations of drainage due to the continental ice sheet are many; they are referred to again under "Stream Piracy."

After the ice sheet had disappeared from the Beaverdell area there was a further invasion of valley glaciers which scoured out certain of the valleys and deposited glacial debris upon their retreat. How many periods of valley glaciation there were we do not know. From their shape we conclude that the valley of the West Fork, Wallace draw, and the lower parts of Trapper creek, Wilkinson, and Beaver creeks, were occupied by valley glaciers at one time. No cirques were found in the Beaverdell map-area, and it is inferred that the valley glaciers which moved down Trapper and Wilkinson creeks and the West Fork river were derived from higher ground to the north. The Beaver, however, rises upon comparatively low ground and its headwaters show no evidence of a névé-field of snow accumulation. A beautiful example of the U-shaped valley occurs at its lower end and this may have been formed by the glacier which occupied Wallace draw and left evidence of its presence in the moraine which lies at the point where Wallace draw enters the Beaver.

The other topographic effects of glaciation in the valleys were the scouring out of rock basins like lower Arlington lake, the deposition of glacial material, and changes of drainage or stream piracy. Examples of glacial deposits are the moraines in Wallace draw, and in the draw south of lower Collier lake.

Stream Piracy.

Evidences of changes in the courses and volumes of streams are many. They seem to be largely due to the disorganizing effect of glacial deposits. The mor[illegible]l occurrence of changes of stream volume is where at the junction of two streams, the smaller valley carries the larger stream, for examples: the junction of Trapper creek and the West Fork, and the junction of Beaver and Maloney creeks. In extreme cases one of the valleys may be dry, having evidently been robbed of its entire flow; such is the case in Wallace draw and in the trough in which the lower Collier lake lies. Wallace draw and the lower portion of Beaver creek into which it opens, together form a valley trough as large as the corresponding part of the West Fork valley. But although they are all developed in the same type of rock Wallace draw is entirely dry and the lower end of the Beaver carries a comparatively small stream. Wallace draw, which is separated at its upper end from the floor of the West Fork valley by a divide only 40 feet high, was undoubtedly at one time the channel of the West Fork river.

The Formation of River Terraces.

After the glaciers had disappeared erosion began to modify the irregular deposits of loose debris left by the glaciers. This material was easily moved and transported in great quantities into the larger valleys, so that the streams were overloaded and began to aggrade their floors. Successive aggradation and cutting down then formed the series of terraces found in the valley to-day.

These terraces are described on page 31, and a series of them is shown in profile in Figure 3. They may have originated in several ways: by successive regional uplifts; by temporary obstructions in the valley bottoms, which caused lakes to form in which flat deposits of debris were laid down, to be later partly cut away and left as a terrace remnant; they may have been caused by simple meander of a rather overloaded stream, accompanying gradual downcutting; or they may have been caused by climatic changes which caused the rivers to deposit their loads at one time and cut into their floors at another. In all probability several of these causes operated in their formation.

We have no definite proof regarding interrupted regional uplift after glaciation and do not consider it necessary to the formation of the terraces, since the river floor was far above the base level of erosion at the end of the glacial period and the river would possess potential downcutting energy sufficient to account for the amount of such downcutting as it has accomplished since.

Temporary obstructions in a river channel are undoubtedly responsible for the formation of some flat deposits which would be partly cut away after the obstruction was removed. Such obstructions would be caused by glacial damming or the crossing of the valley by a hard formation. The broad terrace at an elevation near 2,900 feet, which covers most of the West Fork floor near Wallace lake, is probably a glacial lake floor caused by the damming of the head of Wallace lake by a moraine. An example of a terrace due to rock obstruction is that on the floor of Beaver creek opposite Collier lake. Such obstructions may be used to account for individual terraces, but they do not seem to us adequate to explain whole series of such terraces occurring universally through the length of the larger valleys.

That meandering rivers form small flat plains of deposit on the inside of their meanders is a matter of observation; also that a meandering stream often continues to cut down its channel and that it is continually changing its course, the meanders moving downstream, or being entirely abandoned by cut-offs. The inner flood-plains of any particular meander would, therefore, be apt to be left as a tabular surface by the continually changing river, and stand a chance of being preserved as terraces of irregular form. The old meanders would be gradually filled by flood deposits until only traces of them remained. Terraces formed by meanders should lie first on one side of a river and then on the other, and should sometimes be preserved as isolated remnants in the middle of the valley floor. They should not be very far apart vertically if they are to be due to the normal downcutting of a swinging stream. In plan many of the terraces on the bottom of the West Fork valley occur in just that way and one often lies only 20 or 30 feet over the other. Traces of old channels are not unusual in its wider parts. Rorick lake, below Beaverdell for instance, lies in part of an old abandoned river meander and many older and fainter channels are to be found on the valley floor (Figure 3). We cannot explain all the terraces in this way, however, for in parts of its course to-day the stream is too straight and is cutting down rapidly, leaving narrow terraces rising in steps from its banks.

A final hypothesis for the origin of these forms is that changes of climate, influencing the amount of rainfall and the abundance or scarcity of vegetation, would affect the erosive power of the streams. Stream cutting varies directly as the volume of water and indirectly as the amount of debris carried in the water. A change of climate involving cooler conditions, but not glaciation, would conserve the precipitation as snow and send it down the valley in torrents during the short warm season. At the same time the streams would not carry very great loads because of the partly frozen ground and the result would be downcutting by the great volumes of water rushing down the valleys. A return to warmer conditions would result in a more even run-off, no great volumes of water at one time, and more heavily loaded streams, which would mean that the streams would lay down their load and build flood-plains. Into these flood-plains the rivers would trench during the next cycle. It is a pretty well established fact that climatic changes are cyclic, both as regards rainfall and cold, and such conditions as we have indicated above are, therefore, not exceptional but rather to be expected, especially when the region is far removed from the tempering influence of the ocean. An example of such a cycle of climatic changes on a large scale is the alternation of glacial and interglacial stages which occurred during the Glacial epoch in eastern North America.

A number of hypotheses may thus be put forward to explain the formation of these river terraces. Obstructions in the valley channels appear to account for some of the terrace fragments, and stream meandering may account for others. There remain the hypotheses of interrupted uplift and cyclic changes in climate, to account for alternations of deposition and downcutting. No evidence of uplift was found and the hypothesis of climatic changes is, therefore, proposed to account for the greater number of terraces.

Summary.

We have given evidence for believing that in early Tertiary times parts of the southern Interior plateaus like the Beaverdell area were mountainous and rugged, but that just before the deposition of the later Tertiary lavas they had been reduced to a hilly but not very rugged region; that after the deposition of the lavas a cycle was started which progressed until the whole region had attained the stage of late maturity; that it was then uplifted and certain of the main valleys deeply dissected. Later on the whole country was profoundly glaciated by a continental ice sheet, and the main valleys further visited by local valley glaciers. The effect of glaciation was to remould and partly scour out the main valleys, disorganize the existing drainage, and provide plenty of rock waste for the later streams. After glaciation had ceased, a variety of conditions combined to form a series of terraces upon the valley floors. To-day the cycle of erosion is in the stage of youth, its work is represented by the deep valleys. Between these valleys lie the remains of a cycle in late maturity, the upland, which the young streams will presently destroy. The stage to which this youthful cycle has progressed may be measured by the fact that the upland remnants still cover three times the area occupied by the valleys.

EXPLANATION OF PLATE II

View looking north over the upland and the trough of the Otter river, Tulameen map-area. The point *a* is 14 miles from the camera. The upland in the foreground slopes at the rate of from 240 to 300 feet to the mile toward the trough on the left. *West* of the trough V-shaped canyons, of the period after the "great uplift," may be seen dissecting the upland. Profile 5, Figure 2, crosses the foreground.

EXPLANATION OF PLATE II.

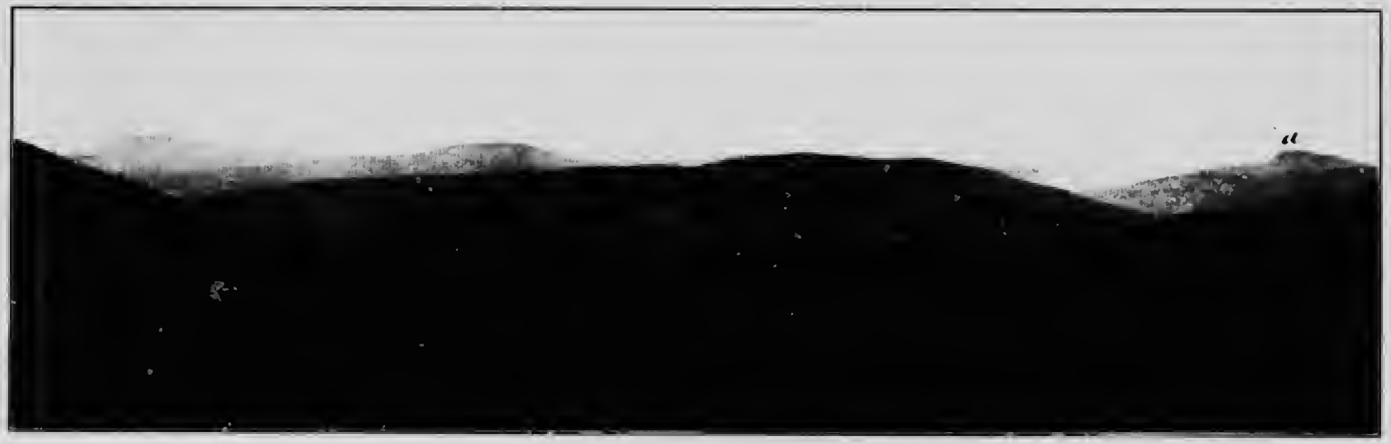
View looking north over the upland and the trough of the Otter river, Tulameen map-area. The point *a* is $4\frac{1}{2}$ miles from the camera. The upland in the foreground slopes at the rate of from 240 to 400 feet to the mile toward the trough on the left. West of the trough V-shaped canyons, of the period after the "great uplift," may be seen dissecting the upland. Profile 5, Figure 2, crosses the foreground.

EXPLANATION OF PLATE III.

View looking west across King Solomon mountain, Beaverdell map-area. Beaver creek is seen in the foreground. A low upland remnant on King Solomon mountain is shown in the middle distance and ridge lines of the upland in the background. At the point a, is a cliff of Miocene lavas on Red mountain.

EXPLANATION OF PLATE III.

View looking west across King Solomon mountain, Beaverdell map-area. Beaver creek is seen in the foreground. A low upland remnant on King Solomon mountain is shown in the middle distance and ridge lines of the upland in the background. At the point *a*, is a cliff of Miocene lavas on Red mountain.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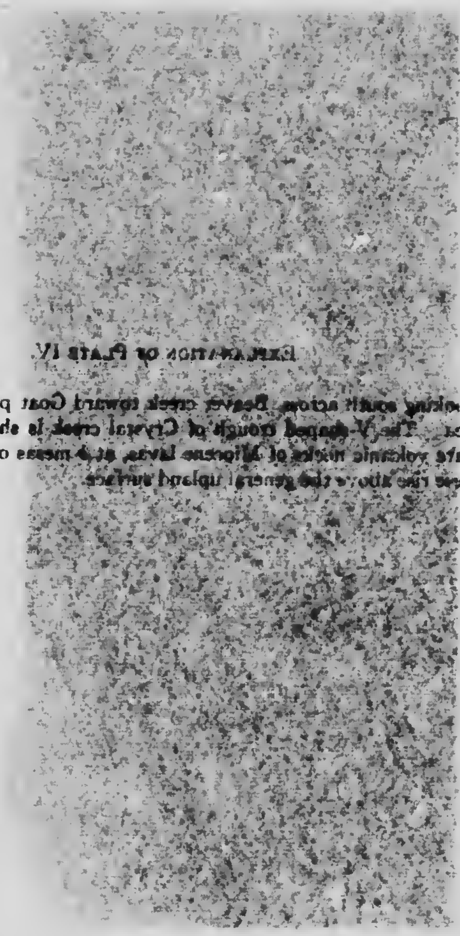


Explanation of Plate IV.

View looking south across Beaver creek toward Goat peak, Beaver[illegible]ell map-area. The V-shaped trough of Crystal creek is shown on the left. At *a* are volcanic necks of Miocene lavas, at *b* mesas of the same character; these rise above the general upland surface.


a
b
b

Explanation of Plate V.

View looking northeast across the valley of the Tulameen river with upland in the distance. The points *a* and *b* on the horizon are 6 and nearly 8 miles respectively from the camera. A variation in the skyline of $\frac{1}{100}$ of an inch on the photograph between *a* and *b* is equivalent to an actual difference in level of nearly 80 feet in the topography. Between *a* and *b* is a wide upland draw with side slopes of about 100 feet to the mile. In the foreground a "flat" surface planes across a centroclinal basin of Tertiary shales and sandstones. See profile 6, Figure 2.


b
a

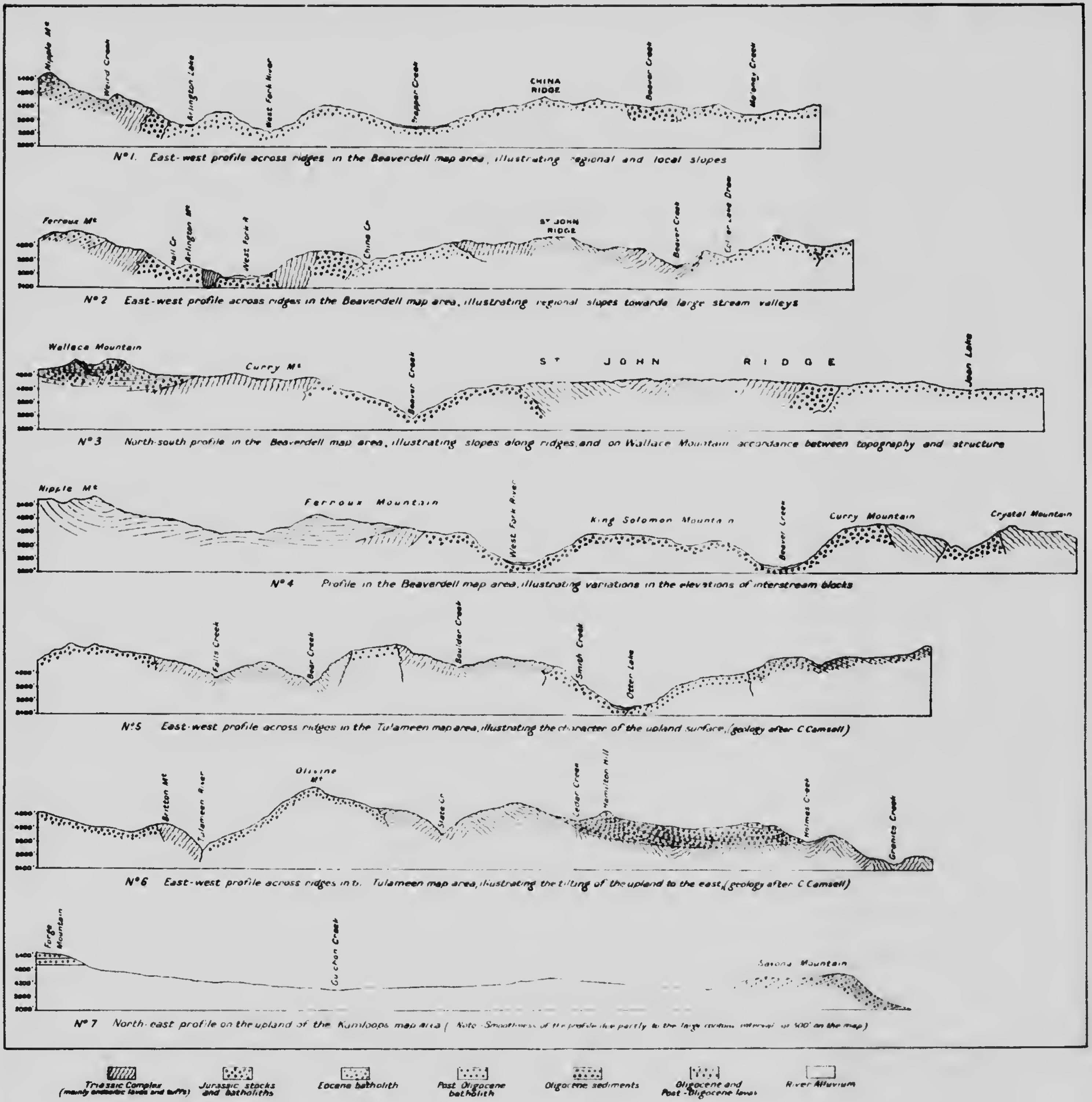
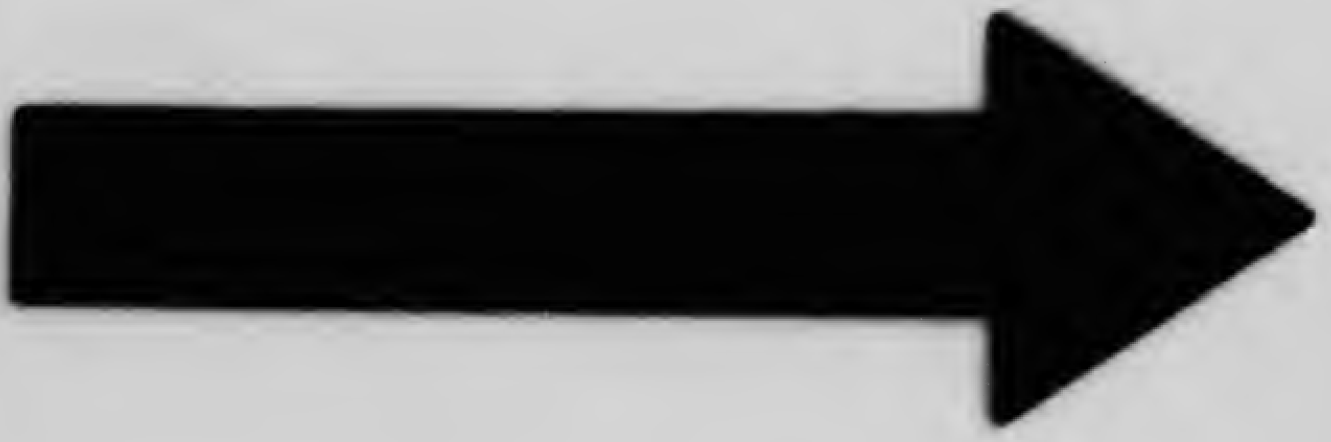


Fig. 2. Character of the surface in the **Interior Plateaus** *of* **British Columbia**

Horizontal Scale 2 miles = 1 inch, Vertical Scale 4000 feet = 1 inch



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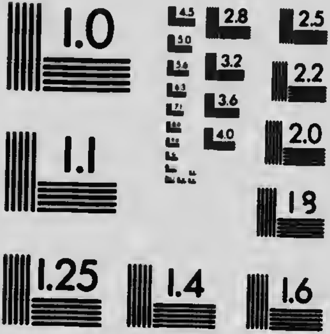

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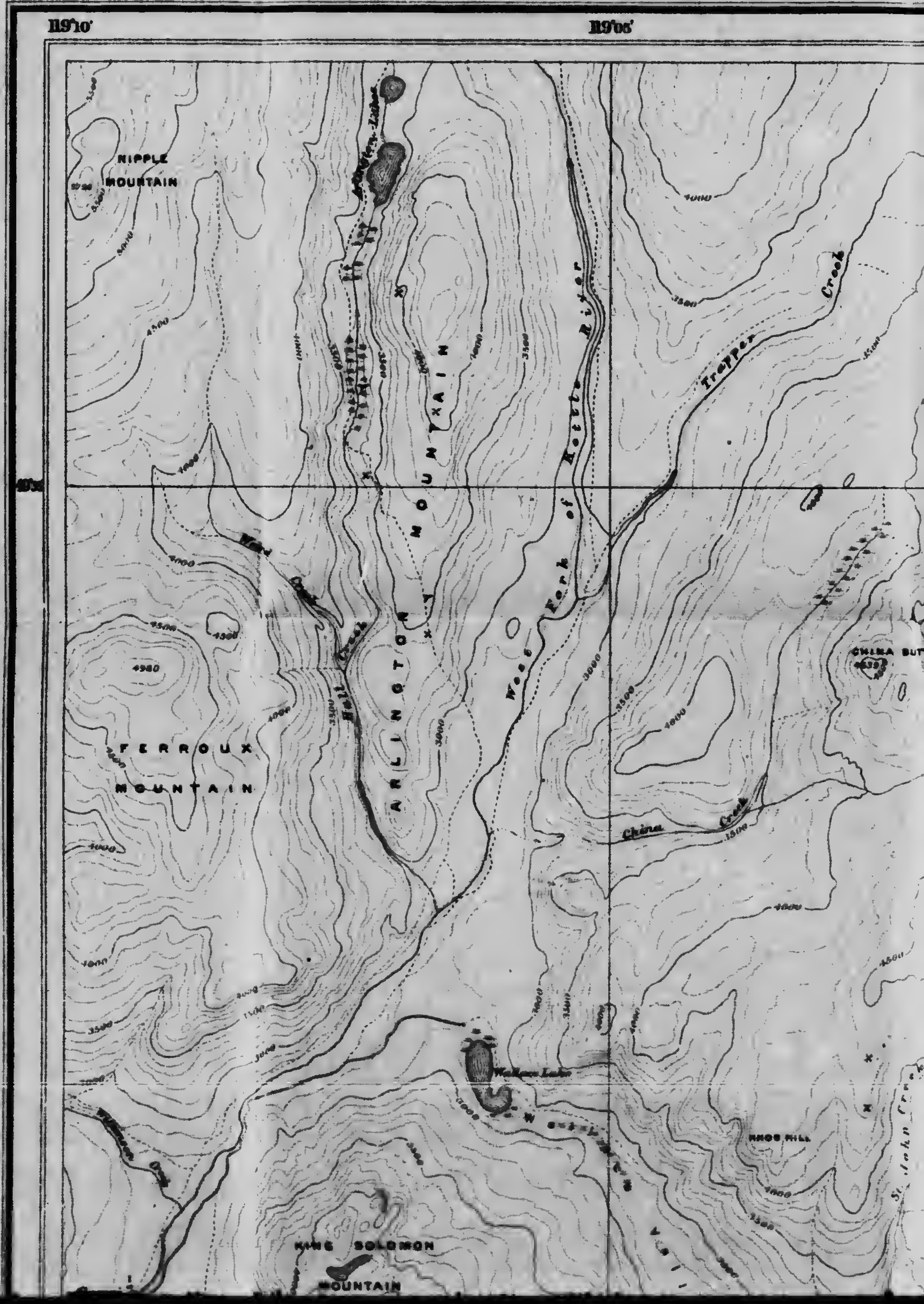

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1911

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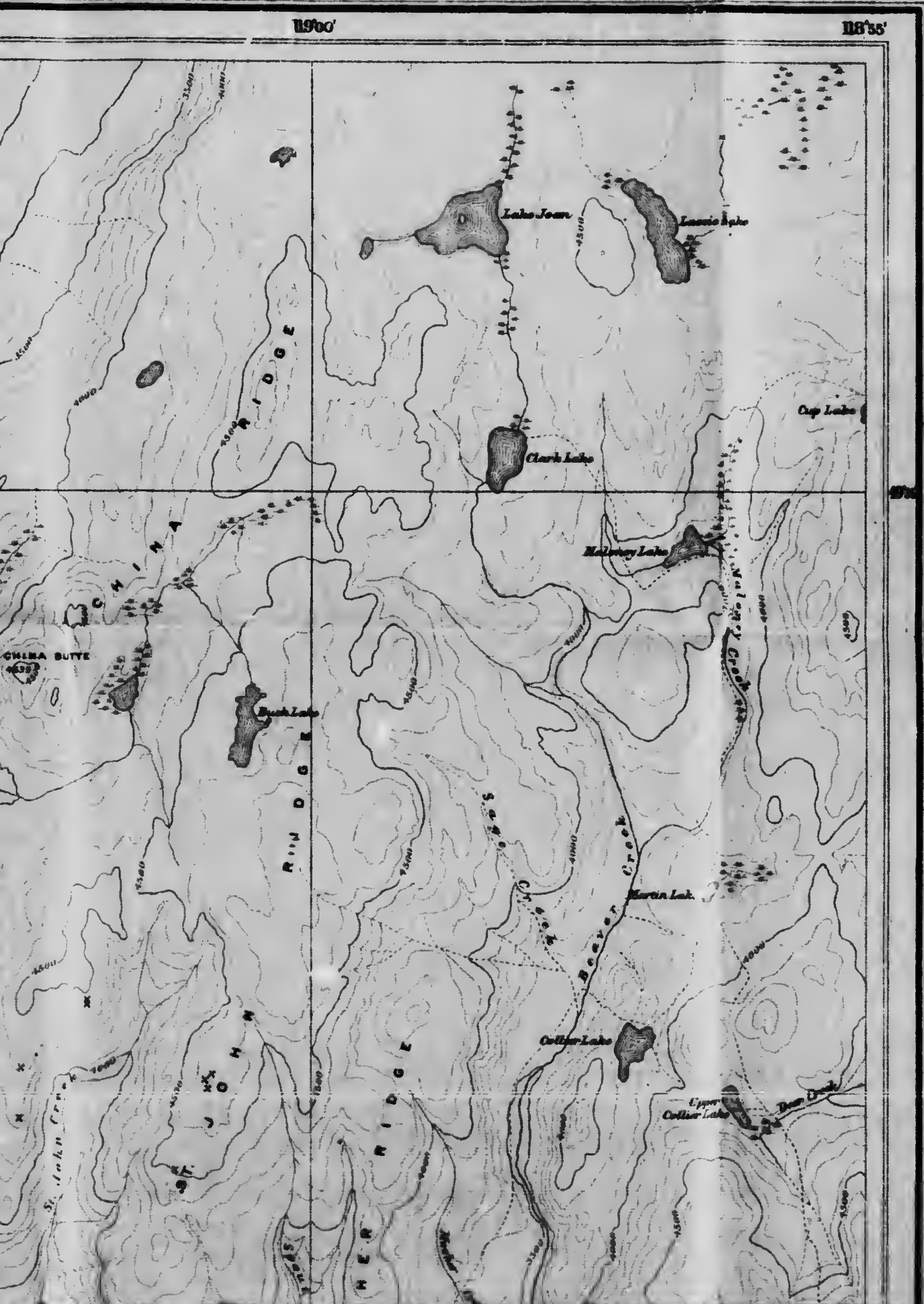

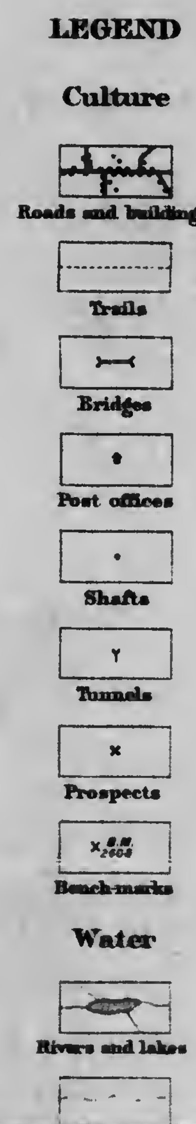

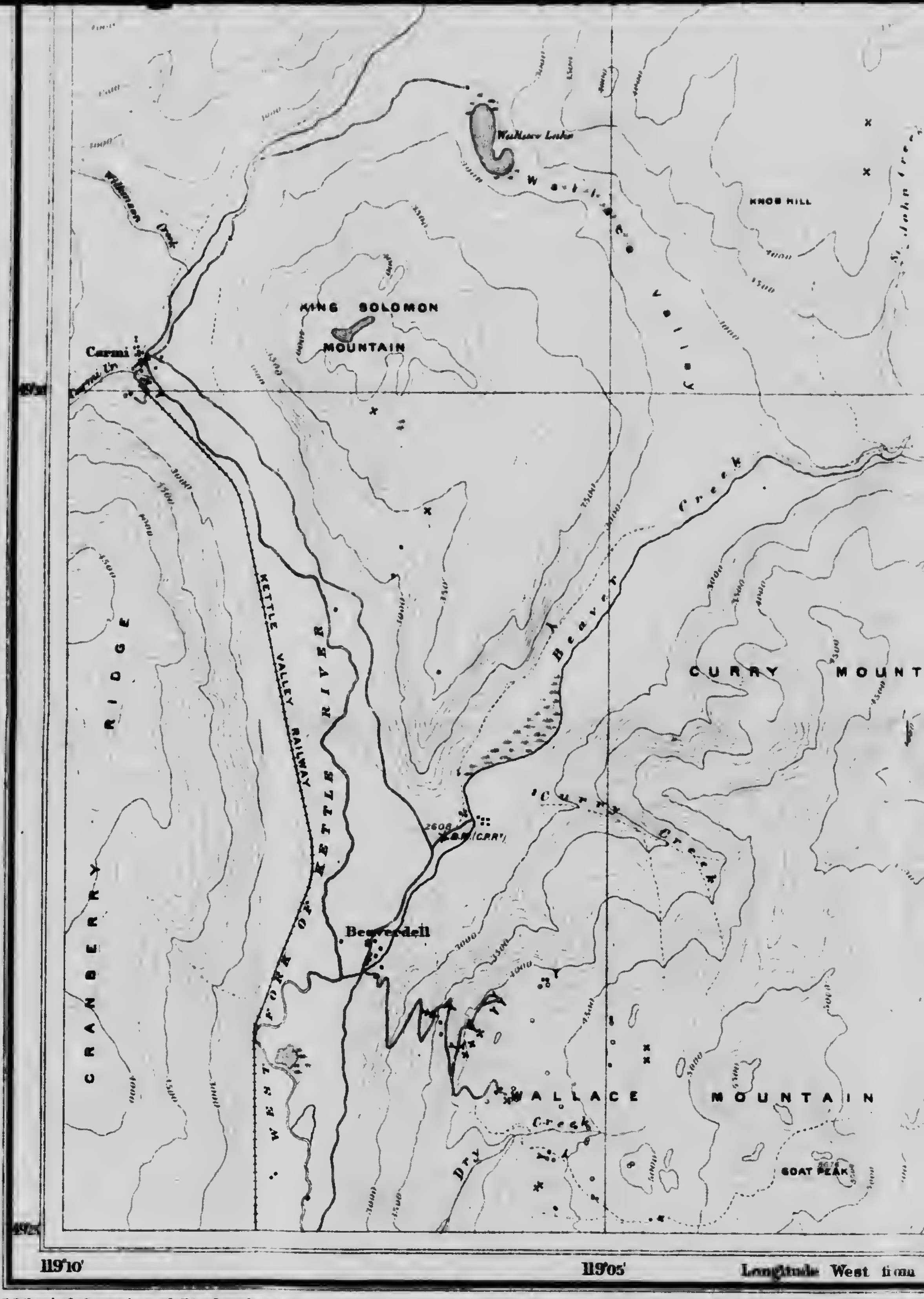

C.O.Senécal, *Geographer and Chief Draughtsman*,
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MAP 36 A

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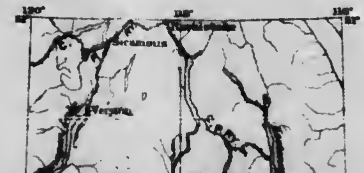

Scale, 100 Miles to 1 Inch

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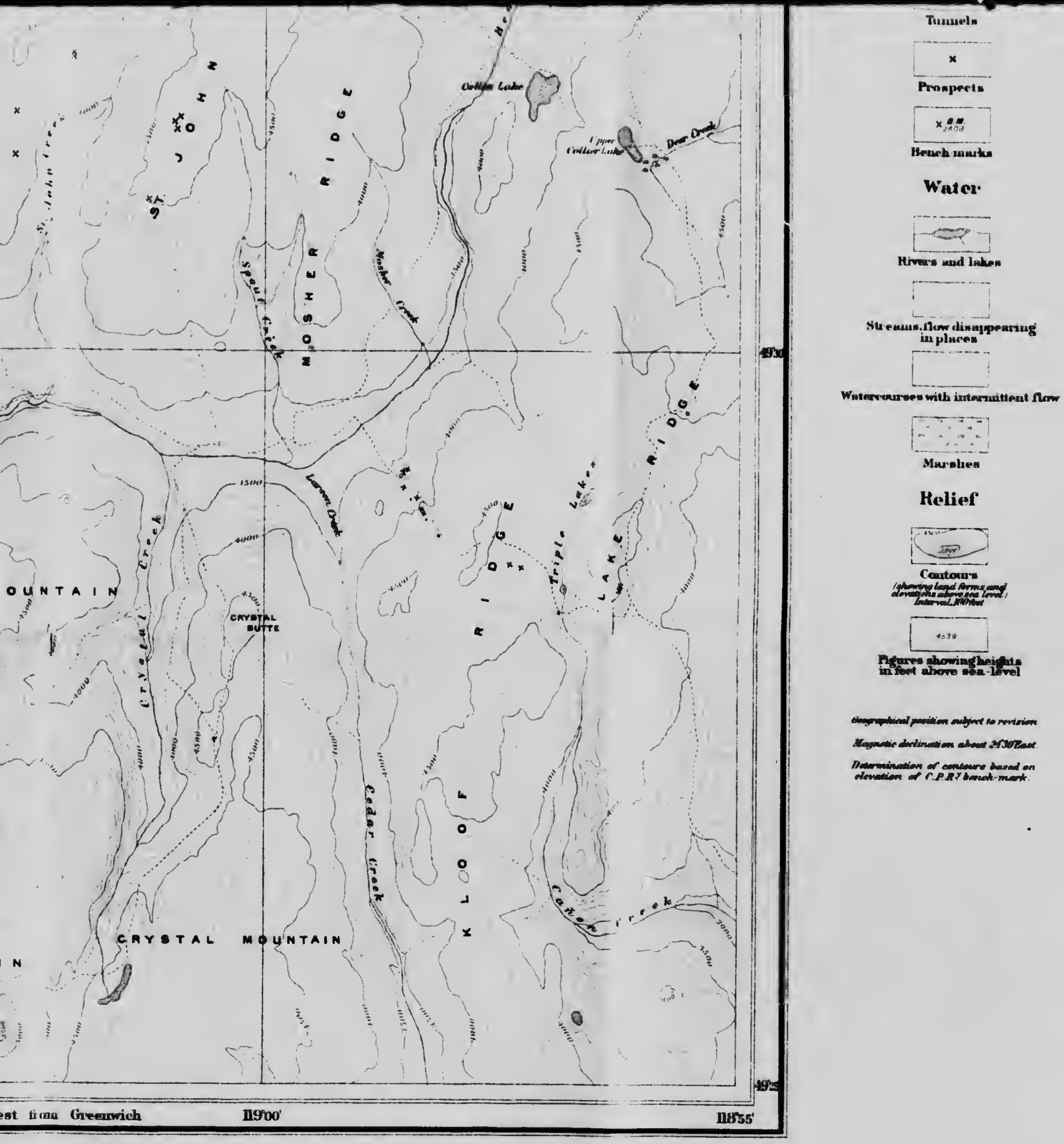

AP 36 A

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