THE ANCIENT FORESTS OF OREGON

BY

RALPH W. CHANEY

CONDON LECTURES

OREGON STATE SYSTEM
OF HIGHER EDUCATION
EUGENE, OREGON : : 1948

THE CONDON LECTURES

The Condon Lectureship was established in 1944 by the Oregon State Board of Higher Education upon the recommendation of the late Dr. John C. Merriam who was, at that time, a member of the faculty of the University of Oregon. The Lectureship was named in honor of Dr. Thomas Condon, the first professor of geology at the University.

The lectures, usually two annually, are delivered three times in the state, namely, at Eugene, Corvallis, and Portland. They are then published in appropriately adapted form.

Condon Lecture Publications

The Ancient Volcanoes of Oregon. By Howel Williams, Chairman, Department of Geological Sciences, University of California. Jan. 1948. Price: $1.25.

Malaysia—Crossroads of the Orient. By Fay-Cooper Cole, Emeritus Chairman, Department of Anthropology, University of Chicago. $ .75.

The Ancient Forests of Oregon. By Ralph Chaney, Professor of Paleontology, University of California. Dec. 1948. $1.00.

The China That is to Be. By Kenneth Scott Latourette, D. Willis James, Professor of Missions and Oriental History, and Fellow of Berkeley College, Yale University. Forthcoming.

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At the Cant's ranch locality, with Sheep Rock in the background, are Eustace L. Furlong, Chester Stock, John C. Merriam, and the author, long associated in the study of paleontology in Oregon. Fossil chestnuts are common here.

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BY

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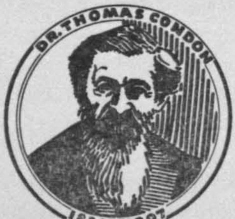

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Preface

THE STUDENT of science is fortunate to be working in a field where the frontiers of knowledge are being constantly extended across the terrain of earlier ignorance. In no subject is this dynamic quality more apparent than to the paleontologist. The next blow of his hammer may uncover a fossil leaf whose like has never before been seen. A bone fragment may lead to his wider comprehension of an animal which has long been extinct. Each isolated fact becomes part of a fabric which makes possible the fuller interpretation of life in ages past.

Since I had the honor of delivering the Condon Lectures in November 1946, there have been two important discoveries in the field of paleobotany which bear directly upon our understanding of the ancient forests of Oregon. One of these is the finding of living redwoods in China, and our realization that it was trees like them, rather than like the redwoods now living along the Pacific Coast, which were once dominant members of Oregon's forests. The other discovery was made in the John Day Basin—the first evidence of the occurrence of leaf impressions in the Rattlesnake formation which forms the rimrock above Dayville.

If I had known about these Pliocene leaves in 1946, or could have interpreted the fossil redwoods of Oregon in terms of their Chinese descendants, my lectures would have been more accurate, my conclusions more significant. In the statement which follows, I have modified my oral presentation to include this newly acquired information. Although I wish I might have used it when I delivered the Condon Lectures, I am glad that the pleasure of our visits to Corvallis, Portland, and Eugene was not delayed until I had witnessed all the discoveries which will sometime widen our vision. Many generations of the paleontologic grandchildren of Thomas Condon will search the sage-covered valleys of eastern Oregon, and climb to Cascade summits, before even the broader brush strokes of this picture of the past can be drawn.

University of California,
Berkeley, 1948.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Introduction

EIGHTY years ago a troop of cavalry returning from Harney Valley crossed the John Day Basin on its way back to Fort Dalles. Coming down the road along Bridge Creek, a civilian member of the party, Thomas Condon by name, stopped to examine the fragments of white shale scattered over the lower slopes of rounded hills. Imprinted on these rocks were needles of redwood and leaves of oak. In the years that have followed, many of us have visited these same hills to ponder the significance of fossil redwoods in a land now inhabited by juniper and sage. To Thomas Condon, pioneer geologist of Oregon, discovery of the record of ancient forests on Bridge Creek brought a desire to learn more about the life of the past; the interest aroused by these shale fragments continued through a long life devoted to the study of Oregon's past, and to teaching several generations of Oregon students.

Condon returned to the John Day Basin whenever opportunity afforded with "a rifle in one hand and my pick in the other" (McCornack, 1928, ch. 5). Many of his finer specimens were sent to John Strong Newberry, with letters describing their occurrence in detail. In 1870, Condon wrote that he hoped soon to go to the Crooked River, since "only a few small bands of Indians remain to be gathered on the reservation, and then one may go there without escort." Newberry's letters in reply promised somewhat cautiously to "pay any reasonable bill of expense incurred"; occupied as he was with other activities, Newberry never adequately completed his study of the Condon collections, although some years later he made brief reference to them (Newberry, 1882). It is recorded in the account of the *18th Annual Meeting of the American Association for the Advancement of Science, held at Salem, Massachusetts, August 18-25, 1869*, that Newberry gave a paper "On the Flora and Fauna of the Miocene Tertiary Beds of Oregon and Idaho," and that he "exhibited a beautiful series of fossil plants collected by Rev. Mr. Condon of Dallas City, Oregon" (*American Naturalist*, 1869). In the years that followed, many men of science made use of the materials and ideas which Condon was assembling. In his discussion of the geology of Oregon (1880), Cope referred to Condon's specimens of *Taxodium* in shales which "are composed of fine material, and vary in color, from a white to a pale brown and reddish brown"; these appear to have been *Metasequoia* from the Bridge Creek shale. He also mentions Condon's "Calamite beds" as occurring at a lower stratigraphic level; the underlying Clarno formation contains many stems of *Equisetum*. Within a few years, many of the leaders of American paleontology and geology were coming to Oregon to study the occurrence of Condon's specimens, and to make collections of their own. Leidy, Marsh, and Cope in vertebrate paleontology, LeConte, the geologist, and in later years Knowlton and Merriam, traversed the routes of Condon's early journeys, and based many fundamental conclusions on his collections and interpretations. With the founding of the University of Oregon, Condon was elected to the chair of Natural Science in 1876. From that date down to the present, Oregon has developed an intellectual center of its own, with important emphasis on the earth sciences, geology and paleontology, and on the related subject of anthropology. No state is more richly endowed with the records of earth history. No region in the world shows a more complete sequence of Tertiary land populations, both plant and animal, than the John Day Basin.

THE ANCIENT FORESTS OF OREGON

Records of the Oldest Forests of Oregon

NOT ALL of the record of ancient vegetation is made up of such modern trees as redwood and oak. During the ages preceding the Cenozoic era in which we live, there were plants living in Oregon which have no survivors in existing forests. As in the case of other historical documents, these oldest records of vegetation are relatively incomplete. Enough is known, however, to provide a general idea of the vegetation of the older eras.

The standard scale which follows shows the eras and periods, and some of the epochs, into which geologic time has been divided for the time since life has been abundantly recorded. Periods and epochs known to be represented in Oregon are preceded by the letter *O*; those whose rocks contain fossil plants are followed by the letter *P*. A survey of this time scale will indicate that records of vegetation are much more complete in later geologic time than in the earlier eras. Most of the Paleozoic and many of the Mesozoic sediments of Oregon were laid down in the sea, and the remains of land plants were not buried and preserved in them.

Cenozoic Era	O Quaternary Period P	O Recent Epoch
		O Pleistocene Epoch P
	O Tertiary Period P	O Pliocene Epoch P
		O Miocene Epoch P
		O Oligocene Epoch P
		O Eocene Epoch P
		Paleocene Epoch
Mesozoic Era	O Cretaceous Period P	
	O Jurassic Period P	
	O Triassic Period	
Paleozoic Era	O Permian Period	
	O Carboniferous Period P	
	Devonian Period	
	Silurian Period	
	Ordovician Period	
	Cambrian Period	

I. THE FORESTS OF THE CARBONIFEROUS PERIOD

During the later periods of the Paleozoic era, forests became well established over much of the earth's surface. They were particularly abundant and widely distributed during the Carboniferous period, when their stems, roots, and leaves accumulated to form the principal deposits of coal in America. These forests, made up predominantly of plants which reproduce by means of spores, but including also some of the simpler types of seed plants, were widely distributed in the eastern part of North America, where their fossil remains have been extensively studied. On the western side of the continent shallow seas covered wide areas, and there are few known occurrences of terrestrial deposits. One of the most significant of these is to be found in the upper part of the Crooked River Basin, on the Mills ranch in southeastern Crook County. In 1928, Earl L. Packard made a preliminary announcement of the occurrence here of Carboniferous sediments, and for several years thereafter the region was visited by field classes from the University of Oregon and Oregon State College. At Packard's request, Charles W. Merriam began a detailed study of these deposits, and in 1938 he and his assistant, S. A. Berthiaume, discovered abundant remains of land plants (Read and Merriam, 1940). The most numerous of these are fronds of fernlike plants referred to the genera *Sphenopteris* and *Dactylotheca* (see Plate I). Jointed stems with whorls of linear leaves are also common; these plants, distantly related to modern horsetails, are assigned to *Calamites* and *Asterophyllites*. There is a conifer named *Dicranophyllum* which has also been found in Europe and Asia, as have all of the other Mills ranch genera. From most of the related floras in other parts of the world, this Oregon forest differs in the absence of the more typical lowland forms, and in the relatively small size of the individual plants. Unlike the sediments in which most Carboniferous fossils occur elsewhere, the matrix enclosing the Mills ranch fossils does not have the dark gray or black color which characterizes swamp deposits in which large amounts of carbon accumulate. All available evidence appears to indicate that this part of Oregon was an upland, rather than a lowland, during later Paleozoic time. Much more must be learned before we can have a full understanding of this ancient landscape and of the forests which covered it some two hundred million years ago. But we may feel confident that a range of hills extended along the southern borders of what is now the John Day Basin. And we know that the forests mantling these hills were not only unlike any now living, but that they showed marked differences from those then living in eastern North America. Already the vegetation of Oregon had developed a distinctive aspect.

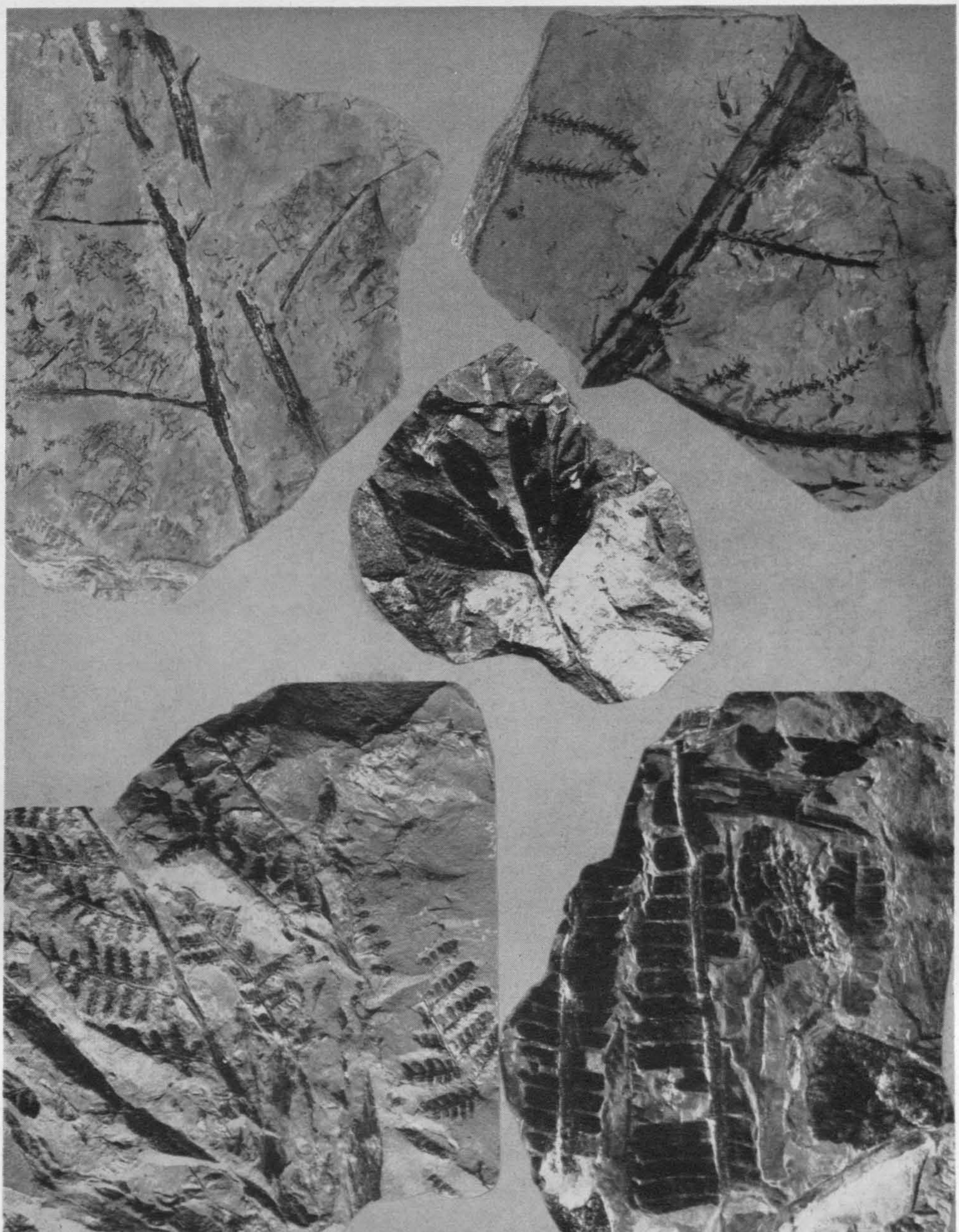


PLATE I.

Plants from the older floras of Oregon. Approximately three-fourths natural size.

Fig. 1 (upper left). *Sphenopteris,* a fernlike plant from the Carboniferous of the Crooked River Basin.
Fig. 2 (upper right). *Calamites,* a Carboniferous horsetail from the Crooked River Basin.
Fig. 3 (center). *Ginkgo* from the Jurassic of Douglas County. *(Courtesy of Encyclopedia Britannica.)*
Fig. 4 (lower left). *Cladophlebis,* a fern from the Jurassic of Douglas County.
Fig. 5 (lower right). *Pterophyllum,* a cycadeoid from the Jurassic of Douglas County.

II. THE FORESTS OF THE MESOZOIC ERA

There are only two areas within the state which are known to have been occupied by land plants during the middle era of the history of life, the Mesozoic era. One of these is near Greenhorn, north of Austin, where fragments of the stem of *Tempskya,* a strange fern unlike any now living, have been discovered in rocks assigned to the Cretaceous system (Read and Brown, 1937). It is rather surprising to find this evidence of dry land in eastern Oregon, for during the Cretaceous period an inland sea covered most of the state. Swimming in this sea were the ammonites whose fossil remains have been studied by Packard. As early as 1864, an Army officer collected fossil snails in the valley of the Crooked River and sent them to Thomas Condon at The Dalles (McCornack, 1928, ch. 4). Even at some of the higher levels of the Blue Mountains there have been found the shells of these and other marine animals, giving evidence of the great changes which have occurred during the long chapters of earth history. We may suppose that the tree fern *(Tempskya)* lived on an island in the great inland body of water which covered not only much of the John Day and Crooked River basins but extended northward into Washington and British Columbia and southward into California.

The second region in which Mesozoic land plants are known to have lived lies in the Coast Ranges of Douglas County, eight miles west of Riddle (Fontaine, 1905). Here, in 1872, the occurrence of fossil leaves was noted in the dense black shales on Buck Mountain by a mining engineer named Todd. Collections of these plants, including those made by J. R. Wharton of Roseburg in recent years, have given us a fairly complete picture of the vegetation of Oregon in the days before the now ruling angiosperms are known to have lived. Ferns, cycads, ginkgoes, and conifers were common (see Plate I). Many of them represent species which were widely distributed in other parts of the world during the Jurassic period, just preceding the Cretaceous. For example, an extinct fern known as *Cladophlebis* has also been found in the rocks of northern Alaska, arctic Siberia, Spitzbergen, northern Norway, western Europe from England to Spain and east across France and Germany, northern Africa, from southern Russia across Asia to China and Japan, India, Australia, New Zealand, Patagonia, and Antarctica; other wide-ranging species make the Jurassic flora one of the most cosmopolitan known during the history of plant life.[1] The cycads, more properly called cycadeoids since they differ in es-

[1] The Jurassic period lasted for some forty million years, during which time plants probably migrated extensively; we are, therefore, not justified in concluding that any one species of *Cladophlebis* lived at all the above-named localities at exactly the same time.

sential respects from surviving plants of this group, are represented by abundant fronds; species of *Pterophyllum, Ctenophyllum, Podozamites,* and *Ctenis* are apparently identical with fossils found in Siberia, China, India, Europe, and Spitzbergen. The somewhat remotely related cycads of today are restricted to tropical environments, where they are never known to occur as abundantly as in the Jurassic of Oregon. The ginkgoes and conifers, like the ferns and cycadeoids, were of kinds no longer living. There is actually only one surviving species of Ginkgo—the temple tree found under cultivation in China. Its leaves are less deeply lobed than those of the Jurassic species, which are known also from Siberia and elsewhere in the northern hemisphere. Wherever they are found in older Mesozoic rocks, the leaves of ginkgoes are divided by deep sinuses, and this lobate shape is considered a primitive character (see Plate I, figure 3). Abundantly represented in the Jurassic of Oregon, these tall trees with fernlike leaves must have given the forest of that period an aspect wholly different from any now in existence. Most of the conifers, too, were of types no longer living, although detached needles resembling those of pine suggest that there may have been some trees resembling those of today. However, it is doubtful whether the trees that bore these needles were true *Pinus,* for at this early period in the development of vegetation few, if any, conifers are certainly known to have acquired the characters of existing genera. As compared with the still more ancient vegetation of the Carboniferous, with its large horsetails and seed ferns, the Jurassic forest from the Coast Ranges of Oregon shows an advance toward modern types, and may be considered to represent an intermediate stage in development. That is just what the name Mesozoic means—an era of intermediate life development; as the middle period of this era, the Jurassic represents the time when all the more archaic plants had disappeared and the period before many modern conifers or the angiosperms are known to have lived.

III. THE FORESTS OF THE CENOZOIC ERA

General Discussion

The history of the earth chronicles great upheavals during which the rocks making up its crust are folded and faulted to form mountain ranges. Following such episodes of deformation come periods of relative quiescence during which these mountains are worn down by the ceaseless activity of water and air. Grains of sand and mud particles accumulate in basins between mountain ranges; in regions of volcanic activity showers of ash, together with lava and mudflows, are added to the rock record. These layers of rock, deposited upon the continents, are termed terrestrial or continental deposits by the geologist. Animal and plant remains, buried in them, tell us of land populations during the ages before man appeared upon the earth. For only a short time, geologically speaking, will these continental deposits endure. Lodged high above sea level, they will eventually be carried down to the ocean basins, and the record of life preserved in them will be lost forever. Most of the terrestrial deposits of ages past have been removed, leaving many gaps in our knowledge of the more remote faunas and floras. Fortunately, a great many of the rocks accumulated during the latest era of time, the Cenozoic, still endure to tell us the nature of the immediate past. Tomorrow, geologically speaking, they too will be gone.

In few parts of the world is the continental history of the Cenozoic era so fully known as in Oregon. Volcanic eruptions on a tremendous scale have covered most of the state with great thicknesses of volcanic ash, and have poured out extensive flows of lava which have protected them from erosion (Williams, 1948). Here and there over the state, streams have cut down through these plateau basalts and into the fossil-bearing sediments beneath. In the valley of the John Day River, these sediments are particularly well exposed, and it was here and in the Crooked River Basin to the south that Thomas Condon made his first discoveries of fossil plants and animals (McCornack, 1928, ch. 4). Many other geologists and paleontologists have come to Oregon in later years, and hundreds of localities have been discovered where the remains of plants and animals have been preserved. A majority of these are on the east side of the Cascade Range where vegetation is sparse and layers of rock containing fossils are therefore well exposed.

Unlike the older deposits of Paleozoic and Mesozoic ages, the rocks of the Cenozoic contain plants and animals closely related to many now living. This is particularly true of the plants, all of which may be assigned to existing families, and most of which belong to modern genera. Because of this close relationship to living vegetation whose environmental requirements may be readily determined, it is possible to reconstruct with a high degree of accuracy and completeness the habitats occupied by the forests of Oregon during the past seventy-five million years.[2] Fossil plants have been called the thermometers of the past because of the evidence they present as to former climates; they are equally valuable as indicators of topography. In order to use them accurately, we must know what kinds of plants are represented; thereafter, comparisons may be made with the environments of living plants to which the fossils show relationship. For example, the sycamore *(Platanus)* is now found largely along valleys at middle latitudes, and its occurrence in a fossil flora is suggestive of a streamside environment in a temperate region. However, it is desirable to base such conclusions on as many kinds of plants as possible, and a whole flora must be studied in order to provide accurate information. We shall consider

[2] This estimate of the duration of the Cenozoic era is based upon the rate of alteration of radioactive elements in the rocks.

in a later portion of this paper the environment indicated by the Mascall flora of the John Day Basin, an exceptionally complete group of plants which appears to have lived on a swampy river bottom. Most of the Cenozoic floras of eastern Oregon are sufficiently large to be of great value in reconstructing past environments. In such a study, the fossil remains of animals are much less significant because, unlike land plants, they move about as individuals and may often die and become buried in sediments far from their usual haunts. When plants migrate—we shall consider the evidence of several of their journeyings—they move not as individuals but as new generations, arising from seeds scattered from the parent trees. Rooted in the ground, they must remain fixed in the habitat best suited to their moisture and temperature requirements. The nature of this habitat is faithfully recorded by their fossil remains.

This brings up the matter of the conditions under which plants are preserved to become fossils. The great majority of them are buried within a short distance of the spot where they lived, in the sediments deposited on the floor of a valley, or in the basin of a lake. Leaves and fruits are most commonly preserved as imprints in these sediments and show the form of the original structure more clearly in fine clay or volcanic ash than in coarser material. Rarely, the fruits or seeds may be petrified by the addition of minerals—commonly, quartz or calcium carbonate—or by the replacement of their original structures by such minerals; reference will be made to the occurrence of petrified seeds near Clarno in the John Day Basin. Stems are commonly preserved by replacement, and the minute details of their cell structure may be shown in petrified wood. When a tree trunk is found upright, with its roots extending out into the surrounding rock, we may suppose that it was buried at the spot where it lived in ages past. When the stem of a tree is found prone, the possibility of its having been carried by a flood must be considered; transportation for any considerable distance is commonly indicated by the worn appearance of this fossil driftwood; if the trunk is relatively undamaged, probably it has not been washed far from its original position. Somewhat wider transportation of leaves and winged seeds is commonly observed, but again if these structures are complete and undamaged probably they have not been carried far. This presumption is especially sound if leaves or seeds of a given species are abundant in the rocks. The occurrence of single, damaged specimens may generally be interpreted to indicate that they have been washed or blown from a distant ridge. But most fossils come from lowland forests, and it is the plants of valleys with which we are most familiar.

THE FORESTS OF THE EOCENE

The Cenozoic era has been divided into several parts, the oldest of which is the Eocene, or the dawn of the recent.[3] On the western border of the state, the Eocene epoch is represented by sediments containing marine molluscs and other invertebrates which indicate a shoreline somewhat to the east of the present coast of the Pacific (Weaver, 1937). Elsewhere in Oregon, Eocene rocks are largely of volcanic origin, including widely distributed layers of tuff and ash which were blown from the mouths of volcanoes and transported by wind and streams to sites of deposition in valleys and lake basins. In many of the finer layers of volcanic ash, leaf impressions have been preserved in great numbers and completeness. Several of the more important localities from which these Eocene fossils have been collected will here be described.

THE CLARNO FLORA

The Clarno formation was named by Merriam nearly half a century ago (Merriam, 1901). At this time, few bridges had been built in eastern Oregon, and the ferry across the John Day River between Fossil and Antelope was known as Clarno's Ferry.[4] Andrew Clarno came into this region in 1866, before the John Day Basin had many settlers. McArthur (1928) records this episode of pioneer days: "When Andrew Clarno settled on John Day River, he had no neighbors. Stockmen in those days did not feel the need of any. When he heard that a friend had settled on a homestead about twenty miles to the east, near the present site of Fossil, he rode over on horseback, and said: 'Bill, don't you think you're crowding me a little?' " Passing years have brought a bridge and new ranchers to the John Day valley, but the cliffs along the east bank of the river remain unchanged from the days of Condon's early visits. In the finer layers of rock here and on the hills farther east have been found one of the most significant Eocene floras in Oregon.

Interposed between older marine rocks of the Cretaceous and the overlying John Day beds, the Clarno formation is made up wholly of volcanic material which was poured out as lava, or was blown out from craters as fragments which accumulated to form volcanic sediments. Where such pyroclastic rocks are coarse-textured, there is little probability of their preserving the impressions of plant structures. But in some of the finer volcanic shales of the Clarno formation, laid down in

[4] The names, Clarno's Ferry and Clarno Bridge, may cause some confusion. In the late 1860's or early 1870's, members of the Clarno family built, and thereafter continuously operated, the first Clarno's Ferry. Clarno Bridge has been in use since its construction in 1909. This information was furnished by Mrs. May G. McRae, secretary of the Clarno Grange, through Dr. Earl L. Packard, of Oregon State College.

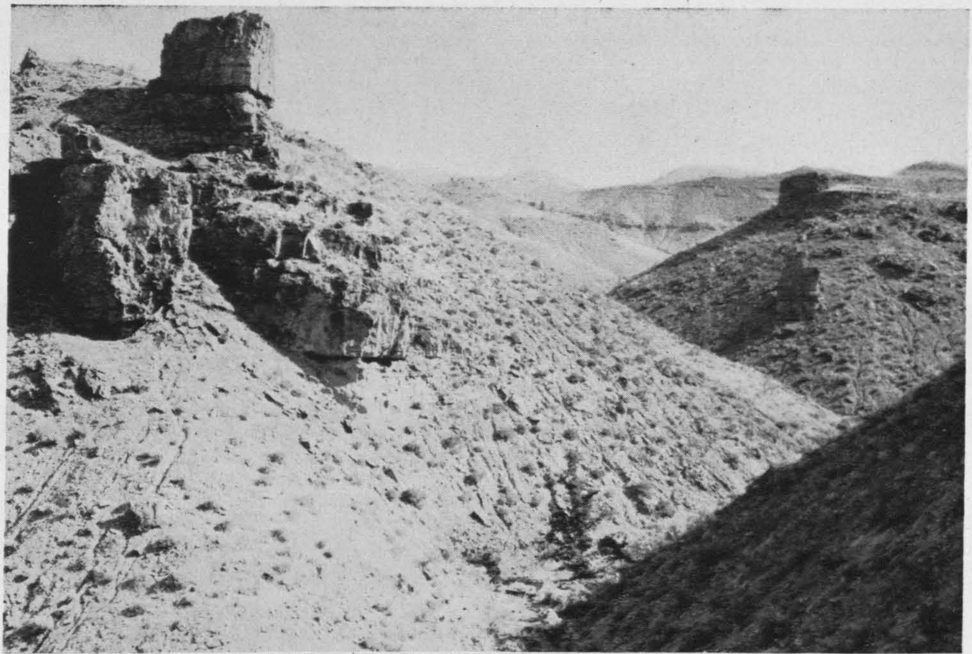
[3] Largely on the basis of fossil mammals, an older division known as the Paleocene has been designated, but this division is not known to be represented in the continental deposits of Oregon.

lake or river basins during eruptions of volcanic ash, the prints of leaves and fruits are so abundant and complete as to give us detailed information regarding the forest which lived here some sixty million years ago (see Plate II). Judging from the known areas where Clarno fossils have been found, this forest was widely distributed in eastern Oregon. In addition to their occurrence near Clarno's Ferry, leaf impressions have been found elsewhere in the John Day Basin on Cherry Creek near the old Burnt Ranch post office, and on West Branch Creek northwest of Mitchell (see Plate III, figure 2). The last of these, discovered by Phil Brogan of Bend, has furnished the most abundant and best preserved of our specimens. Many miles to the northeast, near Pilot Rock, large collections of a similar flora have been made by Dr. Ethel I. Sanborn. A recent discovery on Arbuckle Mountain by Dr. John E. Allen adds a Clarno fossil-plant locality at an intermediate station. On Riverside Ranch in the Crooked River Basin to the south, another flora of Clarno type has been collected (Chaney, 1927, p. 58).

Our first view of Eocene plant fossils brings a sensation of surprise to anyone familiar with the modern vegetation of Oregon; for not one of the leaf impressions resembles the foliage of our common forest trees, such as alder, oak, and maple. Their average size is larger, and their margins are commonly smooth rather than toothed; the curve of their surfaces on slabs of rock suggests a thick texture unlike that of most leaves in temperate forests (see Plate IV, figure 1). Conifers are largely absent, in striking contrast with the vegetation now occupying the Cascade Range and other mountains of Oregon, as well as many lowland areas. No one can fail to note that the plants represented in the Clarno flora are wholly unlike those now to be found anywhere in the state; they represent a forest of much greater diversity than that now living in the John Day Basin where willows and cottonwoods are the only large valley trees, with junipers on adjacent hills. At the outset we may conclude that something has happened since Eocene time which has brought destruction to the plants these fossils represent, and has substituted trees with smaller and thinner leaves, whose margins are commonly toothed or lobed. Here is a record of change, a sequence of events in earth history; this is the sort of problem a paleobotanist is called upon to solve through his knowledge of vegetation, past and present, in other parts of the world (Chaney, 1938).

Turning first to the kinds of trees which made up the forests of the John Day Basin sixty million years ago, we find members of the laurel family among the most numerous. This family, the Lauraceae, is now largely restricted to the warmer parts of the world, although a temperate member, the pepperwood[5] *(Umbellularia californica)*, is a common

[5] Also called Oregon myrtle and California laurel.



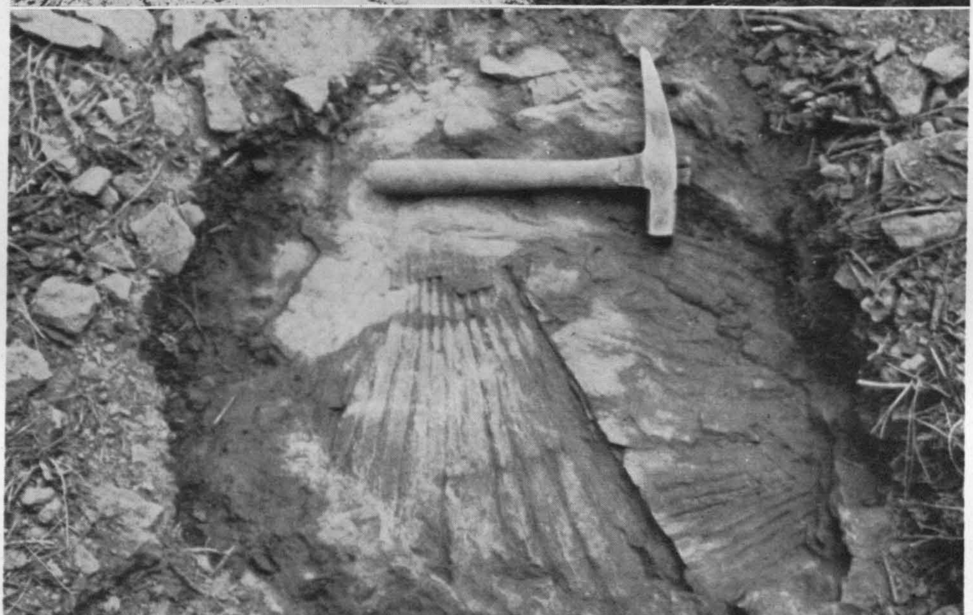


PLATE II.

Fig. 1 (upper). East of Clarno Bridge, the Clarno formation forms bold cliffs. Fossil leaves are preserved in fine layers of ash.

Fig. 2 (lower). Impressions of palm leaves in Clarno shale on Arbuckle Mountain. Pines, firs, and willows grow there today.

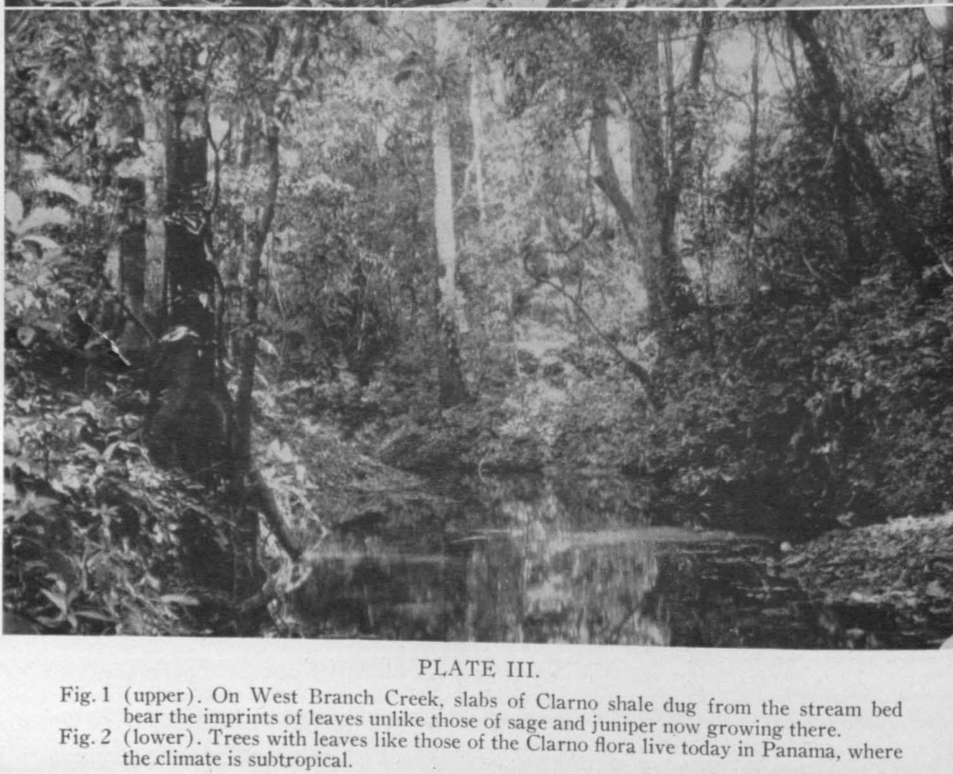


PLATE III.

Fig. 1 (upper). On West Branch Creek, slabs of Clarno shale dug from the stream bed bear the imprints of leaves unlike those of sage and juniper now growing there.

Fig. 2 (lower). Trees with leaves like those of the Clarno flora live today in Panama, where the climate is subtropical.

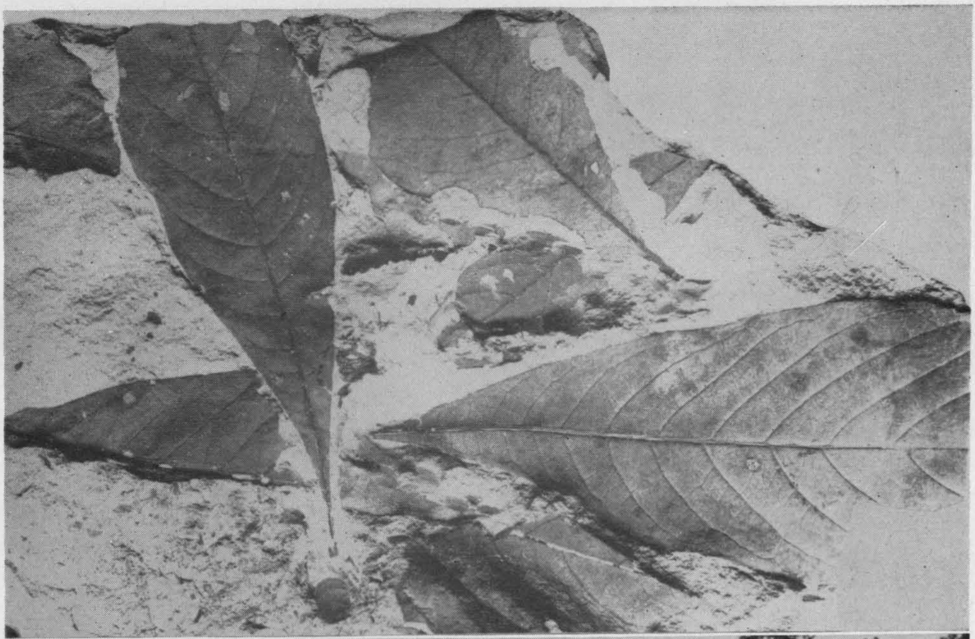


PLATE IV.

Fig. 1 (upper). Large, thick leaves are common in the Eocene floras of Oregon. This aguacatillo (*Meliosma*) has been collected on both sides of the Cascade Range. Approximately two-thirds natural size.

Fig. 2 (lower). Near Goshen, highway construction in the early twenties uncovered many leaves of *Meliosma* and other subtropical trees.

PLATE V.

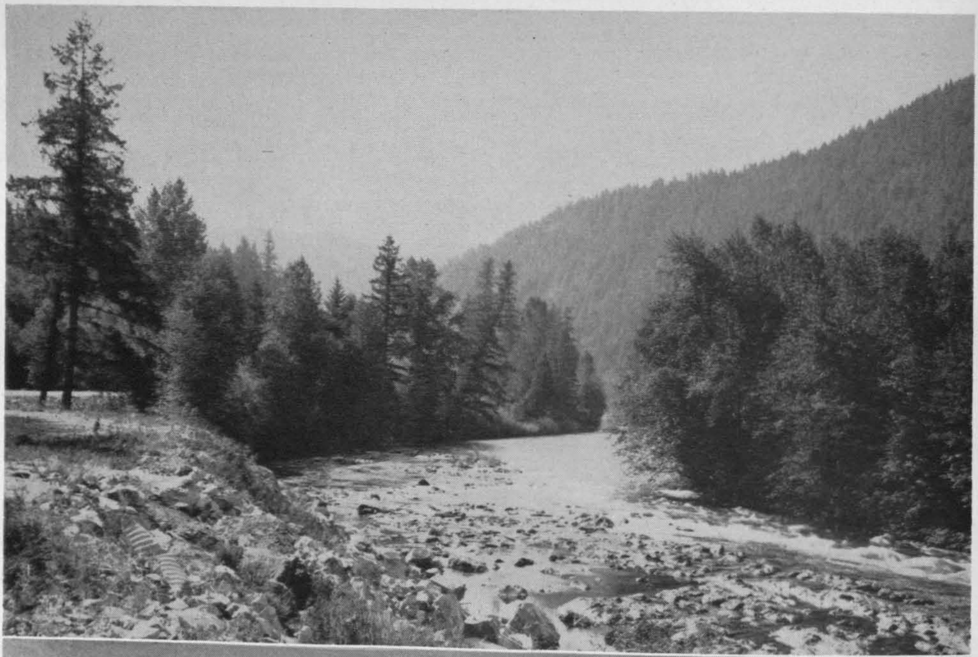
Leaves of this fossil fig *(Ficus quisumbingi)* may reach a length of nearly a foot. Living relatives grow in the tropics of America and Asia. Approximately one-half natural size.

tree in southwestern Oregon. Eocene relatives of the pepperwood are widely distributed in western North America and are assigned to the genus *Persea* which includes the modern avocado. Another related genus, *Nectandra,* is now confined to tropical America but is well represented in the Clarno and other Eocene floras of Oregon. A third member of the laurel family, which supplies camphor and spice, is *Cinnamomum*; this genus is now confined to southeastern Asia, and the modern species from which cinnamon is secured, *Cinnamomum zeylanicum,* has leaves which may be closely matched in the Clarno flora and in other Eocene floras of Oregon. The tropical family, the Sabiaceae, is most characteristic of Asia; one of its genera, *Meliosma,* with many common names such as aguacatillo, ciralillo, and guayaroto, has been recorded from the Eocene of North America at a number of localities, including the Clarno deposits on West Branch Creek (see Plate IV, figure 1). A large, thick fossil leaf is referred to the genus *Ficus,* or fig (see Plate V), and there are numerous large leaves with lobes which appear to represent the ancestors of the sycamore and are assigned the name *Platanophyllum.* Ferns of tropical types are more numerous than in any other Eocene flora from western North America as yet studied. At most localities, notably Pilot Rock, there are abundant leaves of palm. A few miles east of the Clarno Bridge I collected, some years ago, a large leaf of a cycad which is provisionally referred to the genus *Dioon,* which has several living species in Mexico. I was guided to the cycad locality by two enthusiastic and competent fossil collectors, A. W. Hancock and A. D. Vance, both of Portland, and members of the Geological Society of the Oregon Country. These men were also responsible for my visit to a nearby cliff where abundant fruits are preserved, in some cases with their walnutlike seeds replaced by quartz. There are few places in the world where fossil fruits are equally numerous, and future studies will add critical information regarding their relationships. Identification of these fruits may also serve to confirm the determination of many of the leaves of the Clarno flora, although their assignment to genera now living in the tropics seems already well established. With so great an abundance of plant fossils, it is remarkable that only a single Eocene mammal has been collected—the tooth of a rhinoceros, discovered by Hancock in the hills east of the Clarno Bridge. This tooth has been described by Stirton (1944), who assigns it to the genus *Hyrachyus,* which has been found previously in Eocene deposits of the Rocky Mountain region and in China.

Looking to the south, where laurels and other trees resembling the Clarno fossils are still living, we may find in the rain forests of Mexico and Central America environments which suggest the nature of the Eocene landscape of Oregon. Heavy rainfall and an almost complete absence of freezing temperatures characterize the habitat of the modern forest of Panama (see Plate III, figure 2) in its subtropical setting. It is worthy of record that Thomas Condon early recognized the tropical character of the Clarno flora. With his naturalist's perception of the setting in which these plants lived so long ago, he wrote as follows in 1871: "There are many residents of the Pacific Slope who will remember having journeyed from The Dalles, on the Columbia River, to Canon [Canyon] City, among the Blue Mountains. For sixty miles or more the road passes over volcanic materials, which have drifted there from the Cascade Range. Twenty miles farther, and this outflow thins out into a mere capping of basalt on the hill-tops. The hills themselves, and the foundations on which they stand, are here found to be sedimentary rock, wonderfully filled with abundant records of former animal and vegetable life. Oldest of all in sight is the old ocean-bed of the Cretaceous period, with its teeming thousands of marine shells, ... Next in ascending order come the fresh-water deposits of the earlier Tertiaries, so full of leaf-prints of the grand old forests that, during that age of semi-tropical climate, covered those lake-shores. . . . . How strangely out of place a score of palm-trees, a hundred yew trees, or even a bank of ferns, would seem here now! And yet here these once lived, and died, and were buried; and beautiful beyond description are their fossil remains even now, as they are unburied."

Referring to the "wonderful work among these hills" of the John Day River, he says: "The deep valleys that resulted could hardly fail to lay bare important records of the past, cutting as they do through the whole extent of the Tertiary periods. In a deep canyon through which runs a branch of Kern Creek, may be found the remains of a fan-palm, with abundant remains of a beautiful fern—gems of their kind—which no thoughtful mind can see without wonder and admiration. In another ravine are seen in great numbers the remains of a yew, or yew-like tree, that sheds annually, not its leaflets, but its branchlets; for in this form they are found imbedded in the rocks, of almost uniform length and structure. This tree was evidently abundant on these ancient shores, for it can be found at almost every spot where a little stream has washed its miniature delta into the lake. Oaks, too, and occasionally a fine impression of an acorn, or acorn-cup, are found at intervals from this place to the Blue Mountains."

The yew trees he mentions are what we now know as *Metasequoia*. It is of particular interest that Condon suggested that the leafy twigs were shed annually as branchlets, for that is precisely how the living redwoods of China, discovered seventy-five years after he wrote these



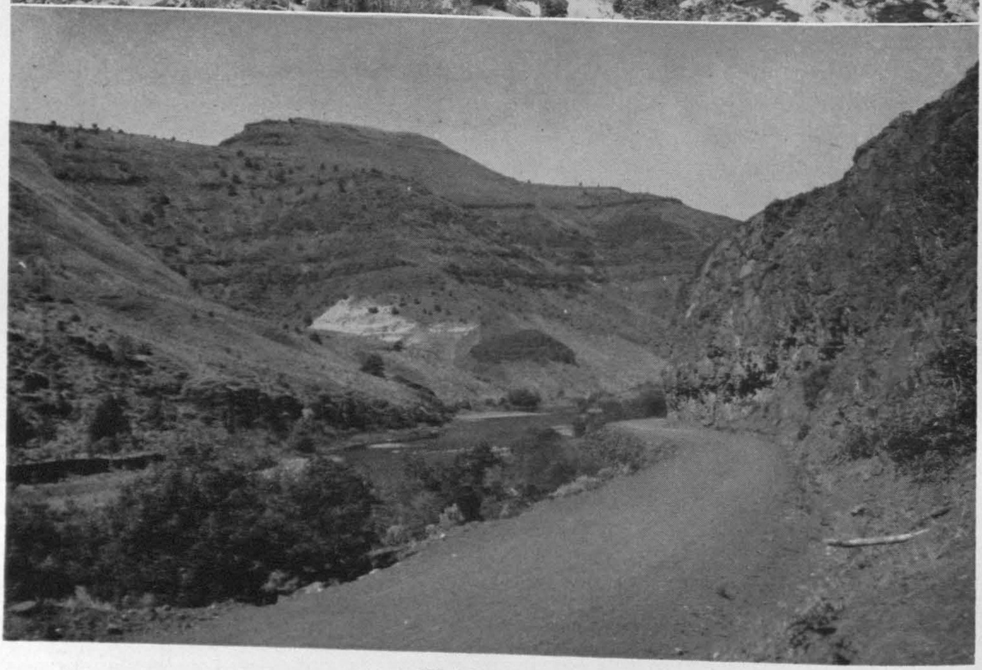


PLATE VI.

Fig. 1 (upper). The McKenzie River, on the windward side of the Cascades, flows down a valley filled with conifers and other large trees.

Fig. 2 (lower). The John Day River, on the leeward side, has a fringe of small willow and cherry trees. Here it has cut down through the flows of Columbia River basalt into the John Day formation (light beds left of center).

words, lose their foliage. Later studies have shown that the beds containing these conifers are considerably younger than those in which the palms occur. The latter are known only from the Eocene in Oregon, while the redwoods lived at the end of the Oligocene, some ten million years later.

THE COMSTOCK AND GOSHEN FLORAS

When comparisons are made between the Clarno flora and the Eocene floras west of the Cascades, a marked resemblance is at once apparent. Most of the plants mentioned as characteristic of the Clarno have been recorded in two well-known floras from west-central Oregon, the Comstock of northern Douglas County (Sanborn, 1935), and the Goshen (see Plate IV) of central Lane County, twenty miles to the north (Chaney and Sanborn, 1933). From other localities extending from Ashland northward to the Canadian border, fossil plants of similar aspect have been collected, together with additional species which are especially characteristic of tropical shores. To Oregon residents familiar with the marked contrast between the vegetation on opposite sides of the Cascade Range, the similarity shown by the fossil plants from west to east across the state can have only one interpretation—no mountain range corresponding to the Cascades was in existence during Eocene time. Today this range interposes a topographic and climatic barrier; on the west the moderating influence of the ocean brings milder temperatures than on the east where the control is continental; rain-bearing winds from the Pacific lose most of their moisture on the westward slope, and as air descends on the eastern side it is more likely to take up moisture by evaporation than to release it in the form of rain. Plate VI shows better than words the difference between the forest on the western approach to McKenzie Pass and the sparse vegetation on the slopes to the east.

We shall see that general uniformity of forests across the state of Oregon persisted from the Eocene down into comparatively late geologic time, and that the Cascades as we know them are a young range of mountains as compared with the Rockies and Appalachians. With the evidence of the fossil plants, and the data supplied by the geologist, it is possible to reconstruct a paleogeographic map of Oregon which indicates its Eocene shorelines, mountains, and drainage. Whenever a new fossil flora is discovered, or some new outcrop of Eocene rocks studied, we shall be in a better position to reconstruct the topography and vegetation of Oregon at the beginning of our era.

Although there were no such major differences in Eocene vegetation as we find in the forests of today, several distinguishing characters are observable from east to west. The presence of palms and cycads in the John Day Basin may be related to the greater relief of the interior, as compared with the lowland-plain topography immediately bordering the shore. On exposed slopes in eastern Mexico in the state of Vera Cruz, near Chavarrillo, there are growing many cycads of the genus *Dioon,* together with palms, oaks, and other angiosperms. In nearby valleys, where a permanent supply of moisture is available, lives a dense forest made up of figs, laurels, and other trees with evergreen leaves resembling those of the Clarno flora. Here is a suggestion of the sort of Eocene environment in which the Clarno cycads could have lived under more exposed and drier conditions than most of the Clarno flora. There is evidence of even higher hills in some of the fossils collected at West Branch Creek, and also near the town of Fossil; these are smaller than other Clarno leaves and show resemblance to the typically temperate Bridge Creek flora to be discussed below. Possibly there was high country not far from these eastern lowlands of the Eocene landscape, from which leaves of temperate upland trees were blown and washed down into the valleys. Another difference from east to west is the somewhat more tropical aspect of the Comstock and Goshen floras which lived along the shore. During the Eocene, as now, certain environments were more favorable to some kinds of trees than to others; those requiring abundant moisture and higher temperatures appear to have lived on valley bottoms and lagoons bordering the shore in the region of the Willamette valley; others lived in the less-sheltered interior habitats of the John Day Basin. However, these differences in climate and topography across Oregon must have been much less then than now, for the plants of today show far greater diversity from west to east, in response to the Cascade barrier. It is clear, from the aspect of the leaves and from the habits of related living species, that the climate across the state of Oregon was of a subtropical type, with little or no frost and with abundant rainfall. The causes for changes in climate since the Eocene will be considered later after we have discussed several other floras which have lived in Oregon during intervening time.

The Forests of the Oligocene

During this epoch, as in the Eocene, there was general uniformity in vegetation from the Pacific shores to the eastern interior of Oregon. But the nature of the forests, as indicated by an exceptionally complete fossil record, had greatly changed. Except along the coast, where mild temperatures persisted, the more tropical kinds of plants had disappeared. In their place we find typically temperate trees, many of which have relatives still living in the United States. This temperate forest had developed in high latitudes during the early days of the Cenozoic era and is known as the Arcto-Tertiary flora because of its northern origin. With the trend toward lower temperatures, it moved southward to middle latitudes by Oligocene time, not only in North America but in Europe and Asia. At the same time, these areas were being vacated by the tropical trees which had lived there during the Eocene. World-wide plant migrations were under way in response to climatic changes.

Plant migrations differ from those of animals in that individual trees are rooted to the ground and must remain at their native sites no matter how unfavorable the environment may become. Unlike the seasonal migrations of the caribou and the plover or the slower spreading by which other animals may extend their ranges perceptibly during a single human lifetime, movements of forests over the earth's surface are accomplished only through considerable segments of geologic time. Discussing the redistribution of forests in later geologic time, Chamberlin (1907, p. 534) had the following to say about trees of the walnut family, a family whose members were represented in the Arcto-Tertiary flora of Alaska during Eocene time and were also present in the Oligocene forests of Oregon:

> Aside from the spreading due to the outward growth of the limbs of the parent-tree and the slight aid of winds, the distribution of these trees seems to be chiefly dependent on squirrels, which have the habit of carrying the nuts short distances and burying them for future use. Now if 15 years be taken as the average time at which a seedling under native conditions comes into bearing, and if a squirrel is always present to carry the first-borne nuts an average distance of 75 feet for burial, and always in the right direction, and always neglects to recover them, and they always grow and escape destruction, the average rate of migration would be five feet per year, or a mile in 1,000 years.

From Cook Inlet, where the Eocene flora of Alaska is best developed, it is nearly 1,800 miles to the John Day Basin. Using Chamberlin's estimate as the maximum probable rate of migration of walnuts and hickories, nearly two million years would have been required for their journey down from the north. Actually, the combination of favorable factors which he mentions could scarcely be expected to have been operating constantly, and the time required for the spreading of these trees from Alaska to Oregon must have been much greater than the minimum above suggested. However, there appears to have been no shortage of time for this plant migration even at a reduced rate, for fully ten million years must have elapsed from the Eocene occurrence of walnuts and hickories at Cook Inlet until they and their associates appeared in the John Day Basin near the end of the Oligocene epoch.

During the ages required for the migration of the Arcto-Tertiary flora southward, a journey not of tree individuals but of tree generations, several of the species which had started out from Alaska failed to survive; other species were added to this forest along the way, so that its aspect upon arrival in Oregon was somewhat modified. In spite of such changes, the general character of the Arcto-Tertiary flora was maintained over a wide interval of time and space. There are many areas in the northern hemisphere where the Arcto-Tertiary character of living forests may still be recognized. The hardwood forests of the eastern United States are one of the best examples of such survival, as we shall see, and to a lesser extent resemblances may be noted in the forests of western Oregon, where the climate of today is relatively humid. But in the eastern part of the state greater changes in living conditions have occurred since Middle-Tertiary time, and we may observe fewer survivors of the forest which came down out of the north during the Oligocene epoch.

THE BRIDGE CREEK FLORA

My first view of the Bridge Creek hills was in 1920. Together with Chester Stock, then an instructor in geology at the University of California, and a graduate student, Richard J. Russell, I had traveled by autostage to Mitchell, where we found that the next stage northward would not depart until the following day. Leaving Stock to bring our bulkier equipment, Russell and I started out on foot over the winding road down Bridge Creek. After an eight-mile walk, we came to a house in a grove of cottonwoods, described in Merriam's paper as Allen's ranch. A young couple named Wade was operating this ranch, and with a little persuasion agreed to provide meals and lodging. Nowadays, one would hesitate to arrive unannounced and ask for such accommodations; but in the days before good roads it was a custom of the country to take care of travelers. Earlier that summer, I had enjoyed the hospitality of William R. Mascall, James Cant, and Jerome Moore in the valley of the John Day River to the east; I had even been left in temporary charge of the Moore ranch, to milk the cows, feed the chickens, and do other chores while the family went to pick huckleberries in the Blue Mountains. After getting established at the Wade ranch, Russell and I started for the fossil locality on a side road which came down out of Bear Creek. My notes for this afternoon read: "Two and a half miles southwest of Wade's (Allen's) ranch where the road to Fitzgerald's passes a small white hill, there are two rounded hills about thirty feet high, one on either side of the road. These are covered with white bits of shale containing leaves." Here was the Bridge Creek locality which Condon had visited more than half a century before (Plate VII, figure 1).

After frequent returns to collect fossils on these hills, I wrote as

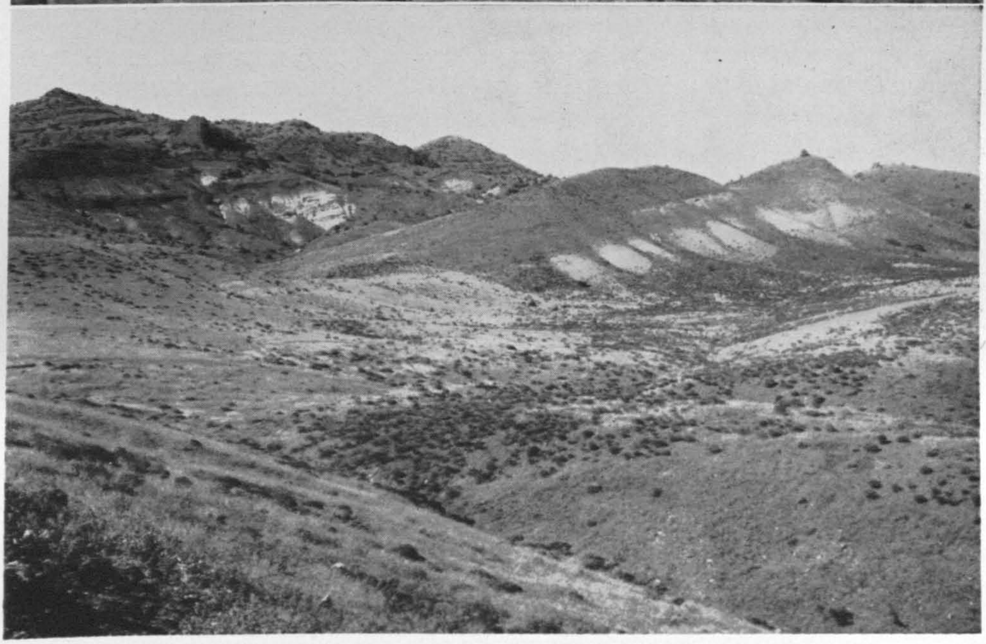


PLATE VII.

Fig. 1 (upper). Low rounded hills at the Bridge Creek fossil locality yield abundant redwood and other fossils. The only trees growing here today are small junipers.

Fig. 2 (lower). During Oligocene time, trees like those at Bridge Creek lived east of Clarno Bridge on Dugout Gulch, where their fossil leaves and fruits are abundant.

follows (1938, p. 638) my impressions at the site of this ancient redwood forest:

> On the many occasions during the past eighteen years when the writer has walked up the valley of Bridge Creek to the fossil locality, he has never failed to sense the contrast between the sparse sagebrush cover of today and the redwood forest which once lived upon this slope. Nowhere are the results of a changing earth more apparent. Here is a region now semiarid and unforested. When redwoods stood upon this slope, scattering their leaves and cones to be buried in the valley, the climate must have been mild and moist, with only slight seasonal change. For the redwood of today grows only in coastal California and Oregon, where the tempering effects of the Pacific and its rain-bearing winds provide a suitable environment. The mountain range which now deprives eastern Oregon of such marine benefits could not have risen to the west before the Miocene, or redwoods would have been absent from the Bridge Creek flora as they are today on the arid hills of the John Day Basin. The factors which brought about this change are the factors which control the development and distribution of life in the world as we know it.

The recent discovery of redwoods in China has modified our ideas of this forest in some respects, as will be mentioned below. But it has not lessened our estimates of change on the Oregon landscape.

The reddish shales, which weather white on exposure, are referred to the lower part of the John Day formation, and represent deposits which accumulated near the close of Oligocene time. They were formed during volcanic eruptions, when great thicknesses of volcanic ash were blown out from adjacent craters, burying wide areas. Strangely enough, there are few bones of animals preserved in the Lower John Day; Merriam mentions finding fragments of rhinoceros teeth and cites an early record of an oreodont skull (1901, p. 294); the only bone I have ever found represents the leg of a quail. But in valley basins where fine ash was blown or washed, the record of plant life is abundant. By contrast, the Middle and Upper members of the John Day formation have yielded an abundant and varied fauna of extinct mammals, including Oreodons, pigs, rhinoceroses, horses, dogs, cats, and rodents; but almost no plant fossils have been found in these beds. A probable explanation for such differences in the character of the fossil record is that conditions favoring the accumulation and preservation of organic remains varied from time to time. At the beginning, valley basins may have been numerous and may have provided more situations in which leaves could accumulate in the flood-plain sediments. Local changes in topography, or even in climate, may later have made this region better suited to grasslands than to forests; the animals above-mentioned would have found adequate food on these upland prairies, and many of their bones would be buried and preserved. Following the deposition of the valley and upland deposits making up the John Day formation, great flows of basalt were poured out over the present area of the Columbia Plateau (see Plate VI, figure 2). The fossil-bearing sediments have been effectively protected from erosion down to our day, when the John Day River has cut down through the lava flows and exposed them for our study.

At the Bridge Creek locality, a single slab of rock, weighing only a few pounds, may show the imprints of dozens of leaves on its surface; when split along its many bedding planes with a broad chisel, scores of additional specimens may be uncovered (Chaney, 1925). In 1923, I quarried 98 cubic feet of leaf-bearing shale from three pits on the low hill to the right of the road (Chaney, 1924); I split the slabs of ashy shale into thin layers which yielded a total of 20,611 specimens, or an average of more than two hundred to a cubic foot. There were about twenty-five different kinds of plants represented, of which birches and alders made up more than half the specimens; 15 per cent of the total were redwood cones and leafy twigs, with oaks nearly as abundant; various other trees, such as elm, sycamore, basswood, hornbeam, and maple, were present in reduced numbers; 173 heart-shaped leaves were found, which are unlike those of any tree now living in North America and which have been identified as belonging to the katsura *(Cercidiphyllum)* of China and Japan.

Thousands of additional leaves have been examined from three other localities in the John Day Basin—a few miles east of Clarno (Dugout Gulch) (see Plate VII, figure 2); north of Picture Gorge (Cant's Ranch) (see Frontispiece); and near Twickenham (see Plate VIII). In all of these areas the remains of redwood are numerous, making up more than three-quarters of the total at the Twickenham locality (see Plate IX). In the Crooked River Basin to the south, a closely related flora from Gray's ranch shows oaks more numerous, with redwoods making up only three per cent (Chaney, 1927, pp. 60-138, pls. 6-20).

When we mention redwoods in the United States, we naturally think of the coast redwoods *(Sequoia sempervirens)* which extend from southwestern Oregon to central California, or of the Sierra redwoods *(Sequoiadendron gigantea)* which occur in isolated areas for a distance of 250 miles along the western slope of the Sierra Nevadas. For nearly a hundred years, since fossil redwoods were first described by Oswald Heer (1855) in Switzerland, all of them have been considered to be the immediate ancestors of these living redwoods, slightly different in some respects but still members of the genus *Sequoia.* Recently, a Japanese paleobotanist, S. Miki, has pointed out (1941) that redwood fossils from Japan differ from the living redwoods of North America in having opposite, rather than spirally arranged, needles and cone-scales; the cones show the further difference of

PLATE VIII.

Leafy twigs of redwood *(Metasequoia)* are abundant at the Twickenham locality, with leaves of katsura and other hardwoods.

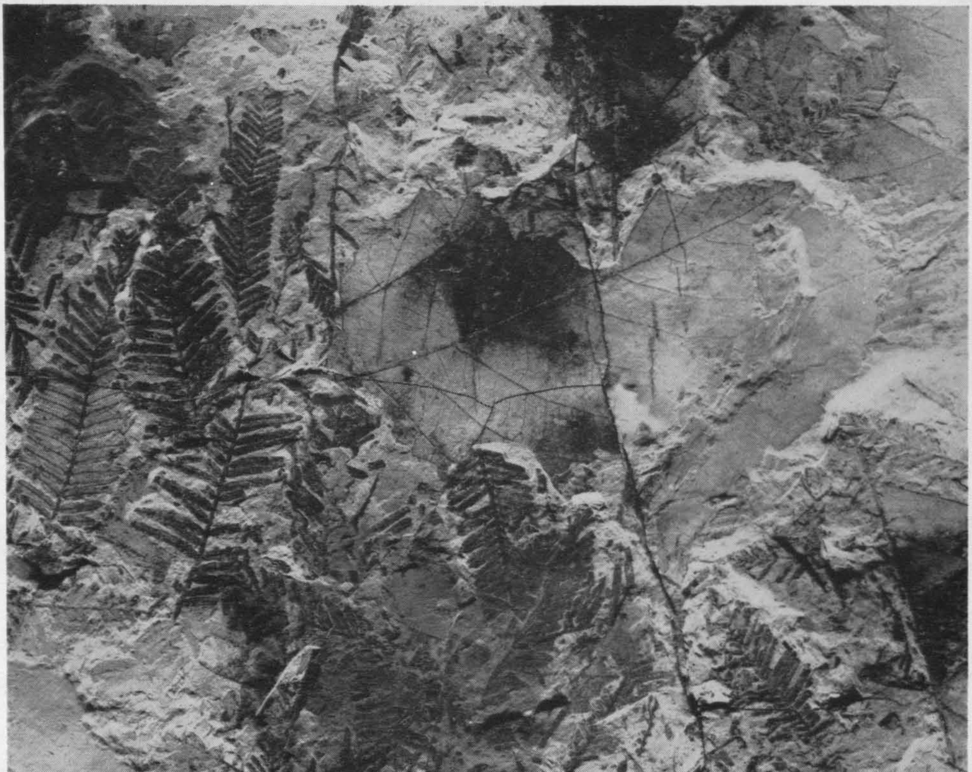


PLATE IX.

Note the opposite arrangement of the needles of *Metasequoia*. Other leaves on this slab from Twickenham are birch (at top) and katsura (at bottom). Approximately three-fourths natural size.

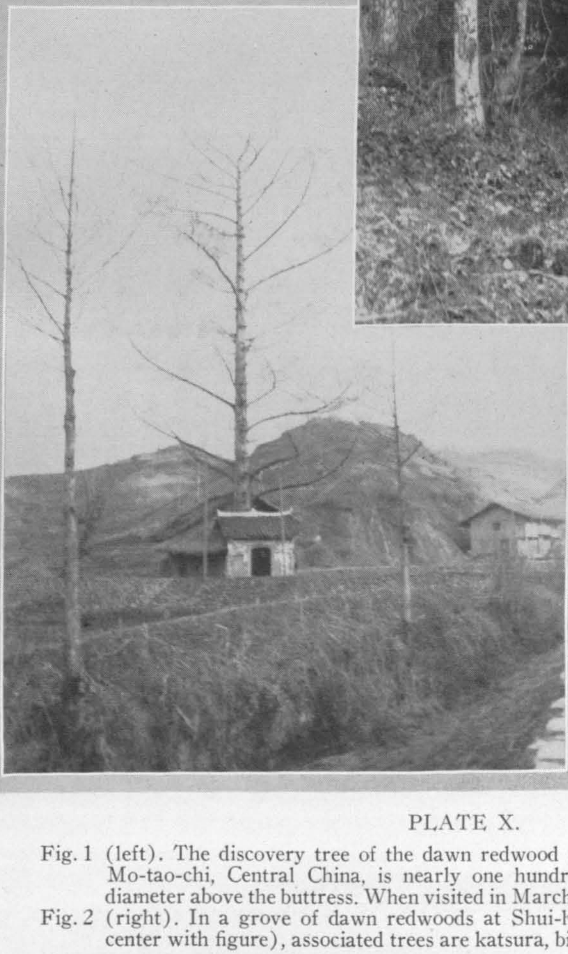


PLATE X.

Fig. 1 (left). The discovery tree of the dawn redwood *(Metasequoia glyptostroboides)* at Mo-tao-chi, Central China, is nearly one hundred feet tall and over five feet in diameter above the buttress. When visited in March, it bore no leaves.

Fig. 2 (right). In a grove of dawn redwoods at Shui-hsa-pa (trees with ribbed bases at center with figure), associated trees are katsura, birch, oak, and chestnut.

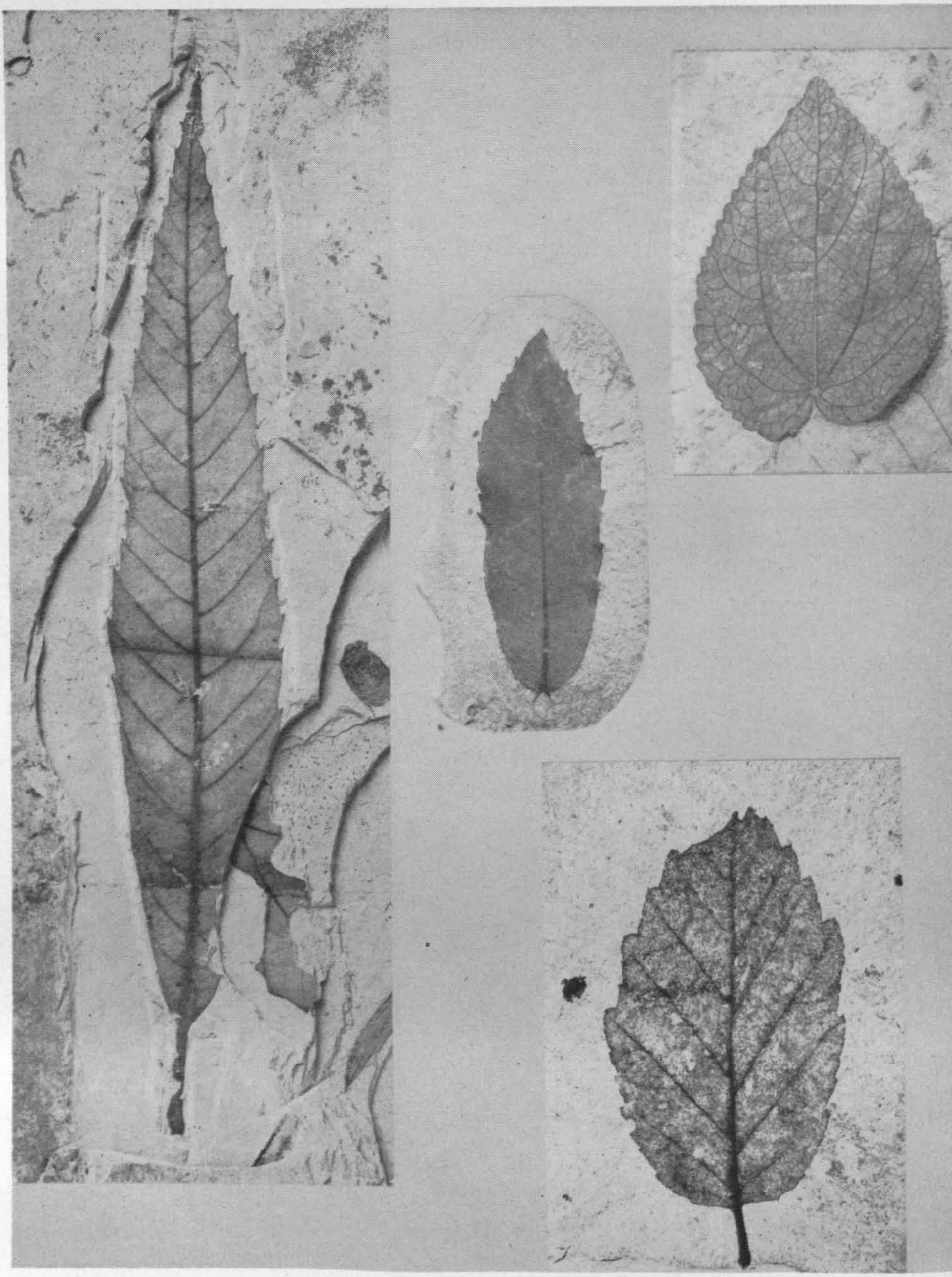


PLATE XI.

Fossil leaves of the Bridge Creek flora.

Fig. 1 (left). Chestnut *(Castanea orientalis)* from the Cant's ranch.
Fig. 2 (center). Oak *(Quercus clarnensis)* from the Gray's ranch locality on the Crooked River.
Fig. 3 (upper right). Katsura *(Cercidiphyllum crenatum)* from the Bridge Creek locality.
Fig. 4 (lower right). Birch *(Betula)* from the Bridge Creek locality.

being attached on a bare twig; Miki also suggested that these ancient redwoods of Asia may have been deciduous rather than evergreen, and assigned a new generic name, *Metasequoia,* to them. Before anyone in the United States had an opportunity to read his paper—for all communication was disrupted during the war years—there came the amazing announcement that living trees of *Metasequoia* had been discovered in Central China. A forester by the name of Wang had encountered a large and unknown conifer in Szechuan Province; the specimens he collected were unlike any previously studied by such leading authorities as W. C. Cheng and H. H. Hu; then Dr. Hu, a student of the fossil as well as of the living plants of China, compared them with the pictures and descriptions in Miki's paper and came to the conclusion that this newly discovered tree was a living *Metasequoia* (Hu and Cheng, 1948). Here was a fossil come to life in the botanically unexplored interior of Asia (see Plate X).

Re-examination of fossil redwood twigs and cones from the John Day Basin, and from scores of other localities in North America and the arctic regions, has confirmed the brilliant discoveries of these Japanese and Chinese scientists. We now know that it was not the Coast redwood of America which ranged widely over most of the northern hemisphere during ages past but the dawn redwood of China, so named because *Metasequoia* appears to stand in ancestral relationship to *Sequoia.* Reconstructing the Oligocene environment in the John Day Basin, we must therefore turn for information to the habitat of the newly discovered redwoods in Central China.

I have recently returned from a trip to the valley at Mo-tao-chi where *Metasequoia* was first found living, and to Shui-hsa-pa, still farther south in the interior of China, where several hundred trees are growing under what appear to be natural conditions. No climatic data are available for this immediate area, but at Chunking, some 150 miles to the southwest, there is a total of 43 inches of annual rainfall, well distributed, though somewhat less heavy during the winter months; at the intermediate city of Chunghsien, the total annual precipitation is 57 inches. There is every indication that Mo-tao-chi and Shui-hsa-pa, at an elevation of about four thousand feet, have a much heavier rainfall than these cities to the west which are on the Yangtze River less than a thousand feet above sea level. At the time of my visit in March, which is one of the less rainy months at Chungking, there were light rains every day and the soil was full of moisture. It is probably not an exaggeration to estimate the annual rainfall at the *Metasequoia* localities at 60 inches or more. Judging from some of the plants which had survived the winter of 1947-48, frost is not common here; at Chungking the lowest temperature recorded in 25 years was 29° Fahrenheit in

January, and the lowest mean temperature was 49° in this same month. The highest mean temperature is 84° in August. The mean annual temperature is 66°. While at the higher altitude occupied by the dawn redwoods there are doubtless greater extremes of temperature, the general aspect of the vegetation indicates an equable climate. Comparison with the Redwood Belt of coastal California shows that winter temperatures, especially recorded minima, are lower there, as might be expected at a latitude from six to eleven degrees farther north. Summer temperatures at stations near the California coast are much lower than in Central China, where climate is of a more continental type; but at interior points in the Coast Ranges this difference is less pronounced. There is a striking contrast in the precipitation regime of the two regions. Most of the rainfall in California comes during the winter months; the summers are largely without rain, although fogs along the coast at this season greatly lessen the effects of the dry season. In Central China seasonal variation is less pronounced and most of the rain falls during the summer. Much is still to be learned regarding the environmental requirements of *Metasequoia,* both living and fossil, but we are justified in concluding that the climate of the region in which it has survived resembles that in the area occupied by *Sequoia sempervirens* in its relatively mild, uniform temperature and its abundant rainfall. And since redwoods of the past probably lived under somewhat varied conditions, perhaps not exactly duplicated in the world today, we may turn both to the valleys of Central China and to the coasts of California and Oregon for information regarding their environment in other days.

In any such attempt to reconstruct the landscapes and climates of the past, we must examine the evidence of more than one kind of tree. Important as was the redwood in the forests of Middle-Tertiary time, there is a long list of other tree species whose testimony must be considered if we are to gain an adequate idea of the Oligocene scene in the John Day Basin. Among these may be mentioned birch *(Betula),* oak *(Quercus),* beech *(Fagus),* chestnut *(Castanea),* sweet gum *(Liquidamber),* and katsura *(Cercidiphyllum),* all of which are recorded from the Eocene deposits of Alaska and are members of the Arcto-Tertiary flora which migrated southward into northeastern Asia at the same time that it came down into the John Day Basin (see Plates IX and XI). The survival of all these trees with *Metasequoia* in the valleys of Central China is one of the most remarkable records of forest continuity known in earth history. Judging from their leaves, there has been no great change in any of these trees during several tens of millions of years. In the ravines at Shui-hsa-pa, we may see how the forests of Oregon appeared long before man came to live here.

With the exception of the dawn redwood and the katsura, both of which are confined today to Asia, all of the other trees still live in the United States. Birch is the only one of them which has survived in the John Day Basin; oaks are largely restricted in Oregon to the western, more humid part of the state. Sweet gum, beech, and chestnut no longer live in western North America but are common members of the hardwood-deciduous forest which has its best development in the Cumberland Plateau of Tennessee and adjacent areas. So we learn that the Oligocene forest of Oregon, as made known by the slabs of shale at Bridge Creek, has been greatly restricted in subsequent time. Part of it lives in the eastern United States, part has continued on in Oregon, and most of it survives in Central China.

THE RUJADA AND RELATED FLORAS

The fossil floras of the area west of the Cascades are less well known than those to the east because of the heavy forest cover which hides rock outcrops. In recent years, several significant discoveries have been made by Professor Warren D. Smith and others in the Willamette valley. At Rujada, near the Laying Creek ranger station, leaf-bearing volcanic sediments are exposed in a cut of an old logging railroad, with overlying basaltic lavas. The flora includes many of the common plants found at Bridge Creek, such as birch, oak, chestnut, basswood *(Tilia)*, and elm *(Ulmus)*. With these typically temperate species there are associated leaves of avocado *(Persea)*, catalpa *(Catalpa)*, lancewood *(Ocotea)*, and palm *(Sabalites)*, whose living relatives occupy warm-temperate and tropical regions and whose fossil occurrence in western North America is largely limited to deposits of older Tertiary age. Instead of the dawn redwood, which in ages past as well as today appears to have been largely interior in distribution, the coast redwood *(Sequoia)* is here numerous. The coastal aspect of the Rujada flora is suggested not only by this occurrence of *Sequoia* but by the surviving members of the subtropical forest of earlier days. In such a situation, plants of the preceding, warmer Eocene might be expected to linger after they had become extinct elsewhere, for near the ocean the moderating effects of the ocean tend to bring milder and more uniform temperatures than in the distant interior.

Within the past several years, a large collection of plants which appear to be related in age to the Rujada flora has been assembled by Professor LeRoy E. Detling from a quarry east of Goshen. This collection also shows a mixture of temperate and subtropical types, as do two smaller floras from Cascadia and Franklin Butte. The first of these was found along a trail through the hemlock forest above the Cascadia ranger station and is inadequately known; the second has been studied by Dr. Sanborn and will soon be discussed in print. All of these Oligocene floras from the western slope of the Cascades are interpreted as coastal, an interpretation which is supported by the discovery of marine shells in associated deposits. In aspect they are intermediate between the Comstock flora of the Eocene and the Bridge Creek of the John Day Oligocene, with tropical relicts of the former and numerous temperate members of the latter. The nearest approach to this composite forest in the existing vegetation of North America is to be found along the South Atlantic and Gulf coasts; here palms, catalpa, and *Persea* live in association with oaks, maples, and other temperate genera; the redwood is not included in this assemblage, where its place is taken by a related tree, the swamp cypress *(Taxodium distichum)*.

Reference to the environment of *Metasequoia* in Central China brings out other significant relationships. At Shui-hsa-pa, where the elevation is 4,000 feet, all of the observed trees growing with the dawn redwood are temperate types such as beech, birch, and chestnut; a few broad-leafed evergreen shrubs, including *Lindera* and *Litsea* of the laurel family, give a warm temperate aspect to the understory in these wooded ravines. According to Professor Cheng, this climax forest is distributed over a wide area at middle altitudes. At lower elevations there are many broad-leafed evergreen trees, and the forest may be characterized as subtropical. Recently, word has come from Professor Cheng that trees of *Metasequoia* have been found near the city of Li-chuan at an elevation of 2,400 feet, in the zone occupied by the subtropical forest. If this is a natural occurrence, it is suggestive of some of the floras of western Oregon during Oligocene time, in which there is also a mixture of temperate with subtropical trees. Future studies of *Metasequoia* in Central China will further increase our understanding of the fossil forests in which this ancient tree is represented.

The Forests of the Miocene

As we come down toward the present in an historical sequence, the record becomes more complete and more readily comparable with that of our day. Most of the trees of Oregon's Miocene forests had leaves similar to those of living species; the vegetation of this epoch has a familiar look to anyone who is acquainted with forests now living in the north temperate zone. Although essentially modern in aspect, the Miocene floras of Oregon may be distinguished by their diversity in composition, for like some of the older plant units these floras contain trees now restricted to widely separated geographic provinces in the northern hemisphere.

THE MASCALL FLORA

Overlying the John Day formation is the great series of dark lava flows which has built up the Columbia Plateau east of the Cascades, the Columbia River basalt. Williams (1948, p. 28) has estimated that these lavas cover an area of some 250,000 square miles to a thickness up to 4,000 feet, and that their total volume is not less than 100,000 cubic miles. Poured out upon an irregular surface, the Columbia River basalt flows have a greater thickness where they covered the lowlands than over the highlands. In the John Day Basin their maximum thickness is 2,500 feet, which seems to indicate that this region stood at a somewhat higher elevation in earlier Miocene time than much of the area to the north where the basalts have a greater thickness. Supporting this suggestion of a pre-Miocene upland is the occurrence of older, pre-Tertiary rocks in the Aldrich Mountains to the south of the John Day valley, and in the Blue Mountains to the east. We may suppose that these adjacent highlands partly surrounded the John Day Basin as they do today, separating it from the Crooked River and Stinking Water basins to the south. and from the Payette Basin to the east.

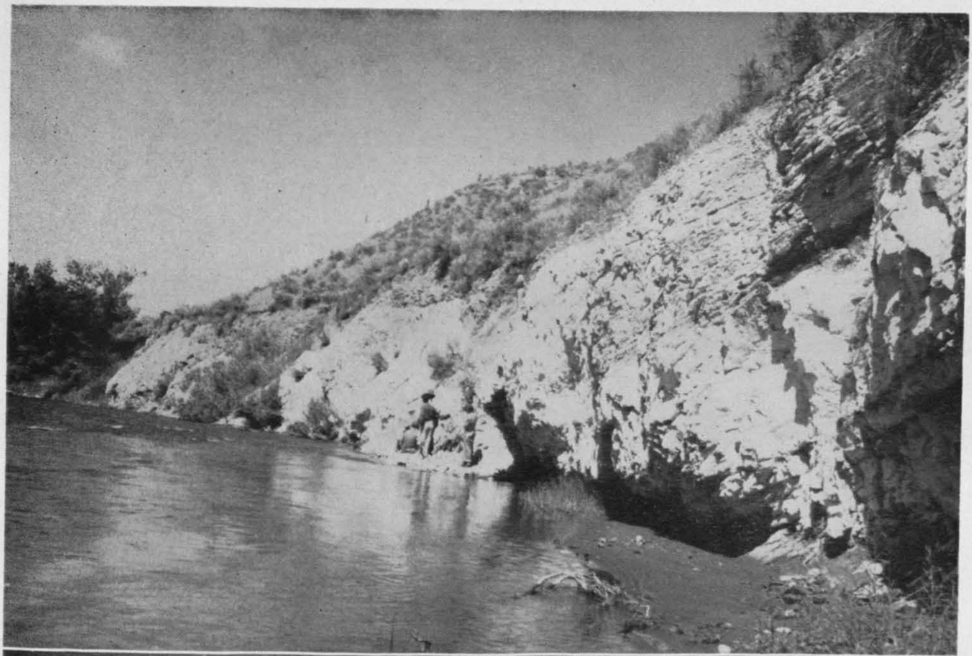
The outpouring of the Columbia River basalt must have disrupted the pre-existing drainage, diverting the courses of major streams, and damming up valleys to form lakes and swamps. Into some of the lake basins so formed there fell volcanic ash blown out by local explosive eruptions. The Mascall formation of eastern Oregon and the Latah formation of Washington and Idaho are the result of this type of accumulation, as is the Payette formation which covers a large basin area in east-central Oregon and adjacent Idaho. A smaller basin of deposition is found in the Austin-Tipton area of the Blue Mountains. To the south, similar deposits have been studied in the Crooked River and Stinking Water basins; still farther south near the Nevada border on Trout Creek and at several localities in northern Nevada and northern California, these light-colored volcanic sediments are widely exposed. Siliceous skeletons of minute aquatic plants, known as diatoms, are commonly mingled with the fragments of volcanic ash and are indicative of deposition in fresh-water lakes, as are associated remains of fish. Into these lakes were blown and washed the leaves and seeds of plants which lived around their shores. This record of Miocene vegetation of the Columbia Plateau is exceptionally complete.

In the valley of the East Fork of the John Day River, from Picture Gorge up to within a few miles of Mount Vernon, this deposit of volcanic and diatomaceous shale is known as the Mascall formation. Near the middle of the past century, the Mascall family settled in the John

Day Basin. A son of these pioneers, William R. Mascall, was operating a ranch just upstream from Picture Gorge when Merriam first visited this region in 1899, and a cordial relationship was established which has continued down through the years. The Mascall formation in this area differs in its geologic relations from similar deposits elsewhere on the Columbia Plateau in that it is not overlain by flows of basalt. However, the fossil flora which it contains is so like those in the Latah, Payette, Stinking Water, and other basins as to indicate sediments of essentially the same age. Williams (1948, p. 31) has described the Mascall formation as follows:

Typically, it consists of andesitic and rhyolitic ash and ashy sediment, delicately tinted in yellows, reds, browns, and greens, with partings of fine, white pumice. In part, these ejecta were carried into the region by winds from the ancestral Cascades, but most of them were erupted by local volcanoes. While some of these Mascall cones, especially in the upper reaches of the John Day Valley, discharged flows of andesite and basalt, the activity of most was strongly explosive rather than effusive. Interbedded with their products are lenses of sandstone and conglomerate formed by rivers winding over broad flood plains. Beds of papery, white, diatomaceous shales, some of them rich in fossil leaves, show that there were tree-fringed ponds and lakes in the lowlands, and seams of lignitic coal denote the existence of peaty swamps.

Halfway between Dayville and Mount Vernon lie the principal localities from which the Mascall flora has been collected (see Plate XII). Of these, the Riverbank locality on Van Horn's ranch is the oldest known, for Condon visited it in the sixties and collected several specimens which Newberry described later. Through information supplied by Condon, Charles Bendire, captain and later major in the United States Army, made collections here during the summer of 1881 (McCornack, 1928, pp. 287-292); these were first described by Lesquereux in 1888, and were discussed in greater detail by Knowlton in 1902 after his visit to the John Day Basin with Merriam during the preceding year. When I first visited this region in 1920, the Van Horn's ranch locality was a part of the ranch of Jerome Moore; it is now operated by his son-in-law, L. E. Cummings. Other nearby localities, some of which have been discovered in later years, have provided a large amount of fossil-bearing shale, of which approximately 975 cubic feet were quarried by a field party from the University of California in 1941. When split along bedding planes with a broad-edged chisel, this rock yielded a total of ten thousand specimens sufficiently well-preserved to be identified, an average of about ten specimens to a cubic foot. As compared with the Bridge Creek shale, where the average content in a count of twenty thousand specimens (Chaney, 1924) was 210 to a cubic foot, this is a surprisingly low yield. There is no reason to believe there were fewer trees in the John Day Basin during the



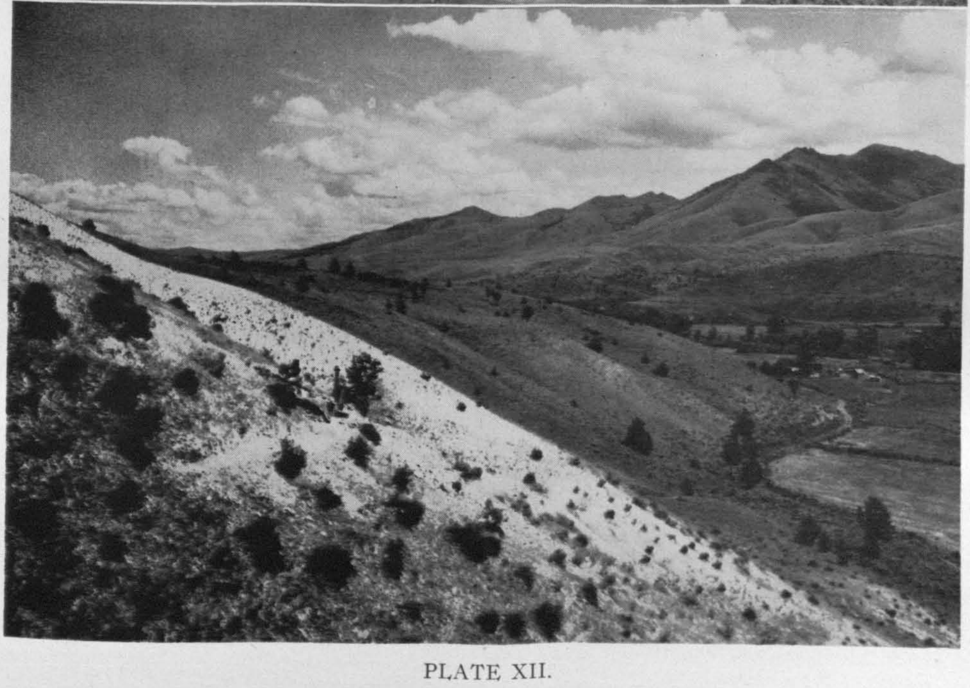


PLATE XII.

Fig. 1 (upper). At the Riverbank (Van Horn's ranch) locality of the Mascall flora, fossil leaves and fruits are abundant.

Fig. 2 (lower). From the White Hills locality of the Mascall flora, a view across the John Day valley to the Aldrich Mountains.

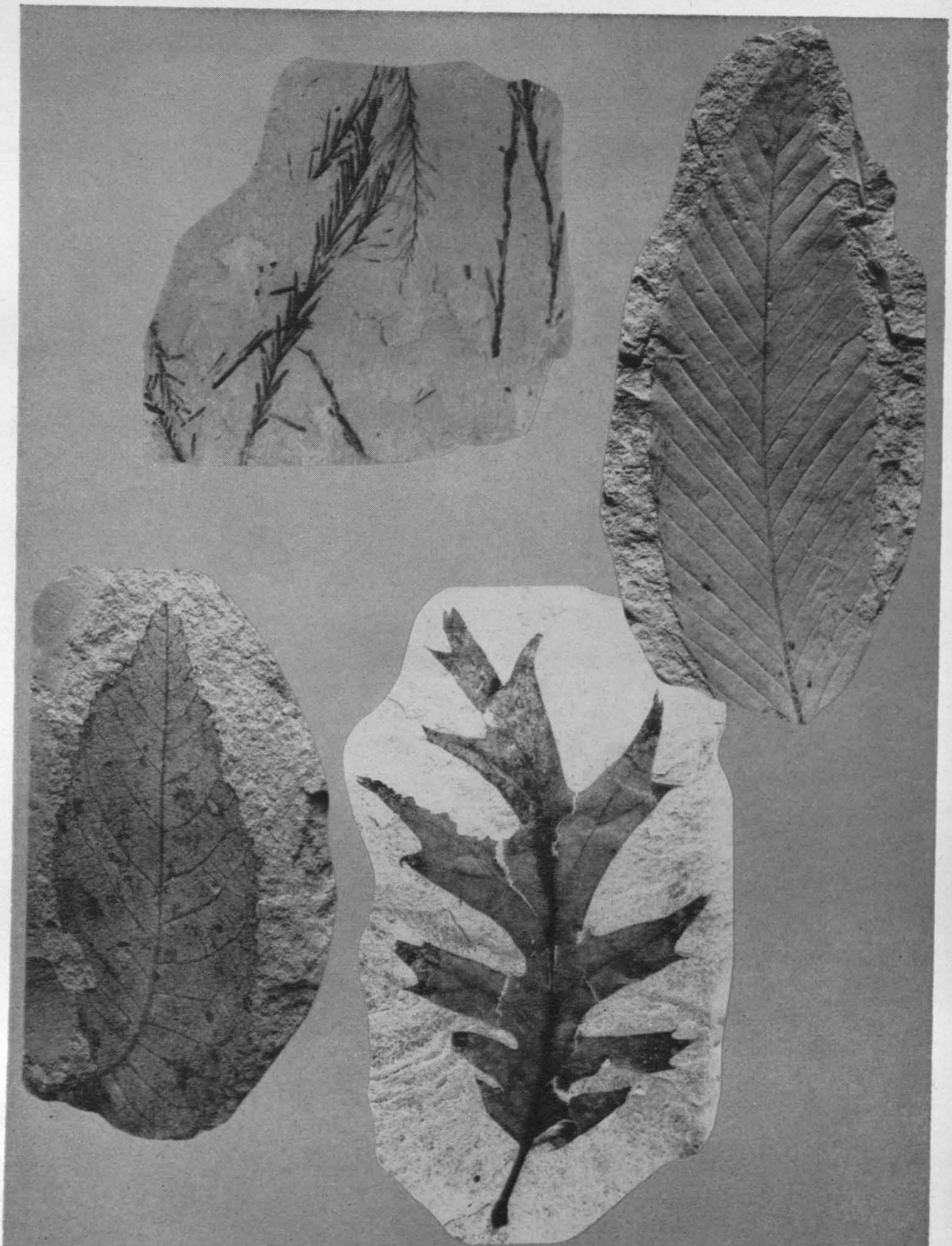


PLATE XIII.

Fossil leaves of the Mascall flora. Slightly reduced.

Fig. 1 (upper left). Leafy twigs of swamp cypress *(Taxodium dubium)*.
Fig. 2 (upper right). Beech *(Fagus washoensis)*.
Fig. 3 (lower left). Leaflet of hickory *(Carya bendirei)*.
Fig. 4 (lower right). Black oak *(Quercus merriami)*.

Miocene than in the preceding epoch. The discrepancy is probably due to less favorable conditions for preservation; if, as seems probable, the Mascall lake basins were larger than those in which the Bridge Creek flora was accumulated, there would have been less concentration of leaves and seeds at any one point and, therefore, fewer fossils in a given volume of sediments. Actually, the number of leaves collected from the Mascall sediments varies from less than four per cubic foot at the Roadside locality 10½ miles east of Dayville to nearly nineteen at the Riverbank locality on Van Horn's ranch, indicating a wide range in rate of leaf accumulation within the Mascall lake basins.

A census taken in the field also showed wide variation in the numbers of leaves and fruits of the 68 kinds of plants represented (see Plate XIII). A total of 3,426 specimens have been identified as the leafy twigs and other structures of the swamp cypress *(Taxodium dubium)*, whose nearest living relative, *T. distichum*, is now found along the Atlantic Coast from Delaware to Florida and around the Gulf of Mexico to the Mexican border, with a broad extension inland up the Mississippi Basin to Illinois and Indiana. A black oak *(Quercus pseudo-lyrata)* is second in abundance, with a total of 1,598 leaf specimens; living relatives of this fossil species, of which *Q. borealis* appears to be most similar, are numerous in the eastern United States, and there is a single related species, *Q. kelloggii*, which ranges through California into central Oregon on the coastward slopes on the mountain ranges. Third in numbers is a hickory *(Carya bendirei)*, with 1,060 leaflets; hickories are now confined to the eastern part of the continent, ranging westward into Texas. There follow in order of abundance: a sycamore *(Platanus dissecta)* which appears to resemble *P. racemosa* of the western United States more closely than any other living species, with 354 leaves; another black oak *(Q. merriami)* with more slender leaves resembling those of *Q. rubra* of the eastern United States, represented by 253 leaves; a small-leafed maple *(Acer bolanderi)* which resembles *A. grandidentatum* of the Rocky Mountains and *A. leucoderme* of the southeastern United States, with 230 leaves and fruits; a redwood *(Sequoia heerii)*[6] which closely resembles *Metasequoia glyptostroboides*, the dawn redwood of Central China, represented by 228 leafy twigs and cones; *Ginkgo adiantoides* whose only living relative has survived under cultivation in China, with 225 leaves in the fossil record; box elder *(Acer negundoides)* whose American equivalent ranges across the continent, and with a similar living species, *A. henryi*, in Asia as well, with 214 leaves and fruits; an elm *(Ulmus speciosa)* resembling *U. fulva* of eastern North America, with 205 leaves and fruits. These 10 most abundant species, with a total representation of 7,793 specimens, make up 78

[6] This fossil species will in the future be known as *Metasequoia heerii*, but until this revision is published the original, though incorrect, name must be used.

per cent of the Mascall flora as known from our collections; in all probability they were among the most numerous trees in the Mascall forest, although at least one, the ginkgo, seems to have been restricted in distribution, for its leaves are common at only one fossil locality.

One of the most striking features of the Middle-Tertiary floras of western North America, already mentioned in our discussion of the Bridge Creek flora, is their mixture of trees whose living relatives are today found in widely separated forests. Four of the abundant Mascall species, the swamp cypress, the hickory, the slender-leafed black oak, and the elm, have living equivalents which are now confined to the eastern side of North America. Two trees, the ginkgo and the dawn redwood, are now represented only in the modern forests of Asia; the box elder has living relatives in Asia, eastern North America, and in the western part of the continent, as well; two species, the broad-leafed black oak and the maple, have living equivalents both in eastern and western North America; there remains only one dominant tree, the sycamore, whose nearest modern relative is confined to the West, though not occurring in Oregon, and it has other less closely related living equivalents both in the eastern United States and in southwestern Asia.

When we consider the modern distribution of the descendants of other Mascall trees, the resemblance of this flora to the forests of eastern North America and eastern Asia is even more apparent. Altogether, there are 35 Mascall species, representing more than half the total, which have modern equivalents now living in eastern North America (see Plate XIV). These are assigned to the East American Element. There is a poplar which closely resembles the swamp cottonwood *(Populus heterophylla)*, now most common in river swamps in the lower Mississippi Basin; a birch similar to the paper birch *(Betula papyrifera)* of the northeastern United States and northward to Hudson Bay; a hop hornbeam with a close living equivalent *(Ostrya virginiana)* in the eastern half of the United States; a beech whose nearest living relative *(Fagus grandifolia)* has a similar range; a chestnut oak similar to *Quercus prinus* of the lower Mississippi valley and the Atlantic Coast. Only two of the genera are now restricted to this region, *Taxodium* and *Leitneria.* An almost equal number of Mascall species, 34 in all, have living equivalents in eastern Asia, and are assigned to the East Asian Element. Several of these fall in genera which are now restricted to Asia (Gymnosperms — *Ginkgo, Metasequoia, Cephalotaxus, Keteleeria;* Angiosperms — *Pterocarya, Zelkova, Cercidiphyllum, Machilus);* but for the most part the equivalents are not greatly different from species also living in the eastern part of North America.

There are only 24 Mascall species which have close living equiva-

PLATE XIV.

Fig. 1 (left). On higher ground bordering the swamp-cypress forest of Arkansas grow oaks, maple, poplar, and other members of the Mascall flora.

Fig. 2 (right). The hardwood-deciduous forest of the Cumberland Mountains of Kentucky is made up of chestnut, birch, oak, beech, and other trees which are common in the Mascall flora.

lents in western North America and which are assigned to the West American Element. Most of these also have equivalents in eastern North America or eastern Asia; in fact, the relationships of Mascall species to the modern plants on the eastern sides of the continents is much more striking than to those on the western. Combining the Mascall plants of the East American and East Asian Elements, there is a total of 55 species which make up 85 per cent of the flora; 16 of these species also have equivalents in western North America, leaving 39, or 60 per cent of the total, which are confined to the eastern sides of the northern continents. The nine species included in the West American Element, whose equivalents are confined to western North America, make up only 14 per cent.

These relations have significant climatic implications, suggesting as they do an environment in which a majority of the trees shed their leaves in winter. Not only most of the angiosperms, but the two most numerous gymnosperms, *Taxodium* and *Metasequoia*, of the forests on the eastern sides of the continents, are deciduous in response to winters during which temperatures may regularly fall below freezing, at least in the United States. By contrast, there are many broad-leafed evergreens and a much larger group of evergreen conifers in the forests now living on the coasts of Oregon and California, where the winters are mild and rainy and the summers relatively dry. The large percentage of deciduous trees in the Mascall flora is suggestive of a climate more like that of Ohio, or of Szechuan at middle altitudes, than that of Oregon at the present time. Studies now in progress[7] include the records of two other large floras, the Blue Mountains flora to the east of the Dayville area, and the Stinking Water flora to the south. Both of these confirm the suggestion that there have been profound changes in the climate of eastern Oregon since the Miocene epoch.

The Forests of the Pliocene

The Pliocene floras of Oregon give us, for the first time in the records of past vegetation, a sense of modern trees—the sorts of trees which are still living in western America. While the gap in time is still several million years, it seems clear that during this epoch the climate and topography of Oregon were much as we know them today. The Pliocene is a record of an immediate yesterday, not of remote ages.

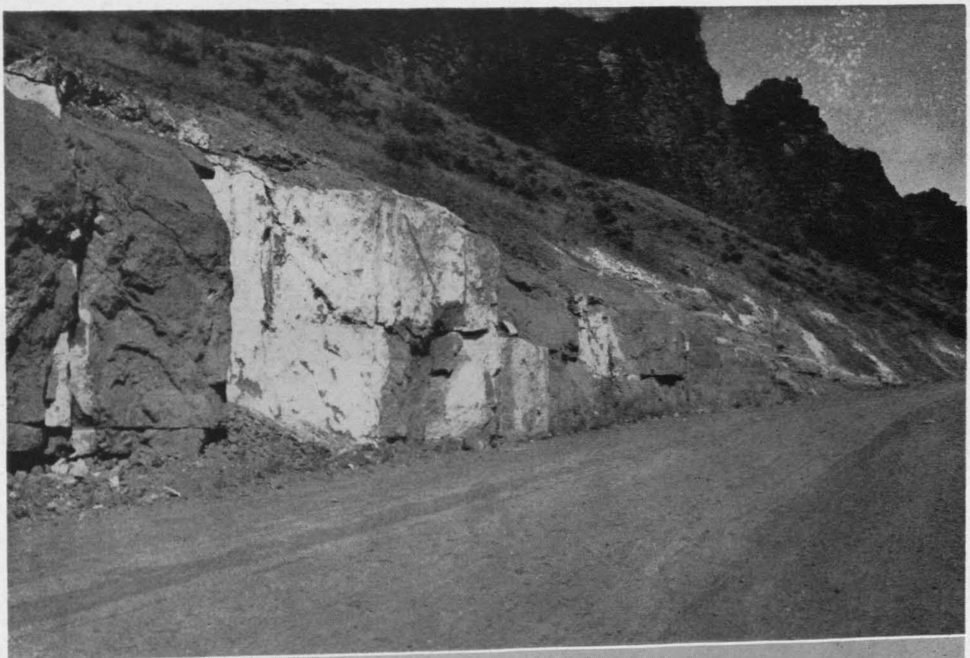
With the progressive trend toward cooler and less humid climate, conditions favoring the preservation of plant fossils were less favorable than in earlier time. To preserve a leaf or a seed in the rocks, rapid burial below the water table is an important contributing factor. The greater episodes of volcanic activity were largely past by Pliocene time, and while there are still many evidences of lava eruption, accumula-

[7] A monograph describing the Miocene floras of the Columbia Plateau is now being prepared by Dr. D. I. Axelrod and the author.

tion of volcanic ash was greatly diminished. For the first time, the rising Cascade Range began to serve as a major climatic barrier to the forests on its eastward, leeward slopes. In the John Day Basin and elsewhere, there is every evidence that rainfall was materially reduced, and that temperatures of a continental type were taking the place of the mild, equable climate of earlier epochs. In this altered environment, none of the subtropical and warm-temperate trees of the Eocene continued on into the Pliocene; many of the members of the temperate Arcto-Tertiary flora also disappeared during Oligocene and Miocene time, leaving only the hardier species which were able to endure cold winters and prolonged drouth. Not only were there fewer kinds of trees, but there were fewer situations in which their remains were buried and preserved. We know less about the vegetation of the Pliocene in Oregon than of any epoch of the Tertiary period.

Thomas Condon was responsible for the discovery and preliminary study of the only Pliocene flora known over all of the state of Oregon for many years. In 1869, he sent to Newberry a small collection from the old stone quarry above The Dalles with the following notation: " 'Group C' is from a sandstone at The Dalles. I have found in it four kinds of oaks and a very fine specimen of acacia, and within a few days a piece of fossil bone beautifully silicified was given me from the overlying rock." (McCornack, 1928, p. 46.) These specimens, labelled "Group C" in Condon's handwriting, are now at the New York Botanical Garden and are among the most significant Pliocene fossils available for study. In his book, *The Two Islands* (1902, pp. 142-145), written when he was more than eighty years of age, Condon showed his understanding of the age and the climatic significance of The Dalles flora in the following paragraphs:

Another of these Pliocene lake beds calls for notice and description. One standing on the streets of The Dalles and looking southward, will hardly fail to notice a well-defined ledge of gray sandstone set against the hills a mile or so from town, and extending westward three or four miles. It is a remnant of an old lake bed that once extended across the valley till its further margin set against the Klickitat mountains. What remains of this lake bed is today an unbroken level, although surrounded by many of the grandest exhibitions of volcanic and earthquake power, proving that no great violence has troubled the region since the waters of a quiet lake deposited its sediment there. All Miocene deposits are disturbed in Oregon. This deposit has not been disturbed; it must, therefore, have been deposited after the disturbance at the close of the Miocene, which would make it Pliocene. But more: a few years ago this rock was extensively used for building purposes in The Dalles. In one of the building blocks taken from the quarry was found a well-defined fragment of a metacarpal bone of a camel, and the camel in Oregon marks the Pliocene. This metacarpal of the camel became of added interest when a few years since a fragment of a very small



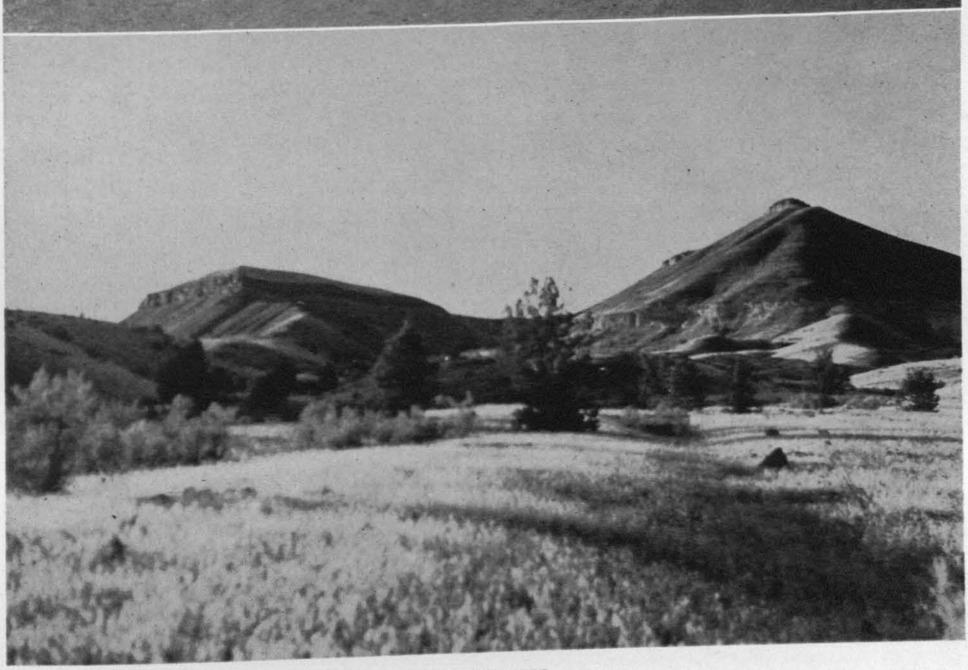


PLATE XV.

Fig. 1 (upper). There are no trees now living along Vanora Grade where leaves of Pliocene aspens and willows have been preserved.

Fig. 2 (lower). Beneath the rimrock of the Rattlesnake formation is a layer of sandy ash in which impressions of sycamore, willow, and elm leaves have recently been discovered.

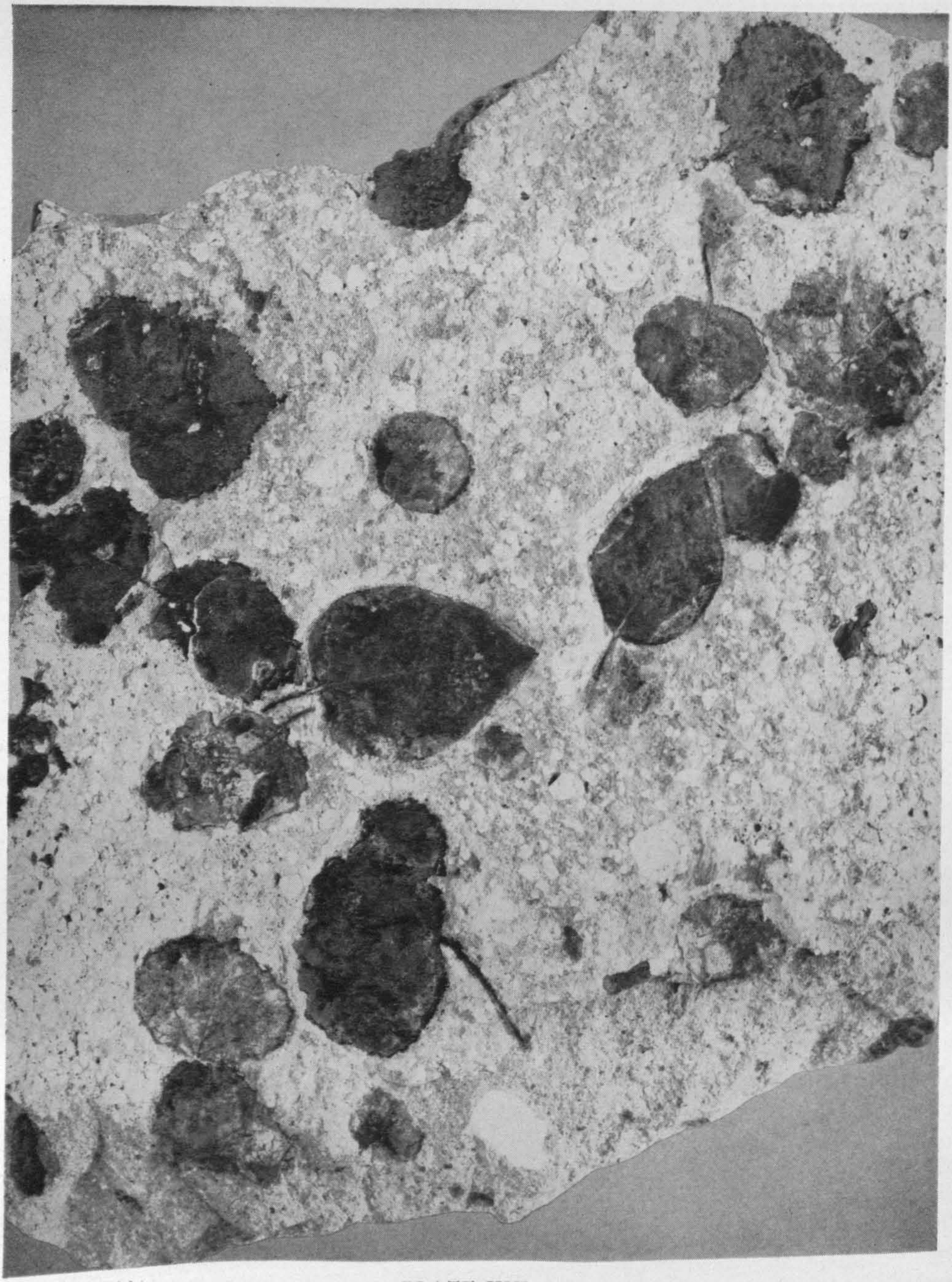


PLATE XVI.

Leaf impressions of aspen *(Populus pliotremuloides)* and cottonwood *(Populus alexanderi)* are abundant on pumiceous tuff of the Deschutes formation on Vanora Grade. Approximately three-fourths natural size.

radius was found, which came into the hands of the writer. This fossil was found among other bones, in an eastern extension of the same gray sandstone. The animal to which it belonged was an Auchenia of the camel family and represents an animal perhaps twenty-five to thirty inches in height.

Years ago the writer designated the group of rocks to which this gray sandstone belongs as The Dalles group and Pliocene.

There is a curious piece of geological history brought to the front in endeavoring to explain the circumstances under which this gray sandstone of The Dalles group must have been deposited in those far away Pliocene times. It today represents the bottom of a former lake. It is two hundred and fifty or three hundred feet above the present level of the Columbia River. The river has, in excavating its present bed, washed away the whole of that lake bed excepting this sandstone remnant, and worn its way through over two hundred feet of solid basalt besides, in reaching its present level. The east and south borders of this lake sediment are concealed by a covering of glacial deposit, under which it may be traced eastward two or three miles. It was from this eastward extension of the rock that the small Auchenia fragment of radius was found, and from this same gray sandstone Mr. D. H. Roberts obtained the distal end of a well-defined metacarpal bone of a larger Auchenia, perhaps the Vitakeri elsewhere noted.

From this same locality the writer, many years ago, made a collection of fossil plants which passed into the hands of Dr. Newbury [Newberry]. In this collection was a specimen of birch and a beautiful branch of acacia, the leaflets all finely outlined upon the gray sandstone and the branch carrying three or four large thorns so distinctly impressed on the rock as to give a vivid impression of its place in plant life. Besides these, there was an intensely interesting group of oak leaves indicating a range of four or five different species, the whole collection leaving on the mind a conviction of a cold, unfriendly climate, producing a stunted growth of leaves.

In 1920, more than fifty years after Condon's initial discovery, I found a ledge of volcanic shale in the valley of Chenoweth Creek, three miles north of The Dalles, which contained numerous leaf impressions. Some of these were the same species he had found; others were new to the flora, including the box elder. This tree is still to be found along streams east of the Cascades, and the whole group of plants with which it was associated during the Pliocene epoch are indicative of a cool, semiarid climate. Willow, oak, elm, and sycamore are among the trees recorded, and all of them still survive along streams in the drier parts of North America and Asia. In numbers of species and specimens, The Dalles flora is in striking contrast to the Eagle Creek flora from the Miocene of adjacent areas, and from the Middle-Tertiary floras of the John Day Basin. It records a later stage in the trend toward modern living conditions in the area east of the Cascades (Chaney, 1944).

During the construction of the Vanora Grade, on the Warm Springs cutoff of the highway from Madras to Portland (see Plate XV, figure

1), a highway engineer noted the presence of leaf impressions on slabs of coarse volcanic shale in the Deschutes formation and reported his findings to Phil Brogan, of Bend, and to Lewis H. Irving, of Madras. In company with these enthusiastic fossil hunters, I visited the region in 1936 and made a large collection of leaf impressions, some of which are shown in Plate XVI. The most abundant species is the aspen, a tree whose living equivalent is still common along streams in adjacent higher regions. Willow, cottonwood, cherry, and box elder make up the remainder of the plants known from the Deschutes flora, and give us a picture of stream-border vegetation much like that to be found from 3,000 to 3,700 feet above sea level in eastern Oregon today. None of these trees is now living along the Vanora Grade, and we may conclude that rainfall in this part of Oregon has been materially reduced since Pliocene time. The relatively small size and thick texture of these Pliocene leaves, as compared with those in the Bridge Creek, Mascall, and other Middle-Tertiary floras of eastern Oregon, are in accord with the trend toward cooler and drier climate; this trend has continued during subsequent time, with the result that trees have been largely eliminated from the lower levels and are now common only in the adjacent Ochoco Mountains and other highlands (see Plate XVII, figure 1) where there is adequate precipitation (Chaney, 1938a).

In the John Day Basin there is a series of rhyolitic flows and tuffs known as the Rattlesnake formation which was accumulated during the middle part of the Pliocene epoch, at about the same time as the Deschutes. The petrified bones of mammals, including horses, carnivores, and rodents, have been found in it by Merriam, Stock, and Moody (1925). During all the years since Merriam first studied this formation, an effort has been made to learn something about the vegetation of the John Day Basin at the time these mammals lived. But it was not until the summer of 1947 that a field party from Oregon State College, under the leadership of Professor W. D. Wilkinson, found leaf impressions in the cross-bedded sediments below the rimrock near Dayville (see Plate XV, figure 2). From my preliminary collections, we already know that elm, sycamore, and willow, all common Pliocene trees, were present along the streams at this time. The full significance of this important discovery will be better understood after additional collections have been made. With the finding of a Pliocene flora in the John Day Basin, the Tertiary section here becomes one of the most completely represented in any part of the world.

To the south on the east flank of Steens Mountain, another small flora of the same approximate age has been found along Alvord Creek. As studied by Axelrod (1944), this flora is known to include such conifers as fir, spruce, and pine, and willow, poplar, cherry, maple, and a

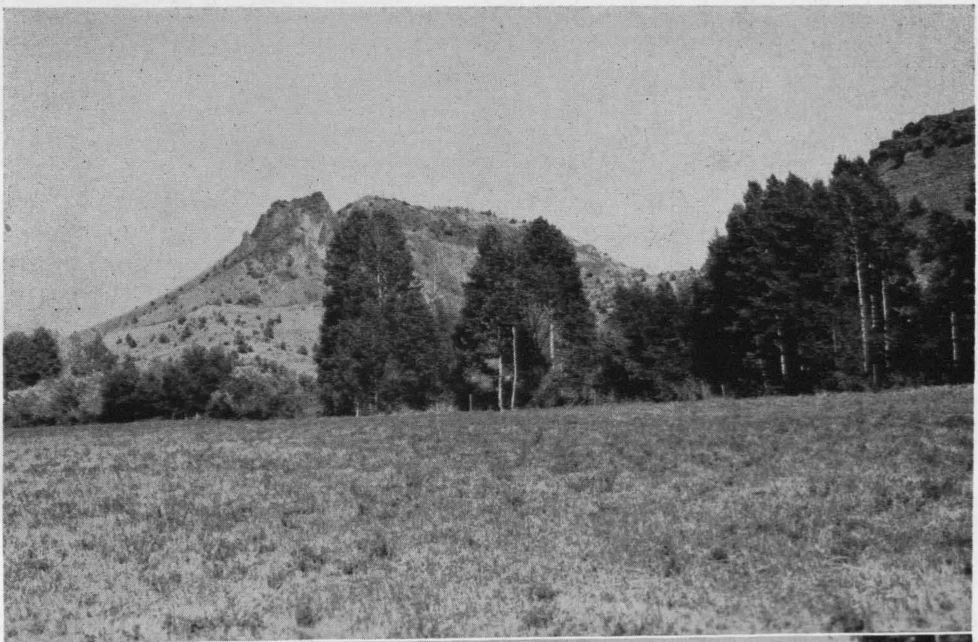


PLATE XVII.

Fig. 1 (upper). Aspens and other trees of the Deschutes flora are now living in eastern Oregon at elevations much higher than during the Pliocene.

Fig. 2 (lower). The forest now living in the Ochoco Mountains, at elevations around five thousand feet, is made up of pine, fir, and larch, with alder, aspen, and maple along the streams.

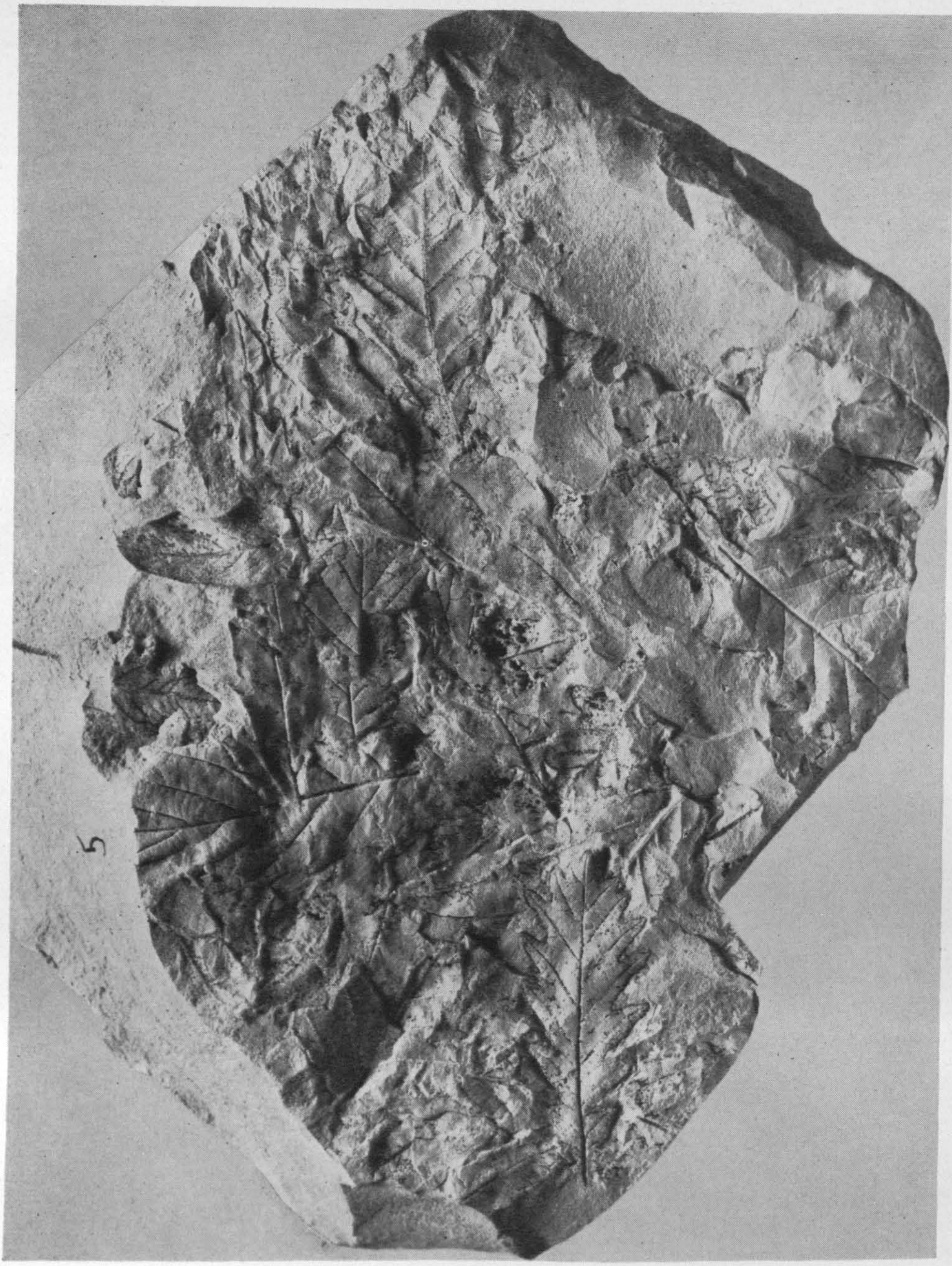


PLATE XVIII.

Leaf impressions of oak *(Quercus winstanleyi)* and willow *(Salix wildcatensis)* cover a slab of shale from the Troutdale formation south of Portland. Slightly reduced.

number of other angiosperms. These trees appear to have lived on the borders of a small lake, when the rainfall was nearly twice as much as it is today. Over all of this area east of the Cascade Range we have noted that the Pliocene vegetation is not only indicative of a drier climate than that of earlier Tertiary time, but that there is evidence of further reduction in rainfall during post-Pliocene time.

It, therefore, becomes important to learn as much as we can regarding the Pliocene vegetation and climate on the west slope of the Cascades. Here, rainfall has not been as greatly reduced as on the east flanks, and the fossil floras might be expected to be less different from those of the Miocene. It is much more difficult to discover fossil deposits here than in eastern Oregon, for the Pacific slopes of the Cascades are covered by a heavy forest. More than thirty years ago, I was guided to the only Pliocene deposits in western Oregon known to contain plant remains by J. B. Winstanley, a student of Condon at the University of Oregon and who until his death was greatly interested in the rocks of Oregon and the fossils he found in them. On several occasions since, I have worked my way up the brushy course of Buck Creek, near Troutdale, to the cliff where these plant fossils occur in the Troutdale formation. R. C. Treasher, formerly of the Department of Geology and Mineral Industries, has discovered within the past ten years a second fossil-plant locality on the road above Camp Collins, a short distance from the Buck Creek locality. Acknowledgment is due him and Lloyd Ruff, formerly of the Department of Geology and Geography of the University of Oregon, for their cooperation. The Troutdale formation was laid down on the west slope of the rising Cascades, and the abundance in it of basalt pebbles may be interpreted as indicating that these mountains were already rather high when it was accumulated. Oak, willow, and elm leaves like those of The Dalles flora to the east are common (see Plate XVIII), but in addition there were several trees, such as sweet gum and persimmon, which are now restricted to regions of heavy summer rainfall. Even more significant is the presence of *Sequoia,* a conifer which was present in eastern Oregon during Miocene time, but which is unknown there in Pliocene deposits. Here we have a tree whose descendant, the coast redwood *(S. sempervirens),* is now limited to the borders of the Pacific, which was then growing in a similar coastal locality during the Pliocene. On the inland side of the Cascade Range, not only is redwood absent from The Dalles and other Pliocene floras, but all of the trees are suggestive of a cool, dry interior climate. The rise of the Cascades to a height at which they became a climatic barrier may be dated as Pliocene on the basis of the differences between the Troutdale flora of western Oregon and The Dalles flora to the east, differences which are still more profound in our day since these mountains have reached their present elevation (Chaney, 1944a).

The Forests of the Quaternary Period

During the period in which we live, glaciers have come down across the northern part of our continent and have extended far down the valleys from the Cascades and other mountain ranges. The climate, which made possible the accumulation of snow to form these glaciers, had a profound effect upon the forests; they were completely destroyed over the areas covered by these moving fields of ice, and even beyond the limits of glacial advance the vegetation was greatly altered.

There are few records of the occurrence of fossil plants in deposits laid down during this time of ice accumulation, known as the Pleistocene epoch. The only specimens I have ever collected are pieces of wood from a cliff near the ocean at Newport. Most, or all, of the pollen which Professor Henry P. Hansen, of Oregon State College, has been studying is of the postglacial age, sometimes termed the Recent epoch. We are, therefore, not in a position to discuss the plant life of the Pleistocene other than to suggest that it appears to have been intermediate between the floras of the Pliocene and the forests of today.

Hansen's extended studies of postglacial forest succession (1947), based upon the minute bodies, known as pollen, which have been blown by the wind and have accumulated in peat deposited in lakes and swamps, give us a remarkably complete picture of changes in vegetation during the past eighteen to twenty thousand years. Climatic fluctuations have favored first one, then another, group of trees, not only in Oregon but elsewhere in the Pacific Northwest. We shall leave to him and others the discussion of this significant record, since our field of inquiry includes only the plant records of greater antiquity.

Looking at the forests now living in Oregon, we see many kinds of trees—maples, oaks, willows, alders, and firs—whose history goes far back into the past, when the Arcto-Tertiary flora was developing in northern regions and beginning its southward migration. From our present forests have been eliminated many species which require rainy summers and most of those which may live only in regions with mild winters. There remain for our pleasure and use only those trees which are suited to the Oregon climate and topography of today (see Plate XVII).

IV. CONCLUSION

The long ages have witnessed great changes in the forests of Oregon. Ancient fernlike trees, and the conifers and cycads of other eras, had given way before the dawn of recent time to modern types of flowering plants and conifers. Yet even in these latest sixty million years of earth history, the fossil record buried in the rocks of Oregon has shown a marked transformation. From the subtropical rain forest of the Eocene to the temperate hardwood-conifer forest of the Oligocene and Miocene, as shown by Plates II, III, IV, and V for the Eocene, Plates VII, VIII, IX, X, and XI for the Oligocene, and Plates XII, XIII, and XIV for the Miocene, there have been wide changes in the character of the vegetation of Oregon and in the terrain upon which it lived. Coming on toward the present, the cool-temperate floras of the Pliocene approach in appearance the forests of today, as shown by Plates XV, XVI, XVII, and XVIII. The juniper and sage which now cover the slopes of the Bridge Creek hills tell a story of extensive modifications in climate when we reconstruct, from our fossil specimens, the redwood forest which once lived there.

In the light of our present knowledge, it is not possible to determine how fully such changes in climate are related to topographic changes, or to what extent they are due to factors outside our planet. There is evidence for believing that the amount of heat coming to us from the sun differs from age to age, and that major trends in climate may be caused by this variation in the solar constant. Imposed upon such trends are terrestrial changes—the uplift of the Cascade Range, the warping of North America above or below sea level so that our Pacific shore has been shifted back and forth from its present position. The altered topography which results from these earth movements has profoundly modified the circulation of air and ocean currents which control our climate. The changes in climate have been as slow as these earth movements. Tens of millions of years have been required to change the setting of the John Day Basin from a subtropical rain forest to a semiarid steppe.

Unless we believe that our continents and mountain ranges are now fixed, never to be altered, and unless we envision a climate subject to no future trends, we may be assured that the vegetation of Oregon will change in the future as it has in the past. We have no present basis for predicting in detail the direction these changes of earth, climate, and forest will take, or what will be the nature of western North America a million, ten million, years hence. But one reliable method of looking into the future is to study the plant life of the past, the sequence of fossil floras preserved in the sediments of yesterday.

John Campbell Merriam, recalling the wooded hill across the valley from his childhood home, has written: "Whoever looks into a forest, whether through eyes of the inexperienced or untutored mind, or with penetrating keenness of enlightenment, finds its windows framing pictures in which the shadowy background presents a challenge to imagination. The trees bordering its vistas impart their strength and beauty even to the darkening areas beyond. With this frame and setting the mystery of the forest has always been a stimulus to inquiry and answer. The groves have ever been temples, because through them we have turned toward contemplation of undefined sources of being and power represented there in qualities of living things."

This great leader and Thomas Condon, who preceded him by nearly a generation, have directed our attention to forests still older, to trees which lived in Oregon before man came to inhabit the earth. When we have studied more fully the record of this ancient vegetation—the leaves and fruits imprinted in deposits of ancient streams, the logs petrified in volcanic ash—we shall have a richer understanding not only of the forests of the past, but those of years to come. As Merriam has told us, "Life through the ages, under the guidance of whatever power there is behind nature, had tended to link the element of continuity with change, development, and progress."

Bibliography

AXELROD, D. I.
1944. The Alvord Creek flora. Carnegie Inst. Wash., Publ. 553, chap. 9.

AMERICAN NATURALIST.
1869. Vol. 3, Proceedings of scientific societies, p. 446.

CHAMBERLIN, T. C. and SALISBURY, R. D.
1907. Geology: earth history.

CHANEY, R. W.
1924. Quantitive studies of the Bridge Creek flora. Amer. Jour. Sci., 5th ser., vol. 8, no. 44, pp. 127-144.
1925. A comparative study of the Bridge Creek flora and the modern redwood forest. Carnegie Inst. Wash., Publ. 349, no. 1.
1927. Geology and paleontology of the Crooked River Basin. *Ibid.*, Publ. 347, no. 4.
1938. Ancient forests of Oregon: a study of earth history in western America. *Ibid.*, Publ. 501, pp. 633-636.
1938a. The Deschutes flora of eastern Oregon. *Ibid.*, Publ. 476, no. 4.
1944. The Dalles flora. *Ibid.*, Publ. 553, chap 11.
1944a. The Troutdale flora. *Ibid.*, chap. 12.

CHANEY, R. W. and SANBORN, E. I.
1933. The Goshen flora of west central Oregon. *Ibid.*, Publ. 439.

CONDON, T.
1871. The rocks of the John Day valley. Overland Monthly. vol. 6, no. 5, pp. 393-394.
1902. The two islands, and what came of them.

COPE, E. D.
1880. Corrections of the geological maps of Oregon. Amer. Nat., vol. 3, pp. 457-458.

FONTAINE, W. M.
1905. In Ward, L. F. Notes on some fossil plants from the Shasta group of California and Oregon. U. S. Geol. Surv., Mon. 48, pp. 221-273, pls. 65-69.

HANSEN, H. P.
1947. Postglacial forest succession, climate and chronology in the Pacific Northwest. Trans. Amer. Phil. Soc., new ser., vol. 37, part 1.

HEER, O.
1855. Flora tertiaria. Helvetiae. vol. 1, p. 54, pl. 20, 21.

HU, H. H., and CHENG, W. C.
1948. On the new family Metasequoiaceae and on *Metasequoia glyptostroboides*, a living species of the genus *Metasequoia* found in Szechuan and Hupeh. Bull. Fan Mem. Inst. Biol., new ser., vols. 1, 2, pp. 153-161, pls. 1, 2.

KNOWLTON, F. H.

1902. Fossil flora of the John Day Basin, Oregon. U. S. Geol. Surv., Bull. 204.

LESQUEREUX, L.

1888. Recent determinations of fossil plants. U. S. Nat. Mus. Proc., vol. 11, pp. 13-19.

MCARTHUR, L. A.

1928. Oregon geographic names, p. 75.

MCCORNACK, E. C.

1928. Thomas Condon, pioneer geologist of Oregon (Univ. Press, Univ. of Oregon).

MERRIAM, J. C.

1901. A contribution to the geology of the John Day Basin. Bull. Dept. Geol., Univ. Calif., vol. 2, no. 9, p. 285.

MERRIAM, J. C.. STOCK, C., and MOODY, C. L.

1925. The Pliocene Rattlesnake formation and fauna of eastern Oregon. Carnegie Inst. Wash., Publ. 347, no. 3.

MIKI, S.

1941. The clay or lignite flora in Japan. Jap. Jour. Bot., vol. 11, pp. 260-262.

NEWBERRY, J. S.

1882. Brief descriptions of fossil plants, chiefly Tertiary, from western North America. U. S. Nat. Mus. Proc., vol. 5, pp. 502-514.

PACKARD, E. L.

1928. New section of Paleozoic and Mesozoic rocks in central Oregon. Amer. Jour. Sci., 5th ser., vol. 15, no. 87, pp. 221-224.

READ, C. B., and BROWN, R. W.

1937. American Cretaceous ferns of the genus *Tempskya*. U. S. Geol. Surv., Prof. Paper 186-F, pp. 127-128.

READ, C. B., and MERRIAM, C. W.

1940. A Pennsylvanian flora from central Oregon. Amer. Jour. Sci., vol. 238, no. 2, pp. 107-111.

SANBORN, E. I.

1935. The Comstock flora of west central Oregon. Carnegie Inst. Wash., Publ. 465, no. 1.

STIRTON, R. A.

1944. A rhinoceros tooth from the Clarno Eocene of Oregon. Jour. Pal., vol. 18, no. 3, pp. 65-67, fig. 1.

WEAVER, C. E.

1937. Tertiary stratigraphy of western Washington and northwestern Oregon. Univ. Wash. Publ. Geol., vol. 4, pl. 2.

WILLIAMS, H.

1948. Ancient volcanoes of Oregon (Oregon State Syst. Higher Educ., Condon Lect. Publ.).