Forest Distribution in the Northern Rocky Mountains

Kirkwood

PRESS OF
MISSOULIAN
PUBLISHING
COMPANY

MISSOULA
MONTANA

Forest Distribution

in the

Northern Rocky Mountains

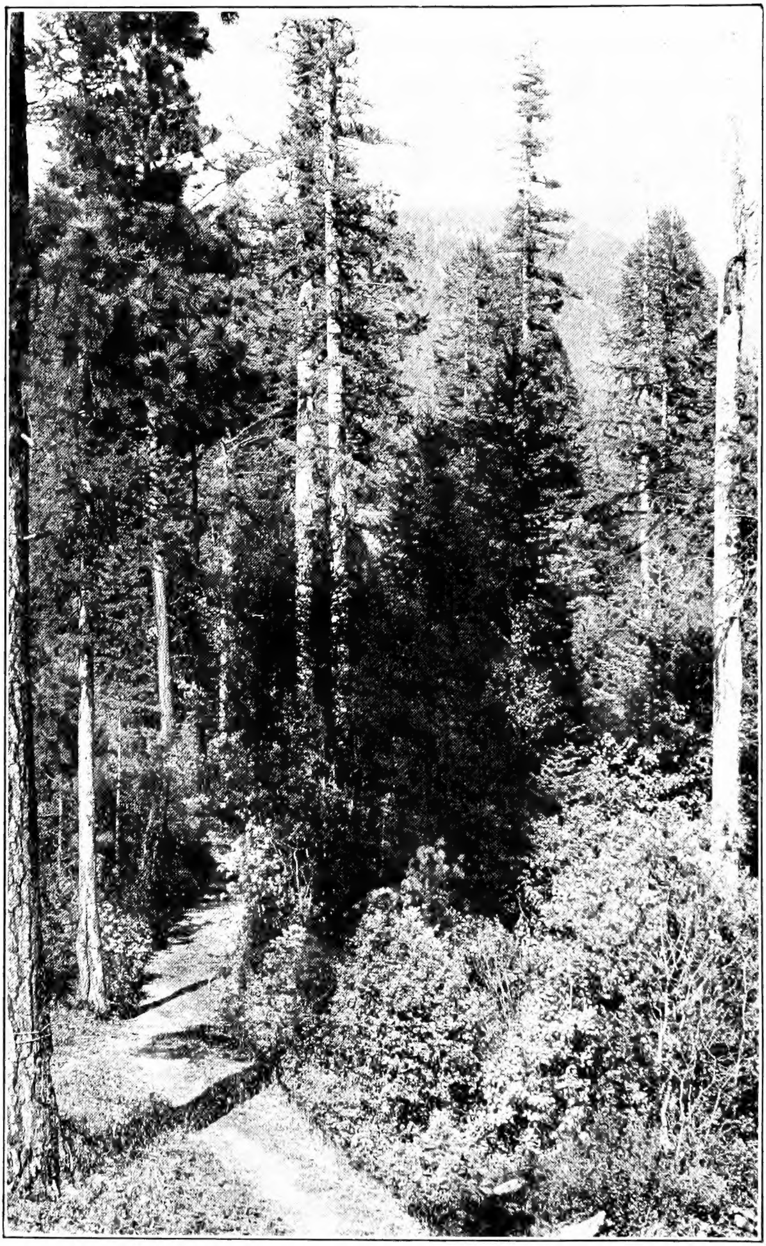

Fig. 31. Larch (*Larix occidentalis*) and pine (*P. ponderosa*) forest along east shore of Flathead Lake. Undergrowth *Holodiscus ariaefolius, Ceanothus sanguineus, Lepargyraea Canadensis, etc.* June.

UNIVERSITY OF MONTANA STUDIES

Forest Distribution
in the
Northern Rocky Mountains

By

J. E. KIRKWOOD

Professor of Botany in the State University of Montana

STATE UNIVERSITY
MISSOULA, MONTANA

JUNE, 1922

Bulletin No. 247—State University Studies Series No. 2

Published bi-monthly at Missoula, Montana. Entered as second-class matter at the postoffice at Missoula, Montana, under act of Congress, August 24, 1912.

THE UNIVERSITY OF MONTANA

EDWARD C. ELLIOTT, Chancellor of the University

The University of Montana is constituted under the provisions of Chapter 92 of the Laws of the Thirteenth Legislative Assembly, approved March 14, 1913 (effective July 1, 1913).

The general control and supervision of the University are vested in the State Board of Education. The Chancellor of the University is the chief executive officer. For each of the component institutions there is a local executive board.

Montana State Board of Education

J. M. DIXON, Governor........................Ex-officio, President

W. D. RANKIN, Attorney General........................Ex-officio

MAY TRUMPER, Supt. of Public Instruction........................Ex-officio, Secretary

A. J. VIOLETTE........(1922)	WHITFIELD SPAIN........(1924)
SYDNEY SANNER........(1922)	J. W. FREEMAN........(1924)
C. H. FOOT........(1923)	JOHN DIETRICH........(1925)
R. C. LINE........(1923)	FRANK ELIEL........(1925)

The University comprises the following institutions, schools and departments:

The State University, Missoula

Established February 17, 1893, and consisting of

The College of Arts and Sciences
The School of Law
The School of Pharmacy
The School of Forestry
The School of Journalism
The School of Music
The School of Business Administration
The Summer Quarter
The Biological Station (Flathead Lake)
The Public Service Division
The Graduate Division

Charles H. Clapp President

The State College of Agriculture and Mechanic Arts, Bozeman

Established February 16, 1893, and consisting of

The College of Agriculture
The College of Engineering
The College of Applied Science
The College of Household and Industrial Arts
Courses for Vocational Teachers
The School of Music
The Summer Quarter
The Secondary School of Agriculture
The Agricultural Experiment Station
The Agricultural Extension Service

Alfred Atkinson, President

The State School of Mines, Butte

Established February 17, 1893

Course in Mining Engineering
Course in Metallurgical Engineering
Bureau of Mines and Metallurgy

George W. Craven, President

The State Normal College, Dillon

Established February 23, 1893, and consisting of

The Teachers' Certificate Course
The Three-years Course
The Course for Supervisors
The Two-years Course
The Rural Teachers' Course
The Teachers' Service Division

Sheldon E. Davis, President

For publications and detailed information concerning the different schools and colleges address the president of the particular institution concerned. Communications intended for the Chancellor of the University should be addresssed to the State Capitol, Helena, Montana.

PREFACE

It is the purpose of the following pages to present a general account of the forests of a region comprising about 175,000 square miles lying across the Rocky Mountains south of the 49th parallel and marked by great diversity of topography, soil and climate. The many factors involved in the development and maintenance of the present physiognomy of the vegetation merit careful study, both as to the sources whence its component parts have been derived and as to the agencies and conditions at present effective in their local movements and inter-relations. It is designed to open the way to a critical study of this area and to emphasize the point of view from which this and all other such studies should be approached.

The usual approach to the study of problems in ecology, both in matters of association and succession and of local and general distribution has up to the present time been mainly from the side of the physical factors involved, and hardly, if at all, from the standpoint of individualities of the species concerned. It is the intention herein to lay particular emphasis upon the latter and, while taking account of the climatic and topographic influences, to stress those characteristics of the most important species as far as known, as furnishing the clue to the solution of problems of competition and dispersal. It is but a truism to say that the fuller the knowledge of the specific peculiarities of a plant the more may its place in the flora be understood.

Acknowledgment of valuable suggestions and criticisms of the manuscript by Prof. John W. Harshberger of the University of Pennsylvania and Dr. Forrest Shreve of the Desert Laboratory of the Carnegie Institution of Washington is due and is hereby gladly rendered.

J. E. Kirkwood.

Missoula, Mont., May 1, 1922.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (*Continued*)

INTRODUCTION

THE following discussion of the distribution of forests is concerned with that part of the Rocky Mountain region and neighboring plains which is included within the State of Montana and adjacent parts of Idaho. These boundaries furnish a convenient definition of an area which presents certain aspects of forest vegetation and which by reason of its extent and location exhibits features of special interest. Here on both slopes of the main divide appears a wide overlapping of the Atlantic and Pacific floras and, while the hemlocks, larches and some other forest species of the north reach their farthest southward extension in the Rocky Mountains, they too overlap, though at different elevations, the most northward reaching elements of the southern vegetation as represented by cactus, yucca and other forms. Moreover, factors influencing the local distribution of species more widely prevalent are modified at least in their intensity by latitude, altitude and other causes.

The complex interaction of climatic, edaphic, biotic and other influences which guide and control the distribution of species is of keen interest to the student of phytogeography, and no treatment of the subject is fair which does not seek to give full weight to the many factors involved, and especially to the nature and requirements of the individual species. Similarly the ecology of local areas must be studied closely from the standpoint of the adaptability and demands of the species of those areas, if lasting results of importance are to be obtained. All questions concerning the dominance of some species and the suppression of others are questions of the interaction of the constituent species and their environment.

Among such questions are the specific light, moisture and temperature requirements at different stages of development and under particular conditions, the rate of growth and the form during youth and maturity, the form and extent of the root system, its strength, functional activity and relation to the soils of particular composition and structure, the reproductive capacity of the species, including not only the amount of seed and the frequency of seed years, but the comparative ages at which seeds are produced, their viability, their mode of dissemination and germination and the time involved, the requisite conditions of successful pollination, etc. In addition to these factors must be considered the matters of specific protoplasmic functions, such as resistance, or susceptibility, to the attacks of destructive insects, or fungi, the range of adaptability in relation to climate and soil. Only by an appreciation of the value of these and other factors can the relative importance of a species in any given area be fully understood. Furthermore, it would seem that no estimate of the influence of these causes is adequate which does not take some account of the time during which the various influential factors have been operative.

The immensity of the task involved in the thorough study of the vegetation of an area becomes the more apparent when we reflect that native vegetation is dynamic, not static, and that the changing quality of the soil through long periods of time is attended by conspicuous changes in the plant covering. Our knowledge of the ecology of a region or locality must in the end be a product of our knowledge of the separate units (species) of that area. It seems, therefore, important that the study of plant geography, or ecology, be approached primarily from the standpoint of the species and merely incidentally from that of the physical conditions.

It is the aim of this paper to present an introduction to the subject of forest distribution in a portion of the northern Rocky Mountains, with a few tentative conclusions, and to point the way to a more thorough study, the results of which should be of importance, both in their scientific and their economic aspects.

Up to the present time, the flora of Montana has been studied chiefly from the standpoint of the systematist. More than a century of botanical exploration, from the time of Lewis and Clark to the present day, has made known to us the principal components of its flora. The first collection within the region was that of Meriwether Lewis in 1806, who traversed the northern part of the State from Lolo Pass in the Bitter Root Range through the Hellgate and Blackfoot country via Sun

River to the Missouri near the Great Falls and thence down the river.

Meehan (42), speaking of Lewis collection, says, "From the few (plants) they did collect, Pursh (47) in his '*Flora Americae Septentrionalis,*' published in London in 1814, refers to 119, many of which he described as wholly new." He quotes from Pursh as follows:

"The collection was made during the rapid return from the Pacific. A much more extensive one made on their slow ascent toward the Rocky Mountains and the chains of the northern Andes, had unfortunately been lost, by being deposited among other things at the foot of these mountains. The loss of this fine collection is the more to be regretted when I consider that the small collection communicated to me, consisting of about 150 specimens, contained about a dozen plants well known to be natives of Northern America."

The plants were probably taken to England by Pursh and finally deposited in the herbarium of A. B. Lambert. Afterward they found their way into the possession of the Academy of Natural Sciences of Philadelphia and the American Philosophical Society. The plants collected on the outgoing trip between St. Louis and Fort Mandan were sent back and received by the Society November 15, 1905.

Among the woody plants of the region collected by Lewis are the following:

Pachystima Myrsinites Raf.
Ceanothus velutinus Dougl.
Rhamnus Purshiana D. C.
Amelanchier alnifolia Nutt.
Crataegus Douglasii Lindl.
Sorbus sambucifolia (C & N) Roem.
Prunus demissa Nutt.
Spiraea discolor Pursh
Philadelphus Lewisii Pursh
Ribes aureum Pursh
Ribes viscossisimum Pursh
Lonicera involucrata Banks
Artemisia cana Pursh
Elaeagnus argentea Pursh

Shepherdia argentea Nutt.
Populus trichocarpa Torr & Gray
Pinus ponderosa Dougl.
Juniperus communis L.
Juniperus horizontalis Moench.

From the time this collection was made it was nearly 30 years before another observation was made upon the flora of the State of Montana, unless we except the visit of David Douglas who at least approached the western boundary in 1826. In 1833, however, Alexander Phillip Maximilian (41), Prince of Neuweid, made notes on the vegetation from Fort Union, near the mouth of the Yellowstone, up the Missouri River to the mouth of the Marias. In the ravines at Fort Union, he observed thickets of oak, elm, box elder, and bird cherry (probably *Prunus Virginiana* L). On the banks of the Missouri were poplars, willows, ash, elm, box elder, etc., with a thick undergrowth of hazel, roses and blackberry. The occurrence of oak, elm, and ash is to be expected along the Missouri bottoms but the present boundary of Montana is about the western limit of their range. It is doubtful if they have since been reported in Montana.

Wyeth's journeys to Oregon begun, in 1832 and occupying about three years, (45), followed a route via Green River and the Snake south of the region here considered, but approaching the western border in Eastern Idaho. On the second of these trips (1834), he was accompanied by Thomas Nuttall. There appears to be no record of his collections on this trip. Wyeth, however, on his return from the first expedition, is said to have ascended the Clark's Fork of the Columbia, thence southward via the Bitter Root and the Big Hole to the Salmon River in Idaho, and from there across to the Big Horn and the Yellowstone. His collections were described by Nuttall and are deposited in the Academy of Sciences in Philadelphia and the New York Botanical Garden.

Charles A. Geyer (19) in 1844 traveled over part of the same route from Clark's Fork to the Yellowstone and the plants which he collected were taken to Europe, determined by Hooker and distributed. At an earlier date, we have a record of his survey of the vegetation of the Missouri River region in the Dakotas in which he lists a number of plants common to Montana.

David Lyall (36), Surgeon and Naturalist of the North American Boundary Commission, visited Northwestern Montana in 1861. His collections were distributed to nineteen important herbaria. In discussing the region visited, he treats of the Rocky Mountains (presumably the main range) and the Galton Range between the Tobacco Plains of the Kootenai and the Flathead Valley. He enumerates those collected between 4,000 and 8,300 feet elevation and mentions the following as occurring in this region:

Pinus monticola Dougl.
" *contorta* Loud.
" *flexilis* James.
" *ponderosa* Laws.
Larix occidentalis Nutt.
" *Lyallii* Parl.
Pseudotsuga taxifolia (Poir) Britt.
Abies amabilis (Loud) Forbes.
" *grandis* Lindl.
Thuja plicata Don.
Juniperus scopulorum Sarg.

John M. Coulter (14), with the Hayden Survey in 1872-3, collected along the Upper Yellowstone and later contributed the first manual of the plants of the Rocky Mountains. Again in 1880, the Big Hole Basin and the Bitter Root were visited, this time by Sereno Watson (4), who also made collections in the Valleys of the Hellgate and the Beaverhead. Rydberg (4) from 1895 to 1897 covered much of the same ground extending the exploration northward as far as Deer Lodge, Helena and the Judith Basin. From 1884 to 1904, Leiberg in the service of the Northern Pacific Railway and later with the United States Geological Survey made some collections within the State and reported on the forests of the Little Belt (32), the Absaroka (31), and the Bitter Root Mountains. Blankinship (4), while Professor of Botany at the State College of Agriculture at Bozeman, made large collections in various parts of the State from 1898 to 1904. These plants have been widely distributed and are largely represented in the herbaria of the State institutions at Bozeman and Missoula.

The largest contributions from the northern part of the State have been made by R. S. Williams and Marcus W. Jones. Williams from 1880 to 1899 made extensive collections, confined, however, mostly to the country about Great Falls and Columbia Falls and the Highwood and Little Belt Mountains. Jones in the subsequent period to 1910 collected largely in various portions of the Flathead Valley from the Lake of that name to the Glacier National Park and the higher altitudes of the Mission, Swan and other northern ranges.

The earliest botanical explorations followed naturally the lines of overland travel. The main highway through the northern region then lay via the Yellowstone River, the Big Hole Basin and the upper forks of the Missouri. The Continental Divide was crossed at Gibbon's Pass leading into the Upper Bitter Root Valley. From that point, the trail followed the Bitter Root River northward to its junction with the Lolo, thence into Idaho via Lolo Pass to the Snake River, or continuing to the mouth of the Bitter Root, and down the Clark's Fork, or the Clark's Fork was left at a point near the present site of St. Regis and a crossing effected into the Coeur d'Alenes. This route was subsequently adopted by the Government for a military road (The Mullan Trail) from Fort Benton, the head of navigation on the Missouri, to Walla Walla.

The various routes were old Indian trails. Lewis and Clark, on their outward journey, followed one of the main highways through the Big Hole, the Bitter Root and Lolo Pass, and on the return by the same route as far as the Big Hole, except that Lewis with a body of men parted company with Clark at the Lolo and followed another highway via the Blackfoot Valley, as above noted. The more southern route was followed by later travelers, and collectors, at least in part namely, Wyeth, Geyer, Watson, Coulter and others. Later with the coming of railroads a more general observation of the flora was made possible.

Many travelers, other than those noted above, might be mentioned, who have contributed notes and collections on the flora of the State from one point or another. Altogether, however, but few parts have been well worked over, many have been superficially studied and some not touched at all. There seems to be no available record of any botanical observations having been made in the Blackfoot Valley from the days of Lewis and Clark to the present time, and probably the upper valleys of the South and Middle Forks of the Flathead have never been visited by a botanist. The latter represents an area some 200 square miles in extent and part of it is isolated, wild and inaccessible. The Yellowstone Valley and the upper branches of the Missouri, especially the Gallatin Valley, the upper valley of the Clark's Fork reaching to Deer Lodge with its principal tributaries the Bitter Root and the Flathead and the regions surveyed by Williams and Jones above mentioned constitute the areas which have received most attention, yet even these, embracing as they do hundreds of square miles, are yet imperfectly known. The higher mountain ranges, especially the heights of the Bitter Root Mountains which form a natural barrier to the eastward migration of Pacific species, still furnish important fields for investigation.

Systematic collections and description represent the most of the work on the Montana flora and almost nothing has been done on the phytogeographical and ecological aspects of the vegetation of the region. A series of brief contributions by Rydberg (53-55), Whitford's (73) study of the Forests of the Flathead Valley, and the work by Leiberg (29-32) above referred to represent about all of the literature on this phase of the plant life of the Northern Rockies. Nothing has yet appeared which attempts to relate the vegetation of the area within the present boundary of Montana to the topographic and climatic influences which have had so large a part in determining its quantity and quality.

The area considered within the scope of this paper comprises a wide belt across the northern Rocky Mountains mostly in Montana. That portion of Idaho, adjoining on the west will also be considered as floristically belonging to this region and as possessing certain points of special interest in this connection. The whole area covered by this paper covers about 175,000 square miles. It is unequally divided between prairie and forest, the latter covering about 75,000 square miles. The prairies differ in their composition and topography and while representing the typical condition in the eastern part of the State, they are broken here and there by forest islands of greater or less extent,

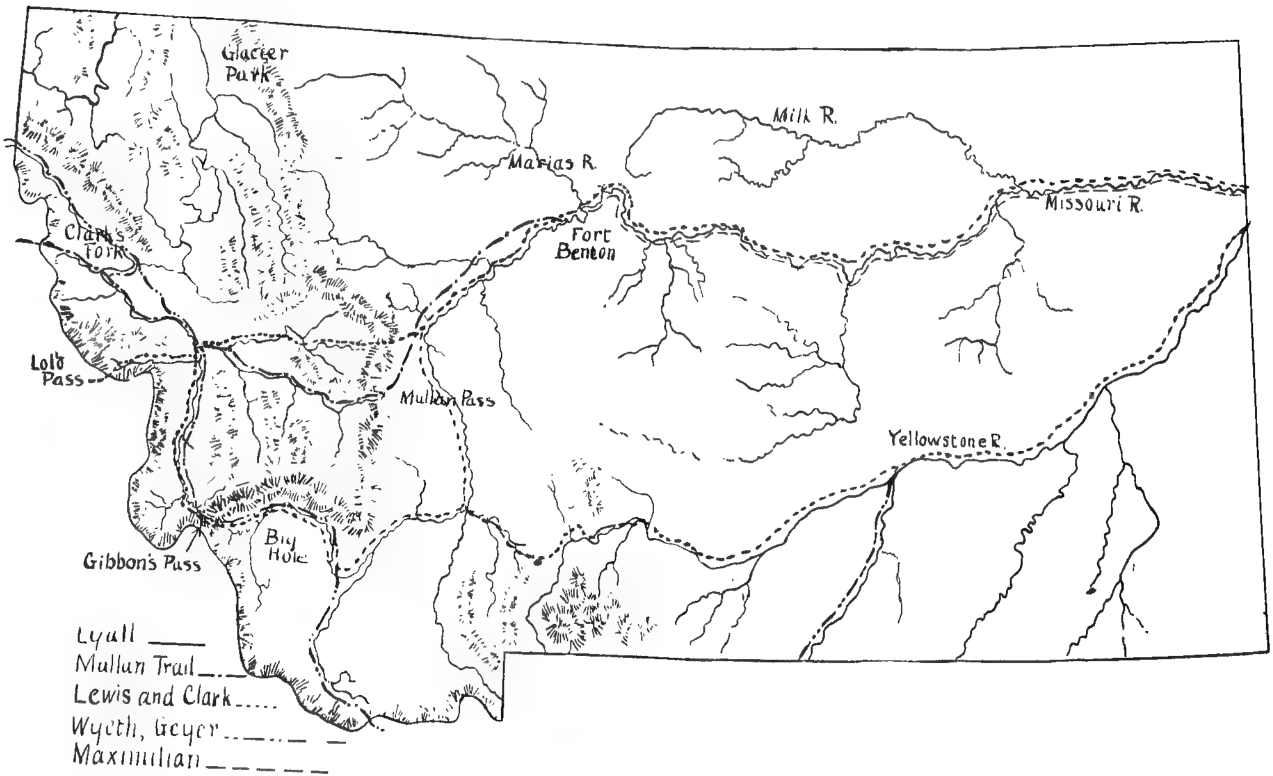

Fig. 1. Routes of early exploration in Montana.

and westward the prairie and forest alternate with frequency depending in the main upon topographic variation. This diversification of the vegetation in response to topographic influence in its relation to climate is one of the most interesting aspects of the plant life of the region, and one of the most characteristic. This influence may, indeed, be said to be the dominant one determining the physiognomy of the plant covering over all the western part of the State.

The flora of the northern Rocky Mountains has been cited as mainly a composite one and such is evidently the case. As the first element may be considered those which are apparently indigenous descendants or derivatives of a former more extensive and probably more uniform vegetation of the Later Tertiary, and those which in subsequent times have evolved from the species from various sources in the migrations subsequent to the close of the glacial period. Most of this region was glaciated and with the recession of the ice was reoccupied from various centers of distribution. We must believe that the forces which then operated in the dispersal of plant life over this area are, at least many of them, still operative and that the invasions from the east, southeast and west, which account for so large a part of the Montana flora, are still in force. However slow the movements of a species may be, in competition with others, in regions already well occupied, there is no reason to believe that its present limits of distribution are fixed.

The vegetation of Montana shows a distinct overlapping of the eastern and western floras. The flora of the Pacific Northwest is well represented on the western slopes of the Rockies in Montana. The number of species, of course, diminishes eastward, yet some of evident Pacific origin have extended their range to the Black Hills and the Great Lakes. Similarly species of the Great Plains appear in the prairies west of the Continental Divide.

In considering, therefore, the distribution and composition of these forests, special emphasis must be laid on the one hand on the specific individuality of the component species and on the other on the combined influence of topography and climate. As a basis for further discussion, the latter factors will be considered first.

CHAPTER I.

TOPOGRAPHY.

THE region here under consideration lies mostly between the 45th and 49th parallels of north latitude. Its width from north to south is 276 miles, and, measured west from the 104th meridian it extends 624 miles across the main and secondary ranges of the Rocky Mountains. The total area is close to 175,000 square miles. This embraces nearly all of the State of Montana and includes a portion of eastern and northern Idaho.

The mountain ranges of Montana have mostly a southeast to northwest direction. They are thus essentially parallel with valleys of greater or less width between. Most of these inter-mountain valleys have in width from two to twenty miles of river bottom and bench land, mostly the latter, which ascends gradually or abruptly into foothills, behind which rise rugged mountains, dissected by numerous strong tributaries of the main streams. The valleys proper are but narrow strips as a rule in the broad drainage basins of which they form a part.

The mountains and valleys have been formed by successive faulting and tilting on a grand scale. The eastern slope of a range usually represents its fault face (7), the western slope inclines more gradually to the foot of the next abrupt ascent. Only two great mountain chains, however, figure conspicuously as barriers in the spread of the flora of the state, the others are of subordinate or negligible importance. One of these is the Bitter Root Mountains and those shorter ranges to the north-west in the same general alignment, the other is the Continental Divide.

The eastern border of Montana on the Missouri lies 1898 feet above sea level. From this point the land gradually rises to the summit 400 miles to the west and drops down again to about 1800 feet where the Kootenai River crosses the western boundary of Montana, the lowest point in the State. The altitude of half the State or more is above 3000 feet. The highest point is

Granite Mountain near Cooke, just northeast of Yellowstone Park, 12,847 feet (38).

The Continental Divide enters Montana on the north at about the 114th meridian nearly 100 miles east of the western boundary of the State. Its direction from that point is southeastward for over 200 miles to a point near the city of Butte, where it swings westward about 75 miles thence 100 miles southeast to the Yellowstone National Park. In the north it is identified with the Livingston Range which, with a rugged crest 7000-9000 feet elevation, traverses the Glacier National Park. Here it is magnificent, precipitous and glacier-ridden, where the "Garden Wall" thrusts a serrated sky-line between the eastern and western drainage. The altitude of the Divide, however, has a wide range of variation. At Summit, where the Great Northern Railway crosses, it has an altitude of 5214 feet. South of this point it rises again to 8000 and 9000 feet with passes below 6000 until it curves westward near Butte. From here to its junction with the Bitter Roots it is relatively low (5500-7000) and is either forested or denuded by fires. From this point to the Yellowstone Park, the Divide, though somewhat higher, is rounded, broad and may be traveled with comparative ease. Along the southern boundary of the State it separates the waters of the Snake River from the ultimate sources of the Missouri. The total length of the Divide, from the northern boundary of Montana to the Yellowstone Park, is upward of 500 miles.

The Bitter Root Range is variously defined. On some maps it is shown as extending from Clark's Fork of the Columbia to Yellowstone Park. Lindgren (34) limits it to 60 miles, north and south trend, from Lolo Pass to the Little West Fork of the Bitter Root River. At this point the geological formations change and southward the structure of the range identifies it with the Rocky Mountains. This portion, generally included in the Bitter Roots, is a northward projecting spur of the Main Divide. With the Bitter Roots proper it forms a natural boundary wall between Montana and Idaho, and divides the tributaries of the Clark's Fork, the Snake, and the Missouri.

The Bitter Root Mountains rise abruptly from the western side of the valley of the same name. The crest of the range lies at an average of about fifteen miles from the Bitter Root

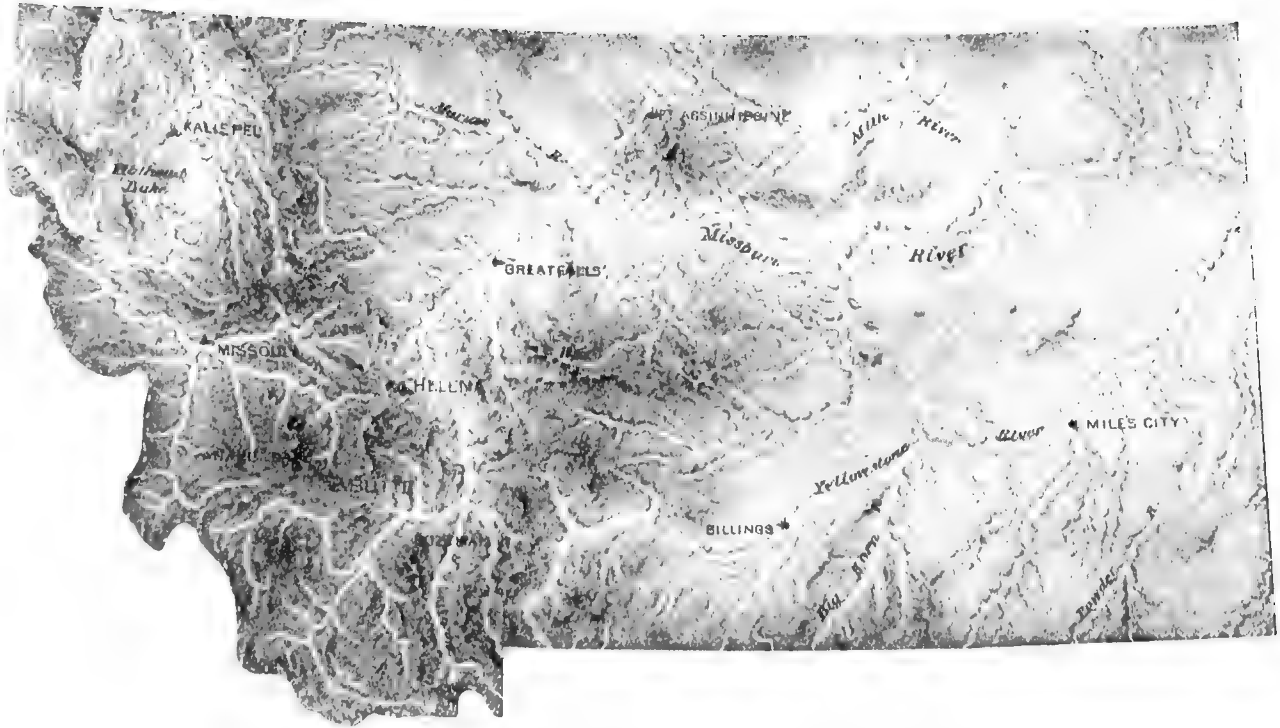

Fig. 2. Physiographic map of Montana. By permission of Rand, McNally & Co.

River, and, especially in their southern part, the mountains present high and rugged ridges and sharp summits, culminating in Trapper Peak, 10,175 feet. From the ridge the slopes descend more gradually to the Clearwater Mountains, which cover an area some 70 miles east and west and 100 north and south. The average elevation of the Clearwaters is about 7000 though occasional summits rise to 8000 feet. The western border falls abruptly to the Columbia Lava Plateau 3000 to 3500 feet. The whole Clearwater series are but the remains of a dissected plateau, now characterized by sharp ridges, jagged granite peaks, innumerable and intricate canyons and chasms, wild and inaccessible. The Clearwater Mountains, however, are important from the standpoint of the flora, and, as we shall later see, contribute an influence to the vegetation beyond their immediate environs.

The Lolo Fork of the Bitter Root River marks the route of the earliest travelers. It also marks the dividing line between the Bitter Root Range and the Coeur d'Alenes. For about 75 miles north and northwest of this pass the character of the topography assumes a different aspect. No longer a single high barrier, but a broad, relatively low series of summits and ridges about 6000 feet in elevation, and, like the Clearwater, dissected by numerous channels. To the east lie the open valleys of the upper affluents of the Clark's Fork, to the north the lower portion of the same river, and to the west the lake country of the Coeur d'Alenes and the Pend d'Oreille. The Coeur d'Alene Range is not marked by the rugged features of the Bitter Root and the Clearwater, but present rounded elevations and a more hospitable aspect. The less forbidding nature of this range as well as its lower altitude are facts which should be noted in passing as having a bearing on the floristic features to be discussed later.

North of the Clark's Fork the slopes rise abruptly to the summits of the Cabinet Range, which extends to the valley of the Kootenai. The trend of this range is from southeast to northwest, and from the junction of the Flathead and the Clark's Fork to Bonners Ferry is about 100 miles. The Cabinets are higher than the Coeur d'Alenes, some peaks rising to 8000 feet and with a topography diversified, rugged and picturesque (7).

The northeastern portion of the range is more like the Coeur d'Alenes, having somewhat the nature of a dissected plateau, but the northern portion assumes the character of a more clearly defined chain.

The Kootenai River enters Montana from the north, curves to the west, then again to the northwest, and after a course of about 80 miles passes over into northern Idaho. In the great bend of this river lies the Purcell Range. These mountains are of moderate height, pushing up to summits of 7500 feet, spread rather widely across the area included in the bend of the river and serve to continue the general barrier along the western boundary of Montana. This is further augmented by the Galton Range which extends from the international boundary at the crossing of the Kootenai to the head of Flathead Lake.

It will thus be noted that an almost continuous mountain barrier extends from Yellowstone Park along or near the western boundary of Montana, through most of its length essentially parallel with the Continental Divide and about 100 miles distant from it. The character and position of this barrier is a matter of importance, as affecting the part between it and the Divide, what is known as Western Montana, an area of about 22,000 square miles. Within this area are included some lesser ranges of which two might be mentioned as adding certain topographic features to the country west of the Divide. These two ranges lie parallel and well within 50 miles of the main ridge. The first, or more western, of the two is the Mission Range (15) which extends for about 70 miles north and south and forms the eastern wall of the lower Flathead Valley. The western face is a fault scarp, the eastern slope is less abrupt. The crest of the range is elevated to 9500 feet at the southern end, and inclines gradually to the north where it sinks beneath a plain of glacial gravels and silts. The southern peaks are rugged and precipitous, deeply cut by numerous cirques and troughs of local glaciers, but northward the lower summits are rounded and heavily forested, the forest extending down to the very shores of Flathead Lake. About midway of the range a bold terminal moraine swings westward from the mountain base, shutting off the waters of the lake on the north from the rolling prairies of earlier glaciation on the south. Through this moraine the Flathead River at the outlet of the lake has cut its way toward its junction with the Clark's Fork some sixty miles to the southwest.

The second of these chains lies between the Mission Mountains and the Divide, and between the Swan River and the South Fork of the Flathead. It is called the Swan Range, is somewhat longer than the Mission, merging at its southern end with the plexus of ridges that form the three-way divide between the waters of the Jocko, the Swan and the Blackfoot Rivers. It is scarcely as high as the Mission Range in the southern portion, but to the north sustains its elevation almost to the main channels of the Flathead River. Its peaks rise to 7000 feet more or less and its sides are less precipitous than those of the Mission on the west and of the main range on the east. It is practically forested to the summit, but with here and there high, barren and exposed ridges.

Having considered the mountain chains which lie west of the Divide, there remain to be considered two or three areas on the eastern side which have a part in the problem. The first of these lies mainly in the southwestern corner of the State, in the forks of the Missouri and among the higher tributaries of the Yellowstone. This group includes the Beartooth, the Absaroka and Gallatin mountains and some lesser ranges. The second group includes the Big Belt the Little Belt, the Crazy and the Snowy ranges and covers an area roughly 10,000 square miles in extent in the central part of the State, in the great bend of the Missouri, north of the Yellowstone and about the sources of the Musselshell. The third comprises the Bear Paw Mountains, the Sweet Grass Hills and lesser elevations in the northern part about the sources of the Milk River. The special features of these will be taken in order.

The first group, embodying several ranges presents features which seem to link it with the main backbone of the Rockies of which it was apparently at one time a part. It includes lofty and rugged peaks and deep, narrow gorges. The highest point in Montana, Granite Peak, stands north of Yellowstone Park and rises to an altitude of 12,847 feet. A high, plateau-like area extends eastward, the Beartooth Plateau, furrowed, pitted and covered by low buttes and rounded elevations. The plateau varies from 10,000 to 12,000 feet in altitude, and slopes grad-

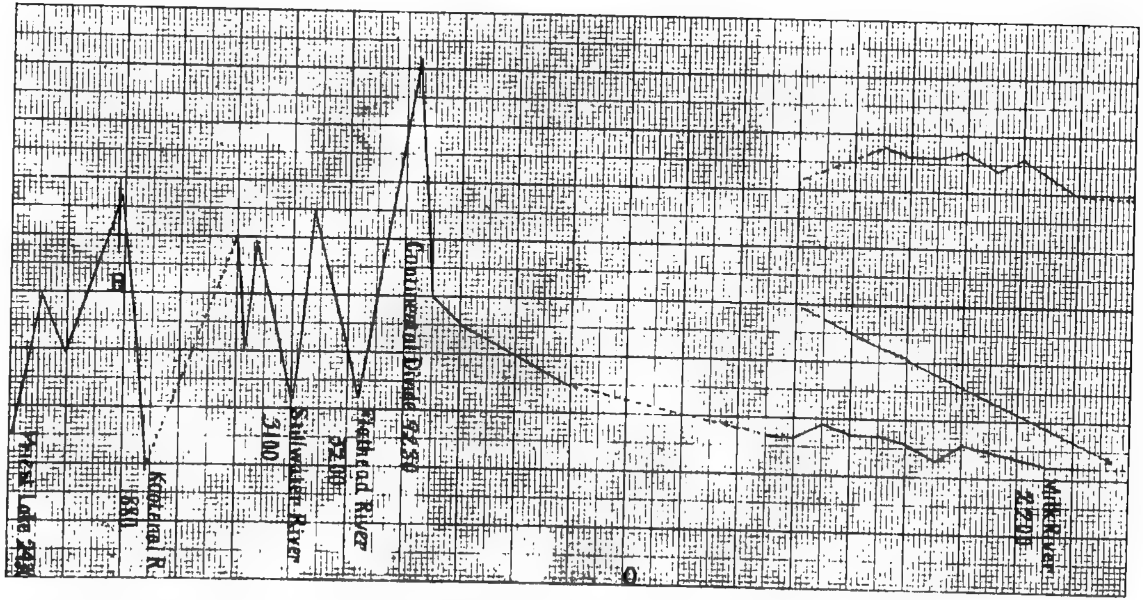

Fig. 3. Section of Idaho-Montana topography on the parallel 48° 30'. B, boundary line. Scale: horizontal, ½ inch: 25 miles, vertical; ½ inch: 1000 feet. O, mean sea level. After topographic maps of the U. S. Geol. Surv. Dotted lines represent gaps filled in from other data.

ually toward the valley of the Clark's Fork of the Yellowstone. The canyons in this section are often mere narrow rifts between nearly perpendicular rock walls, which sometimes rise to nearly 3000 feet above the floor of the canyon, which here and there is strewn with boulders and glacial debris.

Toward the west the country decreases in elevation. The lowest canyons are 4000 feet above sea level and from that all elevations occur up to 10,000 the usual elevations of the East and West Boulder Plateaus. Here again glacial action has left its traces, but not of such a character as to indicate that they have been reduced much in height since the ice age began. Through all this region of high peaks there is not a snow cap, so completely is the not too ample snow dissipated by the summer's wind and sun. Some perennial snow fields lie in the lee of high ridges and peaks where the winds have piled the snow too deep for it to disappear entirely during the short summer.

In this group the Bridger and some lesser ranges form lower plateaus or rounded ridges, forested to the summits, and in outlines far less severe than those of their more lofty neighbors.

In the second area are several groups of mountains which constitute forest islands in the central part of the State. The most western of these, the Big Belt Range, is the only group which is extended in the form of a chain. They lie parallel with the main divide at a distance of 40 to 60 miles for nearly 100 miles in a direction from southeast to northwest. Through the intervening valley flows the Missouri River in places through narrow gorges which Lewis and Clark called the Gate of the Mountains. East of the Big Belts are the Little Belts with spurs radiating from a central elevation and supplying the sources of Smith and Judith Rivers and other minor affluents of the Missouri. South of the Little Belts at a distance of 50 miles more or less are the Crazy Mountains and east at about the same distance lies the Snowy Range. These several ranges are separated by valleys of greater or less agricultural possibilities, and with broad rolling grassy uplands, which gradually merge into sparsely timbered foothills. The higher elevations, in conformity with meteorological conditions, support ample

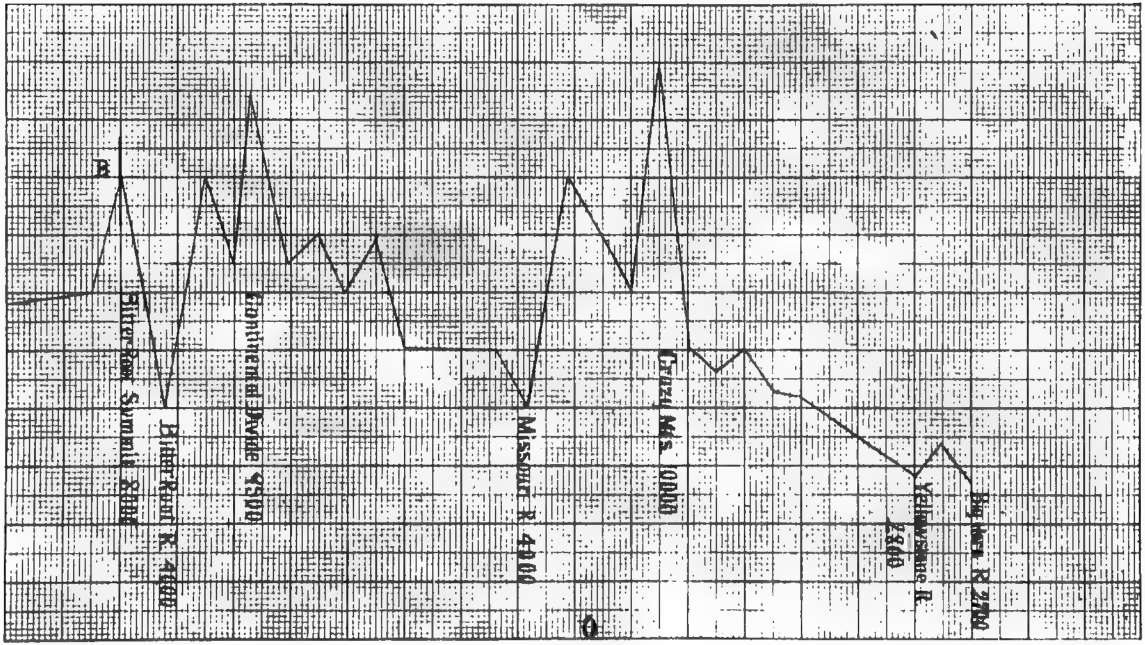

Fig. 1. Section of Idaho-Montana topography along the 46th parallel. B, boundary line. Scale: horizontal, ½ inch: 25 miles; vertical, ½ inch: 1000 feet. O, mean sea level. After topographic maps of the U. S. Geol. Surv.

forests. The ranges here enumerated thus constitute forest islands in the plains country.

Some peaks of this region rise to 9000 feet or more above sea level. In the Little Belts, the central group of the area, the average elevation is above 7000 feet. They are mainly limestone uplifts, seamed by numerous dikes of eruptive rock with extensive areas of metamorphics. The ridge crests are in some places narrow, in others flattened out into plateaus, as at the head of the Lost Fork of the Judith and even marshy in others, as where the divide descends into what was originally part of the South Fork of the Judith Basin. Some of the secondary ranges are largely of igneous rock. Ridges radiate on the eastern slopes of the main axis into long spurs of narrow and winding form which separate the streams flowing to the Judith River. They are seldom high but are usually of low and rounded contour. On the west the spurs are short and steep and on the north they form a labyrinth of tortuous canyons. Many of the canyons throughout the area are narrow and flanked by steep slopes or by limestone cliffs buttressed by talus accumulations. Above they widen out into amphitheater-like basins. To the north of this range a short distance stands a small detached group, the Little Rockies which have an altitude of 6500 feet or less, and support a forest growth.

To the east of the Belts the neighboring elevations of the Snowy Range are separated from the former by Judith Gap, a rolling and fertile prairie country. These summits have elevations of 4000 to 8000 feet and are themselves divided into two groups, the Big and the Little Snowys. The latter is the more easterly and represents the most distant outpost of the Rocky Mountains with forest vegetation between the Missouri and the Yellowstone.

The most southern members of this second general group are the Crazy Mountains. They cover an area of some 360 square miles and reach an altitude of 10,000 feet. Geologically and topographically they resemble the Absarokas of the southern group, from which they are separated by the broad valley and rolling grassy benches of the Yellowstone. They rise abruptly from the plains and their rugged sides and sharp ridges ascend to clear cut peaks often cloud-crested and mantled with snow.

The third group remains to be considered. From the Snowy Range across the Missouri to the north, about 100 miles from summit to summit, lie the Bearpaw Mountains. These are of comparatively low altitude yet of sufficient elevation to support forest growth. They practically constitute a culmination of the divide between the Milk River and the Missouri. They reach an altitude of 6000 feet and with the Sweet Grass Hills and a few other low elevations represent almost the only forested slopes within 100 miles of the main front of the Rockies in a strip 100 miles wide below the Canadian Boundary.

Geologically, of course, the State presents a great variety of formations. The eastern half is mainly Upper Cretaceous (with an extensive coal bearing portion) and Early Tertiary. Later Tertiary formations appear in several isolated tracts in the western part, occupying portions of the Flathead, Bitter Root, Blackfoot, Big Hole, and other valleys, alternating in the southwest and center with larger areas of the Paleozoic. The northwestern portion from the Continental Divide to the boundary and from the British possessions to the head of the Bitter Root Valley is mainly Proterozoic (Algonkian). The Bitter Root Range and the high mountains of the main divide about Butte and southeastward through the Absarokas are chiefly granitic, but the northern ranges are sedimentary. Volcanic rocks and lavas form a very small portion of the State.

The soils derived from these sources are necessarily varied, both locally and regionally. Over much of the eastern part of the State the soil is of that comminuted variety known as loess (18), in many places overlying glacial drift and now supporting a typical prairie vegetation, mostly grasses. It is a fertile soil and when broken up and sown to grains yields heavy crops. Extensive glaciation characterizes the greater portion of the State and morainic deposits are common (9). Many of these are thinly covered with soil and, while fertile enough when provided with water, are usually dry and very difficult situations for plant life. Deltas at the mouths of canyons, river bottoms of silt, sand or heavy clay, and in varying areas and depths, form, west of the divide, a limited part of the vegetation-bearing land, composed of transported materials. The slopes which, in the western portion of the State support nearly all the coniferous forests, are usually formed of fragmented rock, mingled with the products of its decomposition and small additions of humus. The different phases of vegetation on soils of this character are usually expressions of reactions to moisture content in relation to exposure.

While the uplands of eastern Montana are largely of fine soil or gravels the bottom lands are often of fine heavy soil commonly known as "gumbo" formed by sedimentation from decomposed shales (40). These in the aggregate involve a considerable area. They are usually more or less heavily impregnated with soluble salts and are the so-called alkali lands (52). The salts most commonly present are sodium-chloride (very slight) sodium sulphate, magnesium chloride, and calcium sulphate. Sodium carbonate is practically absent. Much of this sort of soil is found in the lower Yellowstone Valley, where strong erosive action is still going on, especially in the "Bad Lands," where the bluffs are dissected into a rugged wilderness of hills and gullies.

Wind action also is still evident. Fantastic forms of sandstone stand isolated here and there, caverns are carved in the faces of cliffs, boulders are gradually reduced and obliterated. Along the crumbling cliffs and on the margins of broken terraces is a fringe of forest growth, scant, scattering and depauperate. The benches above and below support only herbaceous or shrubby vegetation. The stream bottoms invariably support cottonwoods and other hard-wood species.

The eastern slope of the Continental Divide in Montana is drained by the Missouri River, the western slope by the Clark Fork of the Columbia. Along the peaks of the main and outlying ranges are the innumerable sources of these streams; some take their rise in high sub-alpine bogs and meadows, others flow from cirque basins where quiet lakes lie under forested slopes. Of these there are many of varying size and depth. Again there are countless small streams that flow from melting snows all summer, flowing freely by day and ceasing by night. The slopes of all the ranges are thus watered abundantly; every canyon has its brook or torrent which soon unites with others forming swift, clear streams uniting into the main tributaries of their respective systems (17, 49).

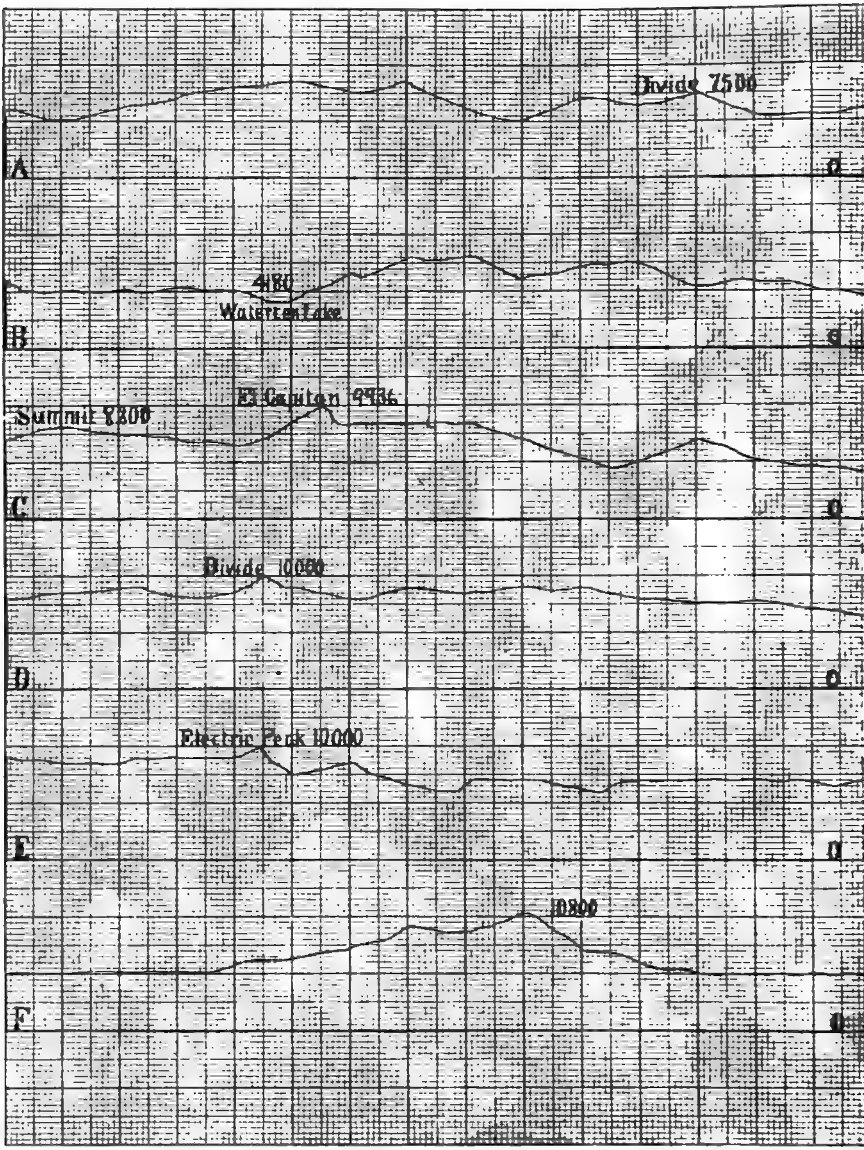

Fig. 5. Profiles of certain mountain ranges in Montana. Scale: horizontal and vertical, ½ inch: about 5000 feet. O, mean sea level. A and B, along the international border (49th parallel) from Kintla Lakes to Belly River, across Glacier National Park and the Continental Divide. C, section of the Bitter Root Range on the 46th parallel; from the summit to the Bitter Root River. D, Continental Divide on the 46th parallel. E, the Absaroka Range and the Yellowstone River on the 46th parallel. F, the Crazy Mountains on the 46th parallel.

The Missouri and some of its lesser affluents drain the whole of the eastern slope of the Divide in Montana, from the Milk River in the north to the ultimate sources of the Madison, over 500 miles. The Jefferson, the largest of these mountain tributaries, is formed by the Big Hole River and the Beaverhead and carries the waters from 250 miles of the Divide, which describes a wide and deep embayment, partly known as "The Big Hole" and occupying the southwestern corner of the State. The Jefferson, the Madison and the Gallatin unite at Three Forks to form the Missouri and from this point on to the mouth of the Dearborn there are no streams of considerable size. From the south the Missouri receives the Musselshell which drains the Crazy and the Snowy ranges, the highlands of the central part of the State. Near the eastern boundary the Yellowstone River enters but its waters have their sources mainly outside of the State, in the Yellowstone National Park and in northern Wyoming, although some are supplied by the Absaroka and the Beartooth Ranges in the southern part of Montana.

On the western slope, from the northern boundary to the head of the Bitter Root, somewhat over 300 miles, the waters are gathered by the North, the Middle and the South Forks of the Flathead, by the Blackfoot, the Bitter Root and the upper source of the Clark's Fork, commonly known as the Hellgate, all uniting to form the Clark's Fork which drains the whole of western Montana beyond the Divide. This stream finds its outlet through the narrow valley between the Coeur d'Alene and the Cabinet Ranges and finally empties into Lake Pend d'Oreille.

The main sources of these rivers lie ultimately in the winter's snows. During the long winters these accumulate, more on the western than on the eastern slopes, and as the warmth of summer dissolves them their waters run off in torrents or, percolating through the soil, feed the numberless springs and sources of the small streams. In February the waters are low, but in June the streams are at flood and their volume is increased as much as 70 fold as measured in second feet. Similarly, on the Atlantic drainage the streams are swollen by the melting snows but the minimum may come in March or in August depending on the location of the stream sources, and the maximum may occur accordingly anywhere from March to June. Measurements of flow indicate that some of the streams at flood may attain more than 1000 times their low water volume, but more often the increase is about 20 to 30 fold.

The tributary valleys of western Montana mostly have a north and south direction and occupy trench-like depressions between high ranges. The valleys are often or even usually narrow, but occasionally broaden out into numerous inter-mountain basins, as some parts of the Flathead and the upper Blackfoot Valley. Some are the basins of old lakes with the evidence of their ancient shore lines still intact. The positions of the ranges and their alternating valleys in most cases is squarely across the lines of eastward or westward movement.

CHAPTER II.

Climate.

THE climatic influences affecting vegetation are chiefly precipitation and temperature. Precipitation as the source of moisture is a matter of interest to be considered in connection with its seasonal distribution, with soil structure and composition, and with temperature, relative humidity and other atmospheric conditions. Data upon most of these points are available from records of the Weather Bureau, from over 90 stations fairly evenly distributed throughout Montana and covering periods varying from three to thirty or more years (70).

The prevailing winds of Montana are from the west. Fig. 6 indicates the direction in different sections of the State. Tables published by the Weather Bureau giving the usual wind direction by months at the numerous stations show west, northwest and southwest with few exceptions throughout the year. Easterly winds at times are strong, but such are usually of short duration.

On the western slope of the Divide the prevailing winds are the bearers of rain, which comes chiefly in the cooler months of the year. In this respect the climate of the western slope of the Rocky Mountains is not essentially different from that of the Pacific Coast west of the Cascades, except in the quantity of the precipitation. The seasonal features are much the same on the whole, however, with lower minimum temperatures. On the eastern slope of the Rockies, however, the rainfall features are diametrically opposite. Here the principal precipitation comes in the warmer months of the year, a fact of distinct advantage to the agricultural operations as well as to the native vegetation of the Plains region, and of importance as linking the climate of the eastern slope with that of the central states of which it is logically a part.

A diagramatic representation of the distribution of rainfall is shown in Fig. 7. The distribution by localities and seasons is shown and it will be noted that at most of the stations on the western slope (Plains, Missoula, Hamilton, Kalispell and Butte)

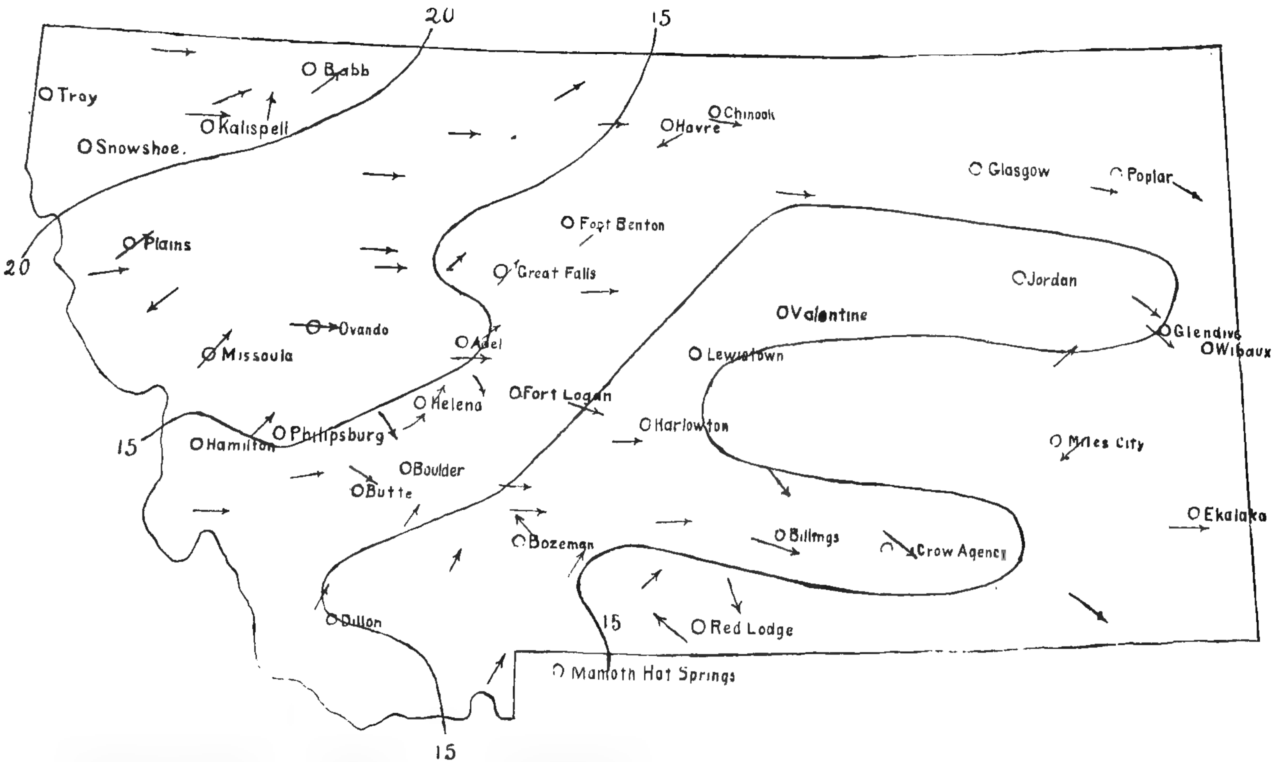

Fig. 6. Chart for Montana, showing direction of prevailing winds, lines of equal precipitation and stations of observation furnishing data herein cited for temperature, precipitation and other factors. From records of the Weather Bureau.

May and June are the months of heaviest rainfall, comprising possibly as much as one-fourth the total of the year, and that the months of July, August and September are comparatively dry.

At these stations the precipitation during the growing season, from April to September inclusive, represents about 54% to 63% of the total of the year. At some places, however, as at Troy, in the extreme western part of the State, the climate more nearly approaches that of the Pacific Northwest, and of the total annual rainfall (about 23 inches) about 35% only occurs during the same period. On the eastern side of the Divide the rainfall from April to September varies from 62% to 82% of the year's total.

The reason for the heavier precipitation during the months of May and June on the western slopes of the Rockies is doubtless due to the altitude of the land and the coolness owing to accumulated snows. During these months the snows are rapidly melting, the rivers are at flood, and the air is more heavily loaded with moisture. By the first of July the snows have mostly disappeared, except from the highest peaks, and the temperature of the whole region becomes noticeably higher. Throughout the whole summer showers occur among the higher mountains, but the valleys and foothills are usually almost rainless during July and August. Most of the observation stations are at moderate altitudes (2,000 to 6,000 feet) so that almost no data are available from the higher ranges, either in winter or summer.

Precipitation during the winter is usually in the form of snow. Table 1 presents precipitation data, both rain and snow, and the stations selected from various parts of the State afford representative figures. Strange as it may seem, the snowfall on the main range of the Rocky Mountains is comparatively light, notwithstanding their greater altitudes. This no doubt is largely due to the Bitter Root and Cabinet Ranges to the west where the snows fall to great depth. The figures from Saltese and Snowshoe are far above anything that occurs on the main Divide, being in the neighborhood of 12 feet for Saltese and 23 feet for Snowshoe. Butte, at an altitude of 5,716 feet, and within a few miles of the Divide, has an average snowfall of less than 5 feet. Philipsburg, at 5,275 feet, has 3½ feet, while

Table 1. Distribution of precipitation in Montana. From data furnished by the Weather Bureau.

Place	Total Precipitation, Inches, Annual Mean	Length of Record, Years	Altitude, Feet	Average Snowfall, Inches	Length of Record, Years
Western Montana (Pacific Slope)					
Missoula	15.84	33	3212	24	23
Ovando	18.36	10	4101	69.8	9
Troy	24.22	15	1880	56.3	11
Hamilton	10.71	11	3575	37.8	7
Philipsburg	15.55	7	5275	42.2	6
Snowshoe	69.70	4	4500	270.9	3
Kalispell	15.73	13	2965	42.1	10
Saltese	37.63	5	3600	142.3	5
Plains	13.00	10	2475	28.6	11
Butte	13.08	14	5716	55.2	14
Southwestern Montana (Atlantic Slope)					
Bozeman	18.60	33	4878	71.1	6
Boulder	10.00	17	4920	30.4	9
Dillon	17.20	10	5147	58.2	9
Fort Logan	13.01	30	6000	....	....
Harlowton	15.50	17	4165	59.9	6
Helena	13.21	29	4110	54.7	29
Red Lodge	20.85	6	5548	115.8	6
Virginia City	15.03	23	5880	....	....
Yellowstone Park	18.97	19	6200	105.2	21
North Central Montana (Atlantic Slope)					
Adel	20.14	12	5200	82.3	10
Babb	22.42	3	4461	103.7	3
Fort Benton	13.38	30	2630	34.2	7
Great Falls	10.48	24	3350	41.1	14
Havre	13.63	30	2505	37.0	10
Lewistown	19.77	14	4010	66 2	10
Northeastern Montana					
Chinook	12.56	14	2502	27.5	8
Glasgow	12.61	15	2092	25.5	7
Glendive	15.48	20	2069	45.4	13
Jordan	11.69	5	......	....	....
Poplar	13.59	17	2020	41.5	13
Valentine	12.72	3	......	....	....
Southeastern Montana					
Billings	14.96	16	3115	43	16
Crow Agency	14.56	30	3041	43.9	30
Ekalaka	13.41	12	....	29.7	9
Miles City	12.75	32	2371	27.2	31
Wibaux	14.19	14	2674	30 6	9

Ovando, at 4,101, has nearly six. It is a matter of further interest in this connection to point to the snowfall in Yellowstone Park at 6,200 feet elevation as being normally 8½ feet and at Red Lodge, 5,548 feet elevation in the Absaroka, 9½ feet. Both of these stations, which represent the highest east of the Divide, are within 80 miles of the summit and in the direct path of the southwesterly winds which sweep across the range at points unprotected by any high barriers to the windward. The Bitter Roots, which shelter the main divide further north, have no influence here, having merged with the main range some 200 miles to the northwest.

If we reckon 10 inches of snow on an average as equal to one inch of water, the equivalent of the winter's precipitation in acre feet would amount to a considerable volume in stream flow and is important in its relation to power and irrigation. It is an important factor as related to the vegetation of the region. In this respect, however, it is not equally distributed, and much of it doubtless is lost by evaporation, but it is swept by winds into gulches and into sheltered pockets in the lee of peaks where, piled to great depths, it furnishes a constant supply for innumerable streams throughout the warmer season. In this form it is less significant to the vegetation of the crests and exposed slopes, except as these are forested and so enabled to hold the snows that they receive. In such cases, which are numerous, the snows become of the utmost importance, and furnish conditions highly favorable for certain species. The countless lakes and streams fed by the melting snows furnish a natural irrigation system, and by furnishing suitable habitats for trees along their banks facilitate the spread of forests over intervening and adjoining areas.

Locally rainfall conditions vary within wide limits. The western slopes of the Bitter Roots are amply watered. The rain bearing winds from the west sweep up their high inclines and deposit their burden in frequent showers and heavy snows. There is probably no part of the Rocky Mountains more heavily watered than the higher Bitter Roots and their western slopes, or with snows so deep. In the lee of this range lies the Bitter Root Valley, and Hamilton, near the center of the Valley and at the foot of the mountains on the east has an annual rainfall

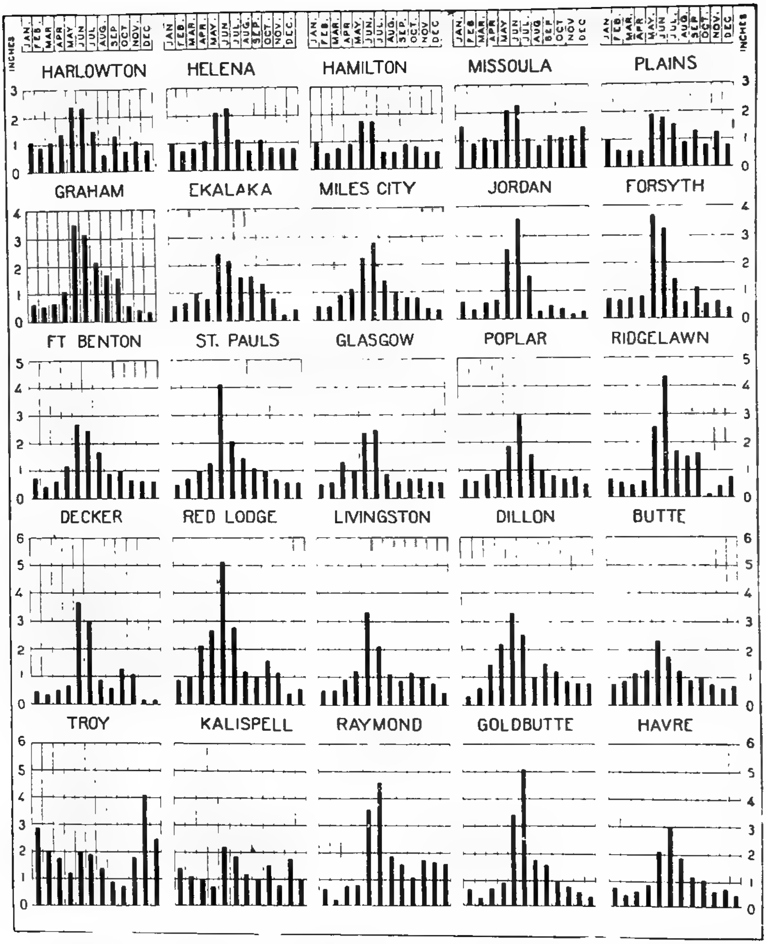

Fig. 7. Diagrams showing monthly distribution of precipitation at twenty-five stations in Montana. From Summary of the Climatological Data of the United States. Reproduced by permission of the Weather Bureau.

of 10.71 inches, the average of 11 years of observation. Missoula, near the mouth of the Bitter Root Valley and on a direct line some 30 miles from the higher Bitter Root summits, has an annual record of less than 16 inches, the average of over 30 years of observation. Similar comparisons may be made in various other places. The heavy precipitation at Snowshoe in the Cabinet Range may be due to the position of the lake country in northern Idaho, lying as it does directly to the west, and to the fact that the southwestern winds have few opposing altitudes to diminish their moisture before striking this range. To the east lies the broad basin of the Flathead Valley with about one-fifth the total annual rainfall which occurs at Snowshoe.

The more amply watered western slopes of the Bitter Root, Coeur d'Alene and Cabinet Ranges are heavily forested, and support a type of vegetation more mesophytic than is to be found in other parts of the region, with some few and limited exceptions. In this feature some portions of northern Idaho may be included and in all such areas in western Montana and northern Idaho there is a conspicuous element in the flora suggestive of Pacific Coast humid conditions and undoubtedly derived from that source. The areas of this character in western Montana are few and are mostly confined to the moister valleys of the Flathead drainage.

East of the Divide the annual precipitation is on the average less. It varies from 10 to 22 inches, but for most places from 10 to 15. The lower plains have less and the amount increases with the altitude. Red Lodge, Babb and Lewistown, situated among or near mountains, have about 21, 22 and 20 inches respectively. The mountainous areas, due to the greater rainfall, have forests of considerable extent, but the plains are devoid of trees except along the streams or under other exceptional conditions.

Relative humidity and the rate of evaporation in Montana have not been established by a sufficient number of observations, but some facts are available from the records of the Weather Bureau at Helena, Havre, Kalispell and Yellowstone Park and from observations by the writer at Missoula, and these are submitted herewith.

Table 4 summarizes the data from the Weather Bureau's publications, which show that the mean maximum at Helena, Yellowstone Park and Kalispell were between 60 and 87 per cent and that the lowest relative humidity of which there is a record is 30 per cent at Helena in August.

Table 2 gives the mean daily relative humidity, maximum and minimum for a period of three years and table 3 the mean daily variations during the same period. The record was made by a standard hygrograph under standard conditions and corrections made from time to time by aid of a sling psychrometer. The instrument shelter, on the University campus, was placed in an area of natural prairie vegetation as dry as usually can be found in the region. A mountain rising to the east shut off the early morning sun, but the station was fully exposed throughout the rest of the day.

From the table of mean daily variations it will be seen that these may range from 50% to 64%. The curve traced by the recording pen shows, especially during the summer months, a rythmic daily rise and fall, the maximum about 6:00 a. m., the minimum about 4:00 to 6:00 p. m. The pen in rising traces a more or less zigzag and irregular line until the maximum is reached. At this point there is usually a sharp peak, for the maximum is of short duration, then a steady downward sweep during the day to the minimum late in the afternoon. The maximum of each day's record usually shows strong throughout

Table 2. Mean daily relative humidity at Missoula. Maximum and minimum.

		Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Max				88	92	94	95	88	87	96	89	88
1915	Min				34	41	40	34	21	38	43	50	60
	Max	86	94	89	84	83	83	83	82	82	83	79	76
1916	Min	64	66	45	34	32	31	24	20	18	34	45	58
	Max	80	80	80	77	77	73	66	67	71	75	73	72
1917	Min	55	51	42	31	25	25	9	13	19	22	52	52
	Max	72											
1918	Min	50											

Table 3. Mean daily variations in the relative humidity at Missoula.

	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1915				54	51	54	61	67	49	53	49	28
1916	22	28	44	50	51	52	59	62	64	49	34	18
1917	25	29	38	46	42	48	59	54	52	55	21	20
1918	32											

Table 4. Data from the Weather Bureau on the mean relative humidity by months at three places in Montana and one in the Yellowstone National Park.

Stations	Hours	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jly.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Helena	8 A. M.	72	73	71	65	66	67	60	59	64	66	68	71	67
	8 P. M.	66	63	56	42	42	41	31	30	39	48	56	65	48
Yellow-	8 A. M.	77	74	77	74	77	74	77	73	71	74	70	76	74
stone Pk.	8 P. M.	71	64	65	48	51	46	36	38	40	55	58	59	53
Havre		80	81	77	62	63	63	57	56	62	68	75	79	69
Kalispell	6 A. M.	86	86	81	78	82	82	78	77	82	86	86	87	83
	6 P. M.	80	73	58	42	49	47	37	36	50	62	76	83	58

the year, even in relatively dry seasons, since the nights are always cool. In the winter the rythmic quality of the curve is much less marked, the maximum is comparatively low and the peak flat, while the sharper angle in the day's tracing now falls at the minimum.

The situation is one of exceptional severity for vegetation. Two months or more of drouth during the summer, mostly cloudless days, day temperatures of 80 to 90 degrees, low relative humidity and a highly porous soil, all tend to xerophytic conditions in the vegetation. This station may be considered the most severe, all points considered, in western Montana. During the season of 1917 10 weeks in June, July and August were without a trace of rain, and but .62 of an inch fell in three months. At the close of this time, in the vicinity of the instruments, soil at the depth of a foot was within 1.1% of actual air dry condition and when heated for three weeks at a temperature of 120 degrees C. gave off less than 2% of its original weight. The lower altitudes in this valley are treeless except where sheltered from sun and wind, a fact which is evidently related to the dryness of the situation.

There is little but inferential evidence as to the rate of evaporation at any point in Montana. One record in the Judith Basin in 1909 showed evaporation amounting to 32.6 inches, presumably for the year. At Missoula during the season of 1917 the evaporation was 14 inches in 10 weeks (July, August and September) from an exposed water surface of 4 square feet protected by wire netting of one-third inch mesh. Sometimes the evaporation was as much as 2 inches per week.

The Signal Service and the Geological Survey have con-

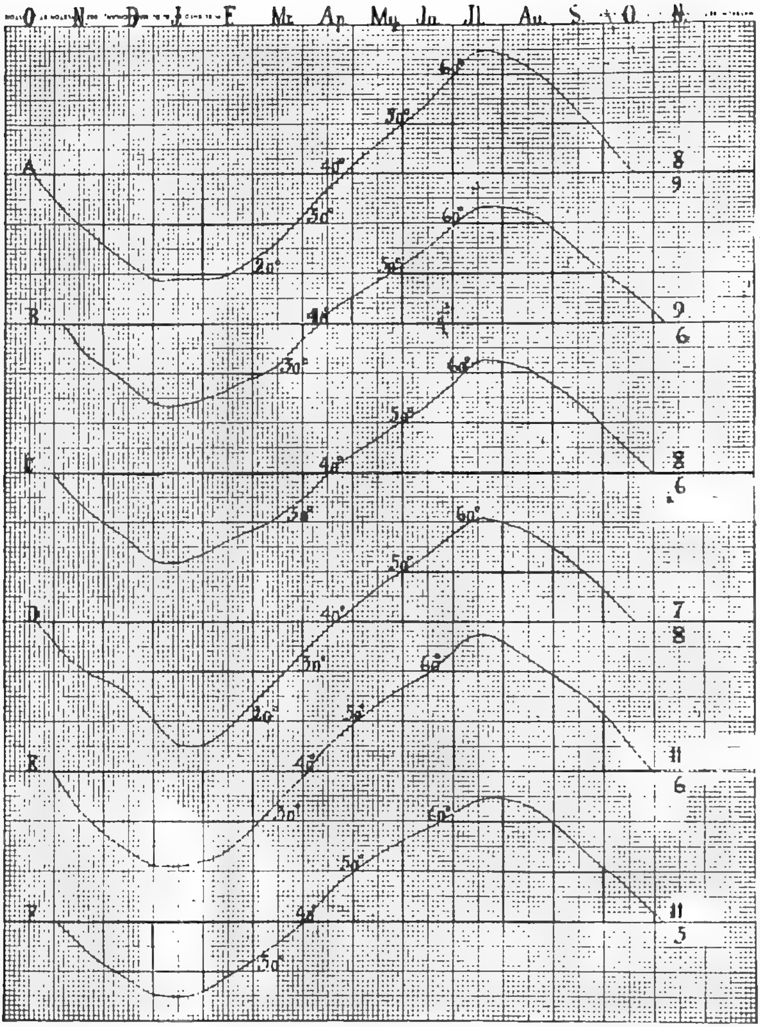

Fig. 8. Mean temperature diagrams for the year. A. Mammoth Hot Springs, Yellowstone Park, altitude 6200 feet. B. Anaconda, altitude, 5300 feet. C. Philipsburg, altitude, 5275 feet. D. Ovando, altitude, 4101 feet. E. Missoula, altitude, 3212 feet. F. Troy, altitude, 1880 feet. The figures at the right represent the ratios of the growing to non-growing seasons. The mean temperatures for the months are on the curves midway between the vertical lines.

ducted experiments showing that evaporation from a water surface on the western plains of the United States may amount to from 50 to 80 inches, and in some localities to even 100 inches a year, while the rainfall (diminishing in inverse ratio) over this area is from 30 to 12 inches and less. (25) In a series of experiments to determine the relation of wind to evaporation they arrived at the following conclusions: evaporation with the wind at 5 miles an hour was 2.2 times greater than in a calm; "at 10 miles, 3.8; at 15 miles, 4.9; at 20 miles, 5.7; at 25 miles, 6.1, and at 30 miles, the wind would evaporate 6.3 times as much water as a calm atmosphere of the same temperature and humidity." During these experiments the temperature of the air was 84 degrees and the relative humidity 50 per cent.

In four years in Montana from 1908 to 1911 the maximum wind velocity was 60 miles per hour. This was in March. Summer winds of 46 miles per hour were reported during the same period. These figures are for the plains country. West of the Continental Divide the winds are much more moderate. Winds which rise to considerable velocity are of short duration. In this section of the State the only places where winds seem to be effective are on high and exposed ridges and peaks, and on the more arid southern and western exposures at low altitudes.

Temperature records from many places in Montana, representing observations of from 10 to 30 years, afford a reasonable basis for judgment of the climatic conditions of the region in relation to the vegetation. The lowest temperature thus far recorded in Montana is -65 degrees, at Miles City, and the highest 117 degrees at Glendive. Glendive and Miles City are about 75 miles apart, and, while the figures just cited as to temperatures represent the greatest extremes for these places and do not at all indicate the usual conditions, they do indicate that that section of the state is subject to seasonal extremes and that the annual range of temperature may be considerable. As a matter of fact it may range from 125 to 175 degrees. Other sections of the State on the plains may likewise be subject to extremes and the annual temperatures range from 120 to 150 degrees. The lowest mean annual temperature in Montana is recorded from Bowen in the Big Hole, averaging 34.1 degrees, and the highest recorded mean annual temperature is at Billings, 47.2 degrees. For the climatological sections established by the Weather Bureau, the mean annual temperatures range as follows:

Northeastern Montana	39.6 to 43.3 degrees
Southeastern Montana	42.9 to 47.2 degrees
North Central Montana	36.8 to 45.8 degrees
Southwestern Montana	34.1 to 45.5 degrees
Western Montana	38.9 to 45.8 degrees

Northeastern Montana is characterized by lower temperatures usually and by higher winds and more sudden changes of temperature than other parts of the state. There is a sudden transition from winter to summer in the middle of June, from snows and freezing weather to the long hot days of summer; autumn is dry, and mild weather often extends to December. The normal temperature for April is about 40 degrees, which marks the beginning of the spring growth of the prairie flora. In the southeastern part of the State there is a wider range of temperature, both daily and annual. During the summer the diurnal variations may be as much as 40 degrees or more. Snow falls from October to March. The north central portion of the State is colder and drier than the northeastern part. The winter minimum sometimes falls to 45 degrees below zero, and the summer maximum of 100 degrees is experienced in many localities. In southwestern Montana the several high ranges of mountains collect abundant snows. High altitudes, low humidity and the absence of high winds are features of this section. The temperature records are more uniform than might be expected, owing probably to the more or less sheltered locations of the various stations of observation. Western Montana is a region of widely differing altitudes and topographic conditions, and in some of the mountain valleys frosts and even snows may occur in all months of the year. In some parts the snowfall is exceedingly heavy.

Two tables are provided giving the significant facts of atmospheric temperatures. Table 5 gives the average mean temperatures during the months of the growing season and the average annual means at 29 different stations in the State. The last six are within the timbered section of Montana and in proximity to important forests. The others are mostly in the prairie country. Table 6 shows the highest and lowest temperatures on record for 35 stations in Montana during the six

Table 5. Average mean temperatures during the months of the growing season and average annual means.

Station	Yrs. Obs.	Apr.	May	June	July	Aug.	Sept	An. mean	Alti-feet
Glendive	20	46.0	56.3	65.1	72.1	71.0	59.4	43.3	2069
Poplar	24	42.9	54.3	63.3	69.7	67.3	57.1	39.8	2020
Glasgow	14	44.3	56.2	62.7	69.9	67.8	56.0	40.2	2092
St. Pauls	9	42.7	50.4	59.2	66.5	67.0	55.8	43.1	4150
Chinook	10	43.0	54.5	62.6	69.9	67.4	56.8	41.9	2502
Havre	29	42.7	54.1	62.4	68.1	66.9	57.6	41.9	2505
Cut Bank	11	38.3	48.8	54.8	60.6	60.0	50.4	38.6	3700
Fort Benton	30	44.6	55.1	62.7	69.6	67.8	57.2	44.1	2630
Great Falls	18	45.5	53.6	60.9	67.8	66.7	57.1	45.8	3350
Fort Shaw	21	40.1	54.1	62.6	68.3	64.7	55.6	44.0	3500
Lewistown	12	42.1	50.4	57.5	64.2	63.0	53.7	42.6	4010
Wibaux	9	46.3	56.2	61.7	69.7	66.8	56.8	42.9	2674
Miles City	31	47.0	56.5	66.3	72.6	71.5	59.8	44.6	2371
Ekalaka	9	43.5	53.0	61.9	68.9	67.9	59.8	43.7	......
Crow Agency	30	46.6	55.6	63.6	70.9	69.5	58.6	45.2	3041
Billings	16	45.3	55.7	62.1	71.7	70.4	60.5	47.2	3115
Fort Logan	24	39.1	48.1	55.8	63.1	61.6	51.1	39.3	6000
Harlowton	14	41.4	51.0	57.5	65.2	64.0	48.1	41.0	4165
Helena	28	44.0	51.8	59.1	66.9	66.2	56.2	43.6	4110
Bozeman	29	40.3	50.0	58.7	65.8	64.3	53.3	43.5	4700
Red Lodge	9	39.6	46.0	55.6	61.2	60.7	52.4	40.8	5548
Virginia City	20	40.0	47.6	55.5	64.5	64.0	53.5	41.2	5880
Yellowstone Park	22	37.4	46.1	53.8	64.7	61.0	52.4	39.5	6200
Columbia Falls	14	42.9	51.0	56.8	63.9	62.4	53.3	42.6	3100
Kalispell	11	42.5	51.0	58.8	64.3	62.9	53.9	42.4	2965
Troy	15	46.1	53.6	58.8	64.2	63.0	55.0	45.1	1880
Plains	11	44.6	51.7	57.5	65.8	64.1	56.0	44.7	2475
Missoula	30	44.8	53.7	59.8	67.1	62.9	55.8	43.8	3212
Deer Lodge	14	40.6	49.2	58.0	62.9	60.3	51.7	41.0	4768

months of the growing season. Again the figures for western Montana are the most significant as representing a more heavily forested region. But in other parts of the State represented by these figures there are forests locally important, or at least forest species more or less common. While it may be seen that in all sections the maximum may rise to 100 degrees or more, the minimum for each month falls more often below the freezing point than above it.

The vital phenomena of plants are mostly confined to temperatures above freezing. While it can be shown that certain functions are performed at a diminished rate below 32 degrees F., it is also evident that all functions increase in vigor in geometrical ratio from this point up to the optimum. The length

Table 6. The highest and lowest temperatures on record for 35 stations in Montana during the six months of the growing season.

Stations	April Max.	April Min.	May Max.	May Min.	June Max.	June Min.	July Max.	July Min.	Aug. Max.	Aug. Min.	Sept. Max.	Sept. Min.
Western Montana (Pacific Slope)												
Hamilton	83	15	90	18	93	30	96	38	94	36	89	28
Kalispell	82	11	88	26	92	31	96	35	95	35	88	24
Missoula	82	4	89	22	96	30	104	34	103	29	93	20
Ovando	76	0	86	19	97	25	98	28	96	25	90	13
Philipsburg	86	7	89	18	88	27	96	30	95	25	93	17
Plains	83	12	87	20	90	29	102	34	98	34	91	22
Snowshoe	63	8	73	16	82	34	91	35	84	30	80	22
Troy	86	10	91	21	96	27	103	29	108	29	100	19
Butte	76	6	81	21	94	26	94	33	94	34	87	20
Southwestern Montana (Atlantic Slope)												
Bozeman	82	-16	94	15	99	26	104	29	112	26	97	18
Boulder	78	-28	84	4	96	10	97	27	97	31	89	30
Dillon	80	1	87	22	94	27	93	32	94	26	91	12
Fort Logan	83	-7	98	10	100	12	96	25	94	25	90	14
Harlowton	84	2	88	15	104	25	103	32	104	29	90	8
Helena	83	6	88	22	102	31	103	36	98	34	91	20
Red Lodge	77	2	81	8	110	25	93	34	96	29	89	12
Virginia City	76	8	83	19	91	25	97	29	92	31	92	21
Yellowstone Park	77	0	89	15	92	20	96	30	93	30	88	0
Adel	79	9	82	7	97	21	94	25	94	25	88	17
Babb	73	6	77	14	80	27	87	30	91	26	82	17
Fort Benton	90	-1	94	20	108	30	111	30	108	27	101	14
Great Falls	88	7	94	20	102	34	103	35	100	35	90	22
Havre	89	4	92	23	108	31	103	41	106	33	92	19
Lewistown	86	12	89	20	105	28	105	30	98	29	98	9

Table 6. (Continued.)

Stations	April Max.	April Min.	May Max.	May Min.	June Max.	June Min.	July Max.	July Min.	Aug. Max.	Aug. Min.	Sept. Max.	Sept. Min.
Northeastern Montana												
Chinook	88	-13	98	13	109	32	106	36	109	32	96	20
Glasgow	89	-2	98	20	109	30	113	36	110	30	100	14
Glendive	96	-6	101	16	107	32	117	36	113	33	103	16
Jordan	91	3	93	19	92	31	103	38	104	32	100	25
Poplar	92	-12	104	15	105	27	110	37	108	33	103	13
Valentine	88	-8	84	21	96	35	104	39	109	34	98	16
Southeastern Montana												
Billings	91	4	99	22	100	26	112	38	104	32	100	21
Crow Agency	89	-8	96	-18	103	31	106	37	105	32	97	20
Ekalaka	87	-11	98	13	100	30	106	35	106	36	103	21
Miles City	90	-7	101	17	107	33	112	31	112	32	102	16
Wibaux	86	10	99	19	102	30	109	32	109	33	106	18

of time, therefore, between the cool weather of spring and autumn, which marks annually the time of awakening and of retarding of plant life, is important as determining to a large extent the limits of the distribution of species when other things are equal, but hotter summers in certain areas may furnish the required total of heat for the support of species which would not be able to endure in another region having a growing period of equal length but of lower temperature.

The length of the frostless period in the year must determine, of course, the northern limit of distribution of certain species of native as well as of crop plants. The sum total of heat required for the maturing of the plant and the production of seeds must in most cases be the minimum even among those hardy species which resist frost, and furnish the northern limit of their distribution. In this region the frostless period of the year varies from 40 days to 4 months or more, depending on location and altitude. Table 7 presents frost data for a number

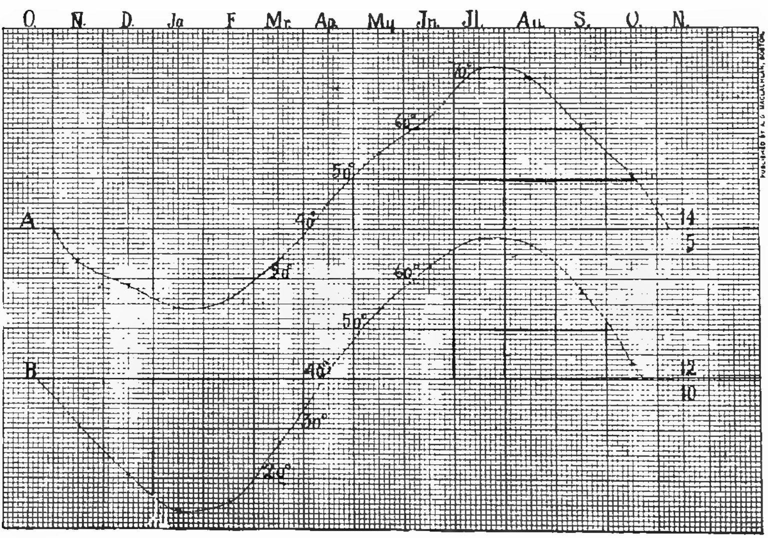

Fig. 9. Mean temperature diagrams for the year. A, at Billings, altitude, 2371 feet. B, at Havre, 200 miles north of Billings, altitude, 2505 feet. The figures at the right represent the ratios of the growing to the non-growing seasons. The mean temperatures for the months are indicated by the cross-marks on the curves, midway between the vertical lines.

Table 7. Average dates of last killing frost in spring and first in autumn.

Station	Years of Observation	Last frost in spring	First frost in autumn
Glasgow	14	May 22	Sept. 12
Chinook	10	" 13	" 11
Glendive	16	" 12	" 22
Poplar	16	" 16	" 11
St. Paul	10	" 29	" 16
Adel	10	June 25	Aug. 24
Chouteau	11	May 30	Sept. 6
Fort Benton	9	" 16	" 30
Lewistown	12	June 5	" 3
Great Falls	18	May 7	" 16
Cut Bank	7	June 14	Aug. 29
Billings	10	May 7	Sept. 16
Crow Agency	27	" 15	" 26
Miles City	18	" 7	" 24
Red Lodge	8	June 13	" 2
Bozeman	8	May 28	" 7
Butte	14	June 5	" 15
Fort Logan	12	" 16	Aug. 30
Helena	35	May 7	Sept. 28
Dillon	9	June 9	" 1
Anaconda	8	" 13	" 4
Columbia Falls	16	" 9	Aug. 22
Kalispell	12	May 13	Sept. 30
Missoula	10	" 13	" 19
Ovando	10	July 4	Aug. 12
Troy	13	June 1	Sept. 7

of stations within the State. In these as in most temperature records, other elements are to be considered besides latitude and altitude. Some stations much higher than others have a longer frostless season and some with a difference of 100 miles or over in latitude have a difference of 30-50 days in the frostless period in favor of the more northerly stations without compensating difference in altitude. The proximity of mountain ranges, the width and direction of valleys, the exposure of the slope, and the direction and velocity of winds, all have their influence on the temperature at any time of the year. Owing to the character of the topography and the extent of the area involved, the figures on temperature can have only the most general significance. Figure 11 gives the mean annual isotherms of 1911, one of the colder years, and indicates the complexity of the temperature problem as far as distribution of species is concerned. When local areas are under consideration their temperatures must be a subject of local investigation.

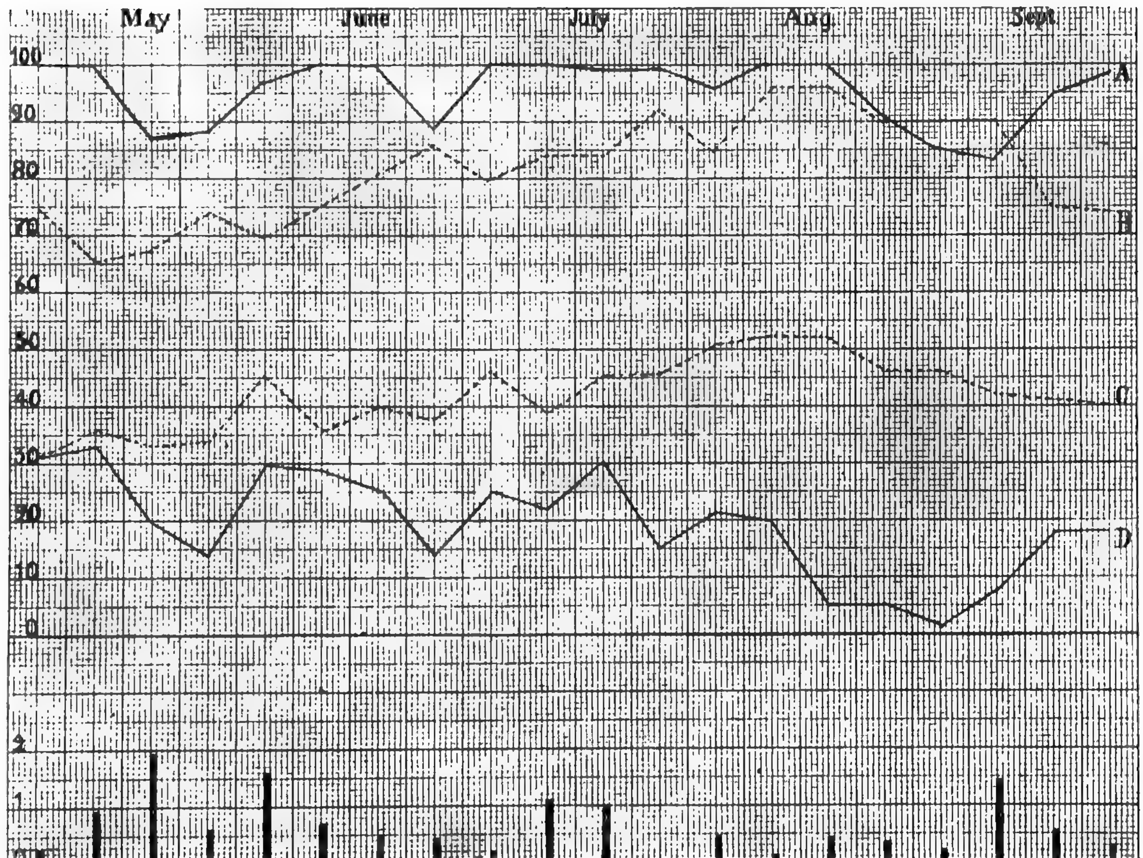

Fig. 10. Chart showing temperature, relative humidity and precipitation at Missoula, May to September, 1915. The continuous lines, A and D, represent weekly means of relative humidity, maximum and minimum respectively. The broken lines, B and C, represent weekly means of temperature, B, maximum, C, minimum. The figures at the left may be read as degrees temperature, or per cent, relative humidity. The heavy black lines below represent precipitation in inches during the same period. Refer to figures at left.

The ratio of the growing to the non-growing portion of the year is graphically shown in Fig. 8, which applies to several stations at altitudes varying from 1880 to 6200 feet. For each station a base line is drawn representing 40 degrees F., the approximate minimum of temperature as related to seasonal vegetative activity. Above and below parallel lines are drawn at intervals of ten degrees. Each diagram thus represents a vertical range of temperature of from 40 to nearly 60 degrees. The mean temperature for each month is fixed by points above and below the base. A line drawn through these points forms a seasonal curve for the temperature of the station. This curve falls below the base during the winter months. Descending sharply it reaches the minimum sometime in January, then it ascends, crossing the line usually in April, and reaches the maximum in July, whence it sinks again to the base line in October or November. Between the curve thus described and the base are included two areas, one above and the other below, which together represent respectively the positive and the negative temperature conditions of the year. They represent also, from the standpoint of vegetation the relative values of the months indicated.

The vertical lines separate the months. The mean temperature for each month is fixed at the middle or half way between the verticals. On some of the curves these points are marked and indicated by figures expressing the mean temperature of the months. (Figs. 8, 9.) The relative lengths of the growing and the non-growing seasons can readily be compared. In some cases the two periods are seen to be about equal, six months of each. In others, the ratio is 5 to 7 in favor of the growing season. The vertical distances determine the areas which are proportional to the values of the periods. In comparison the growing seasons are seen to have relative values of 7, 8, 9, 11, 12, 14, etc., in different parts of Montana, as reckoned by the total areas of the squares. While the curve is a generalized one and the actual temperature variations would show sharp oscillations above and below, the areas included may, in the long run, be taken as fairly representative of the seasonal values.

Livingston (35) has suggested a method of reckoning temperatures in relation to field vegetation according to exponential law. By this method it is conceived that with every increase of 18 degrees F. from 40 degrees to the optimum there is a doubling of the rate of growth and of activity of other physiological processes. MacDougal (37) has applied this principle in devising a method of integrating temperatures, whereby the area below the line of a thermograph record and above the line of 40 degrees may be made to represent hour-degrees in relation to plant growth, when applied to the rate of growth within fixed limits of temperature. In the diagrams (Figures 8, 9) herein presented for Montana the duration and intensity of the growing temperatures is shown. The spaces between the heaviest vertical lines represent months. The same distance between horizontal lines represents 10 degrees of temperature. The tallest of these vertical lines represents therefore 72 degrees as the mean for the month of July at Billings. The lowest here given is 61 degrees which is the mean for the same month at Ovando. In the former case there are as a rule 32 degrees of temperature favorable for growth, in the latter 21. The others may be seen to vary from 22 to 28 degrees. The duration, however, varies, as indicated by the character of the curve which in some cases ascends directly to the maximum and falls off again quickly, in others the higher temperatures are sustained longer and the curve accordingly has a flat or broadly rounded top. These features figure largely in the sum total of the productive temperatures of the locality, and stand in relation also to the variety of crop plants usually grown under irrigation in the several places.

The curves of total heat required for all species must naturally fall within the limits of the curve thus determined for each locality, when established upon the same basis. It is also evident that the curve for the species must more nearly approximate the curve for the locality the higher the latitude or altitude. If the exponential interpretation of temperatures in relation to plant life is applied, it means that in one month of higher temperature as much substance of the plant body may be formed as in a longer period at lower temperature. It must be borne in mind, however, that the brevity of the far northern summer seasons is accompanied by the shortening of the vegetative period and the production of seed in much less time than is required by the same species in warmer climates. Wheats which require

129 days to mature in temperate latitudes, if taken farther north gradually, after some years, reduce the period of life from sowing to ripening to ninety days or less (1). The rapid development of northern vegetation during the short summers is well known. The same is true of alpine floras. Schimper's reference (56) to the effects upon the rate of growth of trees and the period required for their maturity may be cited in this connection, and many other facts of similar import.

The sunshine data for this region are far from being adequate for our purpose but some facts can be given indicative of the conditions. They show an abundance of clear days for the

Table 8. The average sunshine record for four years (1908-1911) in different parts of Montana.

Station	Clear	Partly Cloudy	Cloudy
Miles City	159	125	81
Havre	159	128	104
Helena	120	122	123
Great Falls	160	149	56
Dillon	156	110	96
Butte	151	62	145
Plains	205	7	152
Saltese	227	11	127
Kalispell	110	117	138

limited period to which they apply, though unfortunately the distribution of the clear days by seasons can not be indicated, nor the intensity of the light. In the state the average number of clear days in the year varies from 160 to 178, the number of those partly cloudy from 95 to 108, and those recorded as cloudy from 83 to 101. At Poplar in northeastern Montana, the number of clear days from year to year varies from 260 to 280, those partly clear from 33 to 58, while the cloudy days at the most cover less than two months, varying from 45 to 59 days. These figures as well as those in the accompanying table are to be taken only as a general indication, allowing for errors of observation and the lack of related data. On the Western Slope the clear days predominate in the summer and autumn, though many are scattered through the other seasons. In eastern and central Montana, the rains coming freely in the growing season probably indicates a good many days during the summer at least partially clouded.

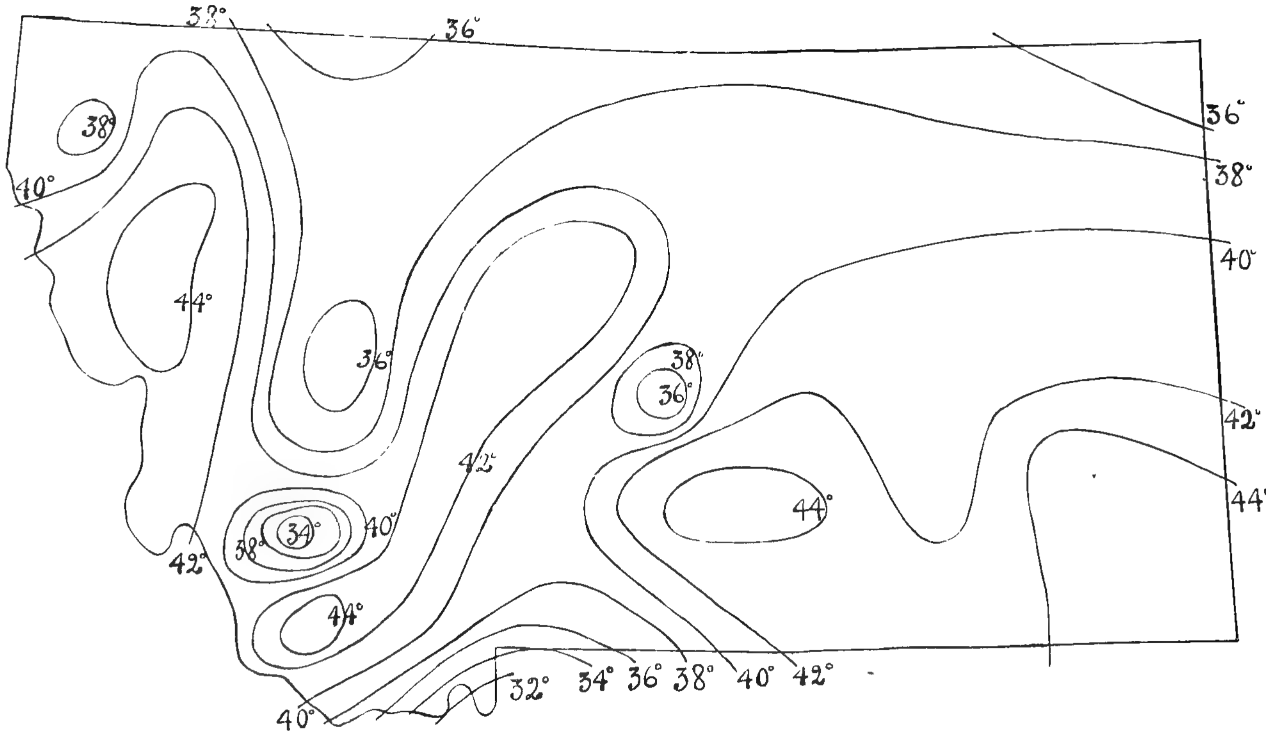

Fig. 11. Isotherms for mean temperatures in Montana, 1911. By permission of the Weather Bureau.

In connection with this reference to light it should be remembered that on the parallels of latitude extending through this region the period of daily illumination during the summer is relatively great. On the longest days of the year, actual darkness hardly amounts to more than 6 hours of the 24. That the amount of carbon assimilated stands in direct ratio to the duration of daylight during the growing season is, of course, obvious.

While the fundamental importance of light in the economy of plant life is widely known, not so general is the knowledge of the relation of light to other climatic factors in the growth of plants, or of the peculiarities, with reference to light, of the particular forest species. In discussing the forest conditions of a region it is pertinent to point out that the amount of light required by a tree is increased with the lowering of the temperature. In warmer latitudes, therefore, a tree may endure a crtain amount of shade, while in more northern regions it requires full exposure to sunlight. A difference of this sort may be seen in the western yellow pine, which in Montana and elsewhere in the northern Rocky Mountains is very intolerant of shade; in Arizona, however, this tree is much less sensitive, and, like many other plants of that region, actually prospers better for a time under a moderate shade. This is, however, not wholly a matter of temperature difference, since the sunlight is more intense in latitudes toward the equator, and, as all plants are attuned to a certain range of light intensity, any excess of light is avoided wherever possible. Whether the difference of behavior is due to a difference of light intensity or of temperature, or both, it finds expression in the appearance of the forest, which must be more open in the cooler latitudes, in order to provide sufficient illumination. This opening of the stand may give an opportunity for the entrance of other species less sensitive to shade, giving rise to a forest of mixed species, and even resulting in the end, perhaps, in the total elimination of the intolerant ones.

CHAPTER III.

Sources of the Vegetation: Migrations.

PRACTICALLY all of the northern Rocky Mountain region and plains have been glaciated and the subsequent plant covering derived from outside areas in later times (24). The sources from which these migrations have ensued were several, including chiefly Atlantic and Pacific elements as indicated by the existing species. A southern element likewise enters to some extent, but is important only here and there locally, so far as the woody species are concerned.

That any relation exists between the species at present growing in this region and those antedating the glacial period is neither impossible nor improbable, but is difficult of proof. Of the many (50) genera of woody angiosperms listed below, mostly from the strata of the Tertiary of this immediate region, nearly all are represented by one or more species within the temperate latitudes of North America, and the majority of the existing genera of like sort in Montana are represented in the fossils of that period. Of the Tertiary gymnosperms three out of four genera are likewise now native to temperate North America, while the earlier Cretaceous genera representative of this group are mostly extinct, though some are allied to existing families. The rich flora of the Tertiary, abounding in broad-leaved, deciduous forests, must have developed under conditions far different from any that have existed since, both as to temperature and moisture, and doubtless far more favorable for the origin of new forms.

The following lists from the works of Newberry (44), Lesquereux (33), Knowlton (28) and Ward (69) are doubtless incomplete but will serve to indicate something of the past history of the flora of this region. The genera at present existing here are marked by an asterisk (*).

GYMNOSPERMS

Araucaria	*Glossozamites*
Sequoia	*Cycadospermum*

Taxodium
**Thuja*
Glyptostrobus
**Pinus*
Ginkgo
Abietites
Cycadella
Cycadeoidea
Nilsonia
Nageiopsis
Zamites
Williamsonia
Araucarioxylon
Araucarites
Leptostrobus
Arthrotaxopsis
Geinitzia
Sphenolepidium
Baieropsis
Cyekanowskia
Cephalotaxus

ANGIOSPERMS

Sabal
**Populus*
**Salix*
**Corylus*
**Alnus*
Alnites
**Betula*
Quercus
Quercophyllum
**Ulmus*
Ulmophyllum
Celtis
Planera
Carya
Juglans
Ficus
Ficophyllum
Protoficus
Liriodendron
Magnolia
Laurus
Sasafras
Tetranthera
Hamamelites
Liquidambar
Platanus
**Amelanchier*
**Prunus*
**Rhus*
Euonymus
Celastrophyllum
**Acer*
**Negundo*
Sapindus
Sapindopsis
**Rhamnus*
Rhamnites
**Vitis*
Cissites
Tilia
**Aralia*
**Cornus*
Nyssa
**Andromeda*
Sapotacites
Diospyros
**Fraxinus*
Cinchonidium
Viburnites
**Viburnum*

It has long been known that in times next preceding the glacial period, in the latest Tertiary, from Spitzbergen and

Iceland to Greenland and Kamtchatka a mild temperate climate prevailed and forests like those from New England to Virginia and California clothed the land. In the words of Gray (20): "We appear to be within the limits of scientific inference when we announce that our existing temperate trees came from the north." All species were probably crowded southward by the ice and doubtless found at least a narrow zone suited for their occupation during the period of glaciation. Upon the retirement of the ice some of these species or their descendants must have reoccupied portions of the land. During all of this period selective influences were undoubtedly sifting out the species which were the distant forebears of our present flora. Climatic, topographic, and edaphic conditions determined the final types of vegetation (prairie, forest, etc.) over large areas of the land reoccupied. Since none of the existing species of this region, as far as we know, have appeared in the Tertiary deposits it seems probable that they have entered or evolved since that period.

The present alpine flora of the northern Rockies shows little evidence of its connection with the Tertiary flora above mentioned. Few species are common to the old and new world, and no closely related forms are here known in the fossil state. Rydberg (55) mentions one woody plant, a dwarf willow *(Salix reticulata)* as common to the arctic regions of both continents and to the higher altitudes of the Alps and the Rockies.

Beyond a few other shrubby willows and heaths, with affinities more or less evident with European species, immediate connection between the woody alpine flora of this region and that of the old world can hardly be admitted. As to some of the subalpine species (admitting the difference of opinion as to the identity of the old and new world forms of *Juniperus Sabina* and *communis* a few may be cited as having general circumpolar distribution in the pre-glacial period. Probably a considerable number of plants may be regarded as indigenous to the northern Rocky Mountain region since the glacial period. Certain species considered by some to be transcontinental are by others divided into two or more species with lesser ranges contiguous or overlapping; without considering the merits of these distinctions it suggests the possible origin of new species from the invading stock.

As to whether a species is immigrant or indigenous is often difficult or impossible to determine. In some cases it may be apparent from geographical evidence that a species has entered from a contiguous or distant area, but in others it may appear to have originated within the area, and if so the question of interest is the identity of the parent race or species, a fact which may be suggested by a comparison with associated or neighboring species, but which, if at all susceptible of proof, can be determined only by detailed structural comparisons or by experimental means. In this paper such conclusions as may reasonably be drawn from geographic evidence or other external facts will be presented, but with appreciation of the uncertainties involved.

With reference to the geographic evidence it would seem that at least three considerations may be recognized. (1) The edge or limits of the range of any species may fall within the region under examination and if so its source may logically be referred to the center from which it seems originally to have emerged. Southward extensions along the Rocky Mountains of boreal transcontinental species, or western margins of the ranges of conspicuous eastern or middle states species lying along the eastern base of the Rocky Mountains or eastern margins of ranges in the case of typically Pacific Coast forms would be cases in point. (2) The degree of development of a species as representing the supposed center of its distribution. The Douglas spruce falls under this category. This species occurs in extraordinary vigor and abundance along the Pacific Coast west of the Cascades, whence it seems to have emerged eastward until it has found its effective barrier in the plains between the Rocky Mountains and the Mississippi River. While this is not usually a safe argument in view of the well known facts of the luxuriance of many introduced forms in various parts of the world, it seems more logical in the case of naturally developed species in their proper ranges to view them as indigenous to the regions of their greatest and most varied development. (3) The geographic center in which the genus or family are conspicuous or characteristic may be regarded as the source from which the outlying species have emerged. The cacti and yuccas of the

Southwest and the Mexican Plateau may be regarded as examples. The representatives of these groups in the Montana flora can be regarded only as having a southern origin. With such points in mind a grouping of species is attempted according to the sources from which they seem to have migrated into the northern Rocky Mountains.

The following species mostly have a northern transcontinental range and appear to have moved southward along the Rocky Mountains into Montana and in some cases far beyond:

**Juniperus communis*
* " *Sabina*
Populus tremuloides
" *balsamifera*
Salix cordata
" *chlorophylla*
" *fluviatilis*
" *Bebbiana*
" *Barclayi*
" *pseudomyrsinites*
Betula papyrifera
**Alnus incana*
Ribes lacustre
" *hudsonianum*
Rubus strigosus
Rosa acicularis
Dasiphora fruticosa
Elaeagnus argentea
Lepargyraea canadensis
Rhus glabra
Rhamnus alnifolia
Cornus stolonifera
" *canadensis*
Andromeda polifolia
**Arctostaphylos Uva-ursi*
Chiogenes hispidula
**Vaccinium uliginosum*
" *caespitosum*
" *ovalifolium*
Sambucus racemosa
Symphoricarpos pauciflorus
Lonicera involucrata

There is, of course, no barrier to the southward movement of species along this highway through the region here under consideration. Five of the above species (marked *) occur around the world in the northern hemisphere. Most of the others are middle or northern Atlantic Coast or eastern species which apparently have extended their ranges far to the northwest, passing north of the Great Plains to the Rocky Mountains and thence southward; some are extensively distributed from the coast of New England and Labrador to Alaska.

The following have entered Montana and the Rocky Mountains from the east:

Populus angustifolia
" *Sargentii*
Salix pedicellaris
Prunus americana
Acer Negundo
Sambucus canadensis

Salix candida *Symphoricarpos orbiculatus*
" *amygdaloides* *Fraxinus lanceolata*
Ribes americanum

Bessey (3) concluded from a study of the trees of Nebraska that most of the species had entered that state from the southeast, influenced largely by the direction of the prevailing winds in the spring and early summer. The cottonwoods, two willows *(S. amygdaloides* and *fluviatilis)* and the boxelder were included in his list. *Populus Sargentii*, which by some authors is considered as at best only a variety of *P. deltoides*, is continuously distributed along all the bottom-lands of the Missouri and the Yellowstone and their tributaries, and evidently has followed up these streams from the lower regions to the southeast. The favorable conditions which woody species usually find on river bottoms and the continuity of such conditions along the many drainage channels across the plains should have provided a larger representation of such species in the Montana flora. The low relative humidity of the plains and the desiccating winds that sweep across them serve apparently as effective preventives of any departure of woody plants from the lower and more favorable levels. The tops of the cottonwoods along the upper tributaries (16) are distorted and repressed as they reach above the protection of the bordering benches. The matter of atmospheric humidity is as important for certain trees as the matter of soil moisture, and specific requirements must be met in one condition as well as another. Whether this is the determining factor or not in this case is impossible to say without further study, but for various reasons it seems probable. *Prunus Americana* is reported only from the eastern part of the state, and on uncertain authority as far west as the Bearpaws, south of Havre. The ash *(Fraxinus lanceolata)* probably occurs sparingly in the eastern end of Montana.

As the western or Pacific slope of the divide is the more favorable for forest growth and is tenanted by a greater variety of species, it naturally follows that the western element is the most conspicuous in the forest flora of the Rocky Mountains. On this point several considerations should be noted. Aside from the more favorable climatic conditions enjoyed by this region, its more ample precipitation, its higher relative humidity and more moderate winds. there is also an historical reason in the events subsequent to the glacial period. The more varied topography of the Pacific Slope from the mountains to the coast furnished conditions of greater diversity and thus more favorable for varied vegetation. Bodies of water formerly occupied areas now sparsely timbered or prairies and these must, at least during the time of their subsidence, have offered conditions more favorable for the existence and the movements of arborescent species. The distance to be covered, no less than the character of the intervening country, has doubtless been a factor, for the distance from the Cascades to the Rockies is less than half of that across the plains eastward from the summit. and the time necessary for movements would have been correspondingly less even if topographic conditions had been equal. Furthermore the direction of the prevailing winds favor the eastward migrations. It is significant also that of the 63 species enumerated below as having entered from the west 27 have seeds winged or otherwise more or less fitted for wind dispersal, 21 bear succulent fruits with small seeds, such as may be carried readily by birds. The others have small or minute seeds. There are no heavy seeded species, unless the whitebark pine is excepted, and the seeds of this tree are eagerly sought by squirrels, birds and other forest animals. There are, of course, few heavy seeded species on the coast in neighboring latitudes. According to all reports no oaks have yet reached Montana either from the west or the east, although they occur in Wyoming.

Following is a list of the species which have entered the Rocky Mountains from the west or northwest:

*_Pinus contorta_
‡_Pinus monticola_
“ _albicaulis_
Larix occidentalis
‡_Larix Lyallii_
*_Pseudotsuga taxifolia_
‡_Abies grandis_
‡_Tsuga heterophylla_
“ _Mertensiana_
*_Picea Engelmannii_
‡_Thuja plicata_
‡_Betula occidentalis_
* “ _fontinalis_
“ _alaskana_
“ _glandulosa_
*_Alnus tenuifolia_
*_Odostemon Aquifolium_
*_Ribes cereum_
*_Philadelphus Lewisii_
‡_Spiraea Douglasii_
‡_Holodiscus ariaefolius_
*_Rubus parviflorus_

#Taxus brevifolia
#Populus trichocarpa
**Salix fluviatilis* [1]
" *melanopsis*
" *exigua*
" *argophylla*
" *Mackenziana*
" *vestita*
" *sitchensis*
" *Geyeriana*
" *Scouleriana*
" *bella*
" *glaucops*
#Rhamnus Purshiana
#Echinopanax horridum
#Cornus Nuttallii
Ledum glandulosum
#Rhododendron albiflorum
Phyllodoce empetriformis
" *glandulifera*
**Menziesia ferruginea*
Rosa nutkana
" *pyrifera*
" *gymnocarpa*
**Amelanchier alnifolia*
**Crataegus Douglasii*
Sorbus scopulina
**Prunus demissa*
Prunus emarginata
**Pachystima Myrsinites*
**Rhus Rydbergii*
Ceanothus velutinus
" *sanguineus*
Kalmia microphylla
Cassiope Mertensiana
#Gaultheria humifusa
Vaccinium occidentale
* " *membranaceum*
" *oreophilum*
" *scoparium*
Symphoricarpos vaccinioides

The species listed above vary widely both as to their abundance and as to the extent of their areal distribution. Some (marked *) are found generally distributed throughout the region under discussion in their appropriate altitudes. Those marked (#) are either rare or uncommon, confined to the localities or altitudes suited to their peculiar demands, which in

---

[1] According to Bebb (Bot. Gaz. 102-108. Ap. 1891), the group *Longifoliae*, to which belong *Salix fluviatilis*, *S. melanopsis*, *S. exigua*, and *S. argophylla*, "is distinctly American, clearly defined on every side, shading off into no other by variation, hybridizing with none. It is not connected with the Old World forms by any synthetic type of the present or of any preceding period, but apparently was derived from the Mexican Plateau at the close of the Tertiary. In keeping with this view it finds its fullest development and greatest variation in form and structure on the Pacific Slope. Eastward it declines in vigor and variability until on the Atlantic Coast it is of rare occurrence from New Brunswick to the Potomac." Taking this view into account, there is some doubt as to whether the species named should be regarded as coming from the south or west. Considering, however, that the group is most fully represented today in numbers and forms in western Oregon and Washington, it seems most probable that they have come into our region from that source and are so listed.

all but a few cases means mesophytic conditions, or they are found only along the western boundary of the State. The other species are more or less abundant locally but have no very wide range, or they may be sparingly and uniformly scattered over the area.

The number of Pacific Northwest species increases with the distance westward from the Divide. As nearly the whole of Montana west of the Range is drained by the Clark's Fork of the Columbia and its several main affluents, the Flathead, the Bitter Root, the Blackfoot, and the Hellgate (the upper continuation of the Clark's Fork and now known by the same name), the region falls naturally into four divisions corresponding to these main drainage basins. Of the two most westerly, the Flathead lying to the north and the Bitter Root to the south, the Flathead presents the most humid conditions and contains the largest number of western species. The Bitter Root, on the other hand, is the least humid and presents fewer mesophytic situations. It lies in the rain shadow of the Bitter Root Mountains. Only in the passes and the deeper gorges of this range are mesophytic conditions found and in these some of the moisture loving species appear, but most of them are excluded by the high barrier to the west.

In discussing the topography it was pointed out that a high mountain barrier extends along the western border of Montana, except where the Coeur d'Alene Range interrupts the higher elevations with a broad plateau-like formation, dissected into numerous canyons and relatively low summits. Just north of this lies the channel of the Clark's Fork bearing all the waters of the Continental Divide over a distance of 300 miles of its western slope. North of this the high ranges again arise, extending far to the north. The Coeur d'Alene Range is occupied by nearly all of the species above ascribed to western origin (30) possibly excepting Lyall's larch and others ordinarily found only on the highest elevations. It is evident that this range is the main highway for the Pacific species into western Montana. The configuration of the land, its low altitude, its proximity to the lake region of northern Idaho, all serve to make this range at once a convenient harbor and highway for the more tender mesophytic species of the Humid Transition. These species ascend the western slopes of the Bitter Roots but usually fail to get over, and again to the north the region is inhospitable on account of its altitude in some places and in others on account of greater aridity.

Some of the species apparently have come into Montana from the northwest along the Rocky Mountains. Some have a distribution from Alaska to Oregon and in the Rockies to Montana or Wyoming. Others seem to have made their way across from the coast by way of the Okanogan country and the Selkirks. Shaw (57) found in the Selkirk Range most of the species listed above. It is not improbable, as already stated, that formerly conditions were much more favorable for a direct eastward migration across the inland basin which now would be impossible.

Certain species in this eastward migration have moved onward across the main range of the Rockies. The Continental Divide in its general course and altitude has been discussed under topography. It constitutes the main barrier between the eastern and western floras. Many species, however, have crossed it both from the east and the west. In many places, up to 7000 feet or more the crest is wooded, sometimes with dense forests, more often with scattered pines and junipers, and here and there a bleak, wind-swept, rocky ridge, tenanted only by low, caespitose perennials of xerophytic habit and structure. While the ridge is not uniformly high, the greater part of its length in Montana is 7000 feet or more in elevation, dropping in some of the passes to less than 6000 feet. These gaps, however, are not wide and climatically are quite different from the Coeur d'Alenes farther west. They share in large measure the rigors of the winters which are long and severe in the neighboring heights. At these elevations the summers are short and the growing season two to three months, with great diurnal range of temperature and with nights frequently marked by heavy frosts. The snow usually disappears during the summer except in patches on sheltered north slopes, or in the glaciers which occupy some of the high depressions in the northern ranges.

Plants are abundant and over most of the high slopes vigorous, during the short season allotted to them, but on the whole the region of the high divide is inimical to many species and in general an effective barrier to eastward and westward movements. It is interesting, however to note how many of those plants among the herbaceous perennials which flourish in such numbers in the high mountain parks are conspicuous elements in the spring floras of lower altitudes, and in some species almost to sea-level. Still other factors besides those of altitude and length of the growing season figure in determining the range of these plants and such are found in their moisture requirements and the trying conditions which at all times beset the crest of the main Divide and all exposed places in its immediate vicinity.

The continental crest in itself is hardly a barrier of sufficient height to prevent transmigrations. Flanked, however, as it is by massive ridges and high parallel ranges, its effect is reinforced by repetition. The topography offers a succession of parallel ridges rising on both sides to the main Divide. These cut by valleys would have even less effect individually as barriers, but they serve to increase the mass elevation and contribute to the general effect upon the climate over a region 250 to 300 miles from east to west, and north and south for some distance beyond the limits of the region here under discussion. The proximity of surrounding peaks has of course a marked influence on temperature, humidity and precipitation and consequently upon the flora of localities, themselves not of great elevation.

The following species of eastern origin have reached the western slope:

Populus tremuloides	*Salix cordata*
Salix candida	*Ribes americanum*
" *amygdaloides*	*Symphoricarpos orbiculatus*

It is probable that some of the species have traversed the Rocky Mountain barrier in many places. In the case of transcontinental species in the north their southward extension has doubtless followed along both slopes of the Divide and wherever else suitable conditions offered.

Those of western or southwestern origin which have reached the eastern slope or the plains are listed below. Some of these have extended their ranges much further than others.

Pinus contorta	*Ceanothus velutinus*
Pseudotsuga taxifolia	*Ledum glandulosum*
Picea Engelmannii	*Phyllodoce empetriformis*

Salix Mackenziana
" *exigua*
" *Scouleriana*
" *glaucops*
Betula fontinalis
Odostemon Aquifolium
Rubus parviflorus
Amelanchier alnifolia
Crataegus Douglasii
Prunus demissa
Pachystima Myrsinites
Rhus Rydbergii
Phyllodoce glandulifera
Menziesia ferruginea
Kalmia polifolia
Cassiope Mertensiana
Gaultheria humifusa
Vaccinium membranaceum
" *oreophilum*
" *scoparium*
Artemisia camporum
" *frigida*
" *cana*

The following species seem to have entered from the southern Rockies or the Great Basin:

Yucca glauca
Atriplex truncata
Sarcobatus vermiculatus
Eurotia lanata
Grayia spinosa
Ribes aureum
Rosa Fendleri
" *ultramontana*
Cercocarpus ledifolius
" *montanus*
Purshia tridentata
Amelanchier oreophila
" *utahensis*
Opuntia polyacantha
Mammillaria missouriensis
" *vivipara*
Gilia pungens
Sambucus glauca
Aplopappus suffruticosus
Tetradymia canescens
" *spinosa*
Chrysothamnus nauseosus
" *viscidiflorus*
Artemisia tridentata
" *spinescens*

Yucca is a common plant in many localities on the plains of eastern Montana. It is usually found on the slopes of the foothills or benches. On the other hand *Opuntia polyacantha,* also plentiful in the same region, is more abundant on the low flat benches. The most interesting species in the above list is the mountain mahogany, *Cercocarpus ledifolius,* which is found as far north in the Rocky Mountains as Helena. It is plentiful about the head of the Bitter Root Valley where it has apparently arrived from the hills of southern Idaho across the Bitter Root Range. *Purshia* probably came from the same source but is somewhat more widely distributed through the Bitter Root Valley and sparsely farther north in the Flathead Valleys and elsewhere. Both of these occupy the highlands, the former the higher rock outcrops, the latter the more gentle southern and western slopes of the foothills.

In addition to the species discussed above there remain a number of woody forms as to the origin of which there seems to be no evidence. Some of these doubtless are indigenous to the region under discussion, others, as Harshberger suggests, may be descendants of species which at some past time had a much wider distribution in the same region.

CHAPTER IV.

General Forest Aspects.

THE forests of Montana cover about one-third the area of the State, or nearly 50,000 square miles. Over much of this area the landscape is diversified by alternate forest and prairie, and the forests, thus divided, extend further east and west and reach to farther limits than the statement in square miles would imply. The forests are continuous for considerable distances only, as a rule, above certain altitudes (4000-5000 feet); below this forests and prairies alternate. The western end of the state, owing mainly to climatic conditions, is far more heavily timbered than the part east of the Continental Divide. From the western boundary eastward the forests in the southern part of the state become gradually more open; in the northern part their volume is better sustained. The rainfall is much heavier in the northwestern part than in the southwestern and the forest development proportionately greater. It presents on the whole a more rugged topography and a greater variety of exposure and shelter. The heavier precipitation is reflected in the drainage and the frequent lakes, springs and streams provide the mesophytic conditions requisite for heavier forests and a greater variety of species. Prairies are smaller and less numerous and continuous forests occur at lower levels, at 4000 feet and above.

In the southwestern part of Montana the lower margin of the continuous forest is at least 1000 feet higher than in the north. About the head of the Bitter Root, the Jefferson and the Big Hole the grasslands may extend in some places to 6000 feet or even more. The topography is less rugged, the country much drier, and the forests accordingly more open. The forest here is sufficiently open to admit grasses and other herbaceous plants. The number of shrubs, however, is much less than in the north, both as to species and individuals.

Throughout the region coniferous vegetation is dominant. Yellow pine and Douglas spruce are the prevailing species over the greater part of the region, as seen from the highways. Broad leaved, deciduous vegetation, is dominant, as a rule, only along the bottom lands and stream banks. It is hardly too much to say that in these places nine-tenths of the forest consists of the species of *Populus, Salix, Alnus* and *Betula*. On the western slope *Populus trichocarpa* is the only large cottonwood of the river bottoms. It is usually accompanied by *Alnus tenuifolia* and *Betula fontinalis*. These three species are found along every stream on the western slope. Along with these, usual or frequent, are *Populus tremuloides, Salix cordata, S. fluviatilis, Cornus stolonifera*, etc.

On the eastern slope and the plains the bottomlands are commonly covered with *Populus Sargentii*, accompanied more or less frequently by *P. tremuloides, Salix fluviatilis, Betula fontinalis, Amelanchier alnifolia, Acer Negundo, Lepargyraea argentea*, etc.

As to the upper limit of tree growth there seems to be no clearly defined timber line except such as may be due to the desiccating influence of wind. Only the crests are usually bare or occupied by stunted pines, spruces or firs and this way occur at relatively low altitudes of 6000-7000 feet, while on neighboring mountains of greater elevation forests may be found extending much higher up the slopes. Other factors, like the steepness and ruggedness of the land have much to do with the matter of forest occupation both as to moisture and as to foothold. Consequently high and pinnacled crests like the southern peaks of the Mission Range, the Bitter Roots from St. Mary's Peak to the Nez Perce Pass, the precipitous declivities of the main range of the Rockies from Glacier Park to Lewis and Clark Pass, the high summits south of Georgetown, all are barren, due in part to their elevated exposure and to the inhospitable character of their surface. Elsewhere the high elevations of rounded contour are forested sometimes by pines, firs or spruces, sometimes by an open stand of Rocky Mountain juniper *(J. scopulorum)* as shown near the Mullan Pass and the Continental Divide southeast of Butte.

The principal trees in the forests west of the Divide are *Pinus ponderosa, P. contorta* and *P. albicaulis, Larix occidentalis, Pseudotsuga taxifolia, Picea Engelmannii, Abies lasiocarpa*, and *Juniperus scopulorum*. Locally *Pinus monticola, Tsuga hetero-*

phylla, Abies grandis and *Thuja plicata* are important, but these are confined to relatively narrow areas. Among the rarer or less important gymnosperms may be included *Larix Lyallii, Tsuga Mertensiana, Juniperus scopulorum, J. communis,* and *Taxus brevifolia.*

East of the main Divide the forest is more open and assumes a more xerophytic aspect. In the more sheltered canyons good forests are developed, but along ridges and slopes, more or less exposed, the trees straggle out in open stands, with lessening frequency as they descend to the foothills and plains. The number of species diminishes also and only the more hardy are represented. The following are the more common trees on the eastward slope of the Rockies and the outlying ranges. *Pinus flexilis, P. contorta, P. ponderosa, Pseudotsuga taxifolia, Juniperus scopulorum, Picea Engelmannii and Abies lasiocarpa. J. communis* and *J. Sabina* also occur, the latter more or less common on prairie slopes. The spruce and fir are confined to the higher elevations; the most common trees at low elevations and about the foothills are the yellow pine, the Douglas spruce and the Rocky Mountain juniper. These are usually present on the bluffs and along the rim-rock at the margins of the valleys of the Yellowstone and the Missouri and their countless tributaries over most of Montana down to the eastern boundary. The higher elevations of land known as the Crazy Mountains, the Snowy Range, the Bear Paws and the Pryor Mountains, and others all support forests of some or all of the above species in greater or less numbers and sizes. However, the forests as such are found only on the mountains and become less and less frequent eastward until the Black Hills are reached. The following summary presents the usual distribution of the species and their approximate altitudes in different parts of the state.

In considering the problem of forest distribution it is essential to determine as far as possible the relative abundance of the constituent species and the place which each occupies in the composite formations of which it is a part. It is likewise important to determine the areas occupied by the several species and to relate the species wherever possible to their controlling factors. In connection with the facts of horizontal extension the altitudinal distribution also claims attention, especially in a region where

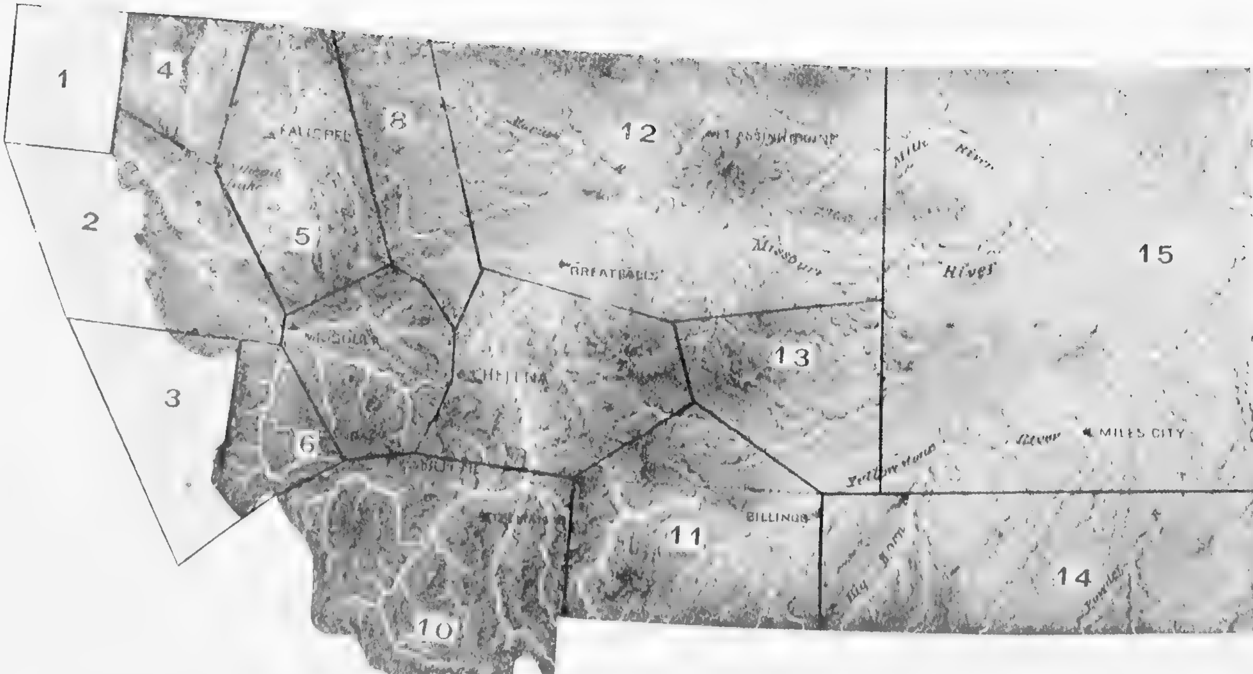

Fig. 12. Forest sectional areas in the northern Rocky Mountains. 1. Priest Lake Section. 2. Coeur d'Alene. 3. Clearwater. 4. Kootenai. 5. Flathead. 6. Bitter Root. 7. Hellgate. 8. Sun River. 9. Belt. 10. Three Forks. 11. Absaroka. 12. Bearpaw. 13. Snowy. 14. Bighorn. 15. Missouri. Sections 7 and 9, unmarked, are northeast of 6 and northwest of 11 respectively.

differences in altitude are so pronounced and where soil and climatic conditions present wide variations.

The facts of horizontal and vertical distribution are presented from various sources,* with data on the relative importance of the various species. By this means it is hoped to present a conception of the forest as it appears in different parts of this region. It is admitted that the data here assembled can be interpreted only in the most general way. The figures on percentages are to be taken merely as indicators of the approximate proportions of the species in the forest covering of the area in question, and not as an accurate final result. The extent of the area and the extent of the work involved must entail a large probability of error. The figures presented below, however, point to safe conclusions as to the facts of general distribution, which is the purpose of this paper, and from this standpoint it is doubtful whether any further refinement of the percentage data would be either necessary or profitable.

A study of the forests of the northern Rockies brings into view certain aspects of their composition and distribution related to particular topographic and climatic conditions of the different geographic units or sections which they occupy. For convenience, therefore, as well as for conformity with the points of ecological significance the area will be considered by sections determined in accordance with certain physiographic features which either individually or in groups seem to stand in some important relation to the flora. Fifteen such sections are recognized. The first three lie in adjacent parts of Idaho, the forests of which, in their composition, should be considered in connection with those of Montana, as in fact being in large degree the immediate source from which many of the species have found their way eastward into the higher mountains and valleys. The sections are numbered from the west and will be discussed in the same order. They are named for some significant physiographic feature. See Figure 12.

The first or Priest Lake Section occupies the panhandle of Idaho and includes the drainage of the Priest River and the Kootenai in Idaho. It extends from the international boundary

* The writer wishes here to acknowledge with thanks the generous cooperation of the officers of the Forest Service in District 1, who supplied much of the information essential to this discussion.

southward to include the southern arm of Lake Pend d'Oreille. It includes some of the most mesophytic conditions of the region. A survey of the forest of this section gives the following data:

Table 9. Forests of the Priest Lake Section.

Species	% Composition	Range of Altitude
Pinus monticola	21-30	2000-5000
" *ponderosa*	7-10	2000-4000
" *contorta*		2000-6000
" *albicaulis*		6000-7000
Larix occidentalis	18-20	2000-5500
Picea Engelmannii	20-25	2000-7000
Tsuga heterophylla	5-	2000-4500
Pseudotsuga taxifolia	8-15	2000-6000
Abies grandis	5-	2000-5500
" *lasiocarpa*		5000-7000
Thuja plicata	9-10	2500-5500
Juniperus scopulorum		3000-5000
" *communis*		4000-6000
Taxus brevifolia		2500-5000

The forests of this section vary from open stands of yellow pine and Douglas spruce in some localities, or in others of typical forests of lodgepole, to the heavy forests of white pine, hemlock and grand fir, such as may be found along the bottoms of Priest River. In this stand is a copious undergrowth of young hemlock and arborvitae, but in many places the forest is too dense to support more than a light undergrowth of broad-leaved shrubs.

The second section, here designated as the Coeur d'Alene, lies southeast of the first. It extends for about 130 miles in length and from 50 to 75 in breadth. It lies about equally in Montana and Idaho, across the Coeur d'Alene Range. It includes on the western side the drainage of the Coeur d'Alene and St. Joe rivers in Idaho, and on the Montana side the lower valley of the Clark's Fork and reaching to the summits of the Cabinet Mountains and Evaro Pass. Its southeastern corner lies near Missoula at the junction of the Bitter Root and the Clark's Fork rivers. This area, as discussed above, is notable for the richness of its flora. It includes the only stations thus far reported for *Tsuga Mertensiana* in this region, and in shrubby and herbaceous forms alike is of marked interest. In this section the species appear distributed as follows:

Table 10. Forests of the Coeur d'Alene Section.

Species	% Composition	Range in Altitude
Pinus monticola	2-36	2100-5000
" *ponderosa*	2-25	2100-5000
" *contorta*	2- 7	2100-7500
" *albicaulis*		4500-7000
Larix occidentalis	6-24	2100-6000
" *Lyallii*		7000-8000
Picea Engelmannii	2-11	2500-5500
Tsuga heterophylla	7	2100-5500
" *Mertensiana*		4000-7000
Pseudotsuga taxifolia	13-25	2100-7000
Abies grandis	-12	2100-5000
" *lasiocarpa*	1-	4000-7000
Juniperus scopulorum	5-15	2100-5500
Thuja Plicata		3000-5000
" *communis*		4000-6000
Taxus brevifolia		2100-5000

With referenec to the differences of percentage composition and altitude some of the facts are worthy of comment. Nowhere is the influence of a mountain range more evident. The Coeur d'Alene section as above described is traversed by a watershed of some 5000 to 7000 feet elevation, extending from northwest to southeast. To the north east flow numerous lesser affluents of the Clark's Fork on the Montana side, to the southwest on the Idaho side the St. Joe and the Coeur d'Alene rivers flow to Lake Coeur d'Alene. This ridge lies squarely across the path of the rain-bearing winds with the result that the precipitation is greater on its western slope. This, together with the greater relative humidity of the lake region supplies the requisite conditions for the growth of the white pine and the species usually associated with it. On the western slope the white pine may reach as much as 36% of the stand, while on the east it is estimated at about 2%. *Abies grandis* forms 12% on the western slope and a negligible amount on the eastern. *Thuja plicata* forms 15 % on the western slope, 5% on the eastern. *Tsuga heterophylla* forms 7% of the stand west of the ridge and a negligible amount on the eastern side. Similarly Engelmann spruce favors the western slope. On the other hand *Pinus ponderosa, Larix occidentalis* and *Pseudotsuga taxifolia* are far more heavily represented on the eastern side than on the western, forming respectively 2, 6, and 13% per cent on the western side, as against 25, 24 and 25% on the drier eastern slope.

Another feature of the difference is in the vertical distribution of the species. On the western side the lower limit of distribution is from 700 to 1000 feet below that of the eastern and the upper limits from 500 to 2000 feet lower. It is noticeable also that certain species like the grand fir and western hemlock are confined to a much narrower vertical range on the eastern than the western slopes, falling within a zone of 1000 to 1500 feet in the former and of about 3000 feet in the latter case. These facts can only be interpreted in terms of the moisture conditions and the lower limits of temperature encountered at the higher altitudes. Several species listed in the table were not of sufficient importance to merit calculation as to their quantitative relations in the forest.

The third or Clearwater section lies on the western slope of the Bitter Root Range and embraces the drainage of the upper branches of the Clearwater, its North, Middle and South Forks. The area reaches the summit of the Bitter Root divide on the east and covers about 100 miles from north to south and from 40 to 60 east and west. The course of its principal streams is mainly westward to a junction with the Snake River.

In its northern part the forest vegetation is more nearly related to that of the western slope of the Coeur d'Alenes. The white pine, arbor vitae grand fir and Douglas spruce are the dominant species. In its southern part these species appear very sparingly, and the dominant species are yellow and lodgepole pines and Douglas spruce. In this part the climatic conditions are merging into those of the arid plains of the Snake Valley. The marked variations in the percentage of different species will thus be interpreted accordingly.

Table 11. Forests of the Clearwater Section.

Species	% Composition	Range in Altitude
Pinus monticola	30	1800- 6000
" *ponderosa*	2-25	1700- 7500
" *contorta*	7-40	2500- 9500
" *albicaulis*	1	5000- 6500
Larix occidentalis	7	3000- 5000
" *Lyalli*		7000-10000
Tsuga heterophylla	3	5000- 6500
Picca Engelmannii	5- 6	2000-10000
Pseudotsuga taxifolia	14-20	1800- 7000
Abies grandis	2.5-13	2000- 5500
" *lasiocarpa*	2	4000-10000
Thuja plicata	14	1800- 5000
Juniperus scopulorum		2000- 5000
" *communis*		
Taxus brevifolia		2000- 4000

Here also in the southern and drier part of the section the various species are found at correspondingly greater elevations.

In the first three sections which cover an area 60 miles or more in width from the Canadian boundary to the Salmon River, a distance of about 250 miles are represented the forests of northern and northeastern Idaho lying adjacent to Montana. This constitutes the White Pine Belt of the Rocky Mountains. With the white pine are the species usually associated as mentioned above and the strip is favored with more ample precipitation and higher relative humidity than the areas lying farther to the east. Although the species typical of this belt do occur in the sections subsequently to be treated they are not except in localities, a dominant feature anywhere over large areas. These conditions are almost entirely limited to the valleys of the Flathead and the Kootenai.

The Kootenai Section, No. 4, covers the area drained by the Kootenai River in Montana, about 3200 square miles. This river crosses the international boundary and enters Montana near the 115th Meridian, flows south about 50 miles and turning sharply to the northwest, recrosses the boundary about 60 miles west of its first crossing. The southern boundary of this section is the summit of the Cabinet Range, the eastern the divide between the Kootenai and the Flathead, sometimes known as the

Flathead Mountains. The Cabinet Range rises, especially at its eastern end to heights of 8000 to 9000 feet, rugged and picturesque. The Flathead Mountains are lower. In the bend of the Kootenai lies the Purcell range, only its southern end reaching into Montana. The range is fairly even in height except a group of sharp summits which rise to 7500 feet near the southern end of the chain.

Table 12. The Forests of the Kootenai Section.

Species	% Composition	Range in Altitude
Pinus ponderosa	9	1900-5000
" *monticola*	5	2200-4000
" *contorta*	17	1900-6000
" *albicaulis*		5000-7000
Larix occidentalis	21	2000-4000
" *Lyallii*		7000-7500
Picea Engelmannii	21	2000-7000
Tsuga heterophylla	14	3000-4000
Abies grandis	14	3000-4000
" *lasiocarpa*		2200-7000
Pseudotsuga taxifolia	18	1900-5000
Thuja plicata		2200-3000
Juniperus scopulorum		
" *communis*		
Taxus brevifolia		

Most of the Kootenai section is heavily forested. In the narrower valleys, on low flats and about lakes are suitable conditions for the white pine, arbor vitae, grand fir and hemlock, on some of the upper benches are extensive pure stands of lodgepole pine, sometimes of young larch. The hills are often covered with open growths of yellow pine.

The fifth, or Flathead Section, covers the drainage of the Flathead River, including the North, Middle and South Forks and the Swan river. It extends its northern line 60 miles along the Canadian boundary and reaches south 180 miles to the extreme sources of the South Fork. Its western margin joins the Kootenai Section, its eastern follows the crest of the Continental Divide. It includes a part of Glacier National Park. The Flathead Section is one of the most significant of Montana, both in its topography and its vegetation. It includes several high and rugged mountain ranges, some of them bearing glaciers. The marks of previous glaciation are extensive and conspicuous. Numerous lakes, large and small, are fed by cold mountain streams, many of which flow from glaciers or perpetual snows. There are many cirque basins occupied by deep, cold and dark waters and fringed by forests of fir and spruce.

Table 13. Forests of the Flathead Section.

Species	% Composition	Range in Altitude
Pinus monticola	3.5-11	3000-5000
" *ponderosa*	2.0	3000-4000
" *contorta*	1.0-14	3000-6500
" *albicaulis*	.5- 1	4000-7000
Larix occidentalis	35.0-50	3000-5000
" *Lyallii*		5000
Picea Engelmannii	20.0-23	3000-6000
Tsuga heterophylla	1	3100-
Pseudotsuga taxifolia	11.0-17	3000-6000
Abies grandis	1	3000
" *lasiocarpa*	1.0	3000-7000
Thuja plicata	17	3000-5500
Juniperus scopulorum		3000
" *communis*		3000-6500
Taxus brevifolia		3000-6000

In this section it will be observed that the white pine, grand-fir, hemlock and arbor vitae are still present but in greatly reduced amounts. Larch and spruce are the main species with lodgepole pine locally dominant. The white pine formation appears usually in the narrower valleys and canyons, protected from excessive influence of wind and sun. The essentially moist condition of the soil is maintained, and atmospheric moisture is relatively high. While the white pine is a less common tree than in some other sections, yet some of the largest trees are found, one on McDonald Creek in Glacier Park measuring seven feet in diameter. Hemlocks also reach a large development in Glacier Park, as in the case of a grove near Avalanche Basin, where some of the trees are three feet or more in diameter.

The ranges in altitude will be noted. In nearly all of the species the lower limit is near the lowest possible altitude in the section. The upper limit in some of these cases extends to the uppermost altitude habitable by trees. This range differs but little in different parts of the section.

The sixth section includes the Bitter Root Valley, an area of about 3000 square miles. It is bounded on the west by the summit of the Bitter Root Mountains and on the southeast it reaches to the crest of the Continental Divide. On the east its margin rests upon the top of the divide between the Bitter Root River and Rock Creek.

Table 14. The Forests of the Bitter Root Section.

Species	% Composition	Range in Altitude
Pinus ponderosa	32.0	3500-7000
" *contorta*	40.0	3500-8000
" *albicaulis*	.2	7500-8500
" *monticola*		
Larix occidentalis	.8	3500-5000
" *Lyallii*		7500-9000
Picea Engelmannii	1.6	3500-7500
Pseudotsuga taxifolia	24.2	3500-7000
Abies lasiocarpa		5000-8000
" *grandis*		4000-5000
Thuja plicata		4000-5000
Juniperus scopulorum		

It will be observed that the prevailing species in this section are those adapted to drier conditions, viz., the yellow and lodgepole pines and the Douglas spruce. All others are in a small minority. The species of the humid forests, the white pine and its associates, are now mostly confined to the upper canyons of the Bitter Root Range. This conforms exactly to the climatic conditions of the section. The Bitter Root Valley has an annual precipitation record of 10.71 inches, representing the average of a good many years of observation. This is a lower figure than is shown at most of the plains stations in eastern Montana. They are, however, the observations at only one station that of Hamilton near the center of the valley. It is easy to understand this condition since the whole valley is sheltered on the west by the lofty Bitter Roots, which effectually intercept the rain bearing western winds. The temperature of the Bitter Root Valley is, moreover, usually a little higher than that of the neighboring localities, which must further influence its water supply.

The lower limits of vertical distribution are considerably higher here than in the preceding sections, a fact correlated with the dryness of the region. The floor of the valley is almost devoid of the species cited and the foothills are mostly bare, rising to the scattering pines at about 3500 feet. The whole section is distinctly in contrast to the northern portion of Number 3 on the opposite side of the Bitter Root Range.

The Hellgate Section is the seventh of the series. It embraces the drainage basins of the upper Clark's Fork (formerly called the Hellgate) and the Blackfoot. On the east and south it reaches to the Continental Divide, which forms a huge arc about the heads of these streams and their principal tributaries. The western limit of this section is the Bitter Root Valley. The whole area is nearly 8000 square miles. It rises gradually to the eastward for about 80 miles, from an altitude of 3200 feet near Missoula to 6000 to 8000 on the crest of the Divide. It is a region of comparatively light rainfall and moderate temperatures. Prairie and forest alternate according to slope and exposure and the forest is often open and the trees of medium size. The upper valley of the Blackfoot widens out at 4000 feet into a broad basin twenty miles or more across, treeless and relatively arid. The upper Hellgate valley presents much the same appearance. Much of both basins is covered with glacial gravels, and drumlins are common especially in the valley of the Blackfoot. The grass range is extensive, and the rolling foothills gradually merge into the wooded slopes which extend from 4000 or 5000 feet to many of the high summits.

Table 15. Forests of the Hellgate Section.

Species	% Composition	Range in Altitude
Pinus ponderosa	3.5-	3500-7000
" *contorta*	-72	3500-9000
" *albicaulis*	1.0-	6000-9000
Larix occidentalis	5	3300-6000
" *Lyallii*		7000-8500
Picea Engelmannii	2.0- 3	3300-9000
Pseudotsuga taxifolia	15.0-23	3300-7000
Abies lasiocarpa	1.0-	3500-9000
Juniperus scopulorum		3300-5500
" *communis*		3400-5500

In the previous cases the percentage composition was in terms of volume estimates; in this it is in terms of the forested areas. In neither case does it give more than a general impression of the relative importance of each species. The figures on this area are with reference to the "type" as it is called by the Forest Service, which means practically the same as the terms society and association in the ecological sense, as where species in pure or mixed stands assume certain characteristic aspects under the control of climatic and physiographic influences.

In this case it will be seen that the leading species are lodgepole pine, Douglas spruce, larch and yellow pine. The larch is confined chiefly to the western side of the section, and to northern slopes and creek bottoms. The yellow pine, often mingled with Douglas spruce, occupies the southern slopes but with its lower limit at 4000 to 5000 feet elevation. The lodgepole is found in dense and extensive stand at high elevations along the main range of the Rockies. *Pinus monticola* and *Abies grandis* are rare in this section and are found only in isolated localities; however, limited stands of white pine are to be found, as in the upper end of the Blackfoot valley close to the Divide, on the Clearwater and elsewhere. Where the moisture is sufficient in the soil, that of the atmosphere seems deficient or the temperatures too low. For the most part this section seems to be beyond the easternmost limits of the white pine, grand fir, western hemlock, arbor vitae and western yew.

The eighth division of the Rocky Mountain forest will here be called the Sun River Section. Its western margin lies along the continental crest from the Canadian boundary to the 47th parallel in a strip 20 miles or less in width. It lies on the eastern slope of the Divide in the narrow timbered zone between the mountain ridge and the prairie foothills. Its northern portion includes a part of Glacier National Park. The Sun River Valley is heavily timbered, but the Teton and Marias Rivers traverse elevated plains and prairies.

Table 16. Forests of the Sun River Section.

Species	% Composition	Range in Altitude
Pinus contorta	50	4000-8000
" *flexilis*	10	5000-8500
Picea Engelmannii	20	6500
Pseudotsuga taxifolia	15	7500
Abies lasiocarpa	4	8500

The above are the principal species found in this strip and their approximate proportions. The larch and whitebark pine are together reduced to about 1% of the entire stand. They are present only near the top of the Divide where they have dropped over from the western slope. It is probable that *Pinus ponderosa* is also represented, though sparingly, as well as small quantities of *Juniperus scopulorum, J. communis* and *J. Sabina.* The situation on the whole is one of low rainfall and of general difficulty for forest species.

The Belt Section (No. 9) extends from the top of the Continental Divide near the head of Clark's Fork eastward over 100 miles including the Big Belt and the Little Belt ranges. From north to south the area extends roughly from Great Falls to the Three Forks of the Missouri, about 120 miles. This section is very largely prairie. Only the higher elevations are wooded, so that the forest for the most part lies above 5000 feet. Besides the Belt Ranges are several other more or less elevated masses, the Highwood Mountains and the Little Rockies, which also are forested.

Table 17. Forests of the Belt Section.

Species	% Composition	Range in Altitude
Pinus contorta	56-84	5500-8200
" *ponderosa*	7-15	7500-8300
" *flexilis*		7500-8300
" *albicaulis*		7000-8300
Picea Engelmannii	2- 6	7000-8000
Pseudotsuga taxifolia	5-44	6000-7500
Abies lasiocarpa		7000-8300

The percentages here are in the area covered by the several species. The variations in the percentages indicate their relative importance on the different mountain ranges in this section. Leiberg (32) gives the volume per cent for the different species in the Little Belts as follows:

Pinus flexilis	8.2
" *albicaulis*	.009
" *contorta*	34.2
" *ponderosa*	.07
Picea Engelmannii	11.4
Pseudotsuga taxifolia	44.7
Abies lasiocarpa	1.4

In addition to the above species it is probable that *Juniperus scopulorum* and *J. communis* are likewise present. Isolated as most of the outstanding ranges are, the influence of the climatic conditions are readily felt, so that the lower timber line is fixed at elevations unusually high. In sheltered canyons and valleys, however, many of the species may descend to where they open out upon the plains.

The Three Forks Section (No. 10) is an area 140 miles from east to west and 100 miles in round figures from north to south. The westward direction of the Continental Divide from the vicinity of Butte, and its wide curve to the south and thence to the east to Yellowstone Park forms a huge embayment, drained by the three main sources of the Missouri, the Gallatin, the Madison and Jefferson rivers, which push their ultimate branches to the high walls of this huge amphitheater. The western portion of the basin is known as the Bighole, particularly that part drained by the Bighole River which is the main western branch of the Jefferson. The basin is traversed by several low mountain ranges, and in altitude most of its floor lies above 5000 feet. The country is largely prairie and only the highest elevations are forested and these with few species and comparatively meager growth. It is largely glaciated and climatically dry and cold.

Table 18. The Forests of the Three Forks Section.

Species	% Composition	Range in Altitude
Pinus ponderosa		5600- 6500
" *contorta*	60-75	5600- 8500
" *albicaulis*	14	7000-10000
" *flexilis*		7000-10500
Picea Engelmannii	4- 5	5500- 8500
Pseudotsuga taxifolia	20	5000- 8000
Abies lasiocarpa		7000-10000
Juniperus scopulorum		6000
" *communis*		

The forests are confined to higher elevations mostly above 6000 feet and consist mainly of lodgepole pine as the main zone, merging below into yellow pine and Douglas spruce and above into limber and whitebark pine, Engelmann spruce and alpine fir. In some places the lodgepole forest covers the Divide at 7000 feet. Only as the summits rise to greater heights does the character of their forest covering assume the aspect imparted by the spruces and firs, though in the sheltered canyons these genera may descend much lower.

The Yellowstone Section (No. 11) occupies the upper Yellowstone drainage in Montana. From the northwest corner of the Yellowstone Park it extends 120 miles along the southern boundary of Montana, and 100 miles to the north including the Crazy Mountains. In this section, covering some 10,000 square miles, are the highest peaks and some of the most rugged topography in Montana. From the Absaroka and the Beartooth ranges flow numerous streams northward to the Yellowstone River, which from the north gains a few affluents from the Crazy Mountains. To the west the Gallatin and Bridger ranges form the watershed between the upper Yellowstone and the Missouri, in altitude varying from 5000 feet in Bozeman Pass to 10,000 on some of the higher peaks. In the Absarokas the highest peak reaches nearly 13,000 feet.

The Yellowstone Valley is broad and treeless, except along the immediate stream bottoms. The coniferous vegetation occurs above 5500 or 6000 feet where a fringe of limber and yellow pine, Douglas spruce and juniper marks the lower edge of the forest. Between 6000 and 8000 feet the lodgepole pine forms almost the whole of the forest, but above 8000 feet gives place to white bark pine, alpine fir and Engelmann spruce. The upper timber line occurs at elevations of 9300 to 9800 depending on direction or exposure, though on the Beartooth Mountains toward the east it ascends in places to 11,000 feet. At the timber line Engelmann spruce is the dominant and most conspicuous species.

Table 19. The Forests of the Yellowstone Section.

Species	% Composition	Range in Altitude
Pinus ponderosa		5000
" *contorta*	50-60	6000- 8500
" *flexilis*		5000- 8000
" *albicaulis*		7500- 9000
Picea Engelmannii	15	6000- 9000
Pseudotsuga taxifolia	21-30	5000- 8000
Abies lasiocarpa		7000-10000
Juniperus scopulorum		7500

The above species are all represented in this section, though some of them very sparingly, and the yellow pine probably the least of all. The above figures were tabulated from Forest Service data and have the advantage of being the most recent obtainable. Leiberg, (31), however, gives a somewhat different and more detailed account as follows:

Pinus flexilis	2.3%
" *contorta*	45.6
" *ponderosa*	.005
" *albicaulis*	5.3
Picea Engelmannii	21.8
Pseudotsuga taxifolia	12.2
Abies lasiocarpa	11.1

In this estimate trees are considered of three inches basal diameter and upwards. Leiberg states that the lodgepole pine forms fully 75% of the forests below the subalpine zone, and even as much as 90% in its own proper belt above the lower fringe occupied by Douglas spruce and limber pine. Leiberg cites also the occurrence of *Pinus monticola* in one locality in the Absarokas but this is very doubtful, as it there would appear to be in a locality far removed from its known range and in the only position reported for it east of the Divide. As it is not now known to the Forest Service in that locality and as the conditions would seem to be so unlike those of its usual habitat, it would seem that Leiberg's report is in error on this point. Engelmann spruce and Douglas spruce are common trees throughout the section in their particular zones. Though the latter is limited to a lower belt, the former is found as low as 6000 feet and from there up to timber line.

The next is the Bearpaw Section (No. 12) including for the most part the Bearpaw Mountains and the Sweetgrass Hills, with altitudes of 6000, 7000 and 8000 feet respectively. These have scant forests of lodgepole and yellow pines, and Douglas spruce. Two junipers (*J. Sabina* and *J. communis*) occur in this region. This section covers about 20,000 square miles, extending along the northern boundary about 200 miles and southward about 100. It embraces a good deal of the Missouri Valley and the upper sources of the Milk River, besides portions of the drainage of the Marias and the Teton. It is mostly prairie with elevation ranging from 3000-4000 feet. The forests where present are found mainly above 5000 feet.

The Snowy Section (No. 13) is occupied mainly by the Snowy Mountains and the sources of the Musselshell River. Some of the peaks of the Snowy Range rise to an altitude of 8000 feet. They are in fact the farthest outpost of the high mountains in Montana east of the main Rockies. They, like the Crazy Mountains and the Belts, are forested only above 5000-6000 feet.

Only four species are here conspicuously represented. These are:

Pinus contorta	76. %
" *ponderosa*	13.5
Picea Engelmannii	6.5
Pseudotsuga taxifolia	4.

These figures, however, are for area covered and not for volume. It is probable also that *Abies lasiocarpa, Pinus albicaulis, Juniperus scopulorum, J. communis* and *J. Sabina* are sparingly represented.

The 14th, or Bighorn Section, covers a few forested areas in southeastern Montana. Various southern affluents of the Yellowstone, including the Bighorn and Powder rivers drain these hills which reach altitudes from 3000-3800 feet. Here also most of the country is prairie, but in the hills especially in the ravines and canyons the few forest species are distributed at all altitudes. On portions of this area the yellow pine (*P. ponderosa*) is reported as forming 95% of the stand and *Juniperus scopulorum* about 2%. *J. communis* is also reported.

In the 15th, or Missouri Section, no forests of any consequence occur. The margins of the benches above the river valley are occupied by a sparse growth of *Pinus ponderosa* and *Juniperus scopulorum* and the isolated elevations here and there are similarly wooded.

Reviewing the facts on general distribution as above stated, several conclusions are evident. In the first place the species decrease in numbers from the west toward the east, until of the fifteen or more gymnosperms of the Idaho forest only four or five appear near the eastern border of Montana. With the decrease in the number of species comes also a decrease in the volume of the forest. The same cause which limits the forest flora to the more resistant species likewise limits the volume production, viz., the lack of sufficient moisture. Again it will be noted that the altitudinal range of the species in most parts of the region is very wide. The influence which tends to narrow the vertical range of distribution is again the influence of scant rainfall and the other conditions which tend toward a xerophytic environment. Such influences not only narrow the vertical range, but push the lower limits of forest distribution further up the mountain slopes.

CHAPTER V

Forest Zones and Formations.

THE forests of the northern Rocky Mountains are included in the Hudsonian, Canadian and Transition zones of Merriam (43). Sometimes the Hudsonian and Canadian are called the supalpine and montane zones respectively (55). The Transition is confined mainly to the foothills, valleys and plains. The Upper Sonoran, if it extends into Montana at all, is confined to the lowlands and benches along the rivers in the plains and bears little relation to the forests. The zones as such, however, are more easily defined by given sets of conditions than by the species which are supposed to represent them, since few species are so clearly limited by temperature, either in latitude or altitude, as to be plainly identified with either zone. This is especially true with reference to the middle zones in this region, viz., the Transition, the Canadian and the Hudsonian. The upper Sonoran and the Arctic-Alpine, as representing the extremes of conditions, are the more clearly recognized by some of their species which, being at the extremes of their ranges, are mainly excluded from the other zones. Such are the Yucca and the cacti of the former and the dwarf willows of the latter, although even some of these may transgress their allotted limits.

Many plants which Cary (11) cites as marking the upper Sonoran of Wyoming occur in neighboring parts of Montana. Among these may be mentioned the following:

**Populus occidentalis (P Sargentii)*	*Yucca glauca*
" *acuminata*	*Opuntia polyacantha*
**Salix amygdaloides*	**Plantago Purshii*
" *fluviatilis*	**Artemisia tridentata*

Five of these, however, (*) are so widely distributed in Montana, and in such varied conditions, as far to exceed the possible limits of the Upper Sonoran Zone.

The Transition Zone is a belt of wide vertical range and diversity. It extends from the benches and plains at 2000 to 3000 feet to the level of continuous forest at 4000 to 6000. It may thus from one part of the region to another cover a vertical distance of 4000 feet. It is largely the foothill country, varying with exposure and location from arid to humid conditions, interrupted and divided here and there by descending extensions of the montane forests. In some places it is the bunchgrass *(Agropyron spp.)* or the bunchgrass and sagebrush *(Artemisia tridentata, A. cana, A. frigida, etc.)* or these merging into open stands of Rocky Mountain juniper, or yellow pine or Douglas spruce, or all of them intermingled. Again it appears in areas in composition similar to the Pacific Coast Humid Transition with hemlock, grand fir, arbor vitae, western yew and many other forms commonly found in the forests of the low lands of western Oregon and Washington. The humid forest is the more rare and is developed where neighboring areas are elevated to the degree necessary to induce condensations and abundant rain, where the valleys are not too wide and where the proximity of considerable bodies of water and the structure of the soil combine to afford the requisite conditions. These are forests of moderate or low elevations, 2000-4000 feet. The forests of the Transition alternate frequently with prairies and the vegetation of this zone extends in the southern part of Montana about 1000 feet higher on the mountain sides than it does in the north, reaching even to 6000 feet.

The forest of the foothills (Transition) merge gradually into those of the montane (Canadian) belt. Especially in the humid forest is the line of demarcation uncertain. Reference to the tables under the discussion of general aspects of distribution will show that in most sections the vertical range of many species may be 2000 to 4000 feet and in different parts of the state some species may be found at altitudes varying from 2000 to 9000 feet. The following figures indicate the approximate extent of vertical distribution of the species of gymnosperms within this region, as far as at present known.

Table 20. Ranges in Altitude.

Species	Minimum Altitude	Maximum Altitude
Pinus ponderosa	1,800	7,500
" *contorta*	1,900	9,500
" *monticola*	1,800	6,000
" *albicaulis*	4,000	11,000
" *flexilis*	3,000	10,500
Larix occidentalis	2,800	7,000
" *Lyallii*	7,000	10,000
Picea Engelmannii	2,000	11,000
Tsuga heterophylla	2,900	5,500
" *Mertensiana*	4,000	7,000
Pseudotsuga taxifolia	1,900	8,000
Abies grandis	2,000	7,000
" *lasiocarpa*	2,000	11,000
Thuja plicata	2,000	5,500
Juniperus scopulorum	1,900	6,000
" *communis*	3,000	6,500
" *Sabina*	2,500	4,000
Taxus brevifolia	1.900	5,000

The wide range in altitude of the species here indicated and the fact that at all elevations between 4000 and 6000 feet, within their range and habitat they are likely to be intermingled makes difficult the distinction between the Canadian and Hudsonian zones, or the montane and sub-alpine, if indeed there is any in this region. The term sub-alpine, when used herein, is intended to designate the forests immediately below the higher crests. The trees of this belt, however, have few species which do not descend to the foothills. The alpine fir, *Abies lasiocarpa,* is the most conspicuous tree at high elevations, but is commonly found in the canyons about Missoula at about 4000 feet and descends at least to 2000 feet along the Kootenai in Montana. The same may be said for the Engelmann spruce. The white bark pine, *(P albicaulis)* also a common timber line tree, is abundant down to 5000 feet in Glacier Park, and scattering individuals may be found occasionally in the valley of the Clark's Fork and its tributaries at 3500 feet or less. The only tree of this region which is confined to the highest elevations is Lyall's larch *(L. Lyallii)* but this species is found only in a part of the Bitter Root Range and along the highest summits of the main divide. The black

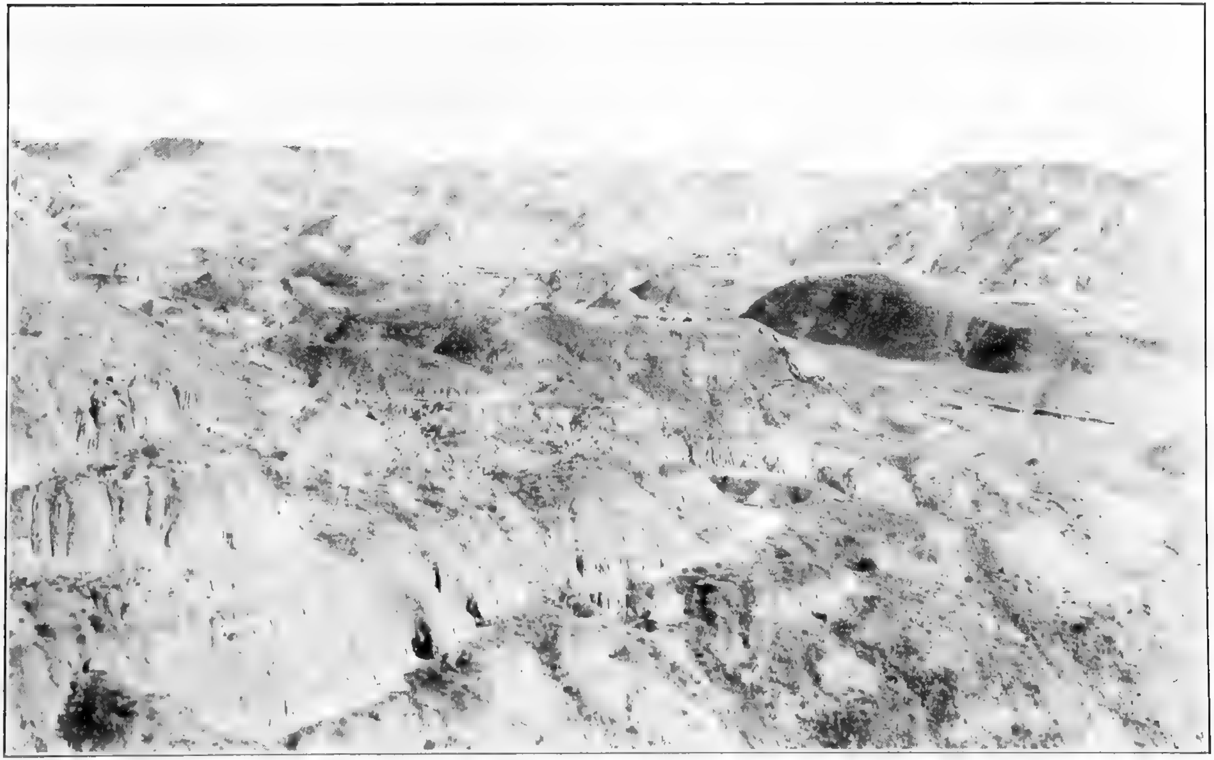

Fig. 13. Badlands near Glendive, Mont. Clay and shale. *Sarcobatus vermiculatus, Grayia spinosa, Atriplex* sp. *Artemisia aromatica, A. cana, Ribes cereum, Stenotus acaulis, Gutierrezia,* sp. May.

hemlock *(T. Mertensiana)* is of still narrower horizontal range, being found in this region only in a small part of the Bitter Root and some of the mountains of Northern Idaho. Ordinarily a tree of the high mountains it was found by the writer in the vicinity of Wallace at 5000 feet in association with *Pinus monticola*. *Juniperus communis*, which forms extensive low thickets at 6500 feet in Glacier Park, is common about Flathead Lake at 3000 and elsewhere at various altitudes.

Of the undergrowth much the same may be said. A few shrubs *Cassiope Mertensiana*, *Phyllodoce empetriformis*, *Salix Barclayi*, etc., are found only in the high mountains. Many other species occur freely at elevations from 4000 feet, throughout most of the upper forest belt. Among such the following may be mentioned:

Sorbus scopulina
Ribes lacustre
Vaccinium membranaceum
" *uliginosum*
Menziesia glabella
Pachystima Myrsinites
Valeriana sylvatica
Erythronium grandiflorum
Calochortus apiculatus
Veratrum californicum
Xerophyllum Douglasii

Before proceeding to a discussion of the several zones it is desired to call attention to a few facts determined for the six species most important and widely distributed. These figures on the viability of seeds and the rate of growth of seedlings are to be interpreted in connection with the behavior of the species in the field. The observations which extend over a period of several years are the results of experimental work by the writer at the University of Montana. The experiments were conducted under the climatic conditions of the prairie, more difficult at Missoula than those to which most of the species are accustomed in their natural situations. Comparisons are made between seeds from different sources. The prosperity of plants in the field is largely measured by their possession of advantageous characteristics among which their seeding behavior and rate of early growth are important.

The special study of seeds and seedlings pertained to six species, viz., *Pinus ponderosa*, *P. monticola*, *P contorta*, *Larix occidentalis*, *Picea Engelmannii* and *Pseudotsuga taxifolia*. The seeds were obtained from various sources in California, Oregon, Washington, Idaho, Montana and Colorado, and their behavior in the experimental operations compared under dissimilar conditions. The seeds within one year of their production showed from 3 to 54% defective in different lots and species as determined by physical examination, while in the beds none of them showed more than 10.4% viable, although the most favorable conditions were provided. This estimate of viable seeds, however, is doubtless much too low, owing to the fact that it was based upon the number surviving at the end of the first season. The percentage of response in germination showed no relation to the percentage of apparently viable seeds by dissection. Thus where *Pinus ponderosa* showed 91% viable by dissection 10.4% actually produced seedlings, while the same species in another lot showed 94% apparently sound there resulted only 7.7% of seedlings, and in the case of the spruce the figures were respectively 91% and 2.8% for one lot and 74% and 3% for another. The only constant relation revealed by the studies seemed to be that the time required for germination is inversly proportioned to the number of seeds responding, or, in other words, percentage of germination and rapidity of response were directly proportional, a condition to be expected. The results obtained from the few species examined and experiments conducted under the favorable conditions of cultivation suggest that the rate of propagation in the field under natural conditions must be very much less. It is seen also that radical differences obtain between seeds from different sources, as to size, soundness, and response in germination, facts which must weigh in the final determination of the place which each species must occupy in the different parts of its range.

Observation of the seedlings of this planting through a period of several years shows a marked acceleration of growth in height after the second year in nearly every case, being least in the Engelmann spruce and most in the larch. The greatest growth in height at the end of the first season was 4½ inches in the case of Douglas spruce, at the end of the second season the larch with 13 inches and at the end of the fourth with 59 inches. The Douglas spruce reached a height of 22 inches at the end of the fourth year, the yellow pine 23 inches, the white pine 13, the lodgepole 27 and the spruce 16, though the latter was exceptional, the heights in other lots of the spruce being

10 or 11 inches. The average heights attained are more significant. Those for the yellow pine at the end of 1, 2 and 4 years were respectively 2, 4 and 18 inches; for the white pine 1, 3 and 9; for the lodgepole 1, 4 and 18; for the larch 1, 8 and 40; for the spruce 1, 2 and 6 and for the Douglas spruce 1, 4 and 12 inches. The disadvantages of delayed growth in competition with other species are of course obvious and these are most pronounced in the earliest stages of growth in each species. As between these species it will be seen that the greatest growth in height occurs in those most intolerant.

In the study of these seedlings parallel experiments were conducted under a lath screen of half shade, 8 feet above the soil. Under such conditions growth was usually slower than in the open, apparently indicating the retarding effect of shade in the growth of young trees. This result, however, was reversed in the case of the larch and Douglas spruce which exceeded in height those grown in the open.

Thus in the case of the seeding habits of various species peculiar conditions obtain which affect their prosperity under the varying circumstances of their environment. Probably few features in the life are so intimately concerned with their prevalence as are those of their seeding habits.

The Foothill Vegetation.

Over a large area of western Montana, from the Divide westward to the Bitter Root Range and embracing the drainage of the Clark's Fork and its tributaries the Bitter Root, the Blackfoot and the lower Flathead, the landscape is strongly diversified by alternate forest and prairie. Forest distribution is in strong relation to topography, sheltered slopes are forested, open and exposed slopes are grassy. The latter are usually, but not always southern or western, often sharply marked in contrast with a vigorous forest at the turn of a ridge which leads to a northern or eastern slope. High slopes rising 2000 feet as in the Hellgate Canyon are thickly wooded on the north with an abrupt transition at the crest to grassland on the southern face. Such alternation of forest and prairie are common and on a lesser scale may be seen in miles of landscape in the Bitter Root and the Jocko Valleys. Even low undulations on the mountainside present the same aspect. Where the direction of the slopes fails to present a sufficient contrast of conditions the transition is more gradual and scattered forest trees are sprinkled through the grass land diminishing in size and numbers with the increase in distance from the main stand until the farthest limits of the forest are represented by a few low pines set at wide intervals. A tension between the prairie and the forest is evident. It is also evident that the forest is gradually replacing the grasses. Here the pine leads the way followed closely by the Douglas spruce, these two and rarely other species, *Juniperus scopulorum*. The migration is usually from above downward, but local conditions may vary this and show a migration from wooded canyons onto the neighboring prairie. An interesting reversal of the usual course is to be seen on Wild Horse Island in Flathead Lake, where the forest, governed apparently by the proximity of the lake waters, became established first at the foot of the slopes and is gradually occupying the higher ground.

Owing to local features of the physiography the directions of the wooded and barren slopes may be altered, or even reversed. The western slopes of the Mission Range, rising from Flathead Lake are densely wooded and steep, while the opposite shore, a series of low foothills, is mainly grass-land. The evident explanation here lies in the influence of the lake upon the moisture content of the westerly winds. The foothills of the west shore lie in the rain-shadow of the Cabinets, a high range to the west. Narrow valleys or canyons extending north and south and transverse to the direction of the west winds sometimes show the western slope more heavily wooded than the eastern. This fact is due, apparently, to the protection from the desiccating influence of the westerly winds afforded by the mountain opposite and the normally higher temperature of a western exposure. In the vicinity of Haugan, near the western boundary of the State, the dry exposures are distinctly northeastern. This locality was once heavily forested but many years ago was denuded by fire. A series of slopes here shows a sharp contrast between the southwestern and western exposures which were, at the time of the observation, in 1910, producing a sturdy young growth of *Pseudotsuga taxifolia, Larix occidentalis* and *Pinus monticola*, and the northeastern slopes on which no reforestation had taken place, but which were occupied by a low and scattering stand of *Ceanothus velutinus.*

That the slopes at Haugan were originally forested by the slow process of conquest which seems to be the rule where the pines invade the prairie is of course impossible to say, but that transitions occur from the grassland to an open pine forest, and then to the full occupation by Douglas spruce, larch and other species, has been pointed out in the case of the forests of the Flathead Valley (73), and apparently is of common occurrence elsewhere.

The severity of the conditions on an exposed western slope is not at first evident. Such slopes are usually covered with tall waving bunchgrass, *Agropyron spicatum*, and a host of herbaceous, plants mostly perennials, among which the following are conspicuous:

Balsamorrhiza sagittata	*Cogswellia macrocarpa*
Senecio canus	*Cogswellia simplex*
Monarda menthaefolia	*Pentstemon Wilcoxii*
Delphinium bicolor	*Arabis Nuttallii*
Zygadenus venenosus	*Comandra pallida*
Mertensia oblongifolia	*Woodsia scopulina*
Cogswellia montana	*Selaginella densa*
Achillea lanulosa	*Lupinus ornatus*
Clarkia pulchella	

The active vegetative period of most of these plants comes early in the season before the rains have ceased, and by the middle or the end of July they have finished fruiting. The test of the season comes during July and August, when scant precipitation, high temperatures, clear skies and dry winds draw from the thin soil almost its last vestige of moisture. Such conditions are impossible for forest trees, except where the seedling is sheltered in the lee of some rock or in the bottom of a gully. Now and then on such slopes a single yellow pine has rooted and grown to large size where one chance in millions has placed a seed in favorable conditions.

A series of experimental operations conducted to determine the practicability of forest planting on sites of this character,

Fig. 14. Near Roundup, Mont. *Pinus ponderosa* and *Juniperus scopulorum.* Typical of the margins of valleys along the Yellowstone, Musselshell and other streams in eastern Montana. The plains above and below are treeless. May.

indicate something of the severity of the conditions involved. Three situations were chosen on the grassy slope of a mountain facing the west and southwest. One of these by reason of a slight depression and less direct exposure to the sun was considered more favorable than the others; the other two areas, lying on a steep and rocky slope directly facing the southwest, were regarded as exceptionally severe. Upon these areas plantings were made in three successive seasons (1910-1912) with considerable numbers of yellow pines, both seedlings and transplants one or two years old. Unusual conditions in the form of drouth and fire at first beset the efforts, but in the end, owing to circumstances attending the planting and a season more than usually favorable, the plantations weathered the first summer with about 25% of the trees surviving.

It was thought that the main difficulty besetting either natural or artificial afforestation was the establishment of the seedling, and that if the first season could be survived they might maintain themselves indefinitely. Such, however, seems not to be the case, for in these experiments the number surviving waned rapidly from year to year until none were left. The stems and leaves eventually turned dry and crisp, and, inasmuch as the planted seedlings could be clearly identified, any conclusion that they had been destroyed by other agencies was obviated.

Growth, as usual under such circumstances, was slow. Even the plants that survived two years or more grew a scant inch or more of stem and a few dwarfed leaves while those of the same stock remaining in the nursery increased by several vigorous inches and a full brush of healthy leaves.

Seeding operations were even less successful, as was expected. Several variations of method gave uniformly negative results. The difficulties that beset natural seeding are largely present in artificial methods and that forest extension over grasslands by natural means is exceedingly slow is generally true and a matter of common knowledge. Along the tension line of yellow pine forest and bunch-grass prairie of western Montana the direction and rate of transition is evident in the scattered pines successively younger and more sparse from the forest outward.

It would hardly be safe to say that successful forestation of such areas with *Pinus ponderosa* is impossible, but the failures attending the above experiments indicate something of the hazards involved. Of all native species of forest trees the yellow pine undoubtedly is the most capable of surviving in such situations, from the standpoint of its water requirements, but in addition to this we may consider also the fact of considerable amounts of seed produced, their high percentage of germination and the facility with which they are sown by the wind. Millions of seeds must be produced for every tree that shows its head above the herbaceous vegetation, and such are very few. These soils absorb practically all the rain that falls, except what is lost by evaporation from the surface of plants. There is rarely any run-off. The soil is porous and stony and absorbs quickly any rain that may fall upon it.

In the invasion of the grassland the constant companion of the yellow pine is the Douglas spruce *(Pseudotsuga taxifolia)*. No more adaptable species is to be found among the forest trees in the northwest. Partial as it is to abundant moisture, nevertheless it resists almost as much drouth as the pine, and grows to large size, albeit more slowly than elsewhere. It is this species which more than any other marks the transition from the open yellow pine to the mesophytic or near-mesophytic forest. On account of its greater tolerance it is capable of supplanting the pine. In these situation, however, it is slow to develope density and grows with the pine in an orchard-like stand and not crowded, as its habit is on more favorable ground.

The western yellow pine and Douglas spruce are, however, characteristic of the semi-arid zones and belts of irregular form and determined by elevation, exposure, precipitation and wind in the tension zone between woodland and prairie. On the Missouri drainage they often occur associated with *Juniperus scopulorum,* either on the foothills or along the rim-rock bordering the benches on the Yellowstone and other streams far out into the plains. Of the two species the yellow pine has a little the best of the struggle as the pioneer in the invasion of the grassland, but owing to its intolerance, is at a decided disadvantage in competing with the Douglas spruce in the better watered soils.

One of the most striking features of the forests at middle elevations, especially on the western face of the divide is the strong influence of topography in the matter of forest distribution. South and southwest slopes are usually grassy, or covered with an open forest of yellow pine and Douglas spruce, the former the more abundant. The northern and eastern slopes usually bear heavy forests in which Douglas spruce prevails, or in which larch is locally strong sometimes over considerable areas.

The difference between opposite slopes is a common and striking phenomenon over wide ranges of landscape and concerns mainly the yellow pine and Douglas spruce. That this is a reaction to soil moisture would seem to be evident. Experimental operations, however, do not wholly support this view. Soil samples taken from the depth of a foot at five different stations on each of two slopes for comparison, the one facing north, the other south, were placed in glass stoppered bottles and removed to the laboratory. This was at the close of a rainless period of three months. By the removal of the stoppers they were allowed to become air dry. After a lapse of several weeks the samples from the slope facing the north had lost an average of 3.0% of their original weights; those from the opposite slope had lost 2.5% of their original weights. The samples were then kept for three weeks in an oven at a temperature of 120 degrees C. At the conclusion of this period the samples of the former lot had lost an additional .9% and of the latter .8%. The total loss therefore, in terms of the original weight, was 3.9% from soil of the northern and 3.3% from soil of the southern exposure. There was a difference therefore of only .6% in moisture between the two series. The southern exposure presented the usual open yellow pine forest with almost bare soil; the other bore a dense cover of young Douglas spruce and larch with ground cover of mosses and other small plants. Comparisons were also made on a series of soil samples from the level gravelly plain and an open treeless slope, covered with grasses and other plants, according to the same methods and subject to the same conditions. The former showed a total water content of 1.9%, the latter 4.3%.

While the evidence from soil examinations is not so convincing as one might expect, the data are too meager to justify conclusions. It may be expected that the longer the period of drouth the more closely will the different sites approach uni-

Fig. 15. Gumbo flat along the Musselshell near Melstone, Montana. In the foreground *Opuntia polyacantha* and *Artemisia* spp. In the background *Populus Sargentii* along the stream. In the distance bluffs bearing mainly *Pinus ponderosa.* May.

formity in the percentages of soil moisture. It is obvious also that the water supply in soils is depleted by absorption and transpiration, which may in large measure account for the dryness of the soil on the more heavily wooded slope.

The yellow pine seldom favors the steeper north slopes, even where space is available, except upon outjutting promontories or elevations, which seems to indicate certain relations to light or temperature. Experimental operations show that the yellow pine grows more rapidly, on the whole, exposed to full light at Missoula than it does under half shade, while the reverse is true of the Douglas spruce.

It has been suggested above that the study of distributional problems should be approached from the standpoint of the nature of the species, rather than from the standpoint of the external factors. Ecological literature has usually been concerned more with the effect of climatic and other factors upon the vegetation as a whole on a given area and for the most part has neglected the critical examination of the specific qualities which identify the important species. From this point of view physical data is none the less necessary, but each species is a complex entity which reacts to its environment in its own way. Each has its individuality and the study of that individuality, the specific reactions to light, temperature, moisture, etc., efficiency in seed bearing, periods of fruiting, immunities and the like, in short the sum total of its resistance and response, must throw light upon the nature of the plant and the conditions of its distribution. Every species is a complex of positive and negative qualities, the positive qualities those that are advantageous, the negative those that are disadvantageous. The balance of these qualities may show an excess for or against the species, and this balance will be found to be proportional as a rule to its geographic range and abundance. The negative qualities are limiting factors in its distribution, the positive make for dispersal. The more stringent the limitations the more circumscribed the distribution locally and generally, although in the latter aspect the limits of geographic range are not due to the lack of similar and suitable conditions elsewhere, so much as to the more effective action of intervening barriers. These conclusions, it is thought, will be supported by reference to the particular species which occur in this region.

The three species which occur most commonly in the foothill regions of Montana are the yellow pine, the Douglas spruce and the Rocky Mountain juniper. Taking first the case of the pine certain highly important positive qualities may be pointed out. This species produces abundant seed amply winged for distribution by the wind and with high percentage of viability. The moisture requirement both as to soil and air is relatively very low, within its range it is subject to a temperature range of at least 180 degrees, and it will grow on soils of widely differing texture and composition. Add to these qualities that of immunity to most diseases and, on account of its thick bark, to ground fires of ordinary intensity, and also the general vigor and robust habit of the tree, and it appears that the yellow pine is equipped with an unusual number of important positive qualities which make for extension and survival. The only serious limiting factor which seems to militate against its success is its intolerance of shade. Owing to this weakness it is largely excluded from moister soils suited to the more vigorous and rapid development of its bulk, and eventually succumbs in the gradual march of succession to the more tolerant species which compose the climax forest. From the point of view here advanced it is this combination of positive qualities which accounts largely for the wide distribution of the species over most of the western half of North America and its common occurrence in most places within its range.

The Douglas spruce offers a similar case. Its seed bearing capacity is large and the light seeds are readily carried by winds to considerable distances and show a high degree of viability. It is a tree of vigorous growth up to maturity and has the added advantage of greater tolerance than the pine, in favorable situations forming dense stands to the exclusion of almost every other green plant. This species also resists as wide a range of temperature as the pine, and seems impartial as to most soils. Toward maturity the tree is largely resistant to slight fires. In its moisture demands, however, it is slightly less resistant than the yellow pine. While a close second to the pine in the tension line between prairie and forest, yet the Douglas spruce more readily shows the effect of adverse condition in diminished growth. The species has a wide range of adaptability. While it grows with the greatest luxuriance in the region of heavy rainfall west of the Cascades it also occupies the outposts of forest vegetation bordering the dry prairies in the Rocky Mountains and adjacent plains. In the latter situations, however, its inferior size and form indicate the hardships to which it is subject. In another way also is it inferior to the pine in the Rocky Mountain region where it succumbs frequently to the attacks of *Razoumofskya Douglasii.* As these negative qualities are only relatively of importance, the Douglas spruce is remarkably well fitted for successful competition and becomes locally here and there in the Rockies, and far more extensively farther west, the dominant species. Its geographic range is greater than that of the western yellow pine.

The extensive distribution of *Juniperus scopulorum,* another of the Transition, or foothill species, seems largely to be the result of its rugged adaptability to adverse soil conditions, both as to moisture and other qualities, and to the effective means of the distribution of its seeds by birds. It is however, never abundant to the extent of forming forests, but appears, in the few places where it is pure, in widely open stands. This fact is perhaps associated with the relative paucity of its seeds and to its exceedingly slow growth. It is nevertheless a species resistent to a wide range of temperature and apparently suited to many different soils.

It is quite evident that the grassy slopes of this region have not been forested since pre-glacial times. The condition about Missoula furnishes an interesting study in this particular. The city is built upon a gravel plain at one time the bed of a supposedly Pleistocene lake; on all sides to the hight of 1,000 feet above the city are clearly marked shore lines of the ancient sea. For miles these may be traced horizontally and they mount one above another in a close succession of slight undulations.

The lines of these shore terraces lie chiefly in loose materials, gravels, soils or broken rock. In view of the effects of large roots upon such materials and the minor displacements consequent in the course of time, it seems impossible that forests could ever have occupied these slopes without obliterating the

Fig. 16. *Populus Sargentii* on the bottomlands of the Musselshell River. Typical of the arborescent vegetation along the streams of eastern Montana.

sharp definition of the shore lines or at least interrupting their continuity.

Some of the foothills are morainal in character, and where unsheltered, support only the herbaceous prairie flora. The higher slopes show numerous outcroppings of the country rock, such as may be found in all stages of disintegration, from jutting bluffs to mere mounds, and usually with more of less exposed talus below. It is significant that such outcroppings, if not too bold, and much of the older talus, is occupied by deciduous shrubs:

Amelanchier alnifolia	*Opulaster malvaceus*
Philadelphus Lewisii	*Rosa Woodsii*
Ribes cereum	*Acer glabrum*
Prunus demissa	

The species which occupy such situations, it appears, may be for the most part those which are plentiful in the region, and not especially xerophytic forms. Some places are occupied by *Populus tremuloides,* which may occur here and there as small islands, sometimes on high grassy and otherwise treeless slopes. On the east and west forks of the Bitter Root the southern slopes, grassy and treeless over considerable areas, support in patches scrubby growth of *Cercocarpus ledifolius.* Over a whole mountain side the rock outcrops may be located at a distance by the gray bunches of the mountain mahogany. It clings to the faces of cliffs and seemingly in the most severe and inaccessible places.

This obvious feature of the distribution of deciduous shrubs over a slope otherwise unfavorable can have but one meaning and that is the locally greater supply of available moisture. Competition of grasses and other plants over most of the area may operate toward exclusion by withdrawing too much water from the soil, but not by the density of the stand, for there is always sufficient space for many more plants than are actually to be found in the sparse and open stand of the bunch grass. The shrubs above mentioned are often seen aligned up and down the slope in drainage channels so shallow as hardly to be noticeable, but apparently supplying the roots from a source hidden under the coarse fragments which compose the surface of the talus.

The "Slide Rock" Succession.

One feature which is noticeable in the topography alike toward all points of the compass are the rock fields which compose extensive slopes of talus and are known as "rock slides" or "slide-rock" Such areas consist of rock fragments mostly under a foot in diameter. The succession of vegetation on these areas is a matter of much interest and importance. As might be expected the rate of development varies much with the exposure.

One of these areas which faces the south in Hellgate Canyon a mile east of Missoula, offers considerable difficulty from the standpoint of vegetation. This slope which rises at an angle of about 40 degrees is one of the older slide rock areas since the cliffs which formed it no longer are evident and the talus merges smoothly into the grassy slope above. Viewed from a distance the shallow channels of occasional drainage are evident and these have been preempted by *Ribes cereum, Philadelphus Lewisii* and *Amelanchier alnifolia,* which extend up and down the slope in bushy, hedge-like rows. In about half a mile of this slope one may count a score of Douglas spruce trees, old and misshapen. A slightly greater number of yellow pines, and an equal number of smaller trees of each species, ten feet in height or less. None of these occur above the line of the slide-rock. Upon closer inspection one finds old stumps of former large trees of 200 to 250 years of age. The larger living trees probably vary from 75 to 200 years of age. There is immediate evidence that on this area of approximately 80 acres there have been seed-bearing trees for fully 200 years, yet the total stand of pine and Douglas spruce combined numbers less than 100 trees, while the number of young seedlings number a scant two score, the progeny of about fifty seed-bearing trees.

The fragments of the talus, at first gray, soon become spotted with minute lichen growth which finally covers the surface with a coating almost black. Most of these lichens are close encrusting forms without even so much as a foliaceous margin of the thallus. This change proceeds slowly, and much more slowly on the southern than on the northern exposures. In the case now under discussion considerable parts of the rock slope are still as bare as when first formed. Elsewhere, however, especially on more favored exposures the slide-rock has become covered with dark lichens and has at a distance the appearance of coal.

Where a trace of soil comes into the talus, wind blown or washed, it supports the following plants:

Agropyron spicatum	*Balsamorrhiza sagittata*
Clarkia pulchella	*Delphinium bicolor*
Leptotaenia multifida	*Achillea lanulosa*
Pentstemon Wilcoxii	*Woodsia scopulina*
Artemisia frigida	

The forests of the northern and eastern slopes are subject to an entirely different set of conditions. Long after the snow is gone from the southern and western exposures it lies in deep drifts on the opposite slopes. Instead of an almost vertical sun as on the former the latter exposure may receive very little direct illumination. It is sheltered from the prevailing winds. As a result of these conditions, the ground water is fairly plentiful and lasts later into the season. These conditions are usually favorable in many places for a near-mesophytic vegetation in contrast to the xerophytic on the opposing slope.

As typical of conditions over a large part of western Montana, the principal discussion will deal with the south wall of Hellgate Canyon just opposite and distant about a quarter of a mile from the slope described above. This slope, of about the same angle, has several outstanding crags, and rugged ridges extending up and down the north slope. Between these ridges are depressions occupied to a large extent by steep and extensive areas of unstable talus.

The forest of the north slope is mainly Douglas spruce and western larch. Yellow pine does not amount to so much as one hundredth part of the stand, and is found chiefly on the tops of the ridges and at higher elevations where it approaches the crest of the ridge toward the southern exposure. This undoubtedly is due to its demand for light. In a few places on the higher slope are thickets of lodgepole *(Pinus contorta)* and here and there a Rocky Mountain juniper *(J. scopulorum)*.

The tops of the ridges extending up and down the slope are occupied by the oldest and largest trees, chiefly Douglas spruce

Fig. 17. *Yucca glauca* near Forsyth, Mont.

and yellow pine. In some places their sides are occupied by mature larch. The rest of these ridges are open and grassy and show evidence of seasonal drouth. Among the grasses (mostly *Agropyron*) may be found *Sieversia ciliata, Zygadenus venenosus, Selaginella densa* and *Arctostaphylos Uva-ursi.* Such conditions are impossible for the larch which seeks the moister situations.

The depressions between the vertical ridges are occupied by lesser vegetation in various stages of development. The slide-rock is thoroughly covered with encrusting lichens. When sufficient hold is provided for mosses these appear, along with the more foliaceous type of lichens.

The first of the mosses to take hold on the exposed rock surface is *Grimmia pulvinata.* Its dark cushion-like growths accumulate sand, dust and vegetable matter, and ultimately furnish a foothold for other small plants.

Places are found in which *Dicranum congestum* fills in between the rock fragments or wholly overgrows them. *Woodsia scopulina* is evident and an occasional *Sedum stenopetalum* and *Heuchera glabella.* At certain points shrubs become established and among these may be observed *Philadelphus Lewisii, Amelanchier alnifolia, Opulaster malvaceus, Ribes cereum, R. saximontanum, Rubus parviflorus, R. strigosus* and others. It is interesting to note the extent to which some of the more favored slopes have become forested. Considerable areas have become covered with a stand of vigorous Douglas spruce about 30 years of age. The trees number as high as 3000 to the acre and so dense is the canopy of their foliage that but few plants and these the most tolerant find sufficient light to support life. Digging away the thin cover of leaf mould one soon uncovers just such rock fragments as form the usual talus.

Elsewhere on the slope the stand may be practically pure young larch, or with some mingling of Douglas spruce. The extent to which the larch is dependent upon the ground water is beautifully exemplified in places on this slope. Long drifts of snow may be seen at the end of March ar early in April lying in the shallow drainage channels and rising out of the drifts are thickets of larch of various ages from small saplings to large trees. One of these belts is not more than 15 feet wide and extends down the slope for some hundreds of yards.

The same history of the slide rock has been observed in many places and the character of its vegetation man be correlated with that prevailing in the locality and with the direction of exposure. The identity of its vegetation varies with the altitude and geographic position but the course of events is usually the same, the lichen crust, the mosses of the Grimmia type, the herbs, the shrubby vegetation and eventually the forest or the prairie, according to exposure and climatic conditions.

The Western Valleys.

Whitford has described the mesophytic type of forest of the Flathead Valley as characterized mainly by the presence of Douglas spruce and western larch but including also *Pinus contorta, P. monticola, Abies grandis, Thuja plicata* and *Picea Engelmannii.* It would seem, however, as indicative of the purely mesophytic type, that the species which should be taken as characteristic are *Pinus monticola, Abies grandis, Tsuga heterophylla,* and *Thuja plicata.* These species are almost invariably, associated with one another in this region and forests containing them are not only of restricted distribution in Montana, but also are marked by other more or less distinctive species among the lesser forest plants. This group will be considered later.

While the Douglas spruce and yellow pine are frequent companions on the southward mountain slopes, the former on the northern slopes in western Montana is frequently associated with the western larch. The mixture of the two species obtains only under the better watered conditions and diminishing the quantity of larch and increasing that of Douglas spruce even to a pure stand, in the direction of the drier situations. On the other hand the larch sometimes attains pure stands on the cooler and better watered slopes.

The western larch *(L. occidentalis)* has several distinctive characteristics. Certain positive qualities stand out conspicuously and certain negative ones are no less prominent. The positive factors in the organization of this species may be summed up briefly as follows: The trees begin early to bear seeds and produce them in abundance throughout a long life. The seeds are small and light, and provided with ample wings by which they are carried far by the wind. In addition to these qualities they retain their viability well and usually show a good germination percentage. When once started the seedlings grow rapidly in height, a feature in which they excel most other species. With age the tree acquires a thick bark which serves it well as a protection from ground fires.

The negative or limiting qualities are seen in the intolerance of the larch to shade, in its rigid demands upon soil moisture, its partiality to cooler climates and its marked susceptibility to disease.

The strong points of the larch are in its seeding habits, and its rapid early growth. The significance of the positive factors is especially evident in local distribution. The seeding ability of the tree often enables it to occupy limited areas exclusively, but such areas are bounded by the special properties of the soil from the moisture standpoint. The temperature relations of the species are such that its most southerly extension in the Rocky Mountains occurs in Montana, and it doubtless is found farther south than it otherwise might be were it not for the topographical conditions which provide suitable situations on northern slopes. While the western larch endures a considerable diurnal range of temperature, it is distinctly a tree of the cooler regions. It is one of the principal trees of the Kootenai Valley, where the annual range of temperature may be from –40 to 108; the days of summer may be hot, but the nights usually are cool and frosts occur in all months of the year.

The rapidity of its early growth in height is probably the most important of all its qualities in competition with other species. Under good conditions trees make a growth of 4 feet in 4 years while under the same conditions Douglas spruce gains a height of about 20 inches, yellow pine about the same and Engelmann spruce less than a foot. Thus if given an equal chance, or even somewhat less, the larch will soon be so far above its neighbors as to be out of all danger from shading. Engelmann spruce sometimes forms forests so dense that nothing can grow beneath their crowns, yet in just such forests one may

Fig. 18. *Lepargyraea argentea* on the bottom lands of the Milk River. Northern Montana, May.

sometimes find two stories, the upper consisting of the crowns of the vigorous larch, the lower a uniform stand of spruce. If it were not for the relative growth in height of the two species such a mixed stand would be impossible.

The larch is severely subject to the attacks of *Trametes pini*, but even so may continue to live for years with ever diminishing increment of growth, before the stem finally gives way. Other fungi are likewise parasitic on the larch but they apparently are less serious in their effects, and the mistletoe, *Razoumofskya laricis*, is in some localities very troublesome.

One of the most significant of the forest societies of western Montana is that furnished by the white pine *(Pinus monticola)* and its associates. Some of the species often associated are *Abies grandis, Tsuga heterophylla, Thuja plicata, Taxus brevifolia, Betula papyrifera, Populus trichocarpa, Lonicera involucrata, Lonicera cilosa, Lysichiton Kamtschatcensis, Acer glabrum, Holodiscus ariaefolius, Ceanothus sanguineus,* and *Linnaea borealis.* Two forms of parasitic fungi are usually prevalent. *Trametes pini* and *Echinodontium tinctorium,* the former attacking the white pine, Douglas spruce, larch and some other species, the latter found almost exclusively on the hemlock and fir.

The aspect of the forest is strongly mesophytic. Tender leafy plants of more or less delicate structure, suited to a humid forest and moist soil, evidence in all species of rapid and vigorous growth, and the attainment of extraordinary size, all point to conditions exceptionally favorable. *Acer glabrum* elsewhere a shrub of ten or fifteen feet, here becomes a tree, 30 feet or more in height and in diameter 8 or 10 inches. The white pine itself may attain 7 feet in diameter, the black cottonwood *(P. trichocarpa)* 3 to 4 feet, the hemlocks 2 to 3 feet, and other trees more or less. The forest floor is usually covered with a litter of branches and leaves among fallen logs, supporting a growth of mosses and liverworts, while fleshy fungi of many genera and species abound. Among the small plants may also be found *Pyrola aphylla, Pterospora Andromeda, Monotropa uniflora,* and *Corallorrhiza multiflora* and other orchids and plants more or less mycotrophic in habit.

Forests of this sort are limited to relatively small areas in

Fig. 19. South slope near Havre, Mont. *Rhus trilobata* and *Artemisia* sp.

this region. They are largely localized and may be separated or surrounded by tracts in which far different conditions obtain. They are found in the valleys and canyons and on the lower slopes of the Flathead drainage, in parts of the Kootenai Valley, and in the northern part of the Bitter Root Range between Montana and Idaho. They are found at their best, as far as the writer's observations have extended, in the valley of the Swan River, and some other tributaries of the Flathead, where they diminish and merge into the drier land formations southward along the east side of Flathead Lake, and in the valley of the Priest River in northern Idaho. In Glacier Park they are to be found in Avalanche Basin, and the valley of McDonald Creek and in other places west of the Continental Divide. The best forests of the Flathead are along the upper courses of its main branches and their many tributaries among mountains and in narrow gorges; the river in its lower course enters the open country where the mesophytic forests gradually yield to more and more xerophytic types. Very little is seen of *Pinus monticola* and its associates below the upper end of Flathead Lake until the slopes of the Bitter Root are reached. The western slopes of this range and the neighboring country of the St. Joe and the Clearwater of Idaho are covered by some of the best of the white pine forests of the northern Rocky Mountain region and this species and some of its associates have crossed to the eastern slope and descended into the valley of the St. Regis and other tributaries of the Clark's Fork. All of this section of Montana from the Kootenai to the St. Regis occupies but a corner in the northwestern part of the state.

Some discussion of the leading species in the white pine forest may now be appropriate. The white pine as the most characteristic element will be taken first. Its salient features may be summed up as follows:

The seeds are well adapted to wind dispersal. The trees show considerable tolerance while young and grow rapidly in height. The species seems impartial as to structure and composition of the soil. The above are the positive qualities. Opposed to these are the facts that seeds are produced sparingly and rarely if at all until the trees are 40 to 60 years of age. The seeds germinate slowly, have low percentage of germination and

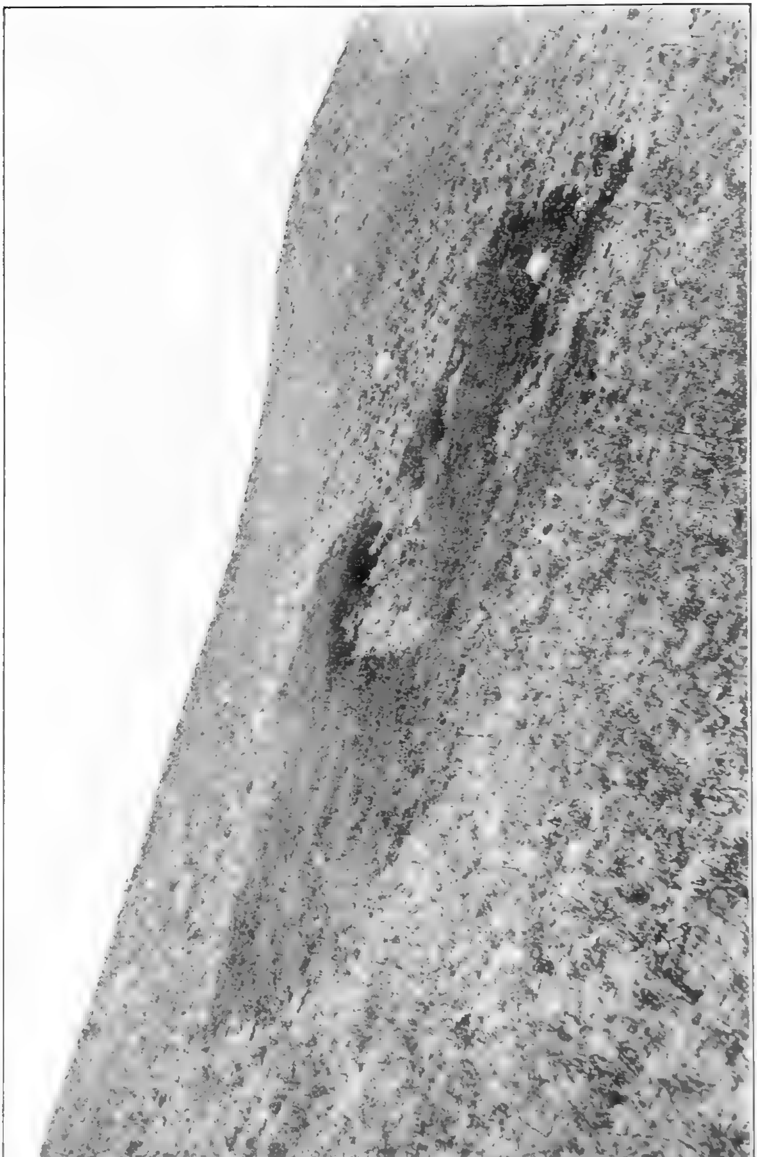

Fig. 20. *Juniperus horizontalis* (*J. Sabina*) on the plains near Havre, Mont.

transient viability. The demands of the species are exacting as to soil and atmospheric moisture, and the temperature range seems normally to lie between -40 and 100 degrees. The trees are very susceptible to disease and are easily killed by fire.

Thus it will be seen that the negative or limiting factors predominate. Among the positive silvicultural characteristics two only are of much significance as far as competition is concerned, viz., the rate of growth and tolerance in early years. These two qualities alone enable the white pine to compete advantageously with all other native forest species and to outstrip many of them in growth. They enable them to enter stands of older trees which are beginning to open as they approach maturity. The importance of these qualities becomes the more apparent when we consider the nature of the species with which the white pine is called upon to compete. The hemlock and grand fir are both very tolerant of shade and may grow in dense stands though such are not frequent in this region. The Douglas spruce, arbor vitae, larch and even lodgepole pine may appear along with the white pine in the same situation and in competition with it. All of the usual competitors except the fir are vigorous producers of seed and hence of special importance in the competitive struggle.

On the whole the white pine can scarcely be said to be fortunate in its seeding habits. The percentage of germinable seed has been shown to vary, according to the size of the cones, from 15 to 90, but mostly 50 or less. The seeds are sought as food by various animals. Moreover the germination response is slow and the seeds may lie even in well tended nursery beds for a year before germination. It is difficult to see, in the complex of influences to which all plants are subject, how any advantage accrues to the tree by such a habit, in view of the fact that such delay may increase the chances for destruction by animals and by decay, and enhance the advantage to other species by increasing their lead in the race. It has also been learned that little seed is produced unless the crowns are well lighted, which indicates that competition is directly responsible for a large reduction in the seed crop. (75.)

An element of weakness in the white pine is its susceptibility to disease, especially to the attacks of *Trametes pini*. Whole stands

Fig. 21. Near Boulder, Mont. *Juniperus scopulorum* in the foreground. In the background *Pinus ponderosa*. May.

of fine timber are in places so seriously affected as to make it difficult to find a sound tree.

The importance of this disease appears not only in the depreciation of the wood for commercial purposes but also in the shortening of the life of the tree and the lessening of its reproductive vigor. The tree is also subject to serious attacks by the bark beetle, *Dendroctonus monticolae,* and owing to the thinness of its bark is readily injured by ground fires.

All of these factors are then very potent influences in keeping the tree within narrow geographic bounds and ordinarily below a medium point numerically over areas which are capable of supporting it. In Montana it is confined to the west side of the Continental Divide. It doubtless reaches its most southern limit in the Rocky Mountains in the Bitter Root range between Montana and Idaho, possibly as far south as Nez Perce Pass, at the head of the West Fork of the Bitter Root, and mostly on the western or Clearwater slopes.

The grand fir *(Abies grandis)* is nowhere in Montana a common tree. Even in the mesophytic forest to which it properly belongs it is seldom conspicuous and it grows in poor form and only to medium size, as compared with the sometimes pure stands of fine, large trees to be found here and there west of the Cascades. The salient qualities of this tree may be set forth as follows: As to its positive characteristics, the grand fir grows rapidly while young and has a considerable capacity to resist shade. It appears not to be particular as to soil composition or structure. The seeds are light and amply winged. On the other hand it is not given to early fruitage in the Rocky Mountains, and its seeds have transient vitality and low germinative capacity. It is not at any time prolific in the bearing of seeds. The species is exacting in its moisture requirements and its temperature range is rather narrow. In addition to these traits the tree is susceptible to disease and is easily injured by fire.

Like the white pine the grand fir wins in competition mainly by reason of its tolerance and rate of increase in height. The early production of seed is a mark of some advantage in the most favored parts of its range, but in the less favorable region of the Rocky Mountains even this feature disappears. The seeds

Fig. 22. A western slope near Missoula, Mont. *Pinus ponderosa* in the distant background. Lower edge of the forest at about 4000 feet altitude. Prairie vegetation consisting largely of *Agropyron spicatum*, *Balsamorrhiza sagitatta*, etc.

being low in vitality and germination are a means of slow and uncertain reproduction.

The grand fir is impartial to soils as to structure and composition, provided they are sufficiently moist. It is usually found on bottom lands or in places where the soil is likely never to be dry. Even under the favorable conditions which usually prevail over most of the country west of the Cascades, this fir is usually found on river banks or in the bottoms of canyons, where it reaches large dimensions. In western Montana the relation to soil moisture is even more strongly emphasized.

The grand fir seems to demand on the whole a higher temperature than the white pine. Its lower limit is about −30 degrees while its upper range is some degrees above the maximum commonly understood for white pine, or somewhat over 100 degrees. In Oregon this species thrives at sea level while the white pine seldom appears there below 3000 feet.

Fire injury in this species is seldom an important matter as the local conditions on river bottoms and similar places are not often such as to invite it. The matter of disease, except for *Echinodontium tinctorium,* is not apparently a serious one.

The control of distribution in this species, therefore, must be largely topographic, with reference to the amount of soil moisture, and on areas which are favorable its size and numbers are determined by competition.

The hemlock *(Tsuga heterophylla)* affords another example of a conifer of mesophytic requirements. In fact it is much more restricted in its local distribution than the grand fir. Its range in western Montana is confined to localities in the northwestern part of the State, in the valleys of the Swan River, the Flathead and the Kootenai. It is found in the valley of McDonald Creek in Glacier Park, and a stand of trees unusually large for this region occurs in Avalanche Basin, tributary to the same stream.

In its positive qualities the hemlock is particularly fortunate. These pertain to two features, its seeding habits and light relations. Abundant seeds are produced, which have a high germinative capacity and the ability to thrive on the humus cover and litter of the forest floor. The seeds, being light and with ample wings, may be carried well by an ordinary breeze. The hemlock is very tolerant of shade and is of fairly rapid growth.

Fig. 23. On the East Fork of the Bitter Root. Along the stream *Alnus tenuifolia*, *Betula fontinalis*, *Populus tremuloides*. High on the slope in the middle background *Cercocarpus ledifolius*. Scattering trees on the slopes are *Pinus ponderosa*. August.

Negatively the species demands abundance of moisture in soil and air, its temperature limits are relatively narrow, lying between about –35 degrees and 95 degrees in this region. It is easily damaged by fire and is moderately susceptible to disease.

The positive qualities of this species are practically confined to two things of particular importance, viz: the seeding habits and tolerance. The hemlock is especially fortunate in both; in the former as providing a great number of individuals in the competition for space, in the latter as successfully opposing the suppressing influence of other species. These are important elements within the suitable areas, but so important in the economy of this tree is the constant presence of a considerable amount of soil moisture, that this factor alone is of sufficient weight to over-balance all other considerations in local distribution. No more definite mark of the nature of the tree in this regard can be found than the habits of the root system, which spreads in all its complex ramifications at the very surface of the soil. Often the roots extend for fifteen feet or more on all sides of the tree just under the layers of forest moss and mould and are more than half exposed when a chance ground fire consumes the combustible material. In such cases, of course, the tree is killed and this constitutes another of the limiting influences which affect the prosperity of the species. Thousands of seedlings of the hemlock establish themselves upon fallen logs, boulders, stumps, etc., wherever mosses and fallen leaves furnish some check to evaporation, and under such conditions they may flourish to maturity. It is not unusual in hemlock woods to find old trees with roots astride a log and reaching down to the ground on either side. Sometimes under such conditions the young seedlings form a veritable carpet. The behavior of the hemlock in these respects, however, is possible only under the most favorable conditions of atmospheric and soil moisture.

The western hemlock is not especially susceptible to disease except in the case of *Echinodontium tinctorium,* by which it is often seriously affected or destroyed.

One other tree of importance remains to be discussed as a member of the mesophytic forest. The arbor vitae *(Thuja plicata)* is frequently conspicuous, and is somewhat more widely distributed than the two preceding species, though sharing to a

Fig. 24. Southern slope in the Lolo Valley. *Pseudotsuga* and *Pinus ponderosa*. *Chrysothamnus nauseosus* and *Agropyron spicatum* in the foreground. August.

large degree their preference for distinctly mesophytic situations. With respect to its particular qualities, the statement may be made as follows:

The positive elements in the nature of the arbor vitae are found largely in its seeding habits. The tree produces an abundance of seed throughout a long life. The seeds show a high germination response, and find a suitable substratum on the mossy litter of the moist forest floor. The seeds are the lightest of any produced by our coniferous species and are easily distributed. The arbor vitae is very tolerant and is not very partial as to soils. It is little subject to serious disease.

The principal negative elements in the composition of this species are its strict moisture requirements, its limited temperature range, its slow growth in its earliest years and its susceptibility to injury by fire.

It is evident that the positive qualities of the species outnumber those of a negative character, but the moisture limitations are locally important to a degree sufficient to outweigh all other considerations. It frequents river bottoms and moist flats, stream banks, the bottoms of canyons and the borders of high lakes in the Rocky Mountains, but in the Coast Mountains of Oregon, where precipitation is ample it occurs plentifully on mountain tops and stony ridges. In Montana it is found mostly in the northwestern part of the State and neighboring regions, and is most aboundant, in the cooler, moisture sections of the north, as on the flats below Lake McDonald and elsewhere in the Glacier Park, and the tributaries of the Kootenai. Fine stands of this tree are pictured by Whitford and Lindgren about the lakes and in the creek bottoms of the Mission and Clearwater Mountains. It forms a conspicuous understory in some parts of the white pine forests of the Priest River Valley where the writer observed it in 1910. It reaches its best development within the limits of moderate temperatures where the soil is perennially moist. The seasonal temperature range must be usually from about -35 to 100 degrees or more but with the usual upper limits of summer heat at 85 or 90 degrees.

In the case of the arbor vitae one seldom finds many small seedlings, such as usually are to be found under hemlocks. The growth of seedlings at first is very slow, rising to a height of

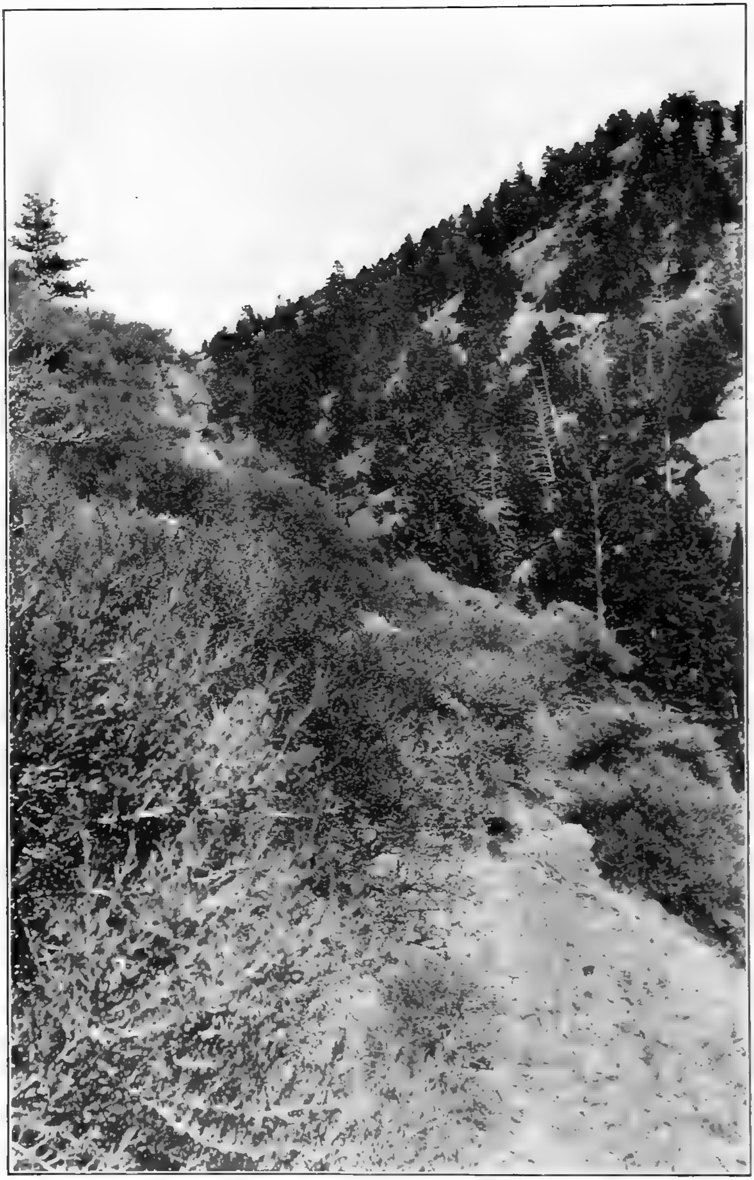

Fig. 25. On the East Fork of the Bitter Root. On the left, slope facing the southeast, *Cercocarpus ledifolius;* on the right, northwest exposure, *Pinus ponderosa* and *Pseudotsuga taxifolia.* August.

six to ten inches in four years, but accelerating for a time during later years. In this respect the tree is at some disadvantage as compared with other species like the fir and hemlock and is saved only by its great tolerance of shade. Thus it may continue for some time under deep shade without suffering suppression. The trees grow to great age and are very tenacious of life; often with much of the trunk and crown dead a few living branches may survive indefinitely. There are few parasites which attack the arbor vitae though owing to its thin bark it easily succumbs to fire and the ground which it occupied may become covered with Douglas spruce or lodgepole pine, or as appeared in one case, with a dense growth of the more rapidly growing white pine and grand fir.

Among the mesophytic companions of the white pine mention should be made of the western yew *(Taxus brevifolia)* while almost a rare tree in western Montana, it reaches a diameter of a foot and a height of twenty to thirty feet, where it occurs in some of the deep, moist canyons east of Flathead Lake, always thriving best in the vicinity of permanent water, but forming a shrubby undergrowth in the shade of old forests. It seldom is abundant, even locally, which may partly be accounted for by the paucity of its seeds and the slowness of its growth. Like some of the other species, however, it may be taken as a good indicator of the humid qualities of the soil and climate.

The broad-leaved, deciduous element in the forests of this zone is seldom conspicuous, but along open river bottoms, *Populus trichocarpa* is everywhere the dominant tree, sixty feet or more in height, three feet or over in diameter, and sometimes with a clear, cylindrical trunk of 40 feet in length. The secondary species on the river bottoms are *Populus tremuloides, Alnus tenuifolia, Betula fontinalis, B. papyrifera, Prunus demissa, Crataegus Douglasii, Salix fluviatilis, S. Bebbiana, S. cordata,* and *S. Scouleriana*. *Betula papyrifera* is much more restricted in its range in Montana than any of the other species and is confined to the northwestern slopes and valleys, where also the aspen shows larger and more abundant development, with *Crataegus rivularis, Ceanothus sanguineus, Ribes lacustre, Rhamnus Purshiana, R. alnifolia, Holodiscus ariaefolius, Spirea lucida* and numerous other shrubs. The trees which appear most con-

Fig. 26. A bluff on the East Fork of the Bitter Root near Medicine Springs. *Cercocarpus ledifolius.* South exposure at an altitude of about 4000 feet. August.

spicuous in the mesophytic pine forest, where openings of the forest permit, are *Populus trichocarpa* and *Betula papyrifera*, often well shaped trees of unusual size.

The mesophytic forest as discussed above is essentially the same as the Pacific Coast Humid Transition. It merges by degrees into the Montane or Canadian forest in northern Montana at an altitude of near 4,000 feet. The white pine shows a tendency to ascend the slopes ahead of its usual companions on the lower levels and so in places becomes identified with the mountain forests.

The Montane Zone.

The forests of the Montane or Canadian zone are not clearly differentiated from those of the sub-alpine or Hudsonian. By reason of the occurrence of some trees more abundantly at higher altitudes and the restriction of a few species of herbs and shrubs to the same elevations the areas immediately below the highest peaks and ridges have a physiognomy more or less their own, but the trees that constitute the bulk of this so called sub-alpine zone also enter largely into the composition of the lower belt, if indeed they do not in some places constitute it fully. The same species which on high and exposed sites are depressed and misshapen may form the main stand of good form and quality a thousand or two thousand feet lower on the mountain side. The species which form the bulk of the Canadian forest zone are *Pinus contorta, P albicaulis, Picea Engelmannii* and *Abies lasiocarpa.* An examination of Table 20 will show the wide range of vertical distribution of these species and reference to the tables presented under the discussion of the sections will show that this feature is not confined to one locality. On the eastern slope of the main Rockies the limber pine *(P. flexilis)* has also a large part in the forests of this zone.

At about 4,000 feet one begins to meet occasional representatives of the higher mountain flora and with mounting altitude their numbers increase until the level of maximum development is reached. This level is not the same on different ranges nor on different peaks of the same range, since the conditions vary.

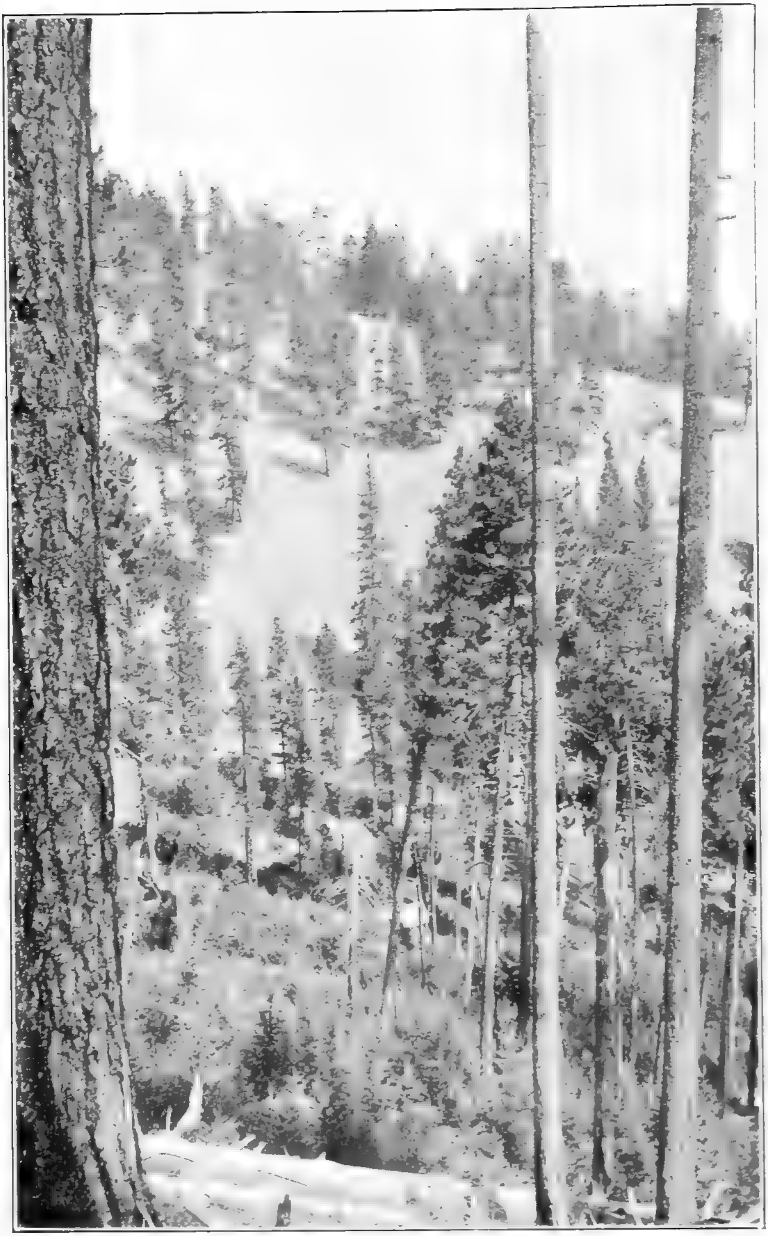

Fig. 27. South exposure, altitude 4000 feet, upper Bitter Root Mountains. Open forest of *Pinus ponderosa*. In the bottom of the canyon a thick stand of *Pseudotsuga taxifolia*. August.

So far as observed, none of the plants seen first on the slope at 4,000 feet or above fail to extend to the sub-alpine zone, some in sheltered canyons and ravines and others on open and exposed slopes. Among such may be mentioned:

Xerophyllum Douglasii	*Menziesia glabella*
Veratrum californicum	*Pachystima Myrsinites*
Vaccinium membranaceum	

Referring again to the trees of the Montane or middle mountain belt, the first of the species from the standpoint of its numbers, its characteristics and the breadth of its distribution is the lodgepole pine *(P. contorta)*.

The lodgepole forests have been studied by Clements (12) in Colorado and by Mason (39) in Montana and elsewhere. From various standpoints they are of great interest and importance. They represent a form which is able with remarkable rapidity to reoccupy denuded land, made possible by prolonged viability of the seed, by the large numbers of seeds produced and the facility of their dispersal. The lodgepole represents a species which by reason of its own power to reproduce is usually prevented from attaining great age and maximum dimensions. The density of the stands, the resinous character of its tissues, and the habitats which it often seeks on high and exposed ridges make lodgepole peculiarly susceptible to fires which often repeatedly sweep the same area. During at least the earlier period of its development the lodgepole stand is often as effective a barrier to the movements of neighboring species as a lake or a snowfield, for stands of trees six to eight feet in height may be so dense as wholly to exclude even the most tolerant of the lesser green plants. In older stands which have begun to open there is, however, opportunity for the entrance of competitors and in some places the white pine may be seen making headway under the much older growth of the lodgepole. Under conditions favoring the entrance of other species the lodgepole must ultimately become supplanted. Whitford has found in the forests of the Flathead Valley the invasion of the lodgepole stand by white pine, lowland fir, Engelmann spruce and occasionally arbor vitae and western hemlock. If the seeds of western larch, Douglas spruce, or other species of rapid growth in height are

Fig. 28. On Wildhorse Island in Flathead Lake. *Pinus ponderosa* and *Pseudotsuga taxifolia* showing an ascending invasion into the prairie. July.

sown with the lodgepole these may become the dominant competitors.

The character of a lodgepole stand clearly indicates a wind-sown forest. Extensive areas are seeded so evenly as to permit of no alternative explanation although authors above mentioned are inclined to question this view. The lightness of the seed and the amplitude of the wing make possible their transportation by even a moderate gale. The behavior of the lodgepole recalls no other species so much as the Douglas spruce, which with great facility in its most favored regions reoccupies clear cut slashings and burns many acres in extent with a uniform thicket growth propagated from the borders. And the seeds of the Douglas spruce are heavier than those of the lodgepole pine.

The reseeding of a burned area by lodgepole presents no difficulties if the area has previously been occupied by that species, even as a partial stand, unless the fire has been so intense as to consume the tops. The writer recalls that the severe fires of 1910 swept a part of the valley of the North Fork of the Flathead River. The ground cover was entirely consumed and the crown fire had stripped the leaves from the branches overhead. Some trees had fallen and among them lodgepoles. Upon examination, within 36 hours after the passage of the fire, the cones of the lodgepole were found open and the seeds were seen lying upon the ground. The opening of the cones had followed after the passage of the fire at an interval sufficient to allow the seeds to fall uninjured, for not even the edges of the delicate wings were singed, a fact which seems difficult to reconcile with the findings of Clements that the flame of the Bunsen burner opened the cones in ten seconds.. If such were the case in a forest fire the seeds must surely perish. In the case above cited, however, the cones evidently were opening slowly, for at the time they were observed they were not entirely expanded. On the top of the standing trees the cones undoubtedly were opening likewise in response to the drying action of the fire and from this vantage were being broadcasted effectively onto the cleared and receptive soil.

Of course the action of fire is not the only means of opening the cones. They may be observed in some cases fully expanded

Fig. 29. In the valley of the Swan River, tributary to the Flathead. *Betula papyrifera*, associated with *Pinus monticola, Tsuga heterophylla, Abies grandis* and other trees, representing the most humid forest conditions of the region. July.

on green trees, but this is relatively rare. There is at hand a branch about a foot in length bearing 27 cones, about evenly distributed over a period of 12 years, and not one of them has begun to open. Of 167 cones collected in August five years ago and kept continuously in the dry air of the laboratory, 70 still show no signs of opening, 14 are beginning to open, and 83 have opened enough to liberate a few over 200 seeds in all. These seeds when tested showed a high percentage viable.

Lodgepole pine is not abundant in the immediate vicinity of Missoula. It is restricted mostly to north slopes at elevations of about 5,000 feet. This feature of its distribution seems to be mainly a response to temperature. Lower elevations though well watered rarely support vigorous stands in this locality, but farther north in the Glacier Park at 4,200 feet, and in the Kootenai Valley at less than 2,000, are vigorous forests of pure lodgepole. In these regions heavy frosts may occur in any month of the year. Northward the lodgepole forests become more continuous and homogeneous; southward the continuous and extensive forests of this species are found at seccessively higher altitudes. Westward, of course, the lodgepole extends to the coast; its eastward distribution in Montana reaches a meridian traversing the State midway. In the north it is found in the Bearpaw Mountains, a low range between the Milk River and the Missouri south of Havre. It occurs also in the Crazy Mountains almost in the exact center of the State and in the Beartooth Mountains northeast of the Yellowstone Park. In this region Leiberg, reckoning trees of all ages with a basal diameter of three inches and upward, concluded that the lodgepole constituted 45% of the forest species, and in the Little Belt 43%. Elsewhere it may be more or less according to circumstances, more where fires have occurred at intervals sufficient to repress competing species, less where time has sufficed for the maturing of the forest and invasion, or where conditions of reproduction have established a mixed stand from the start.

A summary of the biotic elements which enter into the composition of the lodgepole species leaves no doubt as to its fitness and capacity for distribution and survival. Among these several qualities may be mentioned as positive factors. First may be mentioned the abundance of the seed produced, which

Fig. 30. Priest River Valley in northern Idaho. *Pinus monticola, Tsuga heterophylla, Abies grandis, Thuja plicata.* In the foreground *Lysichiton Kamtschatcensis* and *Asplenium Filix-foemina.*

probably excels that of any other native species. Not only is the annual crop abundant but the lodgepole begins early to bear seeds, as early as the sixth year in some places. The lightness of the seeds and their marked adaptability for wind dispersal, their usual high rate of germination and long continued viability are all points of marked importance. The ability of the lodgepole to grow in dense stands operates to exclude other species, and its ability to recover from prolonged suppression further makes for dominance. The lodgepole is also largely resistant to disease. Against these points may be set off certain limiting traits most of which are, however, not very definite or pronounced. There appear to be certain limitations in soil requirements, and light and a marked susceptibility to fire injury.

It has been estimated that the average production of seed per tree in Colorado varied from 20,000 to 50,000. Considering the fact that the tree may begin as early as its 5th year to produce cones and that the cones remain closed for many years and that when seeds are most needed, i. e., just after a fire there is available for sowing not merely one season's crop but the combined fruitage of several years, considering also the extended viability of the seeds and their high germinative capacity it is evident that the lodgepole pine is beyond all competitors in the advantage derived from a reproductive capacity. The facility with which it preempts and holds newly seeded, especially fire-swept lands, is a fact related partly to its preference for bare soil as a seed bed, but more decidedly to the large amount of seed available for distribution at the opportune time. It is found under recorded temperatures of -55 to 112 degrees F. in the United States and doubtless has much wider range. In the same locality (Anaconda) it may be subject to an annual variation of temperature through 165 degrees F.

In the ability to recover after years of suppression is one of the important factors in the persistence of the lodgepole. Unlike many other species which would suffer permanent injury from early shading, the lodgepole, after years of repression is able to push forward rapidly to full vigor and reproductive capacity as soon as the dominating individuals are removed. Especially may this be the case where the cutting or destruction of

Fig. 32. Vegetation in the mountain valleys of the upper Bitter Root, West Fork. On the right *Pinus ponderosa*, in the center foreground *P. contorta*. *Picea Engelmannii* in the background. *Salix Bebbiana*, *S. glaucops*, *Alnus tenuifolia*, etc.

the larger trees of the stand may throw open the land to a contest for supremacy among the local species.

There are few parasites to which the lodgepole is seriously subject, and most of these do not destroy the tree, nor apparently retard its production of seed. The most serious enemies are the bark beetles of the genus *Dendroctonus* which kill the stands. Among the vegetable parasites *Peridermium cerebrum* and *P. Harknessii* and the small mistletoe *Razoumofskya americana* are the most common, but they are seldom conspicuous.

Against these more or less favorable traits may be set off three which have a limiting effect upon its distribution. The soil limitations are not a serious handicap to migration. Locally such limitations are effective as in over-watered soils, the lodgepole requiring well aerated land with a medium amount of available moisture. Some authors hold that the lodgepole shuns calcareous soils, but that is a matter affecting local rather than general distribution. Otherwise the lodgepole seems indifferent as to the qualities of the soil. The effect of the intolerance of this species, as was mentioned above, is seen mainly in the retarding of its growth until such time as the shade may be removed. The specific light requirements of this species, however, like the edaphic relations, are more important locally than as effecting the whole range of the species. In the third negative element, that of susceptibility to fire, is a factor which must in a far-reaching way affect the prosperity of the species throughout its range and operate to reduce the area over which it may hold sway.

Thus it will be seen that the positive factors in the make-up of this species far outweigh those which are negative and which would tend to weaken it in its struggle for survival. Such adaptability is reflected in its wide distribution which extends from the peninsula of lower California almost to the Arctic circle and from the Black Hills to the very shores of the Pacific.

The Engelmann spruce *(Picea Engelmannii)* is one of the most widely distributed trees of the Rocky Mountain forests. Within the boundaries of Montana it has a wider altitudinal range than any other species. From the crests of the highest ranges it descends to the lowest point, within the State (Troy, 1,880 feet) and in Idaho to 1,500 feet. It is a prominent tree

Fig. 33. North mountain slope near Missoula, Mont. Young *Larix occidentalis* in shallow gully. Distribution coincident with snow drifts. March.

of both the Hudsonian and Canadian zones. It is found plentifully both east and west of the divide, forming 11% to 21% in the Belts and Absaroka, 13% in forests of the Kootenai Valley and more or less in other parts. At lower elevations the species finds its best conditions on bottom lands and in cool canyons and frequently reaches 3 or 4 feet in diameter. Pure forests of Engelmann spruce occur and such are found in Glacier Park, over limited areas, in the upper Avalanche Basin and a good, uniform stand on the slopes of Brown Pass over the Continental Divide between Waterton and Bowman lakes.

Certain factors are conspicuous in the nature and habits of this species. It produces abundant seed; the seeds are small, light and amply winged, and easily carried by the wind; the seeds germinate well; the tree endures much shade and the seedlings do well under heavy cover. The trees have great longevity and bear seeds for an extended period of time. On the other hand the Engelmann spruce grows slowly even under the best of conditions; it demands much moisture in the soil; its temperature limits while they may be wide for brief periods (−60 to 108) are more especially favorable toward the cooler end of the scale.

The chief determining factors in the distribution of Engelmann spruce are water and temperature. It has been held (27) that moisture alone is the dominant influence and that low temperatures operate mainly in increasing relative humidity. This seems to be true and the fact that in regions where the species abounds it grows to large size in narrow canyons but may rarely appear in the broader open stretches of river bottoms in the same locality and at the same altitude where conditions are unfavorable for an equal degree of relative humidity. The effect of high relative humidity, however, must not be regarded merely as insuring a greater amount of soil moisture, but, as in the case of the yew and other species, seems to operate directly on some phase of the transpiratory function. Places where soil waters are near the surface and never lacking are seldom if ever occupied by Engelmann spruce under conditions where the weather is continuously warm during several weeks of summer and the relative humidity low. While day temperatures may be occasionally high, in the favored habitat of this species,

Fig. 34. A north mountain slope near Missoula. In the foreground a typical slide-rock area, talus slope. The older talus in the background occupied by *Larix occidentalis, Pseudotsuga taxifolia* and *Salix, Acer, Prunus* and other shrubs, representing an older stage of the formation. March.

the nights usually are cool, almost to frost, and the usual daily temperatures of July and August about 75 to 85 degrees. Engelmann spruce is sometimes planted in Missoula, but does not thrive even under careful summer irrigation, although the Colorado blue spruce *(Picea Parryana)* and the Norway spruce do very well. Within the limits of its range the abundance and dominance of Engelmann spruce is conditioned upon its seeding habits and tolerance. As a competitor with other species it has the distinct advantage of being strongly shade resistant, and this quality is its sole compensation for its slow growth in height. Field seedlings gain in height less than 4 inches in 4 years under conditions apparently favorable. Other data on growth are to be found in Tables 22 and 23.

The growth of this species may easily be checked by fires, as the bark is very thin and the trees easily destroyed. Fires are less frequent, however, in this kind of forest than in some others, owing to the moister conditions under which the tree usually grows. The species is subject to few serious parasites among the fungi, though some among the insects operate to reduce its vitality or shorten its life.

The most frequent companion of the Engelmann spruce at all elevations, but especially in the higher ones, is the alpine or sub-alpine fir *(Abies lasiocarpa)*. It has almost as wide a range of vertical distribution as the spruce, but in altitudes above 6,000 feet it becomes much more conspicuous and abundant, probably owing to the lessened frequency of other species.

The salient characteristics of this species are, in the positive direction, a liberal production of seed from early youth, facility of dispersal and free germination. The species is tolerant and resistant to cold. Negatively its seeds have transient vitality, the tree requires much moisture both in soil and air, its upper temperature limit is low, its early growth is slow and it is not resistant to fires (61).

The alpine fir is the most typical tree of the high mountains in Montana, and from the highest slopes it descends to 2,000 feet in canyons in the northwestern part of the State. The most favorable situations for this species are to be found in the sheltered basins at altitudes from 5,000 to 7,000 feet. It is found usually upon slightly elevated knolls of sloping ground

Fig. 35. Close view of the talus on north slope in the lichen-moss stage. Species of *Caloplaca*, *Parmelia* and other genera on the stones, and of ***Hypnum*** growing between them. Largest stones about a foot in diameter. March.

providing good drainage but where there is sufficient moisture during the growing season. Unlike the spruce it seems to shun the wetter soils. Groves of the alpine fir often shelter snow drifts until August or even through the entire year.

This fir endures the most rigorous climate. Its temperature range must extend from −60 to over 100 degrees for short periods, with the prevailing summer temperatures between 30 and 85 at 6,000 feet elevation. It is the temperature which appears to be the special controlling factor in the distribution of the alpine fir, both local and general. Moisture likewise is influential but is likely never to be absent during the growing season in the zone where this species reaches its best development.

The alpine fir seldom grows in dense stands, but appears more or less scattered and in groups. Its tolerance, however, makes possible a dense forest which here and there is realized over small areas. The foliage of the crowns is dense, especially in older trees where it is sometimes almost impenetrable, and frequently descending to the ground. Young trees may endure shade for years and recover with rapid growth when the dominating influence is removed.

Abies lasiocarpa finds conditions favorable for its growth throughout the Rocky Mountain region from Alaska to Arizona and to some extent in the Cascades and coast ranges. In the southernmost parts of its range its lower limit in altitude is about 9,000 feet.

Another species forming a large part of the mountain forests is the whitebark pine *(Pinus albicaulis)*. It forms sometimes pure forests at 7,000 to 8,000 feet in clear orchard-like stands of trees of medium size a foot, more or less, in diameter and about 40 to 50 feet in height. Sometimes the trees of this species in more favored situations between 6,000 and 7,000 feet may reach a diameter of 5 feet or more, but such are rare. Trunk diameters of two to three feet, however, are not uncommon. On exposed, wind-swept situation at all altitudes within its range it assumes a stunted and spreading habit, usually of 5 or 6 feet in height. The white bark pine is the usual companion of the alpine fir and Engelmann spruce, and its characteristically branching tops can be recognized far and near. It enjoys a natural range from British Columbia to southern California and

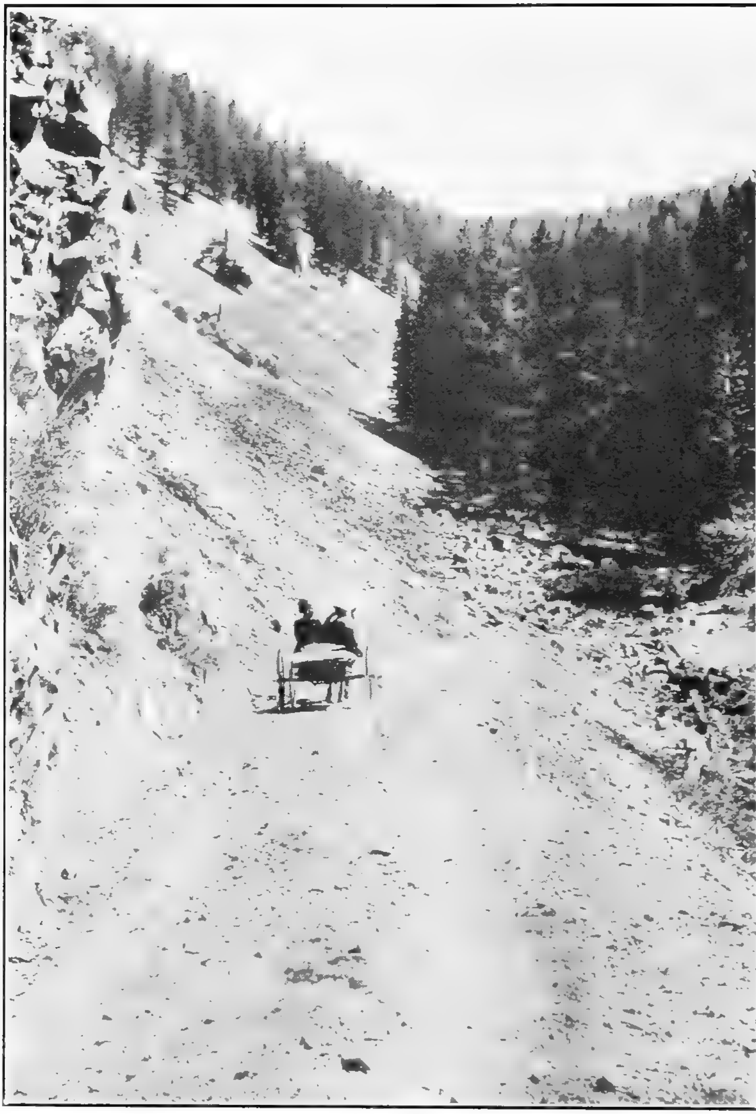

Fig. 36. A slide-rock slope, southern exposure, bearing *Pinus ponderosa* and Douglas spruce. Heavier forest to right *Abies lasiocarpa*, spruce and lodgepole pine. Near head of Bitter Root Valley, about 6000 feet, August.

in the northern Rockies, where it seems to reach its best development at 6,000 feet or above.

The positive qualities of the whitebark pine are few; it produces seed liberally, endures a wide range of temperature and seems adapted to rocky situations and meager soil. On the other hand it is limited by the lack of facility in seed dispersal, the seeds being heavy and large, which also renders them attractive to squirrels and other animals. The tree is intolerant, it thrives only in moist soil and having thin bark is readily injured by fires.

The seeding habits of this species are somewhat peculiar. Wind can have little influence on seed dispersal in a case where the seeds are devoid of wings or structures which serve a similar purpose. The cones do not open to discharge their seeds but disintegrate at the core. Cones falling to the ground if spared by animals, often give rise to trees in groups. Such trees may differ much in size, but an examination of the stem section will usually reveal the fact that they are of the same age. As one tree of the group gains the ascendancy it comes ultimately to stand alone. As the seeds of this species are wingless, their distribution is not dependent upon the wind, and other agencies must therefore account for their dispersal, in which squirrels and other seed-eating animals doubtless have a large share. The rare appearance of seedlings at relatively low altitudes, and where it is practically certain there is not a seed tree within miles, suggests the influence of birds. Among birds it is probable that the chief agency is the Clark Nut-cracker or Clark Crow *(Nucifraga columbiana)*. Skinner (58) states that it prefers pine seeds, sometimes tearing cones to pieces while yet attached to the branch. More often the cone is detached and carried away to a strong limb where it is held with one foot while the bird strikes strong downward blows at it with its pickaxe bill.

In its temperature relations the whitebark pine shows a capacity to endure a wide seasonal range said to be from 60 to 100 degrees, but for the most part it is restricted to cooler levels of elevation, seldom below 6,000 feet in Montana, though the writer has sometimes found isolated individuals at 3,500 feet in western Montana. It is found at about 6,000 feet in Glacier Park and about the same in the Swan Range, from 6,000 to

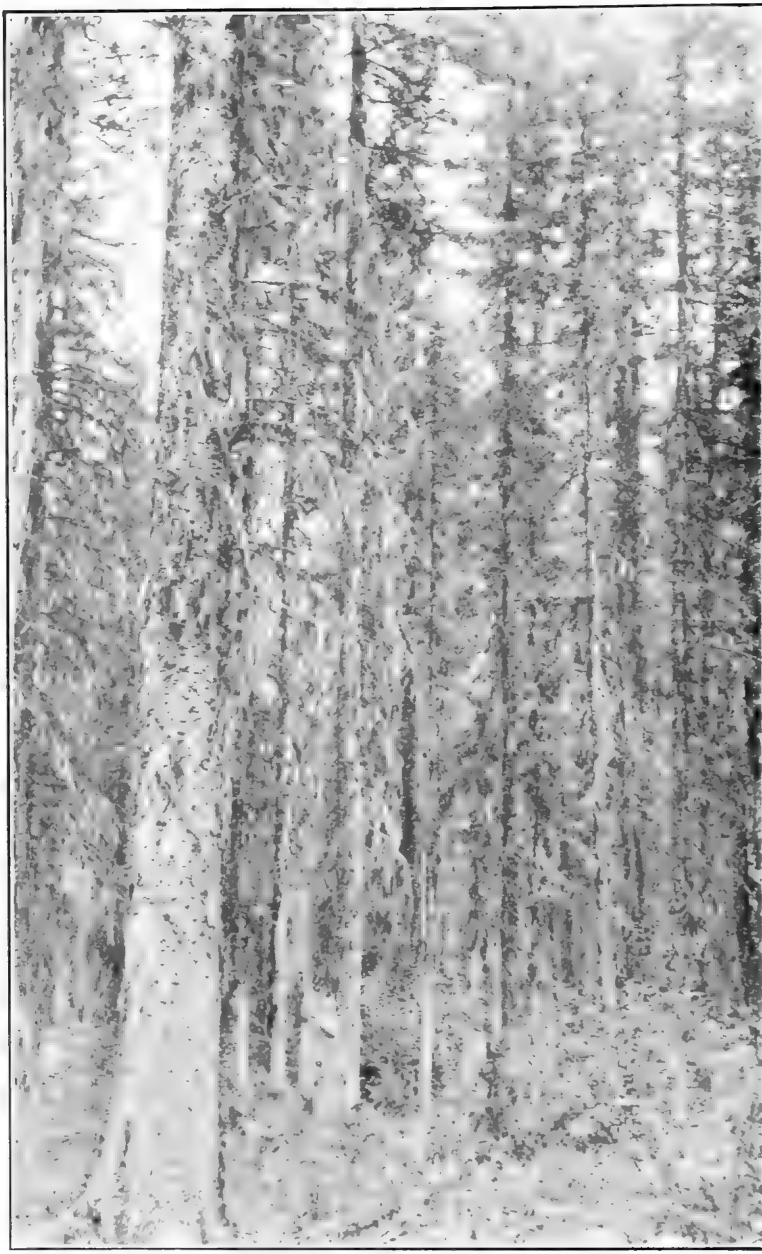

Fig. 37. Pure stand of *Picea Engelmannii* about the head of Avalanche Lake in Glacier National Park. August.

8,000 in the Bitter Roots, and in the Absaroka Range above 7,000. In the Little Belt Mountains it is found only on the highest points above 8,000 feet. Its endurance of high temperatures is only for brief periods at the altitudes which it usually inhabits.

In its local distribution it shuns the wet soils and is found usually on rocky ridges which have better drainage and aeration. Here it grows to its best size and so partial is it to the rock, either fixed or in the form of fragments or boulders, that no case can be recalled where trees of more than seedling size were found in the wet soil. It is a common accompaniment of the topography which is exhibited in crumbling outcrops of rock, alternating with depressed areas composed of finer materials, but seldom occupied by trees except at times the spruce. Sloping mountain sides are also favorite situations for this species. Uniform stands have been found by the writer where the ground cover consisted mainly of a thick carpet, ankle-deep, of small heaths mainly *Cassiope Mertensiana.* Its relation to temperature and to soil conditions are thus the important factors which control its local distribution. Owing to its very thin bark it is easily destroyed by slight fires and areas are known where whole stands are reduced to dry and bleaching trunks with little evidence of reoccupation by the same species, in marked contrast to the progress of the lodgepole pine. At its best the whitebark pine is not vigorous in propagation, and stands once destroyed are very slowly restored. Nevertheless this tree is readily found, as a rule in all the higher altitudes of the State and ranks third among the native species as to the extent, and uniformity of its distribution in this region.

Closely related to this species is *Pinus flexilis,* limber pine, which in this region is found east of the main divide. Cases reported of the finding of *Pinus flexilis* on the west slope in Montana seem not to be clearly substantiated. The two species are similar in requirements and in altitudinal range. The twigs and leaves are practically indistinguishable but the cones differ in form, color, thickness of the scales and manner of opening. The tree occupies high and exposed situations, and responds in the manner of its growth and its form much as other trees in similar situations, severely distorted and repressed.

The positive qualities of this species are found mainly in

Fig. 38. Western slope of the Mission Range overlooking Flathead Lake. Forest of *Pinus ponderosa*, *P. contorta*, *Larix occidentalis* and other species. June.

its liberal seed production, its capacity for resisting a vigorous climate, where the temperature falls to -60 degrees, high winds, adaptability to various soils but not strict in its demands upon soil moisture. It is thin barked and could easily be injured by fire, but in the open stands where it usually occurs there is less danger from this menace than is usual with other species. It seems not to be especially susceptible to disease. On the other hand its disadvantages in the matter of seeding, the limitations in the facilities for dispersal, the size of the seeds and the eagerness with which they are sought by animals, and its intolerance of shade militate against its dominance in the range which it occupies.

The limber pine has an extensive total range from Alberta, southward through the Rocky Mountains to New Mexico and westward to California. In the Belt Mountains it comprises about 8% of the forest species and about 2% in the Absaroka Range. It mingles more or less with lodgepole pine at the upper limits of distribution of that species and in the higher sub-alpine zone is found with spruce, fir, and whitebark pine.

THE SUMMITS.

The sub-alpine zone of the Montana Rockies, as above defined, represents the Hudsonian zone of Merriam and is with reference to all parts of its vegetation, a zone of surpassing interest. Its tree forms are few, it has a limited number of shrubby species and a considerable number of herbaceous perennials. The trees are *Pinus albicaulis*, *P. flexilis*, *Larix Lyalli*, *Picea Engelmannii*, *Tsuga Mertensiana*, *Abies lasiocarpa*, and *Juniperus scopulorum*. In shrubby form *Juniperus communis* also occurs in abundance. All of these except Lyall's larch and the black hemlock have a distribution extending across the State from north to south, and all except these two and the limber pine are found on both sides of the Continental Divide. Two of them, *Picea Engelmannii* and *Juniperus scopulorum*, have a wide range of altitude, from the crest of the divide at 6,000 feet or more down to the lowest point in Montana. *Larix Lyallii* belongs consistently to the high altitudes.

The aspect of the sub-alpine zone is not that of a continuous

Fig. 39. West slope of the Mission Range, east of Flathead Lake. A burn of several years standing being reoccupied by Lodgepole pine (*Pinus contorta*). Original stand largely *Pinus ponderosa*. June.

forest, but of limited tracts of even though usually not dense stands, or more often of bunched trees in small groups, separated by meadows, bogs, lakes, rock fields, snow fields, chasms, etc. Snow is perennial only in small patches, and even the glaciers of the northern part are of very limited extent. The growing season is short, however, and at an altitude of 6,000 feet may be limited to about two months or less during July and August. Heavy frosts usually occur and snow may fall during this time. Small brooks fed by melting snow run low or cease to flow at night and the days are usually long and bright and warm. Vegetation awakens quickly and advances rapidly to flowering, fruition and rest, so that usually before the end of August fresh snows have begun to mantle the peaks and higher ridges.

The Rocky Mountains of Montana have no summer snow line, and in rare cases only a distinct timber line. Most of the high mountains are clothed with trees of fair size almost to their very summits, especially on their more sheltered slopes, and where forests are lacking, the influence is not snow nor cold but chiefly wind and desiccation. Mt. Lolo of the Bitter Root Range, rising to about 9,000 feet, is forested practically to its summit, and Trapper Peak, the highest point of the same range, reaching 10,175 feet, is likewise timbered nearly to the summit. At Gibbon's Pass across the Continental Divide from the Bitter Root to the Big Hole the road passes through a dense forest of lodgepole pine, and where the railway lines cross the divide are scattering stands of pine and juniper. The peaks and high ridges of Glacier Park, from 6,000 to 10,000 feet have no perceptible timber line.

Under the conditions of the very short growing season and other adverse aspects of such situations it is inevitable that the increment of woody plants from season to season should be very small, especially in the cases of trees in situations at all exposed to wind. Trees sheltered in the center of a group make fairly rapid growth. Near the top of the Swan Range a small tree *(Abies lasiocarpa)* about 6 feet in height and about 3 inches in diameter at the ground stood at the edge of a group, but in a sheltered basin with trees back of it rising 40 feet or more. This tree had no limbs on its windward side but to the leeward extended its branches about two feet. A section across the stem

Fig. 40. Forest of Lodgepole pine on Continental Divide between Bighole and Bitter Root Valleys. Alt. 7000 feet. August.

showed 84 rings of annual growth, which could not be counted without the aid of a lens. The accompanying table prepared from observations on the trees of the sub-alpine forest, shows similar conditions, although in neither of these cases were the conditions less than of average advantage, and might have been even better than the usual sites occupied by trees. It will be observed that it required 60 years for the Engelmann spruce to reach a diameter of 3½ inches, 80 years for the pine to reach 4⅜ inches, and 108 years for the fir to attain 4½ inches in diameter. These may be taken as typical figures for most situations in the sub-alpine zone. The altitude in all these cases was about 6,200 feet. The first case cited was in the Swan Range east of Bigfork, the figures in the table are from observations made near Swift-Current Pass in Glacier National Park.

The shrubs most common in the sub-alpine forest are:

Salix Barclayi	*Menziesia ferruginea*
" *vestita*	*Ledum glandulosum*
" *glaucops*	*Kalmia polifolia*
Alnus incana	*Phyllodoce empetriformis*
Ribes lacustre	*Cassiope Mertensiana*
Sorbus scopulina	*Vaccinium erythrococcum*
Crataegus rivularis	" *scoparium*
Pachystima Myrsinites	" *oreophilum*

Of these *Salix Barclayi* forms dense thickets three or four feet in height here and there in basins at the heads of streams in Glacier Park and elsewhere. In the openings in such formation *Kalmia microphylla* occurs along with *Sphagnum* and grasses and sedges.

The other species of willow are plentiful but are not massed and are only locally conspicuous. *Alnus incana,* however, forms pure, dense and matted covering on some of the slopes of the Arctic drainage, and in places elsewhere is prominent in the forest undergrowth. The most characteristic of the high mountain shrubs are some of the heaths and huckleberries, *Ledum, Cassiope* and *Phyllodoce* are especially conspicuous in many places, and *Vaccinium erythrococcum* and *V. oreophilum,* low and slender, are frequent in forests or open parks. Most of the others named have an altitudinal range more or less extensive and are found in the forests of the white pine and hemlock

Fig. 11. Summit of Bitter Root Mountains. Snow on northern slope. Dwarf growth of *Pinus albicaulis*. Near 9000 feet. August.

Table 21. Data on the growth of certain trees of the sub-alpine (Hudsonian) zone. Height in inches.

Pinus albicaulis				*Picea Engelmannii*				*Abies lasiocarpa*			
Height	Diam.	Rings	Age	Height	Diam.	Rings	Age	Diam.	Height	Rings	Age
24	3/8	50	50	11	3/16	20	30†	7	3/16	21	21
28	5/8	25	25	16	1/4	22	22	16	3/8	36	36
36	1 3/16	35	35	27	5/8	42	46†	16	1/2	29	30*
46	3/4	36	36	32	5/8	27	27	31	3/4	41	41
49	1 3/4	60	63*	39	7/8	33	34*	48	1 1/2	60	60
55	1	51	51	61	1 5/8	28	30*	61	2	59	59
72	1 5/16	50	50	62	1 1/2	55	55	82	2 1/4	81	83*
94	2 1/4	60	62*	105	2 3/4	59	59	89	2 1/2	83	83
128	2 1/8	58	60*	165	2 1/2	64	66*	172	3 1/8	84	87*
156	4 3/8	72	80*	180	3 1/2	54	60*	186	4 1/2	108	108

* Stems cut from 1 to 8 inches above the ground. One year allowed for each inch.
† Annual markings on the surface of the stem seemed to indicate greater age; in older stems these disappear.

Fig. 42. A typical subalpine "park" in July, Swan Range, about 6500 feet altitude. Trees mostly *Abies lasiocarpa*. Herbaceous vegetation uniformly low, 10 inches or less, consisting mainly of *Juncoides glabratum, Erythronium grandiflorum, Claytonia megarrhiza, Anemone parviflora, Ranunculus alpeophilus.*

as well as in those of the spruce and sub-alpine fir. In fact most of them may be found at altitudes varying from 3,000 to 8,000 feet under moist and sheltered conditions at the same latitude.

Herbaceous plants of the sub-alpine zone, especially in the open parks, are many and some of those collected by the writer in different places in Montana are as follows:

Lonicera Utahensis	*Claytonia megarrhiza*
Deschampsia atropurpurea	*Anemone parviflora*
Phleum alpinum	*Pulsatilla occidentalis*
Carex atrata	*Draba crassifolia*
" *Montanensis*	*Mitella pentandra*
" *Mertensii*	*Parnassia fimbriata*
Scirpus trichophorum	*Dodecatheon pauciflorum*
Eriophorum gracile	*Epilobium Hornemannii*
Eleocharis acicularis	*Phacelia sericea*
Juncoides glabratum	*Mimulus Lewisii*
Xerophyllum Douglasii	" *moschata*
Veratrum Californicum	*Castilleja miniata*
Erythronium grandiflorum	*Erigeron macranthus*
Calochortus apiculatus	*Arnica ventorum*
Spiranthes stricta	

Usually the whole of the above list may be collected in any of the mountain parks of the Montana Rockies, in flower or fruit between the middle of July and the middle of August. *Juncoides glabratum* is conspicuous and abundant, forming a veritable sod over large areas with grasses and sedges in the wetter portions along the water courses and elsewhere, mingled with *Mimulus*, *Epilobium*, and *Spiranthes*. In the dryer places *Erigeron* is conspicuous along with *Anemone*, *Castilleja*, *Erythronium*, *Claytonia* and many others in a riot of luxuriance and color. On the slopes with better drainage *Xerophyllum* is dominant plant, even on stony ridges and the older talus. *Erythronium grandiflorum*, *Calochortus apiculatus*, *Castilleja miniata* and*Erigeron macranthus* of the above list, and others that might be mentioned, are equally as abundant in many places at altitudes of 3,000 to 4,000 feet as in the mountain parks at 6,000 feet or more elevation, though their flowering season is from one to three months earlier. *Erythronium* in the vicinity

Fig. 43. At an altitude of about 6200 feet in the Swan Mountains. *Abies lasiocarpa* with ground cover of *Juncoides glabratum* and snow bank in the foreground. July.

of Missoula at 3,300 feet opens from the 20th to 30th of April and gradually unfolds at successively higher altitudes on north slopes until in about five weeks, the same phase of development may be found at 5,300. Under such conditions spring, summer and autumn are telescoped into one brief period and the flowers of these seasons at lower altitudes are mingled in one brilliant assemblage, during the few weeks of vegetative activity. So short is the growing season that the plants can scarcely await the removal of the snow and ice. In one year on the 22nd of July in a mountain park at an altitude of about 6,500 feet the writer observed this luxuriance of vegetation where the blades of *Erythronium grandiflorum, Juncoides glabratum* and other plants were forcing their way through sheets of ice an inch or more in thickness. The edges of old snowdrifts condensing into a solid fringe of ice of varying thickness were closely surrounded by the vigorous shoots of numerous plants several inches in height. Some had perforated the ice and others under the thicker parts had pushed upward into it and when the cakes of ice were overturned their bottoms were marked by deep pits plainly evident.

Local differences are thus evident in the length of season and the conditions of development in small areas side by side. This must have its influence upon forest development as well as upon herbaceous vegetation. The earlier an area is cleared of its snow the longer its growing season. The occupation by forest trees of slight elevations above the general surface in protected coves where the snow usually accumulates may be susceptible of this explanation for from such the snow must sooner disappear, while in the alternate depressions it may not entirely melt during the whole summer. The advantages of a relatively long growing season may thus account for the establishment of forest species where otherwise it would be impossible.

SUMMARY.

1. The area here under discussion covers the State of Montana and neighboring parts of Idaho. Approximately one-half of the total area may be said to be forested, but some of the

Fig. 44. A cirque lake in the Swan Range bordered by *Abies lasiocarpa* and *Picea Engelmannii.* Altitude about 6000 ft. July.

forest species extend into the plains eastward over the higher elevations of land and along the margins of the valleys.

2. The altitude of most of this region lies above 3,000 feet. From the eastern boundary of Montana at about 2,000 feet the land rises gradually to the summit of the divide at from 6,000 to 10,000 feet and drops more abruptly toward the west to altitudes of 1,800 feet or less. The region is one of greatly diversified topography with many high and some very rugged mountain chains and intermountain valleys varying in all widths up to 20 miles or over. The general course of the ranges is from northwest to southeast. Geologically the surface formations are largely of the Cretaceous and the Tertiary, with some of more ancient origin. Most of the area has been glaciated and extensive fields are covered with gravels. Mountain glaciers still remain in some of the northern ranges.

3. The climate is relatively dry, the mean annual precipitation varying from 10 to 24 inches in most places with occasional exceptions in the direction of the greater numbers. The rain-bearing winds of the northern Rocky Mountains are from the west and southwest. The mountain chains which lie across their path receive heavier precipitation on their western slopes, resulting in heavier forests upon the western side at elevations mostly above 4,000 feet and correspondingly drier eastern slopes and intermountain valleys with sparser woods or prairies. From the standpoint of temperature the region is one of long winters and short summers, a condition accentuated with the increase in altitude. In different places and at different altitudes temperature of -20 to -50 degrees are frequent but not continuous and the winters are not especially severe. The effect of the lower temperature is seen mainly in the shortening of the growing season and the relative frequency of summer frosts. Low relative humidity and a high rate of evaporation in summer and the seasonal distribution of rainfall add their influence in determining the character of the vegetation.

4. The sources of the vegetation of the region are mainly two. The Atlantic flora and the Pacific flora meet in the northern Rocky Mountains and overlap. Many trees, shrubs, and herbs have entered from the west, either across the wide basin of eastern Oregon and Washington at some earlier time

Fig. 45. Section of a small fir (*Abies lasiocarpa*) six feet in height, two inches in its greatest diameter, 84 years old. Illustrating the severity of conditions for growth in exposed situations at about 6500 feet altitude.

when conditions were more favorable, or more recently by way of the Okanogan country and the Selkirk Mountains, and entering Montana mostly by way of the Coeur d'Alene gateway, form a large part of the plant covering on the western slope of the divide. Most of the woody species represented bear either wind-blown seeds or succulent fruits. Few heavy seeded species have entered the region from any source. The eastern contingent is less numerous among the woody forms. Some of these apparently have followed the streams across the plains, but the larger number have made their way across the continent from the Great Lakes to Alaska and have followed the Rocky Mountains southward.

5. The mountain ranges act as barriers to eastward and westward migrations. The continental crest in itself is not the efficient barrier, but the elevation of a large land mass, consisting of the main chain and its parallel ranges east and west, so affect the climatic conditions over a wide space as to influence the movements of plants. The Bitter Root and Cabinet Ranges form a secondary barrier west of the main divide.

6. About 17 species of Gymosperoms make up the bulk of the Rocky Mountain forest in Montana and Idaho. The number of these is greatest along the western border of the area. Two reasons are assigned for this. First the western part is nearer the source whence most of the species probably came and, second, the climatic conditions are there most favorable. From the western side eastward this number of coniferous species diminishes to three or four on the eastern side.

7. Over much of the western part of the State forest distribution at lower elevations conforms to topographic influences in response to moisture, temperature or light. Above 5,000 feet the forests become continuous over most of the mountain region, clothing the mountains to their summits, except in some cases where desiccating influences render the peaks untenable for woody species. There is no summer snow line on the mountains of this region and no upper timber line that is constant or clearly defined or subject to a particular elevation.

8. The life zones, according to Merriam, are represented indistinctly. The foothill region of yellow pine and Douglas spruce represents largely the Arid Transition intergrading through the

larch and Douglas spruce on northern slopes to the marked Pacific Coast Humid Transition of the northwestern valleys where the strongest mesophytic conditions of the region prevail. The main body of the forests on the mountain sides belongs to the Canadian zone and consists largely of lodgepole pine, spruce, larch, whitebark pine and alpine fir. The Hudsonian Zone is nowhere clearly delimited from the Canadian and most of its species make up a large part of the forests between 5,000 and 10,000 feet. However, at the higher elevations the alpine fir, Engelmann spruce, and whitebark pine are the principal trees, though of inferior size and form owing to the severe conditions there found.

Literature.

1. Abbe, Cleveland. First report on the relations between climates and crops. Bull. Weather Bureau U. S. Dept. Agric. 342: 1-386. Au 1905.

2. Bessey, C. E. Plant migration studies. Univ. Neb. Studies 5: 1-26. Ja 1905.

3. ——————. The forests and forest trees of Nebraska. Ann. Rep. Neb. State Board Agric. 1899.

4. Blankinship, J. W. A century of botanical exploration in Montana. Montana Agric. Coll. Sci. Studies 1: 3-31, 1905.

5. ——————. Report of the botanist. Bull. Mont. Agric. Exp. Sta. 32: 38-44, 1902.

6. Boerker, R. H. Ecological investigations upon the germination and early growth of forest trees. pp 1-89. pl. 1-5. Lincoln, Neb. Ja. 1916.

7. Bowman, Isaiah. Forest physiography. New York. 1911.

8. Briggs, Lyman J. and Belz, J. O. Dry farming in relation to rainfall and evaporation. Bull. Bureau Plant Ind. U. S. Dept. Agric. 188: 1-71. *pl. 1. f. 1-23.* N 1910.

9. Calhoun, Fred H. H. The Montana lobe of the Keewatin Ice Sheet. Prof. Paper U. S. Geol. Surv. 5: 1-62. *pl. 1-7 f. 1-30.* 1906.

10. Calkins, F. C. A geological reconnaissance of northern Idaho and northwestern Montana. Bull. U. S. Geol. Surv. 384: 1-112. *pl. 1.* 1909.

11. Cary, Merritt. Life zone investigations in Wyoming. U. S. Dept. Agric. Biol. Surv. N. A. Fauna 42: 1-95. *f. 1-17.* 1917.

12. Clements, F. E. The life history of lodgepole burn forests. Bull. U. S. Dept. Agric. 79: 1-56. *pl. 1-6.* Ja. 1910.

13. Cooper, William S. Alpine vegetation in the vicinity of Long's Peak, Colorado. Bot. Gaz. 45: 319-337. *f. 1-8.* My 1908.

14. Coulter, John M. A catalogue of plants collected in 1872 in portions of Montana, Idaho, Wyoming and Utah. Ann. Rep. U. S. Geol. Surv. Terr. 6: 747-792. 1873.

15. DAVIS, W. M. The Mission Range, Montana. Proc. Nat. Acad. Sci. 1: 626-628. D 1915.

16. DWIGHT, T. W. Forest conditions in the Rocky Mountain Forest Reserve. Bull. Forestry Branch Dept. Int. Canada. 33: 1-62. *pl. 1-19.* 1913.

17. FOLLANSBEE, ROBERT, MEEKER, R. L. and STEWART, J. E. Surface water supply of the Missouri River drainage, 1906. Water Supply and Irrigation Paper U. S. Geol. Surv. 208: 1-90. *pl. 1-5.* 1907.

18. FREE, E. E. The movement of soil material by the wind. Bull. Bur. Soils U. S. Dept. Agric. 68: 1-272 *pl. 1-5.* 1911.

19. GEYER, CHARLES A. Notes on the vegetation and general character of the Missouri and Oregon Territories, made during a botanical journey from the State of Missouri, across the South Pass of the Rocky Mountains to the Pacific during the years 1843 and 1844. Lond. Journ. Bot. 4: 479-492, 653-662, 1845. 5: 22-41, 198-208, 285-310, 509-524. 1846.

20. GRAY, ASA. Forest geography and archeology. Am. Journ. Sci. and Arts. 16:—. 1878. (Bull. U. S. Geol. Surv. Terr. 6:62-77. 1880.)

21. GRAY, ASA and HOOKER, JOSEPH D. The vegetation of the Rocky Mountain region and a comparison with that of other parts of the world. Bull. U. S. Geol. and Geog. Surv. Terr. 6: 1-77. 1880.

22. GRIGGS, ROBERT F. Observations on the behavior of some species at the edges of their ranges. Bull. Terr. Bot. Club. 41: 25-49. *f. 1-6.* Ja 1914.

23. HALL, H. M. A botanical survey of San Jacinto Mountain. Univ. Cal. Pub. 1: 1-140. *pl. 1-14.* Je 1902.

24. HARSHBERGER, J. W. Phytogeographic survey of North America. Die Vegetation der Erde, XIII, Leipzig, 1911.

25. HARRINGTON, M. W. Review of forest meteorological observations. A study preliminary to the discussion of the relation of forests to climate. Bull. For. Div. U. S. Dept. Agric. 7: 23-122. *f. 1-60.* 1893.

26. HAYDEN, F. V. Plants collected during the exploration of the upper Missouri by F. V. Hayden. Rep. Sec. War. 2: 726-747. 1858.

27. HODSON, E. R. and FOSTER, J. H. Engelmann spruce in the Rocky Mountains. Circ. For. Serv. U. S. Dept. Agric. 170: 1-23. S 1910.

28. KNOWLTON, F. H. A catalogue of the Cretaceous and Tertiary plants of North America. Bull. U. S. Geol. Surv. 152: 1-247. 1898.

29. LEIBERG, JOHN B. Notes on the flora of western Dakota and eastern Montana adjacent to the Northern Pacific Railroad. Bot. Gaz. 9: 103-107, 126-129. 1884.

30. ————. General report on a botanical survey of the Coeur d'Alene Mountains in Idaho during the summer of 1895. Cont. U. S. Nat. Herb. 5: 1-85. *pl. 1.* Ja 1897.

31. ————. Forest conditions in the Absaroka division of the Yellowstone Forest Reserve, Montana, and the Livingston and Big Timber Quadrangles. Prof. Paper U. S. Geol. Surv. 29: 1-148. *pl. 1-2* 1904.

32. ————. Forest conditions in the Little Belt Mountains Forest Reserve, Montana, and the Little Belt Mountains Quadrangle. Prof. Paper U. S. Geol. Surv. 30: 1-75. *pl. 1-2.* 1904.

33. LESQUEREUX, LEO. Contributions to the fossil floras of the western territories. III. Cretaceous and Tertiary Floras. Rep. U. S. Geol. Surv. Terr. 8: 1-283. *pl. 1-59.* 1883.

34. LINDGREN, WALDEMAR. A geological reconnaissance across the Bitter Root Range and Clearwater Mountains in Montana and Idaho. Prof. Paper U. S. Geol. Surv. 27: 1-123. *pl. 1-15.* 1904.

35. LIVINGSTON, B. E. Temperature coefficient in plant geography and climatology. Bot. Gaz. 56: 349-375. 1913.

36. LYALL, DAVID. Account of the botanical collections made by David Lyall, M.D., R.N., F.L.S., Surgeon and Naturalist to the North American Boundary Commission. Journ. Linn. Soc. 7: 124-144. 1864.

37. MACDOUGAL, D. T. The auxo-thermal integration of climatic complexes. Am. Journ. Bot. 1: 186-193. *pl. 17-18.* Ap. 1914.

38. MARSHALL, R. B. Results of spirit leveling in Montana. Bull. U. S. Geol. Surv. 482: 1-154. *pl. 1.* 1911.

39. MASON, D. T. The life history of the lodgepole pine in

the Rocky Mountains. Bull. U. S. Dept. Agric. 154: 1-35. Ja 1915.

40. MATHEWS, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. Bull. U. S. Dept. Agric. 447: 1-12. N 1916.

41. MAXIMILIAN, ALEXANDER PHILIPP. Reise in das innere Nord Amerika in dem Jahren 1932-34. Coblenz, 1841.

42. MEEHAN, THOMAS. The plants of Lewis and Clark's expedition across the continent, 1804-1806. Proc. Acad. Nat. Sci. Phila. Ja 1898.

43. MERRIAM, C. HART. Life zones and crop zones of the United States. Bull. Div. Biol. Surv. U. S. Dept. Agric. 10: 1-79. *pl. 1.* 1898.

44. NEWBERRY, J. S. The later extinct floras of North America. Monog. U. S. Geol. Surv. 35: 1-295. *pl. 1-68.* 1898.

45. OREGON HISTORICAL SOCIETY. The correspondence and journals of Captain Nathaniel J. Wyeth, 1831-36. Sources of the History of Oregon. 1: —. Eugene. 1899.

46. PIPER, CHARLES V. Flora of the State of Washington. Cont. U. S. Nat. Herb. 11: 1-637. *pl. 1-18.* O 1906.

47. PURSH, FREDERICK. Flora Americae Septentrionalis. London. 1814.

48. RAMALEY, FRANCIS. Remarks on the distribution of the plants in Colorado east of the Divide. Postelsia. 1902: —.

49. Report National Conservation Commission. Papers on the conservation of water resources. Water Sup. Paper U. S. Geol. Surv. 234: 1-96. *pl. 1-2.* 1909.

50. ROBBINS, M. W. Climatology and vegetation in Colorado. Bot. Gaz. 49: 256-280. Apr 1910.

51. ROSS, D. W., WHISTLER, J. T. and NOBLE, T. A. Report on progress of stream measurements for the calendar year 1905. Columbia River and Puget Sound Drainage. Water Supply and Irrigation Paper U. S. Geol. Surv. 178: 1-250. *pl. 1.* 1906.

52. ROWE, J. P. and WILSON, R. A. Geology and economic deposits of a portion of eastern Montana. Univ. Mont. Studies, I. 1: 1-58. *f. 1-27.* Missoula. 1916.

53. RYDBERG, P. A. Vegetative life zones of the Rocky Mountains. Mem. N. Y. Bot. Gard. 6: 447-499. Au 1916.

54. ———. Phytogeography of Montana. Bull. Tor. Bot. Club. 27: 292-294. 1900.

55. ———. Phytogeographical notes on the Rocky Mountain region. Bull. Tor. Bot. Club. 40: 677-686. D., 41: 89-103. F., 459-474. S., 42: 11-25. Ja., 629-642. N., 43: 343-364. Jl. 1913-1916.

56. SCHIMPER, A. F. W. Plant geography on a physiological basis. English Translation. Oxford. 1903.

57. SHAW, CHARLES H. Vegetation of the Selkirks. Bot. Gaz. 61: 477-494. Je 1916.

58. SKINNER, M. P. The Nutcrackers of the Yellowstone Park. The Condor. 18: 62-64. 1916.

59. SMILEY, F. J. The alpine and sub-alpine vegetation of the Lake Tahoe region. Bot. Gaz. 59: 256-286. *f. 1-4.* Ap 1915.

60. SUDWORTH, GEORGE B. The pine trees of the Rocky Mountain Region. Bull. U. S. Dept. Agric. 460: 1-47. *pl. 1-25. mp. 1-10.* My 1917.

61. ———. The spruce and balsam fir trees of the Rocky Mountain region. U. S. Dept. Agric. Bull. 327: 1-43. *pl. 1-25. mp. 1-10.* F 1916.

62. ———. Forest trees of the Pacific Slope. U. S. Dept. Agric. Forest Service. 1908.

63. THWAITES, R. C. Maximilian's travels in N. America. Early Western Travels, 1748-1846. 21: 10-16. 22: 384-385.

64. TORREY, JOHN. Catalogue of the plants collected by Mr. Charles Geyer, under the direction of Mr. I. N. Nicollet, during his exploration of the region between the Mississippi and the Missouri Rivers. Sen. Doc. 26th Cong. Washington. 1843.

65. TRANSEAU, E. N. On the geographic distribution and ecological relations of the bog plant societies of northern North America. Bot. Gaz. 36: 401-420. *f. 1-3.* D 1903.

66. ———. The relation of plant societies to evaporation. Bot. Gaz. 45: 217-231. Ap 1908.

67. TURESSON, GOTE. Slope exposure as a factor in the distribution of *Pseudotsuga taxifolia* in arid parts of Washington. Bull. Tor. Bot. Club. 41: 337-345. Je 1914.

68. VISHER, S. S. Report on the biology of Harding coun-

ty northwestern South Dakota. Bull. S. D. Geol. Surv. 6: 1-126. *pl. 1-6.* Mr 1914.

69. WARD, LESTER F. Status of the mesozoic floras of the United States. Monog. U. S. Geol. Surv. 48: 1-616. *pl. 1-109.* 1905.

70. Weather Bureau. Summary of the climatological data of the United States by sections. 26: 1-4. *f. 1-2.* 27: 1-7. *f. 1-2.* 28: 1-7. *f. 1-2.* 39: 1-7. *f. 1-2.* 30: 1-6. *f. 1-2.*

71. WEAVER, J. E. A study of the vegetation of southeastern Washington. Univ. Neb. Studies 17: 1-114. *f. 1-48.* Ja 1917.

72. WEAVER, J. E. and THIEL, A. B. Ecological studies in the tension zone between prairie and woodland. Bot. Surv. Neb. NS. I. 1: 1-57. *f. 1-38.* Ap 1917.

73. WHITFORD, H. N. The forests of the Flathead Valley. Bot. Gaz. 39: 99-122. F. 194-218. Mr. 276-296. Ap. *f. 1-23.* 1905.

74. ZON, RAPHAEL, and GRAVES, H. S. Light in relation to tree growth. Bull. For. Serv. U. S. Dept. Agric. 92: 1-59. *f. 1-10.* Je 1911.

75. ZON, RAPHAEL. Seed production of western white pine. Bull. U. S. Dept. Agric. 210: 1-15. Ap 1915.