BULLETIN 92

FOSSILS IN OREGON

A COLLECTION OF REPRINTS
FROM
THE ORE BIN

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

1977

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Margaret L. Steere, Editor

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PALEONTOLOGICAL TIME CHART FOR OREGON

ERA	PERIOD	EPOCH	CHARACTERISTIC PLANTS AND ANIMALS	AGE*
CENOZOIC	QUATERNARY	HOLOCENE	Plant and animal remains: unfossilized.	0.11
		PLEISTOCENE	Mastodons and giant beavers in Willamette Valley. Camels and horses in grasslands east of Cascade Range. Fresh-water fish in pluvial lakes of south-central Oregon.	2-3
		PLIOCENE	Sea shell animals along Curry County coast. Horses, camels, antelopes, bears, and mastodons in grass-lands and swamps east of Cascade Range. Oaks, maples, willows in Sandy River valley and The Dalles area.	12
	TERTIARY	MIOCENE	Sea shell animals, fish, whales, sea lions in coastal bays. Horses (Merychippus), camels, Oreodonts, rodents in John Day valley. Forests of Metasequoia, ginkgo, sycamore, oak, and sweet gum in eastern and western Oregon.	26
		OLIGOCENE	Abundant and varied shell animals in warm seas occupying Willamette Valley. Three-toed horses, camels, giant pigs, saber-tooth cats, Oreodonts, tapirs, rhinos in central Oregon. Forests of Metasequoia, ginkgo, sycamore, Katsura.	37
		EOCENE	Tiny four-toed horses, rhinos, tapirs, crocodiles, and Brontotherium in central Oregon. Variety of shell animals in warm seas covering most of western Oregon. Subtropical forests: Palms, figs, avocados, pecans, walnuts, and ferns in central Oregon.	60
MESOZOIC	CRETACEOUS		Ammonites, Trigonia, Inoceramus, and many other shell animals in seas extending into eastern Oregon. Tree ferns (Tempskya) on land areas.	136
	JURASSIC		Brachiopods, ammonites, gastropods, nautiloids in seas in central Oregon. Marine reptiles on southern coast and in central Oregon. Tree ferns, cycads, ginkgos, and conifers on land areas.	195
	TRIASSIC		Sponges, corals, ammonites, gastropods, nautiloids in seas of central Oregon.	225
PALEOZOIC	PERMIAN		Limestone reefs, fusulinids in seas of central Oregon.	280
	CARBONIFEROUS		Brachiopods and corals in seas of central Oregon. Ferns, Calamites on land areas in central Oregon.	345
	DEVONIAN		Corals and bryozoans in seas of central Oregon.	395
	PRE-DEVONIAN		No recognizable fossils.	

*in millions of years

CONTENTS

INTRODUCTION

This booklet contains 22 articles on fossils published in The ORE BIN between 1954 and 1976: 11 are about fossil plants; 6 are about fossil animals; and 5 describe fossil localities. No articles on microfossils are included.

Most of the articles are reprinted in their original form. Exceptions are those in the old format, which have been arranged here to fit the present ORE BIN page size.

The older articles in this collection have been slightly revised to conform to present-day spelling and usage of formation names, and some new data and references have been added. Special attention has been given the report on the fossil localities of the Sunset Highway area because of the proximity of these localities to Portland and the large number of people who visit them. Most of the Sunset Highway localities were re-examined, and the descriptions were updated to make that article more useful.

Information about fossil localities in the Eugene area was made current through the assistance of Dr. Ewart Baldwin, University of Oregon. In addition, some of the information on the Salem-Dallas area was revised.

It was not practical to visit all of the specific localities mentioned in these articles; it is probable that some no longer exist; highway construction, urban development, weathering, and over-zealous digging by fossil hunters have taken their toll on many of the outcrops. In some cases, fossil sites once accessible to the public are now posted as private property, and permission to enter must be obtained from the owner.

M.L. Steere
Geologist

FOSSIL PLANTS

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July 1960

FOSSIL WOODS OF THE THOMAS CREEK AREA, LINN COUNTY, OREGON

By Wallace Eubanks*

Identifying Fossil Woods

The purposes of identifying fossil woods are to aid in geological dating; to verify and supplement identification of fossil leaves, fruits, and flowers; to trace the movement of plant associations through time and across land areas; and to satisfy the curiosity of man.

Fossil wood, to be identifiable, must show clear and undistorted cell structure. Much of the fossil wood commonly collected in Oregon shows poor structure because the cells have been either crushed during geological changes in the earth or destroyed by chemical processes. In general, the ordinary grey-brown woods of western Oregon, as well as the black carbonized woods, have good cell structure. But most of the colorful eastern Oregon woods, which are usually highly agatized or opalized, have lost their identifiable characteristics. The wood best suited to polishing is usually the poorest for identification.

It should be pointed out at the start that identification of fossil woods is based entirely on comparison with living woods. No book on fossil-wood identification has as yet been published. Identifying fossil woods is a painstaking job and sometimes frustrating because many fossil woods have no exact living counterpart. Furthermore, they lack the useful characteristics of living woods, such as weight, color, odor, taste, and hardness.

Since the system of plant classification and nomenclature established for living plants is also used for fossil plants, standard textbooks of botany will supply this basic information. In addition, books on living woods will furnish detailed descriptions of wood anatomy and nomenclature (see bibliography).

Although it is possible, with a little practice, to recognize a few types of fossil woods without a microscope, comprehensive work requires magnification ranging from 30 to 400 power. The reason for this is that woods are differentiated on the basis of certain cell types and arrangements,

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* Supervisor, Timber Section, Assessment and Appraisal Div., Oregon Dept. of Revenue

and these features are visible only under considerable magnification. For example, the woods of Acer (maple) and Cornus (dogwood), which are very similar, can be distinguished only by examining the cells of the rays. Likewise, Pinus (pine) and Picea (spruce), which also look very much alike, can be distinguished only by observing the nature of the epithelial cells around the resin ducts.

In order to study the features of fossil wood with a microscope, it is first necessary to prepare thin sections of the three standard views of wood structure, namely, the cross, radial, and tangential sections (Figure 1). Orienting the cuts to obtain these three views of the cell structure is the most difficult part of making the thin sections. The cut sections are ground to a thickness of only one or two cells so that light will pass through and the details of each kind of cell will be made visible. All three views are then placed on one slide.

The next step is to determine whether the wood is hardwood or conifer by inspecting it under low magnification (Figure 2). After this distinction has been made, the minute details of cell arrangement are studied under the microscope. For most hardwoods, a microscope with 150 power is adequate, but for conifers, 350 to 400 power is necessary for observation of the cross-field pitting.

By means of keys to the features of wood anatomy, together with published descriptions and photomicrographs of known woods, it is possible to arrive at an identification of a particular piece of fossil wood. As a general rule, however, fossil-wood identification is limited to determination of genera only.

Fossil Woods of the Thomas Creek Area

The Thomas Creek area includes the Thomas Creek drainage and the Jordan Creek drainage above the confluence of those two streams in Ts. 9 and 10 S., Rs. 1 and 2 E., Linn County, Oregon (see map).

Fossil wood in this area is unique in that most of it is in place where it grew some thirty million years ago. Many stumps and logs ranging from 1 to 4 feet in diameter are imbedded in tuff exposed by erosion of the covering material. Some are carbonized while others are silicified or partly opalized. The stumps and logs occur as single scattered specimens and also in groups of two or three. In the bed of Thomas Creek there is one unusual group of 17 stumps.

A study of the fossil woods in this area has revealed 13 genera, 3 of which are conifers (Pinus, Sequoia, and Tsuga), while the remainder are hardwoods. They are listed below in alphabetical order with the common names added.

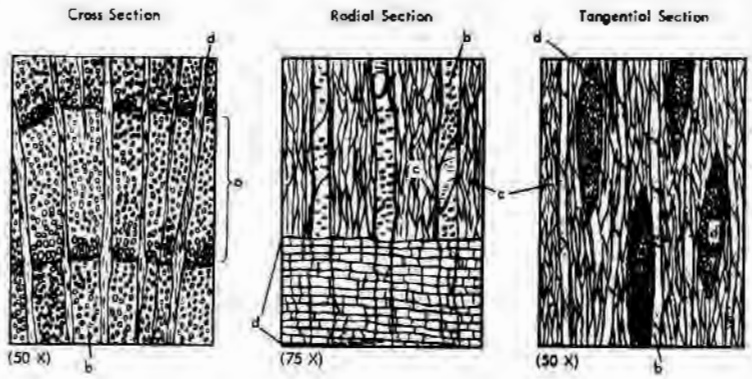


FIGURE 1: - Three standard views of Platanus (sycamore) wood: a) annual growth; b) vessel; c) fiber; d) multiseriate ray.

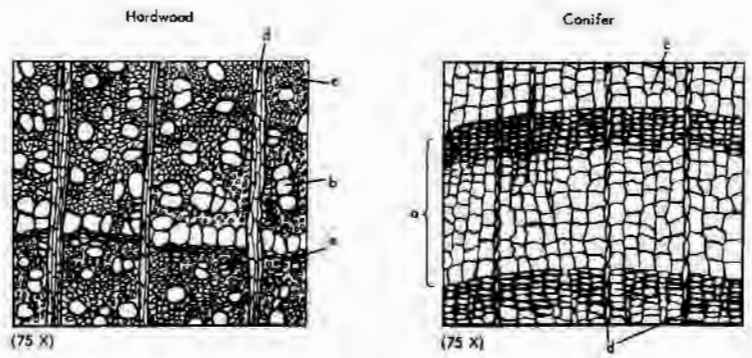
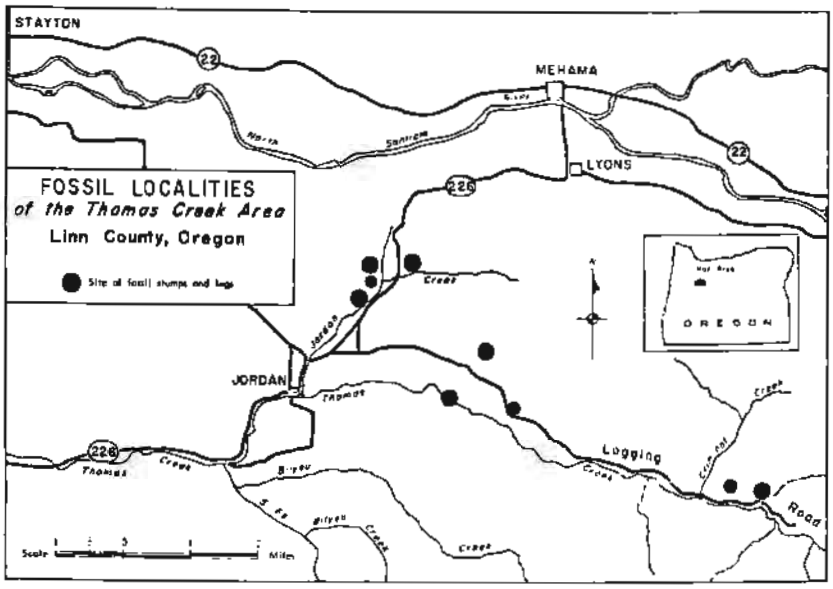


FIGURE 2: - Cross sections of typical conifer and hardwood: a) annual growth; b) vessel; c) fiber; d) multiseriate ray; e) parenchyma.

1. Alniphyllum - (Japanese)
2. Carpinus - hornbeam
3. Carya - hickory
4. Cinnamomum - cinnamon
5. Diospyros - persimmon
6. Fagus - beech
7. Fraxinus - ash
8. Pinus - pine
9. Platanus - sycamore
10. Quercus - oak
11. Reptonia - gargura (Indian)
12. Sequoia - redwood
13. Tsuga - hemlock

In addition to the genera listed, several other kinds of wood were found that could not be identified because of poor cell structure or because of lack of comparable living woods. Most of these are believed to be conifers.

The most abundant fossil woods in the Thomas Creek area are Sequoia and Platanus. Indeed, it is a rare plant locality in western Oregon that does not produce these two woods. It should be noted, however, that the specimens of fossil wood identified as Sequoia may be instead Metasequoia, or dawn redwood, as the distinctive needles and cones of Metasequoia are frequently found in the fossil leaf beds of this region. The living woods of these two trees are nearly identical, and the fossil forms are rarely distinguishable. Although ginkgo leaves occur in the area, no fossil ginkgo wood was found among the identifiable material.



A significant change has occurred in the forests of the Thomas Creek area since the time when the fossil plants were growing there. Of the genera listed above, only ash, oak, and hemlock are now present in the Thomas Creek area; the remainder grow in other regions, some very distant. Metasequoia, the fossil remains of which are abundant in Oregon, lives today only in remote parts of China. Sequoia, or coast redwood, a common fossil in the western margin of the Cascade Range of Oregon, now grows only in the fog belt of northern California and extreme southwestern Oregon. The majority of the hardwoods listed now live in warm-temperate to semitropical climates, although there is considerable latitude in their natural habitat, depending on species. As a whole, the fossil woods of the Thomas Creek area indicate a mild, moist climate averaging somewhat warmer than at the present time.

Smith (1958) has studied the geology of part of the Thomas Creek area and has mapped the plant-bearing tuff as part of the Mehama Formation of Oligocene to Miocene age. His dating was based on fossil leaf assemblages and stratigraphic relationships of the rocks. The present study of the fossil woods offers no reason to dispute this age interpretation.

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FOSSIL WOODS SUPPLEMENT KNOWLEDGE OF THE SUCCOR CREEK FOSSIL FLORA

By Wallace Eubanks*

The name Succor** Creek implies an area rich in fossil flora. It is, of course, the name of a drainage which arises partly in Idaho, flows in a northerly direction along the state line in Malheur County, Oregon, and finally crosses into Owyhee County, Idaho, where it empties into the Snake River (figure 1). The name Succor Creek also carries with it the association of other names such as Rockville School, McKenzie Ranch, Specimen Ridge, Fenwick Ranch, and Owyhee Reservoir, which in the past have been landmarks for the important fossil beds.

The Succor Creek Formation

The areas mentioned above are located within Miocene lake-bed sediments which crop out all along Succor Creek and are wide spread in the general area. These beds were named the Payette Formation by Lindgren (1900), and they retained this name for many years, but they are now referred to as the Sucker (Succor) Creek Formation (Kittleman, 1962; Kittleman and others, 1966; Baldwin, 1964; and Corcoran, 1965). This is the oldest Tertiary rock unit exposed in these parts of Oregon and Idaho.

The Succor Creek Formation consists of a thick series of tuffaceous sediments which are principally fine grained, thin bedded, and nearly white. In some areas, coarser tuffs of brown, yellowish, or greenish color are common. Basalt and rhyolite dikes and flows, also present within the series, evidently poured out during the deposition of the lake beds.

The age of the Succor Creek Formation is considered to be middle to late Miocene on the basis of fossil plants and vertebrates. Chaney and Axelrod (1959) and Graham (1962) correlate the leaves, fruits, and pollen

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* Supervisor of Timber Section, Oregon State Tax Comm., Salem, Oregon.
** Phil Brogan, Chairman of the Oregon Geographic Names Board, reports that "Succor" Creek is now official. Action reversing the earlier official spelling, "Sucker" Creek, was taken by the U.S. Board on Geographic Names in the spring of 1966 on recommendation of the Oregon Geographic Names Board, following considerable historical research. The reversal was one of the few ever made by the national board.

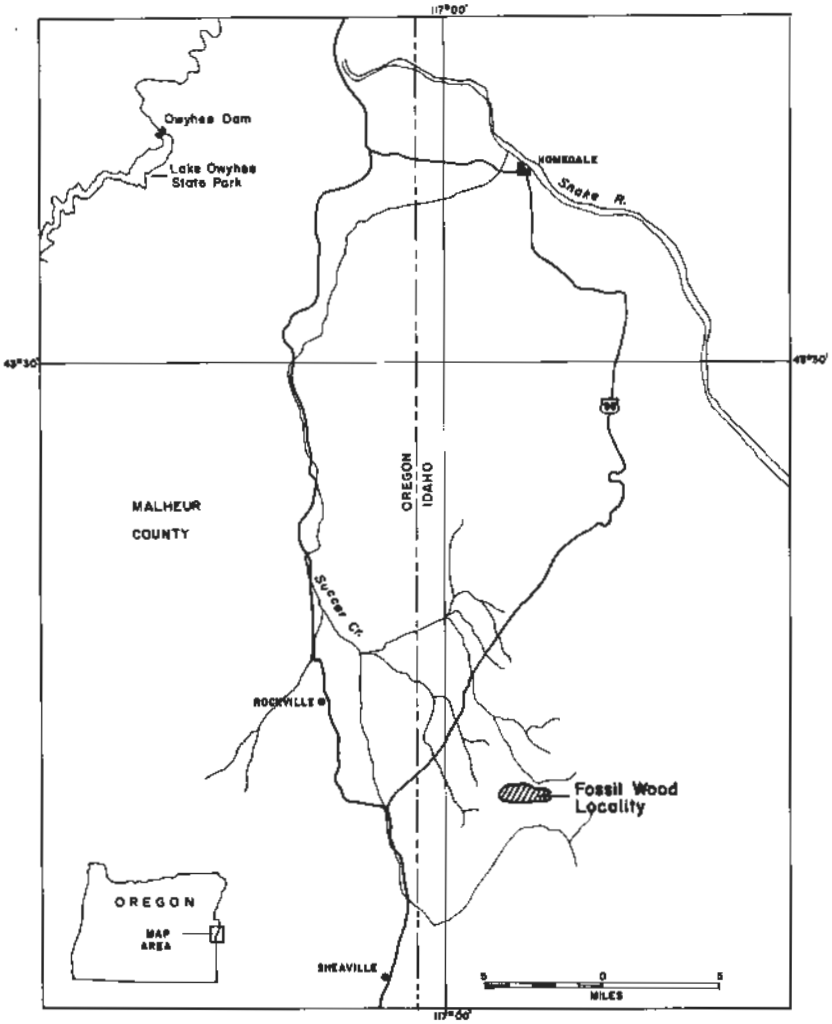

Figure 1. Index map of the Succor Creek area, Oregon-Idaho, showing fossil wood locale from which specimens were collected for study.

with those of the Mascall Formation of middle to upper Miocene age. Scharf (1935) concludes that the fossil vertebrates found in the lake beds are also generally equivalent to those in the Mascall Formation, and he assigns the strata to the middle Miocene or perhaps the early part of the late Miocene.

Studies of the Fossil Plants

Flora of the Succor Creek area first become known through Knowlton's study of Lindgren's collections (Lindgren, 1900). In Lindgren's report (p. 97-98), Knowlton lists more than a dozen types of fossil leaves. Since that time Chaney (1922), Berry (1932), Brooks (1935), Arnold (1936, 1937), and Smith (1938, 1940) gathered material from various parts of the Succor Creek area and analyzed it. A more recent work by Chaney and Axelrod (1959) presents a systematic study and correlation of the Miocene fossil floras of the Columbia Plateau, including the Succor Creek flora.

The most recent and the most comprehensive study of the Succor Creek flora is by Alan Graham (1962) for a doctoral dissertation. Graham gathered new specimens and analyzed them along with the previous collections and conclusions made by earlier workers. In addition to work with leaves, flowers, and fruits he made use of many thousands of pollen and spores to aid in identifying the various plants. As a result of this study, several plant types were renamed and new ones were added to the list. The trees and shrubs totaled 47 genera with 67 species. In addition several herbs, grasses, and ferns were found in the flora.

A summary of the tree and shrub genera from Graham is given below, with common names in parentheses. Some Asiatic forms have no common names in English.

Abies (white fir)
Acer (maple)
Alnus (alder)
Ailanthus (tree of heaven)
Amelanchier (serviceberry)
Arbutus (madrone)
Betula (birch)
Castanea (chestnut)
Carya (hickory)
Cedrela (cedar)
Crataegus (hawthorn)
Cornus (dogwood)
Diospyros (persimmon)
Ephedra
Fagus (beech)
Fraxinus (ash)
Ginkgo (ginkgo)
Glyptostrobus
Gymnocladus (coffee tree)
Hydrangea
Ilex (holly)
Juglans (walnut)
Lithocarpus (tanbark oak)
Mahonia
Magnolia (magnolia)
Nyssa (gum)
Oreopanax
Ostrya (hop hornbeam)
Pinus (pine)
Platanus (sycamore)
Populus (cottonwood)
Ptelea
Picea (spruce)
Pteracarya
Persea (avocado)
Pyrus (pear)
Quercus (oak)
Sassafras (sassafras)
Symphoricarpus (snowberry)
Shepherdia
Salix (willow)
Thuja (cedar)
Tilia (basswood)
Tsuga (hemlock)
Ulmus (elm)
Zelkova

These genera are represented by living trees and shrubs of three separate geographic regions. The principal group is found in the Appalachian Mountains of the eastern United States. Genera such as Carya, Fagus, Gymnoclodus, Ostrya, Tilia, and Ulmus are now living in the eastern forests. Another group is represented by trees growing along the western slopes of the Cascade Mountains. This group includes Abies, Pinus, Quercus, Lithocarpus, and Picea. The third group is made up of plants currently found in Asia, such as in certain provinces of China. Examples are Ginkgo, Glyptostrobus, Ailanthus, and Zelkova.

These plant associations reveal the fact that the fossil flora of this period grew in locations which ranged from swamp to rocky mountain sides with considerable difference in elevation, and in a climate which varied from a winter low of 30° to summer highs of about 90°. Annual rainfall was probably on the order of 50 to 60 inches and well distributed throughout the year. The trees such as Cedrela and Oreopanax show that subfreezing temperatures occurred rarely.

Analysis of Succor Creek Woods

A study by the author in 1960-1961 of fossil wood structure and identification of woods from one portion of the Succor Creek area was made in order to supplement the knowledge of the flora as determined previously from leaves and fruit. Specimens were gathered at the head of a branch of Succor Creek at a spot in Idaho about one mile southeast of the crossing of U.S. Highway 95 with the state border (see figure 1).

This particular area has been the source of black, opalized wood encased in a white matrix. Rockhounds have mined several acres of the deposits in search of the material. However, miscellaneous pieces of wood not suitable for the collectors' purpose were more satisfactory for the study of wood structure. These pieces ranged in size from several hundred pounds to pieces of perfectly preserved twigs only an eighth of an inch in diameter. Wood structure of many specimens is excellently preserved, even to the details which are visible only at 200 magnification and greater.

The study of Succor Creek woods revealed that there is a considerable correlation between the genera identified from the leaves and fruits and genera identified from the wood structure. The wood, of course, did not yield all the different genera represented by the leaves, perhaps because the wood was more difficult to preserve than the leaves and perhaps because the wood sampled is not representative of as wide an area as the leaves, which could have been carried by the wind and water for long distances. One outstanding lack of wood genera is the oak or Quercus. Usually a fossil wood locality will yield oak if it is at all present. Perhaps it was just a quirk of fate that the author did not find a piece in that particular location.

Genera established through study of wood structure are as follows:

Acer (maple)
Alnus (alder)
Arbutus (madrone)
Betula (birch)
Castanopsis (chinquapin)
Celtis (hackberry)
Evodia
Fraxinus (ash)
Pinus (pine)
Platanus (sycamore)
Populus (cottonwood)
Prunus (wild cherry)
Sequoia (redwood)
Ulmus (elm)
Umbellularia (laurel)

Of these the Castanopsis, Celtis, Evodia, Prunus, Sequoia, and Umbellularia do not correspond to the genera named from the studies by Chaney and Axelrod (1959) and Graham (1962). However, all of these except Evodia are found in other portions of fossil forests of the Miocene epoch in Oregon.

It is not possible to determine species through fossil wood structure as it is from leaves and fruit or pollen, because many species of one genera having quite different leaves and fruits will have wood structure so similar that it is not practical to distinguish between them in the fossils. Consequently, in the above list only the genera are given. Woods not identifiable were also found in this location and perhaps future study will add to the list.

It is interesting to note that trees of past geological ages were also infected with insects, borers, and fungi as evidenced by the work of all three found in the fossil samples.

Method for Identifying Fossil Wood

Identification of trees by consideration of the wood is achieved through study of the cellular composition and arrangement within the wood. To the casual observer, or even to the cabinet maker and others familiar with the use of wood, it appears to be only a solid mass of fibres. With live woods the qualities of hardness, color, odor, and pattern of grain are apparent and are the means by which many people distinguish different kinds of wood.

Actually, wood is made up of many types of cells in many variations of arrangement. It is the systematic classification and knowledge of these variations that enable the identification of trees to be made through the structure of wood. This information concerning structure has been set up in the form of keys and lists for many of the trees and larger shrubs of the world. However, no such listing is available for fossil woods alone. Fossils are usually identified by relating them to living plants. By correlating the structure of fossil plants with the structure of living plants which are classified and named under uniform international rules, it is possible to achieve identification of the fossils even though they are several million years old.

In working with woods from the Oligocene, Miocene, and more recent epochs, it is not difficult to correlate the structure with present-day live

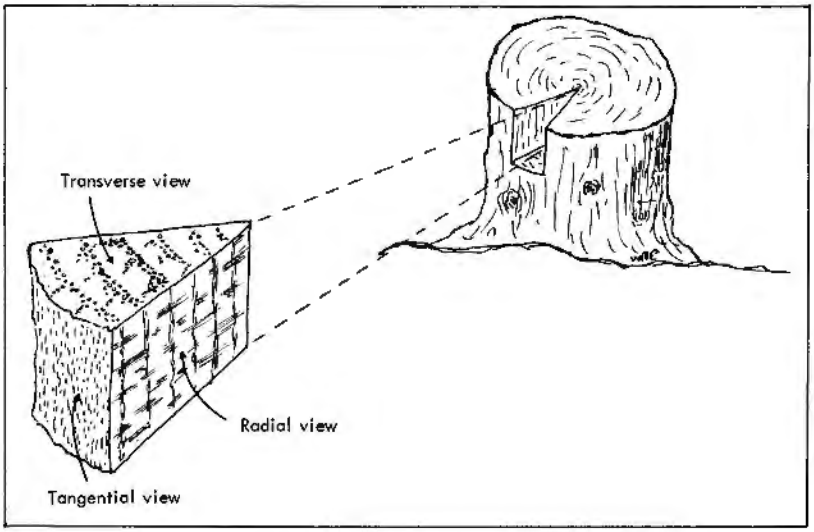

Figure 2. Sketch of tree stump and enlarged wedge of wood removed from it to show proper orientation of sections for microscopic identification.

woods. With wood from older geological periods, however, difficulty is experienced with correlation because of the greater changes in the plant structures during those millions of years.

Study of the minute structure of fossil woods from the Succor Creek area was made with polished pieces and by thin sectioning. Thin sections are made from the fossils by cutting very thin slices -- a sixteenth of an inch in thickness or less -- from properly oriented faces of the piece (figure 2). These slices are then polished on one side, fastened to a microscope slide glass, and ground on a small lap or by hand until the light passes through the material and the cell structure becomes visible through the microscope. This technique is fairly simple for the hard, opalized or agatized woods but other techniques must be employed for the soft carbonized material.

By using the hand lens and microscope, the cell structure of the woods can be studied and the characteristics listed by standard definitions and terminology set up by the International Association of Wood Anatomists. After listing the characteristics of anatomy of each of the woods, a search is made of classified characteristics of live woods to find a correlation of live to fossil. The woods are considered to be similar if most characteristics correspond and none of the most important ones disagree.

An example may be made of the wood, Prunus -- one of the types found in the Succor Creek area. The thin section of this wood was made to show the tangential, radial, and transverse views of the structure (figure 3). Upon study of the wood by microscope, the following characteristics were listed:

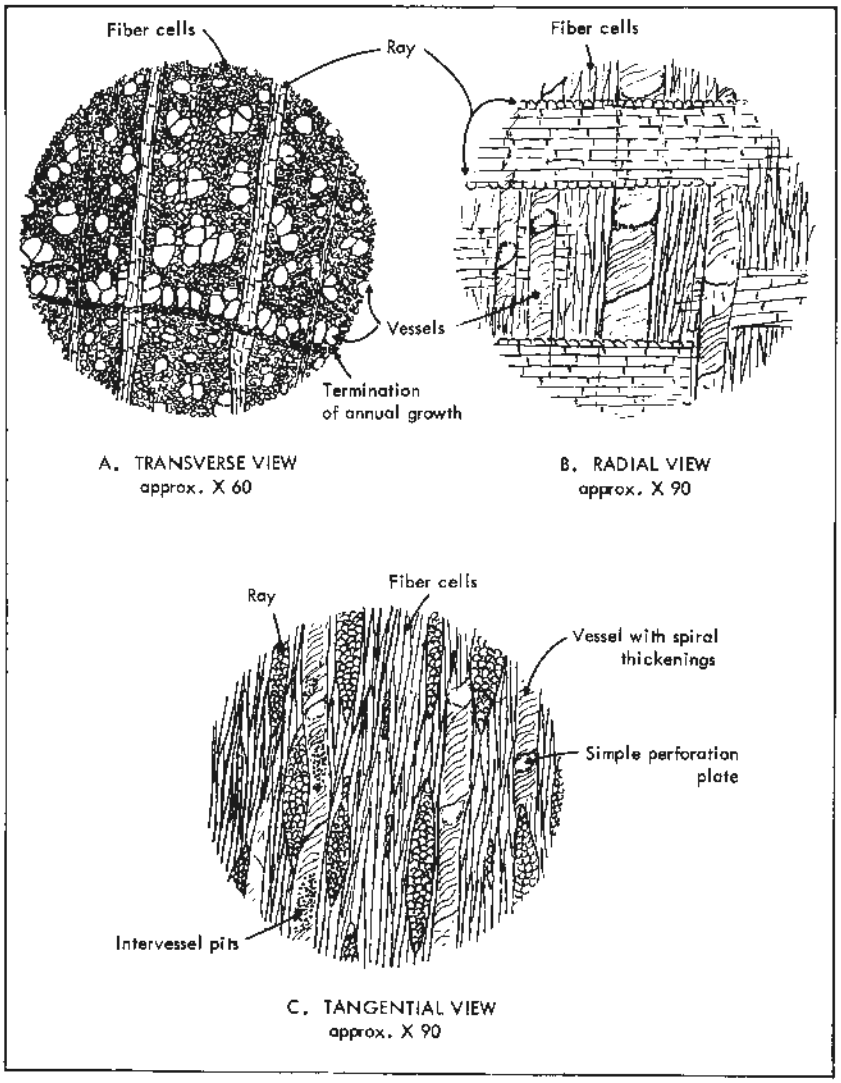

Figure 3. Microscopic structure of fossil Prunus from Succor Creek area.

Transverse view (figure 3-A)

Pore arrangement diffuse to semi-diffuse with pores small and indistinct to the naked eye. Those at the beginning of the growth season slightly larger than the late-year pores and aligned in a more or less uniseriate row, otherwise fairly evenly distributed. Growth rings are fairly distinct.

Parenchyma is not visible. Rays are plainly visible to the naked eye, are as wide as the vessels and occasionally wider. This piece of wood had traumatic resin ducts in a long, tangential string which did not show in the particular thin section.

Tangential view (figure 3-B)

Rays not storied, 2 to 4 seriate, mostly 3 seriate, homogeneous to heterogeneous type III; spiral thickening present in vessels; intervessel pits very small, crowded, orbicular; fibres not storied, not septate.

Radial view (figure 3-C)

Perforation plates simple; rays verified as to type; presence of spiral thickening in vessels verified.

A systematic check of these characteristics with the keys showed that the fossil wood agreed closely with the living Prunus, especially the North American representative of the genera. No significant differences between the fossil and live wood structures could be determined.

Summary

The writer has studied fossil woods from lake beds in the Succor Creek Formation and has added six genera of trees to the Succor Creek flora list. Previous workers based their studies on leaves, fruits, and pollen. Identification of the wood was done by examining thin sections under high magnification and comparing growth structures with those of living woods.

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The Fossil Woods near Holley in the Sweet Home Petrified Forest, Linn County, Oregon

By Irene Gregory*

Introduction

Scattered deposits of Tertiary fossil (petrified) woods are to be found throughout most of the Western Cascades adjoining the eastern side of Oregon's Willamette Valley, but those deposits making up the area known as the Sweet Home Petrified Forest in Linn County are among the most abundant and well known.

The abundance of the area's fossil wood is evident even to the casual traveler. It may be seen crushed or as fill in driveways, in fences and retaining walls, and in decorative garden work. Larger pieces -- stumps and logs -- mark driveway entrances and hold up mailboxes; barn floors have been built of it and abandoned wells filled with it. Farm people of an earlier day considered it a great nuisance -- a feeling perhaps carried over, justifiably, by today's landowners at times harried by avid rock hunters.

Of particular interest to the author is a small area near Holley which has yielded, and which still contains, much significant paleobotanical material in the form of almost perfectly preserved and exquisitely detailed silicified fossil woods with much variety as to species. This small area is on the J. J. Marker ranch (SW¼ sec. 12, T. 14 S., R. 1 W.) located 5 miles by road east of the town of Holley in Linn County, Oregon. This is the locality with which we are mainly concerned in this report (figure 1).

It has seemed appropriate to undertake a study of this fossil wood location on the Marker ranch, since it and much of the adjacent land will be flooded eventually by impoundment of the waters of the Calapooia River behind a dam at Holley. The dam, which is in the planning stage by the U.S. Corps of Engineers, would raise the waters in the reservoir to the 694-foot contour. The present elevation of the Calapooia at the dam site is about 540 feet. A preliminary map drawn up by the U.S. Engineer District, Portland, shows that our collecting area will be included within this maximum pool boundary (figure 2).

Although the main purpose of this report has been to describe the fossil woods at the Marker ranch and theorize on their origin, it seemed appropriate to add a section on wood identification. Because of the wide interest in fossil wood and the lack of published information on identifying it without the aid of a high-powered microscope

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*Mrs. J. M. Gregory is a paleobotonist and an authority on fossil wood anatomy.

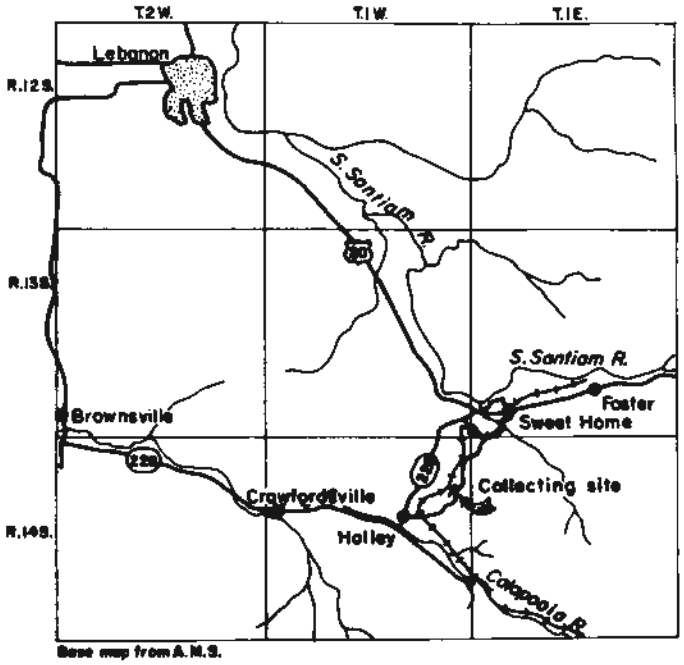

Figure 1. Index map of the Holley-Sweet Home area, showing location of the collecting site.

and technical training, it was felt that a summary of pointers on how to recognize some of the fossil woods in the Sweet Home area on the basis of gross anatomy would be useful to the amateur.

Acknowledgments

Grateful acknowledgments are extended to staff members of the Oregon Department of Geology and Mineral Industries for help and guidance in compiling this report, for geologic assistance in the field, and for photographic work. Special appreciation is expressed to Mr. and Mrs. J. J. Marker for their always pleasant cooperation and kind permission to carry on field work at their Holley ranch. Appreciation is also extended to Her Majesty's Stationary Office, London, England, for permission to reproduce 16 photomicrographs of wood anatomy from the Forest Products Research Laboratory in England.

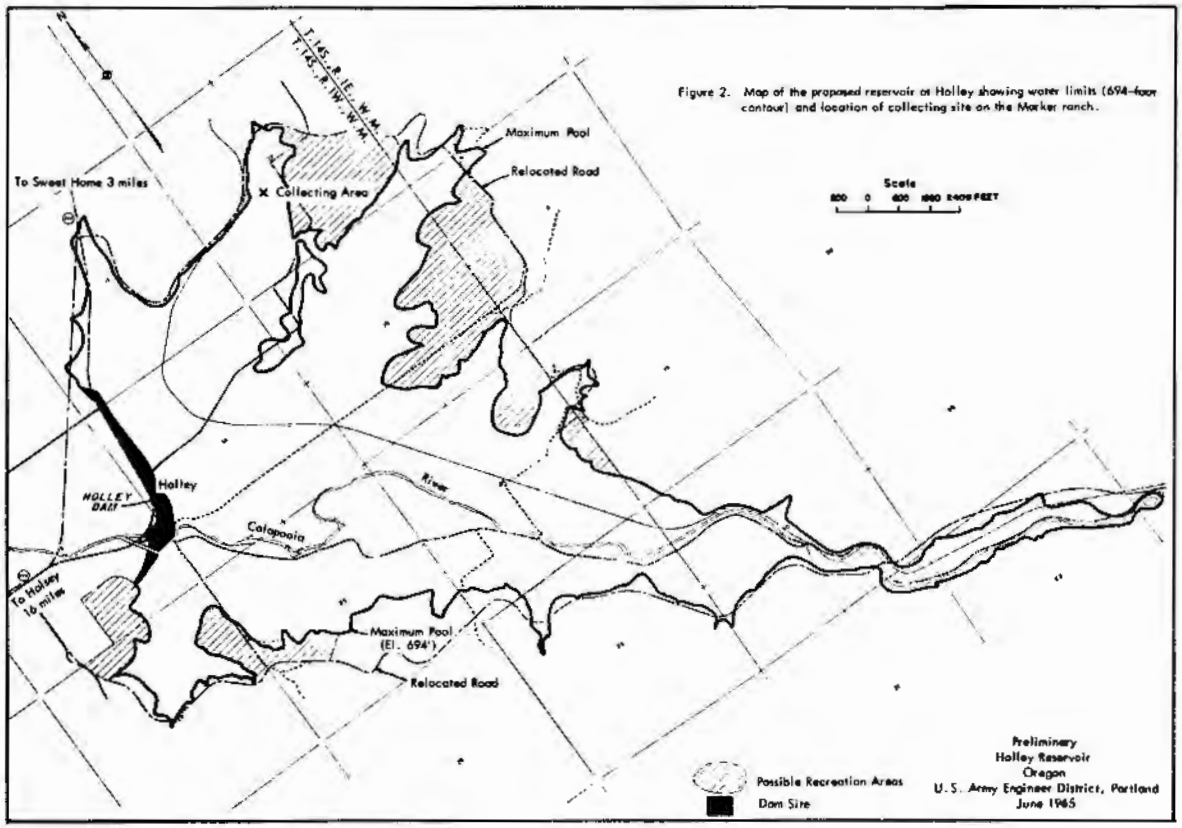

Figure 2. Map of the proposed reservoir at Holley showing water limits (694-foot contour) and location of collecting site on the Marker ranch.

Fossil Wood Studies as Applied to the Area

Published paleobotanical records of fossil wood in the Sweet Home area are scarce. Hergert and Phinney (1954) report specimens of a vessel-less angiosperm and describe and figure Trochodendroxylon beckii as the type of the new form genus Trochodendroxylon. Richardson (1950), in a master's thesis on the Sweet Home Petrified Forest, records several localities with trees petrified in situ. Beck (1944) has referred to the large number and exotic character of unidentified woods at Sweet Home and expresses himself as "completely at a loss to account for them." But in no case has the fossil wood flora, as such, been described.

Geologic Studies as Applied to the Area

The most comprehensive geologic study depicting the stratigraphy, structure, and petrology of the Western Cascade Range is by Peck and others (1964). Their work places the Sweet Home-Holley area in the Little Butte Volcanic Series of Oligocene to early Miocene age. This series of volcanic rocks, which is hundreds of feet thick and wide spread, consists of lava flows and vast amounts of tuff and ash that erupted from local volcanoes over a period of several millions of years. It is in these deposits of tuff and ash that the fossil wood is so abundant.

The plant-bearing rocks interfinger to the west in the vicinity of Brownsville with marine beds of the Eugene Formation, which contains fossil sea shells. Because similar relationships of terrestrial and marine environment occur elsewhere along the eastern margin of the Willamette Valley, geologists have been able to reconstruct the paleogeography of the region and give some idea of what the area looked like between 20 and 30 million years ago. Williams (1953) has shown that the Cascade Range as it appears today was not in existence, but, rather, the region was occupied by large volcanoes, their lower flanks clothed in luxurious vegetation. Rivers whose headwaters may have reached far back into central Oregon flowed westward to the sea.

Snavely and Wagner (1963) provide a geologic map of Oligocene-Miocene time that shows our area to have had a coastal environment located in a large marine embayment extending well into the present Willamette Valley (figure 3). Staples' (1950) discovery of salt crystals replaced by quartz in some of the fossil wood of the Holley area furthers the seacoast theory by showing that the wood was impregnated by salt from sea water before petrification.

There is evidence in the Sweet Home-Holley area to indicate that in later Miocene time the land was elevated and the sea withdrew. Lavas related to the Columbia River Basalt to the north poured out on a surface of hills and valleys that had been eroded in the older rocks. One area occupied by the basalt is at the site of the proposed Holley dam where this resistant rock already forms a natural constriction in the valley of the Calapooia River.

Description of the Collecting Site

The collecting site on the Marker ranch is situated in one of the northern fingers of the reservoir area (figure 2). The site is drained by a small stream that flows southwestward into the Calapooia River. A study of topographic maps (Sweet Home and Brownsville quadrangles) reveals that this small, intermittent creek occupies a well-defined valley (figure 4) which extends from the Calapooia near Holley to the South Santiam near Sweet Home. An explanation for its presence is suggested by Richardson,

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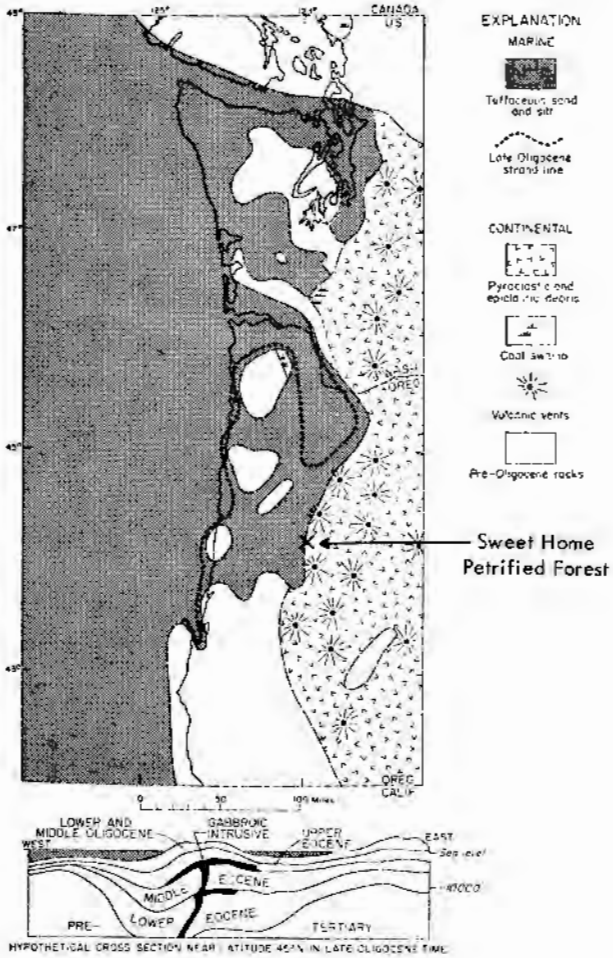


Figure 3. Paleogeologic map of western Oregon and Washington during Oligocene time (from Snavely and Wagner, 1963). Location of Sweet Home Petrified Forest area is indicated.

who indicates the possibility of either the Calapooia or the South Santiam having flowed through this gap at some time in the past.

The valley floor at the Marker ranch is underlain by a layer of closely packed pieces of fossil wood (figure 5), and it is possible that this layer extends throughout the lower portion of the reservoir area. The margins of the reservoir and the hills above it are composed of volcanic ash and tuff containing an abundance of fossil wood, some of it still standing in place as stumps (figure 6). Erosional processes that carved the valley system apparently removed the particles of ash and tuff that surrounded the wood and left the heavy silicified material behind as a lag product or residual deposit on the floor. The pieces of wood are fairly large and angular and thus have not been carried far. Presumably the trees had already been silicified and fragmented by earth pressures before accumulating as a concentration of alluvium.

The individual pieces of wood at the Marker ranch bear no relationship whatsoever to each other as to species. Theories to explain the anomalous association of varieties are offered below.

Variety of Species

Systematic list

Fifty-four different fossil woods from this small collecting area of about two acres have thus far been identified by the author (table 1). These represent only a portion of the material collected; many additional specimens remain to be thin-sectioned and identified. As a convenience, the commonly used name of each is listed first, followed by the generic name of the most similar extant species together with its family.

Possible sources of specimens

It is at once apparent that the list of identified specimens in table 1 represents members of several types of plant communities, some of which, by the durable nature of even unsilicified wood, may have been transported long distances from their place of growth.

So as a departure from usual paleobotanical form, rather than attempt to reconstruct a picture of the physical growth environment of this fossil flora by separating its component parts into ecological associations as we know them today, we shall instead speculate and theorize as to the possible origins of the species that have accumulated here:

1. Tropical woods present could well represent Eocene species -- remnants of an earlier, warmer climate adapted to the later but still moderate Oligocene seacoast environment of our area, much as palms have adapted today to the climates of England and northern Scotland. Interesting correlations may be noted here with the Goshen flora (Chaney and Sanborn, 1933).

2. Many trees were petrified *in situ*, having been covered by rapid and repeated falls of ash from erupting volcanoes located nearby and to the east. At present, remains of some stand upright in place in several Sweet Home locations (Richardson, 1950). Notable among these are the sycamores (*Platanus*), typical stream-bank, bottom-land species. Tops of stumps of a large grove of sycamore trees are visible at ground level in a valley on the McQueen property (on border of sections 7 and 18) where their bases have been covered by material eroded from the surrounding steep

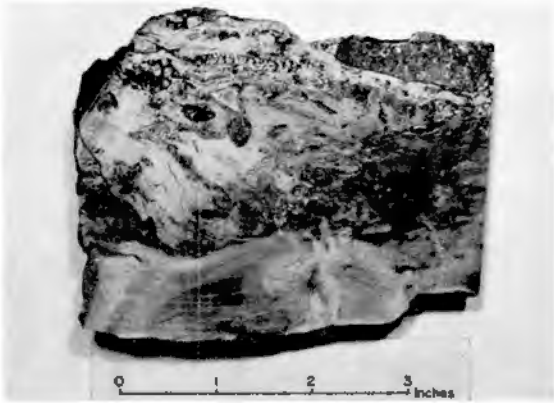
Table 1. Check List of Species Identified.

Common Name	Genus	Family	Common Name	Genus	Family
Pine	Pinus	Pinaceae	Sweetgum	Liquidambar	Hamamelidaceae
Larch	Larix	Pinaceae	Katsura	Cercidiphyllum	Cercidiphyllaceae
Fir	Abies	Pinaceae	Sycamore	Platanus	Platanaceae
Redwood	Sequoia	Taxodiaceae	Cherry	Prunus	Rosaceae
Dawn Redwood	Metasequoia	Taxodiaceae	Honey Locust	Gleditsia	Leguminosae
Incense Cedar	Libocedrus	Cupressaceae	Kentucky Coffee Tree	Gymnocladus	Leguminosae
Cypress	Cupressus	Cupressaceae	Yellowwood	Cladrastis	Leguminosae
Willow	Salix	Salicaceae	South American Cedar	Cedrela	Meliaceae
Cottonwood	Populus	Salicaceae	Entandrophragma	Entandrophragma	Meliaceae
Walnut	Juglans	Juglandaceae	Holly	Ilex	Aquafoliaceae
Hickory	Carya	Juglandaceae	Maple	Acer	Aceraceae
Birch	Betula	Betulaceae	Maple	Acer pseudoplatanus	Aceraceae
Alder	Alnus	Betulaceae	Buckeye	Aesculus	Hippocastanaceae
Bluebeech	Carpinus	Betulaceae	Cascara	Rhamnus	Rhamnaceae
Hazel	Corylus	Betulaceae	Grape	Vitis	Vitaceae
Beech	Fagus	Fagaceae	Sterculia	Sterculia	Sterculiaceae
Chestnut	Castanea	Fagaceae	Schima	Schima	Theaceae
Chinquapin	Castanopsis	Fagaceae	Tupelo	Nyssa	Nyssaceae
Sweet Indian Chestnut	Castanopsis indica	Fagaceae	Dogwood	Cornus	Cornaceae
Oak	Quercus	Fagaceae	Alniphyllum	Alniphyllum	Styracaceae
Elm	Ulmus	Ulmaceae	Persimmon	Diospyros	Ebenaceae
Magnolia	Magnolia	Magnoliaceae	Ash	Fraxinus	Oleaceae
Myrtlewood	Umbellularia	Lauraceae	Devilwood	Osmanthus	Oleaceae
Camphorwood	Cinnamomum	Lauraceae	Cordia	Cordia	Boraginaceae
Sassafrass	Sassafrass	Lauraceae	Reptonia	Reptonia	Myrsinaceae
Trochodendron	Trochodendron	Trochodendronaceae	Catalpa	Catalpa	Bignonaceae
Actinidia	Actinidia	Actinidiaceae	Virburnum	Viburnum	Caprifoliaceae

Figure 4. View looking southeast across valley at Marker ranch. Small body of water is a stockpond.

Figure 5. Layer of fossil wood exposed in bed of creek on the Marker ranch.

Figure 7. Fossilized tree bark that had been riddled by boring insects before petrification. Enlargement (below) of upper left portion shows insect tunnel filled with silicified eggs.



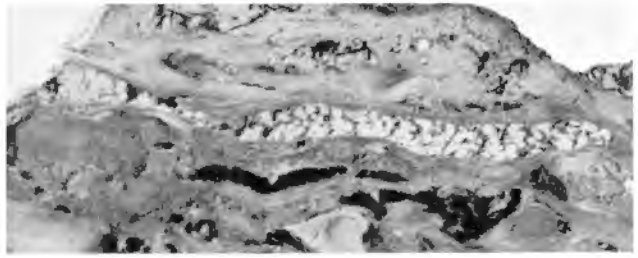


Figure 6. Fossilized stump of a hardwood tree standing where it grew 30 million years ago.

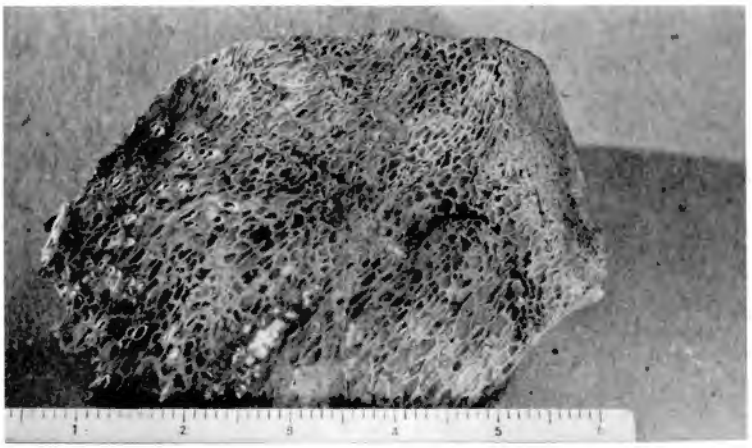


Figure 8. Pocket rot cavities in incense cedar, commonly mistaken for palm wood.

Figure 9. Quartz pseudomorphs after halite crystals in wood that was impregnated by salt water before petrification.

PLATE I.

(Furnished by Forest Products Research Laboratory, London, England.)

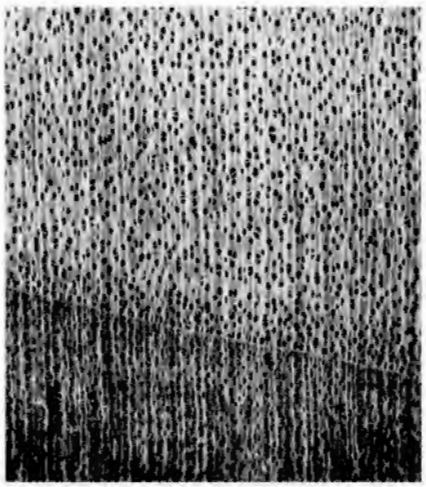


Figure a: Salix
Willow

Figure b: Carpinus
Hornbeam

(All photographs 10 x)

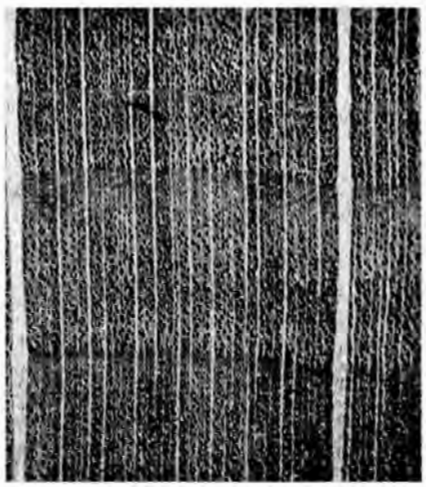


Figure c: Fagus
Beech

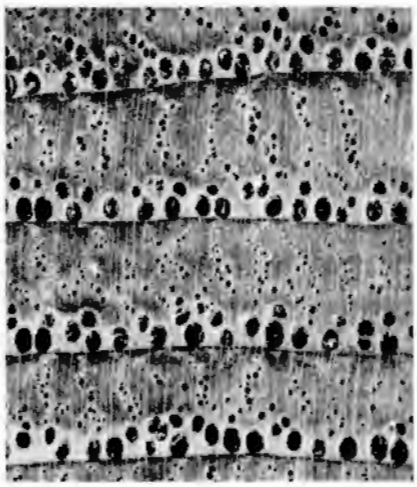


Figure d: Castanea
Chestnut

PLATE II.

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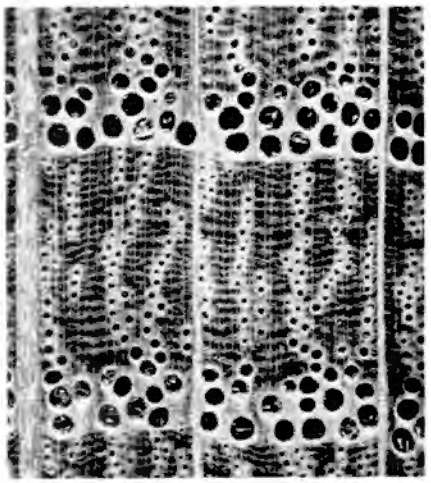

Figure e: Quercus
Oak

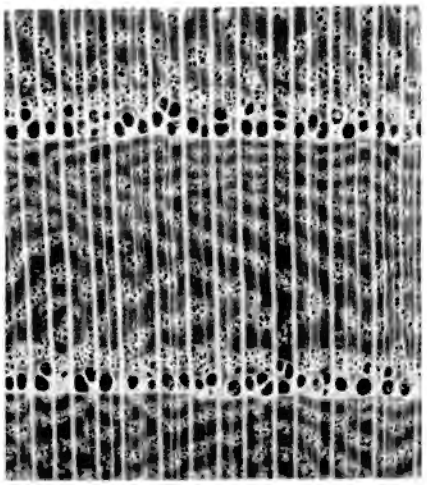

Figure f: Ulmus
Elm

(All photographs 10 x)

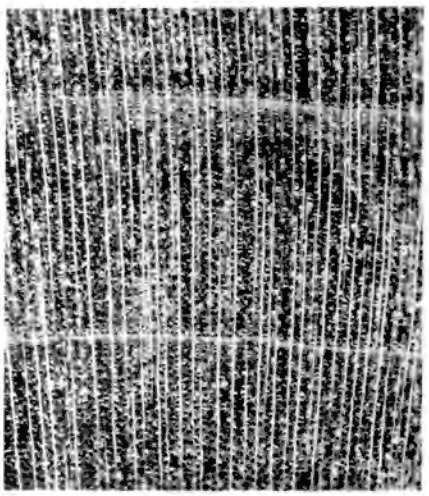

Figure g: Magnolia
Magnolia

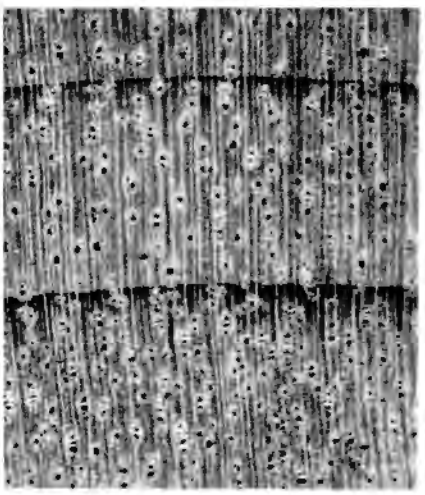

Figure h: Umbellularia
Myrtlewood

PLATE III.

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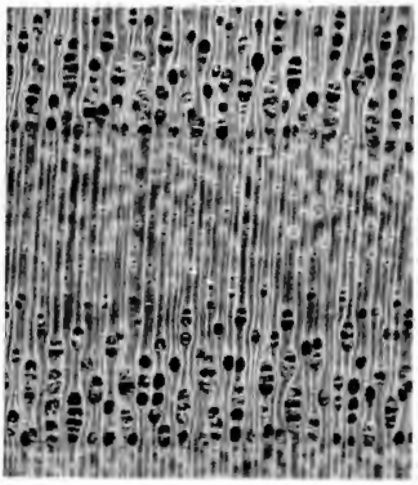

Figure i: Sassafrass
Sassafrass

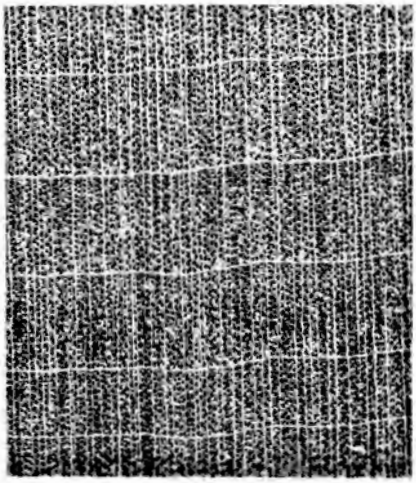

Figure j: Cercidiphyllum
Katsura

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Figure k: Platanus
Sycamore

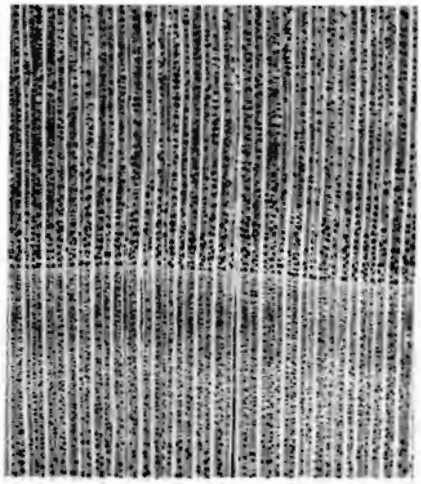

Figure l: Prunus
Cherry

PLATE IV.

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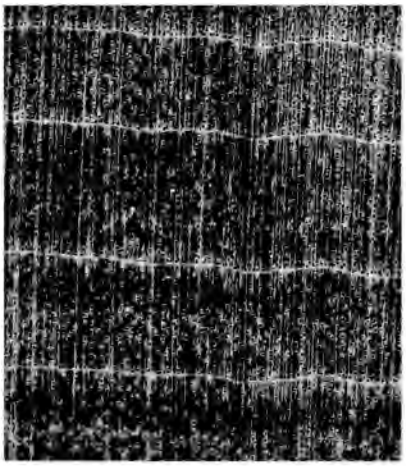

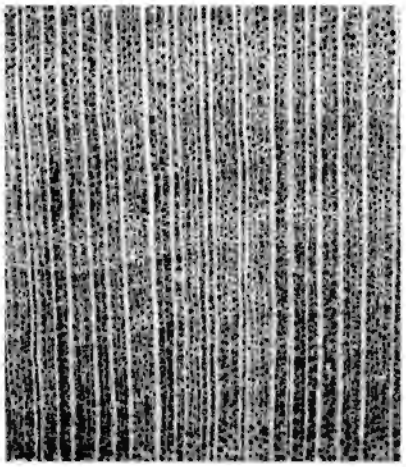

Figure m: Aesculus
Buckeye

Figure n: Cornus
Dogwood

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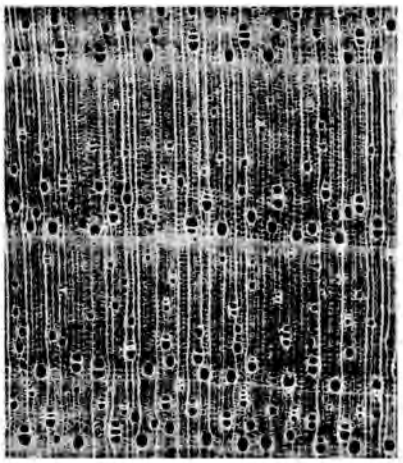

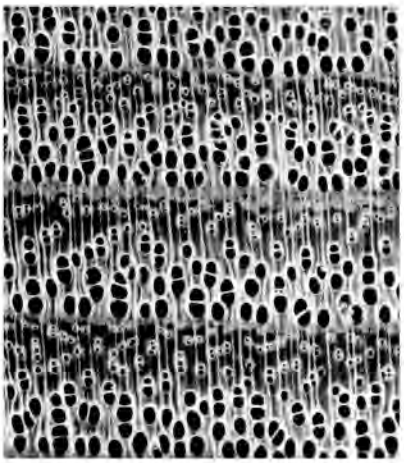

Figure o: Diospyros
Persimmon

Figure p: Fraxinus
Ash

hillsides.

3. Westward-flowing streams, carrying quantities of pyroclastic debris originating from volcanoes to the east, constructed large deltas where they reached the coast. Specimens of fossil wood which show considerable transportation wear might well represent live-woods of the time carried by flooded streams from the interior and deposited as a part of such deltas. Fossil woods of earlier Eocene time, transported and buried in a similar manner, could be present in Oligocene rocks in much the same way that the Cretaceous fern, Tempskya, is found in later Eocene Clarno deposits in in the Greenhorn Mountains of northeastern Oregon. Here the fossilized wood was eroded from the enclosing rocks and redeposited in younger sediments.

4. Asiatic species reported to occur only rarely in Tertiary fossil woods could have arrived as random logs of driftwood by way of the sea. An example of this is Actinidia, not previously reported as a fossil wood and found at Holley thus far as a single specimen consisting of an almost complete trunk section. Logs transported as driftwood from offshore islands of the time (or from unlimited distances in the Eastern Hemisphere) and carried into the marine embayment may have been entrapped in coastal swamps and petrified after burial in stream sediments or falls of ash. Another wood -- the Asiatic genus Schima of the tea family (Theaceae) -- might have had such a source. The absence of branches and twigs and the preponderance of woods representing trees rather than shrubs help give credence to the idea that at least some of the material arrived at the locality as stripped-down, water-worn tree trunks.

5. Many of the specimens collected have inclusions of quartz pseudomorphs after halite crystals. We have found thus far, as did Staples (1950), that the inclusions were contained only in the fossil woods found as float and not in those petrified in place in the area. A collected specimen of Castanopsis indica, or Indian sweet chestnut (Asiatic), whose structure shows it to be a portion of a large tree trunk, is almost completely replaced with quartz pseudomorphs after halite. The distribution of the halite indicates that the solution had access from all sides as in floating and might have been absorbed during a long period at sea.

Preservation of Detail

The process of petrification still remains somewhat of a mystery and scientists are not in agreement as to what actually takes place. A number of mineral substances can cause petrification, but the most common is silica. Silica in ground water infiltrates the buried wood and by some complex chemical process is precipitated within the plant tissues. Cellulose and lignin are often still present in the silicified wood.

Whatever the particular process involved in the petrification of the highly silicified wood at Holley, it has resulted in the preservation of its finest anatomical details to such a degree that in many instances it comes close to being identical with its living counterpart of today. Furthermore, many of the specimens show little, if any, distortion in either shape or size of the structures required for identification. This is of much importance in wood recognition where comparative size of an anatomical feature -- ray width for example -- could be the critical factor in deciding to which genus that specimen should be assigned.

Indeed, so accurate is the preservation that wormholes with castings, insect eggs, grub holes, pitch pockets, dry rot, fungus growths, growth abnormalities of all kinds, plus all manner of the ills and defects that trees may fall heir to, are faithfully reproduced (figure 7). Also preserved are inclusions of gums, crystals, and other foreign substances sometimes found in the cells of living woods. These can be of value

in differentiating one species from another. Honey locust (Gleditsia), for example, has deposits of gum in its vessels, while the wood of the closely related and similar-appearing Kentucky coffee tree (Gymnocladus) does not.

An interesting side light here is the proper identification of so-called "palm-wood" specimens, many of which have been collected in the Sweet Home-Holley area. Figure 8 shows a piece of incense cedar (Libocedrus) riddled with pocket-rot cavities caused by a fungus (possibly Polyporus, which causes such rot in this species of wood today). The empty cavities were subsequently filled with clear silica during petrification. A cut made at an angle across the tube-shaped cavities produces the same "eye" effect that palm wood's vascular bundles do when cut. Examination with a 10x lens will show the "eyes" to be the empty pocket rot cavities, whereas true palm "eyes" will be filled with material having well-defined organized cell structure.

Rarity and Uniqueness

The fossil woods at the collecting site include a number of types seldom reported elsewhere. Among these are the Trochodendron, a vessel-less hardwood of great interest to wood anatomists because of its unique and primitive structure (Hergert and Phinney, 1954). Other rare woods present are Reptonia, Sterculia, Schima, and Actinidia, none of which grow in North America today but which are found as live woods in Asiatic countries. Their presence in the Marker ranch assemblage suggests the probable occurrence of other exotic species among specimens collected by the author but not yet identified.

Among the interesting woods that no longer grow natively in this region are Cinnamomum, the genuine camphorwood of the Orient, and Cedrela, the cigar-box wood of South America.

Adding to the value of the study area is the presence of the quartz pseudomorphs after halite in some of the fossil woods, as described by Staples (1950). This mineralogical oddity is considered to be unique to the Holley area, since no other such occurrence has been reported in the literature.

Conclusions Regarding the Collecting Site

While the original sources of our specimens may remain uncertain, we can be sure that 1) the abundance of fossil wood, 2) the variety of species present, 3) the faithful preservation of minute anatomical details, and 4) the rarity and uniqueness of some have made this collecting area a valued paleobotanical study and research area.

Wood Identification Based on Gross Anatomy

While it must be strongly emphasized that the positive identification of fossil woods (based on thin-sectioning and a microscopic study of their minute anatomy) lies entirely in the realm of the specialist (Eubanks, 1960), the serious hobbyist can achieve much enjoyment and personal satisfaction in tentatively identifying his material on the basis of its gross anatomy with the aid of a 10x hand lens.

In the Tertiary fossil woods of the Pacific Northwest there are many species that had advanced to such a degree that they very closely resemble their living counterparts of today; persons familiar with wood-grain patterns may readily recognize a common live-wood, such as oak, in their fossil materials. In this regard it is helpful

to bear in mind that any live-wood "know-how" is quite readily transferable to the fossil material, excepting, of course, the diagnostic qualities of odor, taste, feel, weight, and color. Color in fossil woods derives entirely from minerals present in the host rock during petrification and in no way relates to the species of the wood.

Preparation of specimens

In this more elementary identification process observations and comparisons are made mainly on the transverse (across the grain) view of the wood -- that is, the cut made in sawing off a log for firewood. To compare a fossil wood with a known live-wood, both must be oriented so that a transverse view can be cut (or found, as can often be done with a piece of fossil wood collected in the field). The living wood cells will have been crushed in sawing and will appear "fuzzy" at 10X. To get a clear picutre of the pore and ray pattern, an old-fashioned straight-edged razor which has been well sharpened or an "Exacto-type" woodcarving knife should be used to shave off carefully a thin, even horizontal layer on just a small area of the cut surface of the wood. A half-inch square will generally be ample. This surface should then provide a clear, uncrushed view of the wood cells. Avoid a sloping cut into the wood, which will give a distorted, untrue wood-grain pattern. Moistening the cut surface will sharpen the details in some live-woods, but will blur others. Both methods should be tried.

The fossil wood, cut by rock saw (or as found), can be studied more easily if it is sprayed lightly with any of the transparent plastic finishes available today. Even hair-spray will suffice. Often a well-preserved petrified wood specimen will have a weathered or naturally bleached outer surface that will give a much clearer picture of its structure than will the inner cut surface. For this reason it is well to work with a "heel" of material, where both cut and natural surfaces are available for viewing.

Comparing specimens

The wood specimens should be held so that a good light falls on the cut surface. Hold the lens close to the eye and gradually bring the cut surface up toward the lens until the cell structure is clear and in focus. At this point the fossil wood must be examined painstakingly over its whole surface to find the area where the vessel (hole) and ray (line) pattern is clearest and appears "normal" as compared to live-woods. A pitfall to watch here is that during petrification sometimes either vessels or rays or both may have faded out or have become extremely distorted as to size. This can lead to much confusion on the part of the novice and expert alike, and points up the necessity for painstaking examination to locate what seems to be the most "true-to-life" appearing section of the specimen.

The same kind of comparison with a specimen of correctly identified fossil wood is another way to track down the kind of wood involved.

Use of Photomicrographs in Wood Identification

Perhaps the most valuable tools in wood identification are photomicrographs of the anatomy of selected wood specimens chosen because they so well typify that particular species. However, such material is generally not available in any significant quantity. Thus, we are fortunate in having obtained permission to reproduce a series of such photomicrographs from Bulletin 26, "An Atlas of End-grain Photomicrographs

for the Identification of Hardwoods" prepared by Forest Products Research Laboratory, England (plates 1 through 4). The species illustrated represent familiar live-woods of today which have been found as fossil woods at the Holley collecting area and in other Pacific Northwest Tertiary petrified wood deposits.

Close examination of petrified specimens might well disclose the presence of any of these woods in individual collections. A similar cut of the same species of live-wood, if available, prepared for viewing as described above and combined with its matching photomicrograph will provide an invaluable basis for identifying a similar fossil specimen.

Features to observe

In such a comparison based on gross anatomy, the aim is to learn to recognize over-all grain patterns. The 10-power lens mentioned is most suitable for this, since a higher power will enlarge and blur the condensed design or pattern we wish to recognize.

The patterns are based on varied arrangements of pores or vessels (which appear as holes) and rays (lines of cells running like a radius from the bark toward the center of the tree).

Growth rings

Most woods show concentric circles on cross-section. These rings indicate annual growth, and are distinct in woods where the cell size varies greatly at different times of the year. Early spring wood will have large, fast-growing cells; later, slow-growing summer wood cells are small and dense. In tropical climates woods do not usually show distinct annual rings, since growth rate is constant throughout the year and each year's growth merges into the next with little perceptible change in cell size. This is an interesting feature to watch for in fossil woods.

Porous and nonporous woods

Other points to notice are the difference between woods with no pores (nonporous), which includes most coniferous or "needle-trees," which are also called "softwoods," and woods with pores (porous), which generally include the "hardwoods."

The porous woods or hardwoods can be further divided into ring-porous woods in which the larger spring pores form a well-defined band at the annual growth ring, as sassafras and ash, and diffuse-porous woods, in which the pores are distributed evenly throughout the growth ring, as magnolia and katsura.

Pore arrangements

Also significant are pore arrangements. They may be grouped in many ways -- in clusters, in groups of two or three, in straight or radial chains (chestnut), in slanting chains called echelons and in many other ways. In conifers scattered resin canals may sometimes occur. On cross section these appear to be extra large "pores," but are actually canals running vertically along the grain.

Rays

Rays appear as straight lines on the transverse surface, varying in width from heavy (oak) to too fine to be seen with the naked eye. Comparative width of rays is often a diagnostic feature. Sycamore, with broad rays of generally uniform width, can thus be differentiated from beech, whose broad rays are fewer and separated by groups of distinctly narrower width.

Parenchyma

Soft tissues (parenchyma cells) are short, thin-walled cells not usually distinguishable individually with a hand lens. But collectively they form innumerable varied patterns that are useful in identifying woods. Persimmon is characterized by a fine, net-like or reticulate parenchyma pattern. Myrtlewood can be verified by its typical "halos" formed by parenchyma cells that encircle each pore. Straight and wavy bands of varying widths running crosswise to the rays frequently occur. Terminal parenchyma at the annual growth ring is a feature of other woods, such as magnolia, where it appears as a light line easily visible to the naked eye. Many other types and combinations of types occur.

Forestry and botany texts will provide detailed information and references on wood anatomy, nomenclature, and classification of plants that may be applied to fossil wood. Paleobotanical texts such as "Ancient Plants and the World They Lived In" (Andrews, 1964) often carry sections with brief botanical summaries expressly written to provide the necessary basic information needed for venturing into the field of fossil plant life.

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FOSSILIZED PALM WOOD IN OREGON

By Irene Gregory*

Introduction

To geologists, petrified palm wood is a significant material. Its occurrence in the fossil record serves as an indicator of past climates and age of the rocks. To hobbyists, its attractive patterns and ease of identification make it a sought-after species. Since its anatomy is one of the least complicated of fossil plant materials, it is easily recognized; its unique appearance makes it difficult to mistake it for any other species, with the possible exception of certain fossil ferns.

This report is concerned primarily with fossil palm wood; however, since leaves and fruits are also important in the fossil record these parts of the palm are reviewed. In addition, the geologic history of palms and their occurrence as fossils in Oregon is summarized.

Identification of Palm Wood

Paleobotanists in the past have generally assigned petrified palm trunks to Palmoxylon, a genus name designed to include fossil stems with scattered bundles having fibrous caps. Fossilized palm leaves can often be referred to living genera, and there is a trend to apply these names to fossil palm wood also, where warranted. The writer is following the procedure of applying names of living genera to fossil specimens that are sufficiently well preserved to reveal identifiable anatomical structures.

A type of palm present in an assemblage of semi-tropical Eocene woods being investigated by the author is palmetto (Sabal), collected from a small outcropping of the Clarno Formation in Crook County, Oregon. Material for thin sections of the transverse (figure 1 A & B) and longitudinal (figure 2 A & B) views shown was taken from a trunk specimen that was

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*Mrs. J. M. Gregory is a paleobotanist and an authority on fossil wood anatomy.

Figure 1-A

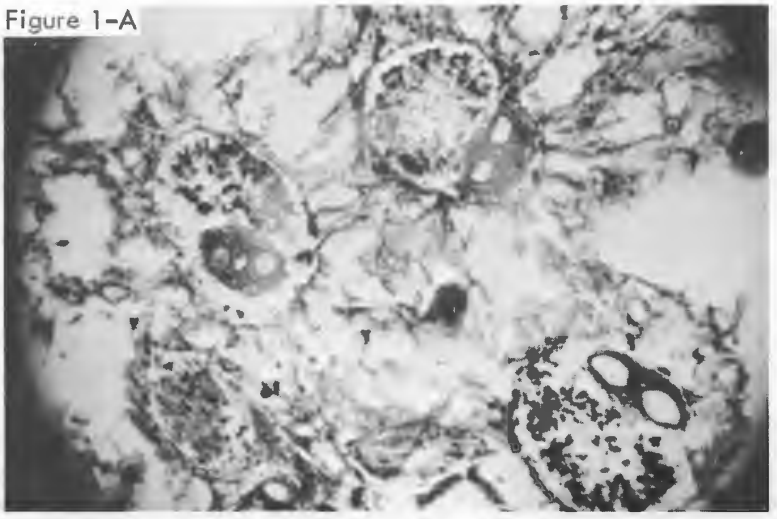
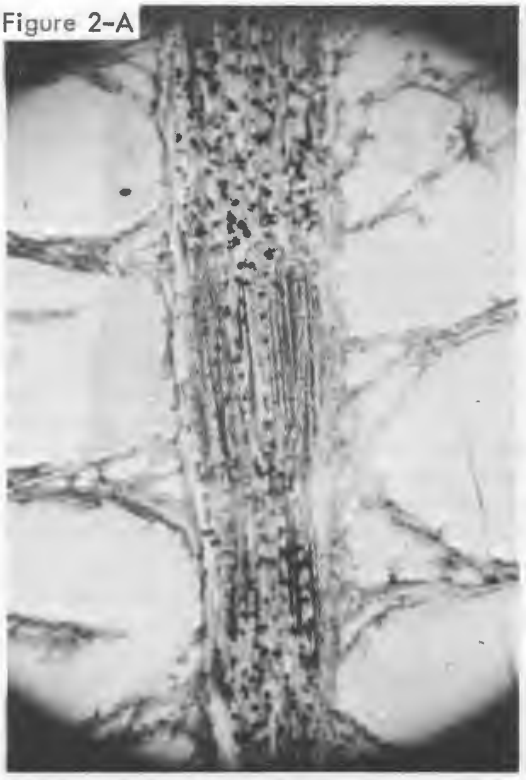


Figure 2-A



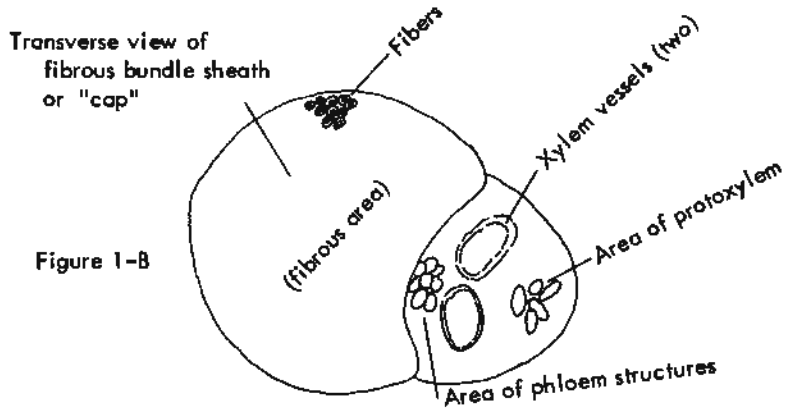


Figure 1-B

Figure 1. Transverse views of Eocene palm wood from Crook County.

A. (opposite page) Photomicrograph 45 X.

B. (above) Sketch showing detail of fibrovasculor bundle in upper right portion of figure 1-A. Compression of wood before petrification produced ovol shape of xylem vessels, which normally are circular.

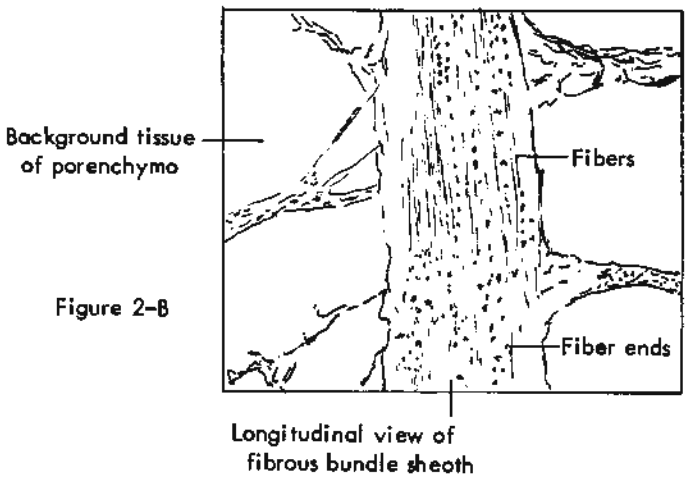


Figure 2-B

Figure 2. Longitudinal views of Eocene palm wood from Crook County.

A. (opposite page) Photomicrograph 45 X.

B. (above) Sketch showing detail of longitudinal view.

approximately 6 inches in diameter during growth, but was compressed to an oval shape by earth pressures before petrification took place. The specimen is silicified, its vascular bundles replaced with blue agate. The remainder appears black, owing to the presence of manganese, but in thin section it is a clear amber color. The unworn condition of this specimen, as well as that of other warm-climate species occurring with it, indicates the probability of its having been petrified in situ. The photomicrographs shown here are thought to be the first published record of the minute anatomy of the wood of a fossil palm from Oregon.

All of the genera, both living and fossil, making up the palm family exhibit similar anatomical structures. Their wood consists of separate fibrovascular bundles scattered in a pith-like background tissue of parenchyma cells. In cross section the parenchyma cells appear thin walled and somewhat hexagonal in shape, and fill all the spaces between the very conspicuous bundles which have prominent fibrous caps (bundle sheaths) (figure 1 A & B). The bundles run longitudinally in the stem and on out into the leaves; in cross section they show as dots or eyes and when cut lengthwise appear to be tubes (figure 2 A & B). The two (possibly three) larger pores in each bundle are xylem vessels; the area between the xylem and the fibrous cap may show phloem structures.

Although the characteristic anatomy of palm results in a distinctive appearance, on casual examination it may be confused with cross-section views of petioles of the fossil fern Acrostichum or portions of Tempskya fern masses in which cut leaf-traces resemble palm eyes.

General Botanical Background of Palms

Palms are considered to be the first angiosperms (flowering plants of today) to appear in the fossil record. Angiosperms include two groups:

1) Dicotyledons - having complicated net-like veining of leaves and producing two leaves (cotyledons) when their seed germinates; they make up most of our flowering plant species of today.

2) Monocotyledons - with but one seed-leaf (cotyledon) and parallel leaf-veining as in grasses, lilies, and palms; they provide the remaining small percentage of angiosperms.

In the fossil plant record, palms are significant as being one of the few monocotyledons to be preserved. Their durable woody nature lends itself to petrification, which is not so with the many other more herb-like plants of this group. Check lists of fossil plants invariably include but few monocotyledons.

Environment

Most palms require a minimum temperature of 42°F. and higher; only a few can adapt to a slight amount of frost. Of the several hundred recognized genera living today, nearly all are inhabitants of the tropics. The few representatives living in the United States are native only to the southern climates. Palmettos grow along the Atlantic Coast from North Carolina to Florida. Other types are limited to the Florida Keys, the area near the mouth of the Rio Grande in Texas, and to southern Arizona, California, and Hawaii. About 2000 species of palms are known today, of which 25 belong to the genus Sabal.

In the fossil record, the association of palm with other tropical species of plants shows that palms of the past had the same temperature needs as exist today, making their presence as fossils conclusive evidence of warm climate. Many of the floras containing palm leaves are associated with coal beds, signifying a swampy environment.

Stems (trunks)

Living palms can be separated into genera by cross-section views of their wood, which show different appearances based on the comparative number, size, and distribution of the fibrovascular bundles or "eyes." For example, Serenoa bundles are thin and widely but uniformly scattered through the whole wood; Thrinax has coarser, fewer and closer bundles; Cocos bundles are very numerous near the edge of a cross section and few in the center.

Palms have woody stems of varied habits, but most are well-proportioned trees remarkable for their uniformly cylindrical, typically unbranched shapes. The trunk is generally thickened near its base and is well anchored by a mass of simple, also unbranched, but contorted roots. The number of roots emerging from a coconut palm can be as many as 13,000. The fossil plant material known as "palm root" when cut shows wildly irregular oblong and circular shapes, each of which includes the typical stem structure and distribution of bundles as described above.

Since they lack a continuous cambial layer, palms are incapable of growth in thickness by adding new layers of cells as do our familiar timber trees. Thus no annual growth rings are formed. With no tree rings to count, age usually has to be based on associated historical data.

The girth of a palm is determined during its earliest years, the one main growing point being the terminal bud. Some tree types grow as much as 150 feet high. The diameter of palm stems may range from less than half an inch to two feet or more. Since palm trunks usually do not branch, the rock hunter's so-called "limb" sections of fossil palm probably represent the main stem or trunk of that individual plant. In some fossil species these may be so small as to appear reed-like, as in Reinharditia of Central

Figure 3. Fossilized trunk fragments of the rattan-type palm from the Eocene Green River Formation, Eden Valley, Wyoming. Approximately 3/4 natural size.

Figure 4. Portion of a fossil palm leaf (Sabalites eocenica) from Clarno-age rocks in northeastern Oregon, approximately ½ natural size. (From Hergert, 1961)

America today.

Other types of palm stems that might be found as fossils include the rattans, climbers of today in India and the East Indies living in semi-tropical environments similar to that of the Eocene in Oregon. The two main living genera of this type are Calamus and Daemonarops, which have slender, bamboo-like stems of uniform diameter with very long internodes. Their leaf rachis (leaf stalk) is prolonged into a spiny, hook-like tendril that enables them to climb over the tallest surrounding vegetation; their stems may grow as long as 500 to 600 feet, making them the lengthiest stem on earth, with the possible exception of seaweed. They produce the commercial rattan used for cane-chair matting, bentwood furniture, and the like. The familiar rockhunter's material, "cane," from the Eocene Green River Formation in Eden Valley, Wyoming, is a fossil representative of this type of palm stem (figure 3). Specimens are found with internodes as much as 10 or 12 inches in length and showing trunk rings (leaf-base scars).

Additional stem variations that could occur as fossils include the prostrate or creeping stems of certain palmettos (Sabal) which are surrounded by a dense mass of contorted roots. Other examples are the horizontal stem of Nipa, a genus confined to southeastern Asia today, and the short vegetative shoots of Bactris and Raphis which form bushy or shrub-like clumps.

A characteristic feature of most living palm stems is the leaf bases. If the leaf bases fall off, distinctive scars remain on the trunk, but if they remain attached to the trunk, the strong lower part of the leaf stalk often forms a clasping fibrous webbing that hangs in a ragged mass around the trunk. This mass can make a thick, dense mat several feet long. Some fragments of fossil palm show only this fibrous trunk cover.

Leaves

At an early stage, the single-leaf seedlings of most palm genera look much alike; as fossils, all can be easily confused with grasses. The mature leaf forms are distinctive, although those of cycads and some tree-ferns have a superficial resemblance. The leaves, in general, are borne as a crown at the tip of the trunk. Types of palm leaves include the fan-shaped leaves of palmetto; a simple pinnate or feathery form as in the coco palm; or a bi-pinnate as in fish-tail palms whose leaflets are attached to lateral branches of the main leaf rachis.

Most fossil-palm records refer to fan-shaped leaves; reports of pinnate-type leaves are rare in the literature. Fan-shaped palm leaves have been found at several localities in the Eocene of Oregon (figure 4), and silicified petioles or leaf stalks have also been collected.

Fruit and seeds

The fruit of palms, borne in clusters, is a drupe or berry and usually

one seeded; seldom do 2 or 3 seeds occur. Sizes range from that of a currant to the double coconut weighing 40 or more pounds - the largest seed known. A great number of variations in the basic form occur. The fleshy part may be almost lacking or may be pulpy or oily; the pit layer may be hard and dense as in coconut or thin as in palmetto. Many palms continue flowering and fruiting throughout the year. The coconut is thought of as the typical palm seed or nut, but more typical are small seeds - some less than half an inch in diameter - that are produced in huge clusters by many species.

Figure 5. Two views of a small fossil seed of the coconut-type palm. Seed is 1 inch in diameter (photograph courtesy of T. J. Bones).

Figure 6. Two views of a tiny fossil palm seed 8 mm in diameter. Seeds were probably borne in clusters (photograph courtesy of T. J. Bones).

Fossil palm seeds are in general referred to the genus Palmocarpon. The durability of some palm seeds makes possible their remaining in excellent condition while traveling vast distances by ocean current, resulting in some confusion as to the validity of certain fossil-palm records at ancient coastal locations. Reports of Oregon palm-seed occurrences have been confined mainly to the Clarno area of central Oregon (figure 5, cocanut type; figure 6, small seed).

Geologic History of Palms

The geologic history of palms goes far back into the fossil record, where they are considered to be the first of the angiosperms (flowering plants) to develop. Records of occurrences are numerous, with the earliest now tentatively considered to be the almost completely preserved palm-like leaves reported from the Middle to Upper Triassic of Colorado by Roland W. Brown (1956), who suggested they should be regarded "tentatively but credibly" as a primitive palm. The simple elliptic leaves of Sanmiguelia lewisi were borne alternately on a rapidly tapering stem. They were collected from red calcareous sandstone of the Dolores Formation near Placerville, Colo., in the vicinity of the San Miguel River, and constitute one of the more important paleobotanical discoveries of our time.

LaMotte (1952) cataloged a great many references to fossil palm throughout the world, including the earliest definite palm-wood record, Palmoxylon cliffwoodensis from the Upper Cretaceous Magothy Formation of New Jersey. Palm leaves occur in the Lower Cretaceous Dakota Group of the Rocky Mountains region, and in the Upper Cretaceous Nanaimo Group on Vancouver Island, British Columbia.

Records of palm from the Eocene are numerous. The famous Eocene London Clay flora in England contains an abundance of fossil fruits of Nipa, a tropical Asiatic palm of today (Reid and Chandler, 1933). In North America, palms are best displayed in Eocene rocks (Arnold, 1947). One particularly outstanding account is that by Knowlton (1930), who lists 14 forms from the Denver Basin, 8 based on leaves, 5 on fruits, and 1 on a silicified trunk. He reports huge leaves as large as 5 feet in diameter. Of the genera described, Sabal was the most abundant and widely distributed.

Among other notable North American Eocene floras containing palm are the Wilcox and Claiborne floras of the Gulf Coast areas (Berry, 1916 and 1924); the Raton flora of northern New Mexico and southern Colorado (Knowlton, 1918); the Jackson flora of Texas; the Eden Valley flora of Wyoming (Brown, 1934); the Puget flora of Washington and British Columbia; the LaPorte flora of California (Patbury, 1935); and the Clarno flora of Oregon.

Fossil palms, associated with other warm-climate plants, are found at the Alaskan leaf localities of Kupreanof Island and Matanuska Valley (Hollick, 1936). The flora is considered by Wolfe and others (1966) to be

Oligocene in age. Present here are two fossil-palm species, Flabellaria florissanti and Flabellaria alaskana, that are referable to the fan palms of the Arecaceae, a group that is today strictly subtropical and tropical and that bears out the suggested subtropical Oligocene climate of coastal Alaska.

Miocene palm occurrences noted by Arnold (1947) include that of the Tehachapi flora of the western Mojave Desert (Horse Canyon, Kern County, Cal.) and the Barstow beds (Mule Canyon, Yermo, Cal.). Axelrod (1950) describes Pliocene age palms from Palmdale, Cal.

The geologic history of palms in Oregon parallels that shown elsewhere in North America. Their first appearance during the Cretaceous was followed by relative abundance during the Eocene; Oligocene records are limited to palms in relict warm-climate floras of the coastal region. No fossil palms have been reported, as yet, from post-Oligocene rocks in Oregon. Miocene and Pliocene floras reflect a cooling trend in the climate. Some paleobotanists believe there was a gradual migration of palms southward during the Miocene and Pliocene toward their present association with tropical and subtropical floras of today in extreme southern United States, Mexico, and Central America.

Fossil Palm Record in Oregon

Cretaceous

The fossil record shows palms to have first occurred in Oregon during the Cretaceous. In 1958, a nut, together with an ammonite included in a concretion, was found near Mitchell, Wheeler County, and was identified as a palm seed of the genus Attalea from the Albian stage of the Cretaceous by the late Roland W. Brown, U.S. National Museum (see also Berry, 1929). This occurrence is noteworthy as being considered the earliest flowering-plant record (late Lower Cretaceous) of north-central Oregon. The specimen was kept in the U.S. National Museum (letter from E. M. Baldwin, October 24, 1958 to Lan Hancock; courtesy of Viola L. Oberson).

Eocene

Arbuckle Mountain area: The first Eocene palm record for Oregon was that of Mendenhall (1907) reporting on a coal prospect on Willow Creek, Morrow County. This location was about 22 miles southeast of Heppner in a mountainous region just west of the divide (Arbuckle Mountain) between the Willow Creek and the John Day River drainages. Monocotyledonous leaves were collected and sent to F. H. Knowlton who regarded them, on the basis of additional species collected, as being Eocene in age.

Chaney (1948) in "Ancient Forests of Oregon" pictures layers of fan-type palm-leaf fossils from the Arbuckle Mountain shales. Hogenson (1957), in an open-file report on the ground-water resources of the Umatilla River

basin, recounts the collecting of fossil leaves in the Arbuckle Mountain area from shales containing carbonaceous material altered to lignite or bituminous coal. He states: "Plant fossils from several carbonaceous seams were studied by Roland W. Brown of the U.S. Geological Survey. He determined the Eocene age of the formation from these fossil plant identifications." Listed were Sabalites and other warm-climate trees including Magnolia.

Pigg (1961), in a University of Oregon master's thesis, reviewed the occurrences and used the dating of palm-leaf fossils as Eocene in determining the age of lower Tertiary sedimentary rocks in the Pilot Rock and Arbuckle Mountain areas. He mentions the occurrence of palm leaves as much as 4 feet across. Hergert (1961), in a summary of the plant fossils in the Clarno Formation, includes palm (Sabalites) leaves in a list of plants from the Pilot Rock locality.

Clarno area: Eocene palm is best known from the Clarno area, the type locality for the Clarno Formation and also the site of Camp Hancock, Oregon Museum of Science and Industry's famous outdoor laboratory for fossil plant and animal studies.

The Clarno Formation has been well described in the literature (Merriam, 1901; Hodge, 1942; Wilkinson, 1959; and Baldwin, 1964). It is composed almost entirely of andesitic volcanic material - chiefly lavas, mud flows, breccias, and tuffs, including some water-laid sediments. The formation overlies older marine rocks of Paleozoic and Mesozoic age. The Clarno sediments contain abundant silicified plant remains, mainly tropical and subtropical in nature, including palm at a number of localities (Chaney, 1948). The fossils occur in lenses of volcanic ash that accumulated in shallow lake bottoms, either by direct ash falls or by erosion and redeposition of such material. At some localities the plants are in carbonaceous shales associated with coal beds. The type exposures of the Clarno Formation can be seen about 2 miles east of Clarno Bridge in Wheeler County.

Near the type locality are the Clarno nut beds (SE$\frac{1}{4}$ sec. 27, T. 7 S., R. 9 E., Wheeler County), which are world famous among paleobotanists for their well-preserved seeds, nuts, and fruits as well as other plant parts (Scott, 1954). The nuts and other plant remains are enclosed in a bedded volcanic tuff that was laid down in very late Eocene time. A potassium-argon age of 36.4 million years was recently obtained for an overlying welded ash-flow tuff (Swanson and Robinson, 1968).

The lack of stratification within the nut beds, plus the presence of standing Equisetum stems, seems to indicate that the material accumulated by very rapid deposition. Arnold (1952) suggests that the nut beds may have been deposited during a flood.

Many fine collections of plant material have been made from the Clarno nut beds, but the most remarkable is that of Thomas J. Bones of Vancouver, Wash. Mr. Bones describes his work:

"I first visited the Clarno nut and seed beds in 1942 and discovered that finding specimens there was a real challenge to the collector. At first I could find only some of the larger nuts, but later discovered that by careful working, seeds even the size of poppy seeds could be found. The larger seeds and nuts are worked out in the field as a hard rock mining operation, by digging and breaking. The smaller seeds are obtained from matrix material that is brought home, broken down, screened and looked over with a magnifying glass."

"Walnut, grape, magnolia, moonseed, palm, pistacia, elder and water lily are some familiar plant seeds found that continue to grow on earth. Many of the hundreds of seeds found at Clarno represent plant species now extinct. Dr. Richard A. Scott, USGS, has worked on identification of this Clarna material."

Although most af the original Thomas J. Banes callection has been permanently located in Washingtan, D.C. in the National Museum of the Smithsonian Institute since 1961, Mr. Banes has continued collecting and has accumulated many more equally notewarthy specimens since that time.

Among the fossil plants found by Mr. Bones in the Clarno Formatian are wood, leaves, leaf fronds, and seeds representing at least eight different genera of palms. Other collectors have found palm in the Clarno area, including trunks and root masses. One of the largest of these specimens is a jasperized stump of typically rounded appearance that is 3 to 4 feet in diameter and estimated to weigh 2 tons. For many years it was on display in Antelope and was considered by its owner to be a meteorite. Later it praved to be one of the largest fossil palm stumps ever found in Oregon or, indeed, anywhere (Richard Rice, oral communication, April 1969).

Other areas: As geologic mapping in Oregon has increased, the presence of many additional areas occupied by rocks of the Clarno or equivalent age in central and eastern Oregan has become evident. The accurrence of fossil palm wood at some of these localities is proving to be a factor in age determination. Recently such a determination was made for the Dooley Rhyolite of the Ironside Mountain area of eastern Oregon by W. D. Lowry ("Geology of the Ironside Mountain quadrangle, Oregon," State of Oregan Department of Geology and Mineral Industries Bulletin, in manuscript form) (figure 7).

Other localities, as yet nat nated in the literature, contain fragmented fossil palm wood of presumed Eocene age spread over areas of many square miles in eastern Oregon. In same places the palm wood has been eroded from Clarno-age rocks and transported ta areas of younger formatians, as in the Jamieson-Huntington region. Pieces af silicified wood, fossil "bog" containing palm wood and root chips, portions of palm leaves, and other palm debris have been collected from various places by rack hunters.

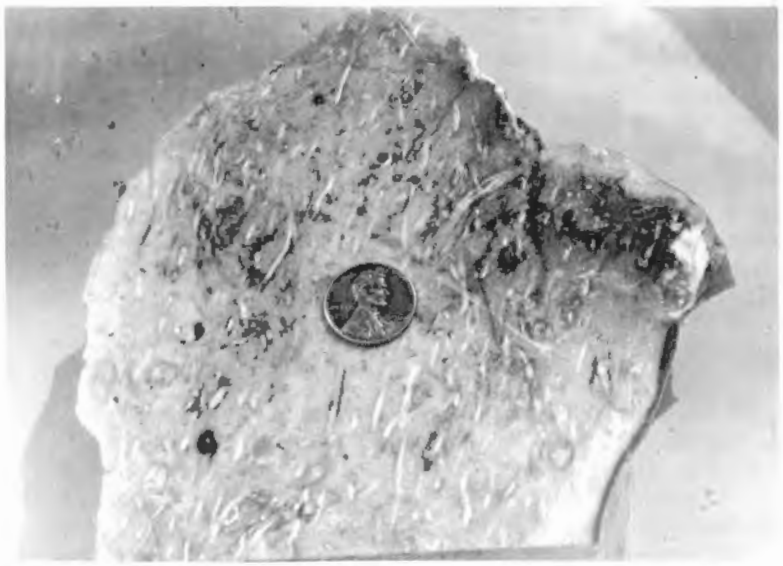


Figure 7. Longitudinal view of fossil palm wood from the Ironside Mountain quadrangle, Baker County, Oregon.

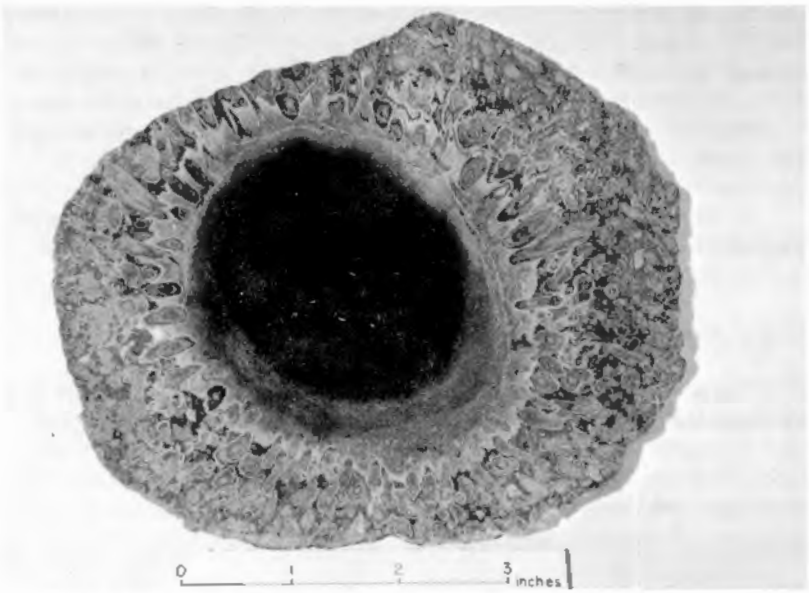


Figure 8. Cross section of an entire fossil palm trunk (about 3 inches in diameter) surrounded by a thick layer of roots. Dark mineral impurities in silica obscure typical "eye" pattern of trunk. Specimen found in Sams Valley near Medford, Oregon (Richard Rice collection).

Much is float, and in most occurrences the original source of the material is not known. Whole sections of palm wood have been seldom reported from rock-hunter localities of eastern Oregon.

West of the Cascades in the Medford area, palm wood occurs in areas mapped by Wells and Peck (1961) as late Eocene nonmarine sedimentary rocks, equivalent in age to the Clarno Formation east of the Cascades. Complete sections of petrified palm wood have been found (figure 8). The presence of palm is to be expected in other western Oregon Eocene localities as an associated species with other warm-climate and subtropical fossil plants.

Oligocene

As yet, fossil palm wood and leaves have not been noted with certainty from the John Day Formation of central Oregon, which contains an abundant flora of temperate-climate species. The palm-wood specimens thus far reported from the John Day have occurred as float and are considered to represent reworked material of Eocene age.

West of the Cascades, palm-leaf fragments are reported from two localities in Oligocene rocks. One is in the Eagle Creek flora of the Columbia Gorge area, described by Chaney (1920). The other is in the Rujada flora (Chaney, oral communication, February 1969). The Rujada* flora, described by Lakhanpal (1958), is situated near Layng Creek Ranger Station about 23 miles east of Cottage Grove. Here, in tuffaceous sediments, are leaves of temperate species as well as palm, catalpa, avocado, and other subtropical and warm-temperate trees. The presence of these relict species of warmer Eocene times is thought to be due to the relatively mild and uniform coastal climate of Oligocene time which enabled them to carry on long after their extinction elsewhere under less favorable climatic conditions.

In spite of the wealth of tropical and subtropical woods in the Sweet Home petrified forest near Holley, no palm has as yet been encountered there by the writer (Gregory, 1968).

General distribution

The accompanying map (figure 9) shows some of the localities in Oregon where fossil palm has been found as leaves, fruits, or wood. Probably many more such localities can be added to the map in the future as additional specimens are reported. Most of the occurrences shown on the map represent fossil palm material that was found in place. That is, it was enclosed

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* The name "Rujada," which is so often mispronounced, is made up from the initials of two loggers, R. Upton and J. Anderson, together with the initials of the Department of Agriculture. It is correctly pronounced Rue-jade-ah.

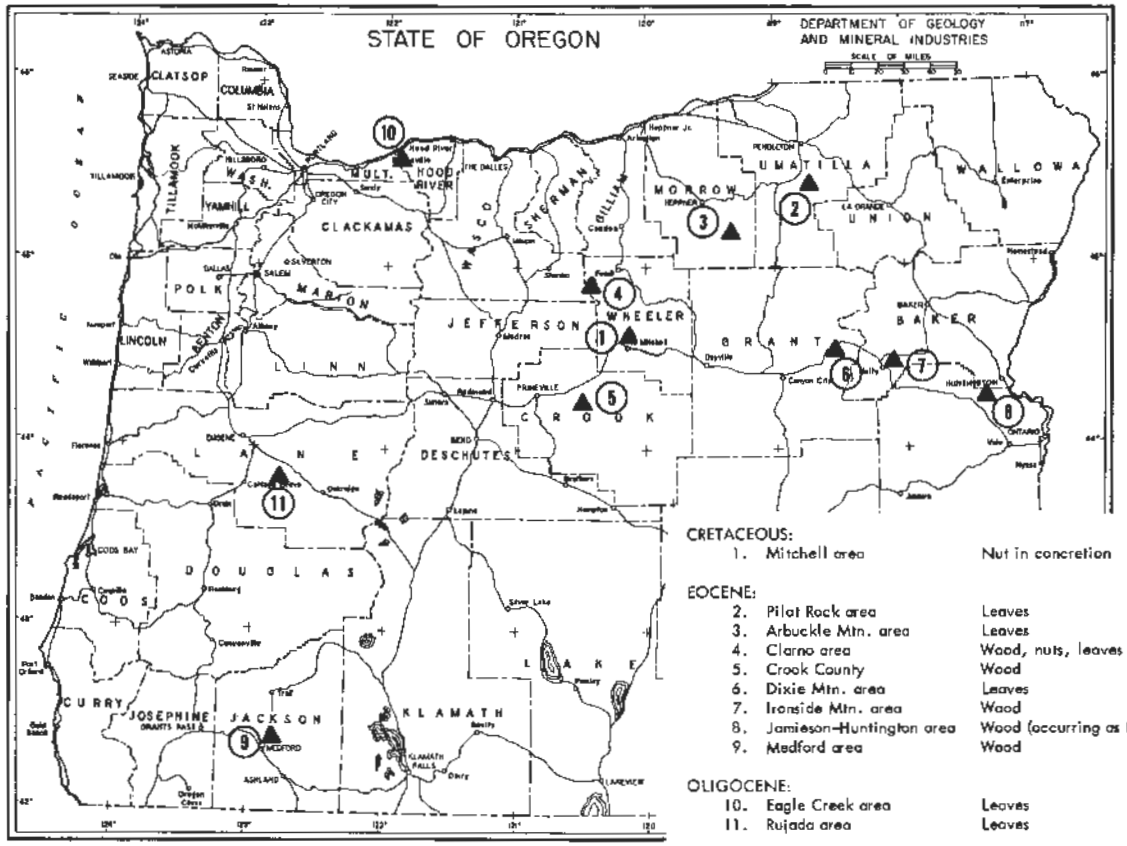

Figure 9. Some fossil palm localities in Oregon.

in or intimately associated with the geologic formation in which it was originally buried before petrification. Fossil palm fragments occurring as float have less geologic significance.

Suggestions for the Rock Hunter

Reports of palm-wood occurrences from both east and west of the Cascades are frequent. However, many specimens, when examined under magnification, show no cellular structure and are actually various forms of orbicular agate and jasper or oolitic material. Others do prove to be palm, but the locations for all are a closely held secret of the finders, palm wood being one of the rock hunter's materials that has developed a certain desirability and "mystique" of its own. Prized varieties of palm wood for jewelry making include an ivory-colored jasp-agate with snow-white "eyes," as well as jet-black palm wood also with white "eyes." More commonly it is found in soft, blue-gray shades. Occasionally, a specimen of a deep, rich maroon color is found.

Hobbyists who wish to determine whether or not a specimen is palm wood can generally do so with a 10 X lens. After orienting the specimen to get a possible transverse or cross-section view, they should look for scattered "eyes" all with a similar pattern and each having two (rarely three) tiny, solid-looking dots (vessels) on one side. A longitudinal cut through an eye will show it as a lengthwise line or tube. If, instead, it appears as a short line or is ball shaped, the specimen is more probably one of Oregon's ubiquitous oolites rather than the sought-after palm.

Acknowledgments

Grateful appreciation is expressed to members of the State of Oregon Department of Geology and Mineral Industries for photographic work and for valuable assistance in preparing the manuscript for publication. Gratitude is extended also to Thomas Bones, Jim De Mastus, Dwight McCorkle, Richard Rice, Fred Roner, and the many others, including members of the Gregory family, who provided information, specimens, collecting privileges, and field assistance.

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A FOSSIL PINE FOREST IN THE BLUE MOUNTAINS OF OREGON

Irene Gregory*

Introduction

A petrified wood deposit in the Blue Mountains of northeastern Oregon appears to be the fossilized in situ remains of a pure stand of Western White Pine (Pinus monticola Dougl.) of probable Eocene age. Intensive search produced no additional species in the collecting area.

The fossil pine forest is in the Burnt River drainage basin at elevations between 4200 and 5000 feet. The wood occurs over a wide area both in place as low stumps and as scattered logs and chunks. Growing among the fossil material is a living forest of another species of pine, representing a difference in age of as much as 40 million years.

Geologic Relationships

The Burnt River fossil pine wood area is included in the geologic mapping of the Canyon City AMS quadrangle by Brown and Thayer (1966), who show the bedrock units in the vicinity of the wood locality to consist of the Clarno Formation of Eocene age overlain by the Strawberry Volcanics of Miocene-Pliocene age.

Because the locality appeared to be situated near the contact of these two formations of widely differing ages, a more detailed geologic survey was needed to determine the host rocks for the fossil wood. Howard Brooks, geologist of the Oregon Department of Geology and Mineral Industries field office in Baker, who was mapping Tertiary rocks in adjacent areas, kindly offered to investigate the locality. He reported as follows (written communication, November 26, 1971):

> "The slope on which the pine wood occurs is underlain chiefly by a gently dipping sequence of interlayered andesitic tuff breccias and tuffs that were at least partly waterlaid. Wood fragments up to 2 feet in diameter were found entirely as float, but the absence of any nearby exposures of younger rock units or gravels seemingly precludes the possibility of a source other than the underlying breccias and tuffs.
> "Pardee and others (1941) in mapping the Sumpter quadrangle included the andesite tuff breccias of this region in the lower

*Mrs. J. M. Gregory is a paleobotanist and an authority on fossil wood anatomy.

Tertiary section. Brown and Thayer (1966) also regarded the andesite tuff breccias as lower Tertiary in age and mapped them as part of the Clarno Formation.
"James McIntyre and I found fossil wood and leaves in Clarno lithologies at several locations in this and adjacent areas. Dr. Jack Wolfe (written communication, July 22, 1971) assigned Clarno dates to the fossil leaf collections. Some of the fossil wood collections are being sent to you for identification."*

Prior to the present study, pine was not commonly recognized as a component of the Eocene forests of Oregon. The writer has found it to be in abundance not only in the Burnt River locality but also in nearly every Clarno wood locality investigated. It occurs in association with both subtropical and temperate types of fossil wood. Pines should thus be considered one of the typical Eocene trees of Oregon.

Description of the Pine Deposit

Wood

The fossil wood deposit represents a dense, unmixed stand of *Pinus monticola*; such pure stands are also a characteristic growth habit of the living *P. monticola*. Petrified trunks up to 5 feet in diameter, branches of many sizes, and the typical slender twigs of this species--all the component woody parts of complete trees including bark--are present. Although d.b.h. (diameter breast high--that is, measured at $4\frac{1}{2}$ feet above the ground) has been measured at a record of 8 feet in living specimens, more normally this is $2\frac{1}{2}$ to $3\frac{1}{2}$ feet. Most of the fossil trunk specimens are also 2 to 3 feet in diameter (Figures 1 and 2). Since none show tapering, they may be assumed to represent the middle portions of the tree, which in mature living specimens range from 150 to 180 feet in height. No root-wood has been observed; it presumably remains buried at depth in growth position. Any associated understory of shrubs or herbs of the time has been destroyed or is still buried; this is true also of cones and needles, which have not been found at this locality.

Bark

Fossil bark eroded from exposed trunk sections litters the area as in living pine forests, and some still adheres to the fossil trunks. The bark is often found broken into the peculiar small, square blocks that are

*All of the wood collections from the Clarno localities sent by Mr. Brooks were found to contain pine.

Figure 1. Exhumed trunks of Pinus monticola in Burnt River area.

Figure 2. Gross structure of the pine wood is well preserved in this specimen. See pick for scale.

characteristic of living P. monticola after it reaches a trunk size of approximately 12 inches in diameter. Growth patterns of bark are quite constant within a genus, and some have characteristics unique to the species, as in P. monticola (Figure 3). Distinct microscopic structure of bark, particularly when combined with wood structure, can also be an important feature in identification (Chang, 1954).

Pitch (?)

Of frequent occurrence in the soil zone around the fossil stumps are masses of silicified material that look like pine pitch. Since none of the specimens found thus far are attached to the fossil wood, this identification is uncertain. However, Dr. Lloyd S. Staples, who examined some of the samples, suggested that although the material was completely silicified and lacked residual matter, it would be entirely possible for masses of pitch to become silicified in an environment so highly charged with silica (oral communication, November 29, 1971).

Methods of Identification

Pine is one of the few fossil woods that can be readily identified in the field by means of a hand lens. For more precise microscopic identification as to species, the wood must be exceedingly well preserved and be examined in thin-section views of transverse, tangential, and radial cuts. Much of the wood of the Burnt River locality is replaced by opaque jaspers with scattered pyrite, which obscure the minute details of structure. But some of the highly silicified specimens exhibit very well-preserved, anatomical details of cell structure. These have made it possible to identify this wood as to species, rather than to genus only, as is the case with most fossil woods.

Botanical Classification

Pines and other needle-trees are conifers. They belong to one of the main divisions of plants called Gymnosperms, meaning that they have exposed seeds which are usually borne in cones, as is denoted by their order name, Coniferales. Because of the comparative ease with which their wood is worked, they are classified also as "softwoods" in contrast to "hardwoods," a term which has come to include all dicotyledonous trees such as oak or maple; these belong to the other main plant division, Angiosperms, that have seeds enclosed in a fruit and bear true flowers. Each type of wood has its own structure; that of a typical softwood is shown in Figure 4, which is a diagram of the transverse view of white pine (P. monticola).

Figure 3. Petrified bark cut and polished to show pattern of structure.

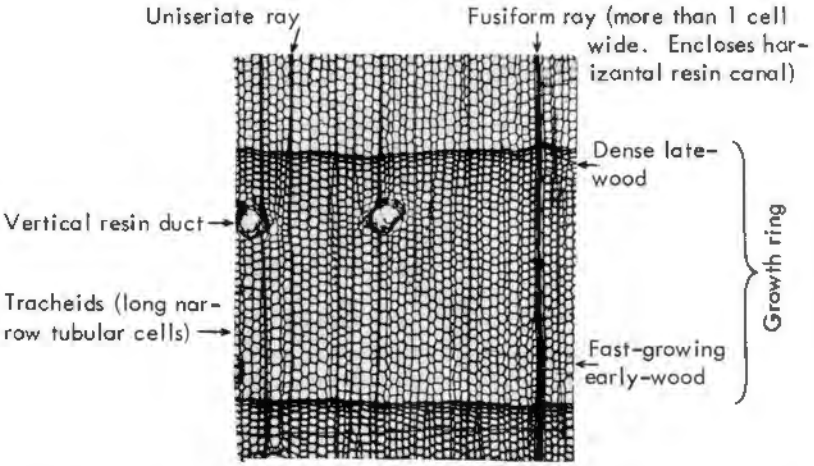


Figure 4. Anatomical features of Pinus monticola, a typical softwood; transverse view. Approx. 50X.

Systematic Description

Class	GYMNOSPERMAE
Order	CONIFERALES
Family	PINACEAE
Genus	PINUS Linnaeus

Pinus monticola Dougl.

(Figure 5A, B, C)

Anatomical description

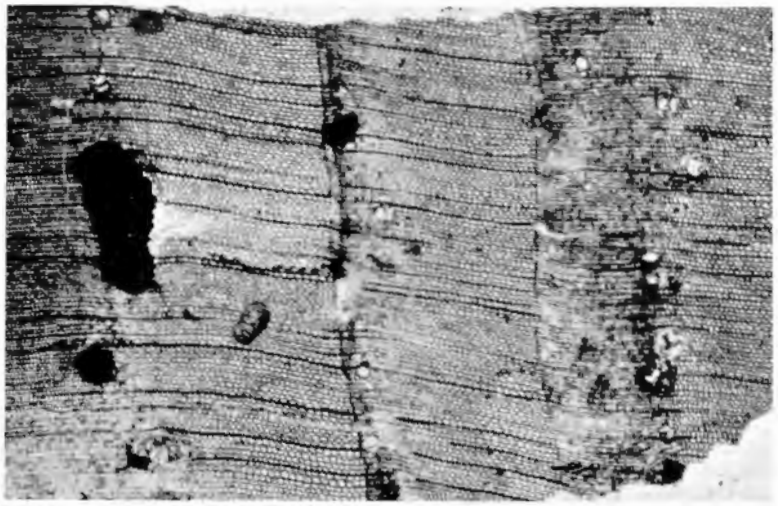
Growth rings: Distinct. Marked by a narrow band of denser (slow-growing) late-wood at outer margin. Fast-growing (larger celled) early-wood takes up most of the ring. Transition from early-wood to late-wood is very gradual.

Tracheids: Arranged in definite radial rows. Up to 50, but average 35 to 45 microns in diameter; bordered pits in one row (sometimes 2) on radial walls. Pits to ray parenchyma windowlike and large; 1-2 (usually 1) per cross-field.

Longitudinal parenchyma: Not visible.

Rays: Very fine. Not visible to naked eye except those few larger that enclose a transverse resin canal. Of two types but mostly uniseriate, 1-10 cells high as seen on tangential. Also scattered fusiform rays enclosing horizontal resin canal; 2-3-seriate in thickened area, tapering to uniseriate above and below; up to 12 cells high. Ray tracheids present in both types of rays, non-dentate.

Resin Canals: Vertical: easily visible with lens. Numerous. Scattered through central and outer part of ring. Solitary. Rarely two or three side by side. Appear as vertical streaks or lines on tangential. Epithelium thin-walled. Often occluded with tylosoids. Average diam. 135-160 microns. Horizontal: inconspicuous. Rather sparse. On transverse appear as more prominent wood rays irregularly spaced. Scarcely visible with lens on tangential. Avg. diam. less than 60 microns.



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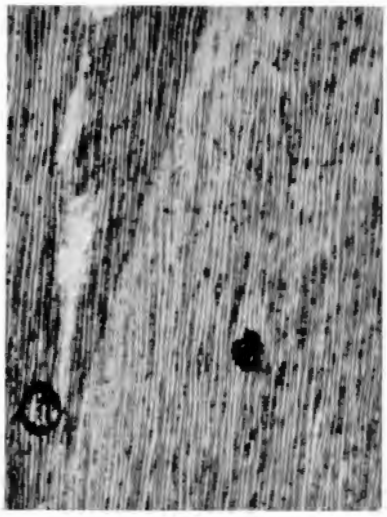

B C

Figure 5. Photomicrographs of thin sections cut from fossil Pinus monticola from the locality in the Blue Mountains, Oregon. A. Transverse view; B. Tangential view; C. Radial view. (Photography by Thomas J. Bones, Vancouver, Washington.)

Discussion

Wood of the genus Pinus is easily distinguishable from other conifers because of its characteristic vertical resin ducts that can be plainly seen on the cross section with a hand lens; they appear as small rounded holes scattered about among definite, neatly arranged rows of cells (tracheids) of uniform size and approximate rectangular shape. Resin ducts are found also in other conifers such as spruce, larch and Douglas fir, but in these genera they are far less numerous and arranged in characteristic group patterns rather than scattered about as in pines. Vertical resin ducts are actually tubular intercellular spaces that carry resin in the sapwood; they are lined with a sheath of resin-secreting cells (epithelium). When using a high-power microscope, the thin walls of the epithelial cells of the resin ducts are the feature that serves to separate members of the genus Pinus from all other conifers. Horizontal resin ducts, inconspicuous and enclosed in rays, are also sparsely present in pines and may be seen under a microscope on the tangential surface.

All fossil pine wood has structures hardly distinguishable from similar pines living today; apparently pines adapted so successfully to climates of the time that only minute evolutionary changes have come about during the intervening ages. Consequently names of living pines can be applied to the fossil forms. That this also is true of the needles and seeds of pine is borne out by Wolfe (1964), who describes P. monticola parts from the Tertiary as being indistinguishable from similar specimens of extant P. monticola.

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AN ANCIENT ACACIA WOOD FROM OREGON

By Irene Gregory*

A small, localized outcrop of tuff in central Crook County, Oregon, mapped as Clarno Formation of late Eocene to early Oligocene age by Waters (1968), has yielded fossil wood of both stem and roots of the genus Acacia. The paleobotanical occurrence is unusual in that fossil stem wood and root wood of the same species are rarely found together.

The occurrence consists of what is believed to be the remnants of a single tree. It lies horizontally in a matrix of fine-grained tuff in an outcrop area of about 200 square feet at the summit of a low hill. Although the leaves, twigs, and small branches are missing, limbs and roots 10 to 12 feet long (but segmented by earth pressures) and trunk sections are present. The prime condition of the wood, which shows no fungus rot, insect infestation, or distortion from drying, indicates that the tree was literally buried alive.

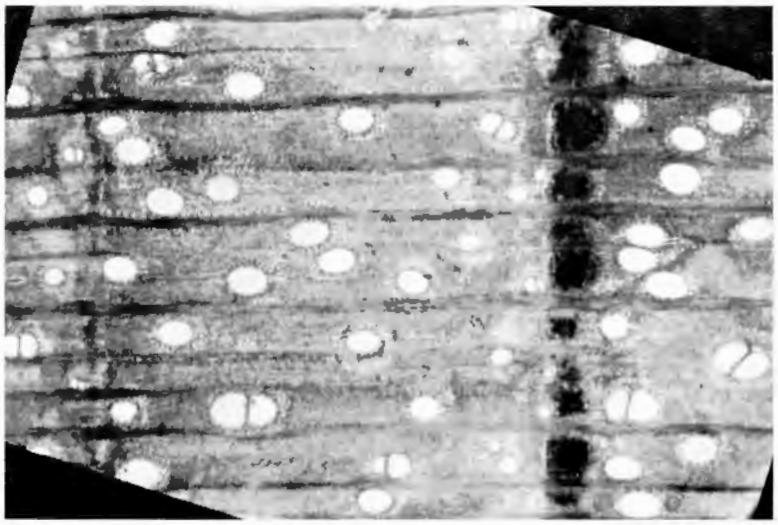
Conditions of burial and preservation can only be surmised. Possibly in Clarno time the acacia grew near a stream in the vicinity of an active volcano. Torrential flood waters undermined the tree, tore it loose, swept it along stripping it of its leaves and small branches, and finally left it stranded. Before the wood could deteriorate, it was buried by showers of volcanic ash and silicified. Erosion has now removed the volcanic cover and has exposed the fossilized tree, much of it still in place.

Photomicrographs of thin sections cut from the fossil wood (figures 1, 2, and 3) show structural details to be so well preserved that the diagnostic features necessary for identification are as definitive as in living wood.

Acacias in the Fossil Record

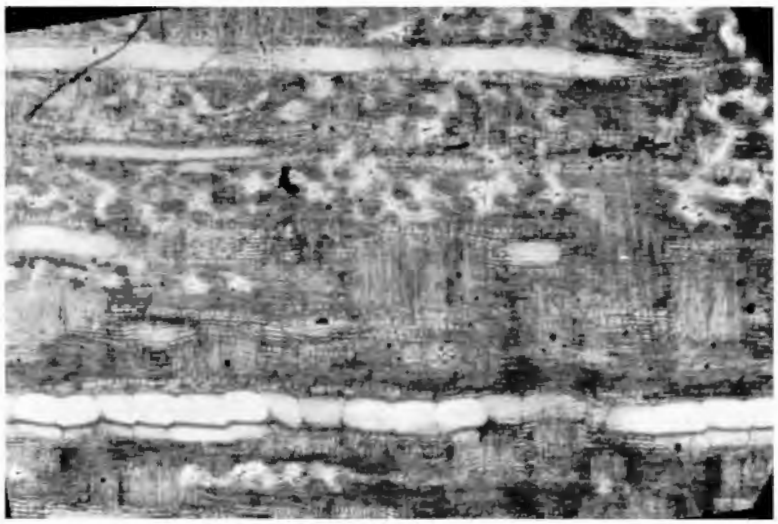
Reports of fossil acacias are few. Leaves are recorded chiefly from Eocene deposits of Alaska and Texas and from the Oligocene Florissant flora of Colorado. A well-preserved seed pod compared with Acacia farnesia (a tidal swamp species) is included in the Eocene Lower Bagshot flora of England -- a tropical lowland assemblage (Chandler, 1964). Deporta (1961)

*Mrs. J. M. Gregory is a paleobotanist and an authority on fossil wood anatomy.



↑ Figure 1. Transverse (cross section) view of stem wood of the acacia. Magnification approximately X 30. Photograph by Thomas J. Bones.

↓ Figure 2. Radial view of stem wood of the acacia. Magnification approximately X 30. Photograph by Thomas J. Bones.



found Acacia sp. in an Oligocene-Miocene pollen flora of Colombia which includes palms and members of several subtropical angiosperm families such as Malvaceae, Bombaceae, and Sapotaceae.

Knowlton (1902) listed Acacia oregoniana Lesq., consisting of a nearly perfect complete seed pod, from the upper Miocene Mascall beds in Grant County, Oregon. But on the basis of additional collections of similar seed pods from the same locality, Chaney and Axelrod (1959, p. 207) have assigned Knowlton's specimen to Albizzia oregoniana.

As far as the author is aware, only one other specimen of fossil wood from the Pacific Northwest has been considered to be a possible Acacia. Prakash and Barghoorn (1961) report on a specimen they catalog as Leguminoxylon occidentale, as follows: "The nearest approach to the structure of the fossil which we have been able to establish is the genus Acacia and within this genus, the species A. ferruginea. One aspect of the fossil which renders its identification more difficult is the tangential compression failure which preceded mineralization, thus exaggerating the ellipticity of the vessels as seen in transverse section. In view of these facts, it seems more desirable to designate the fossil to family rather than to genus."

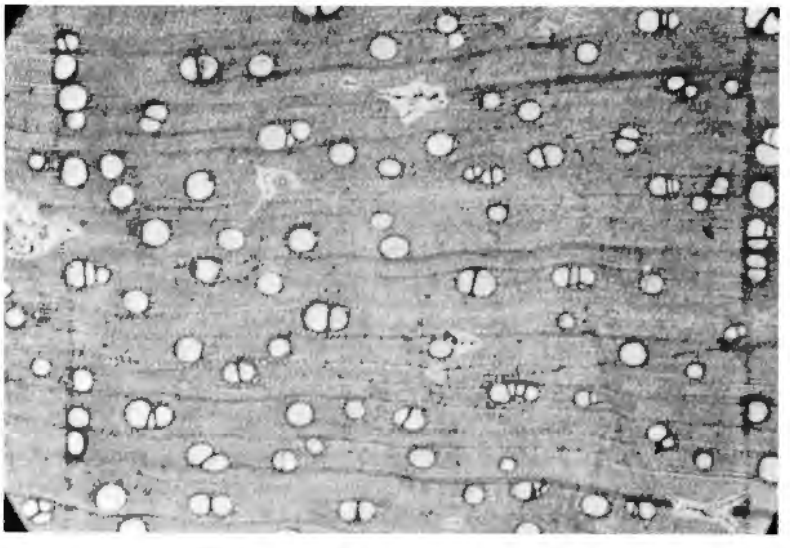


Figure 3. Transverse (cross section) view of root wood of the acacia. Magnification approximately X 30. Photograph by Thomas J. Bones.

Anatomical Description

Genus: Acacia
Sub-family: Mimosoideae
Family: Leguminosae

Growth rings: Indistinct and inconspicuous. Delimited by a fine line of sporadic terminal parenchyma with infrequent small vessels embedded in it. Rings vary greatly in width.

Vessels: Medium. Visible without lens. Diffuse-porous. In widest rings, those in center one-third of ring are largest. Some rings exhibit (at beginning and end of ring) a distinct zone of vessels smaller than those in rest of ring and embedded in the terminal parenchymo. Evenly distributed. 5 to 15 per sq. mm. Mostly solitary with a few radial rows of two (and less frequently) three cells. Occasionally, two cells are contiguous in the tangential plane. Also scattered irregular clusters or nests of mixed small and large pores (not present in every ring). Perforation plates simple; somewhat oblique. Vessel segments are short (0.2 - 0.4 mm.). Rother thick walled and forming conspicuous vermiform lines along the grain. Deposits of gum are frequently observed in the vessels. (In the fossil specimen these happen to be the same red-brown color as in the living wood.)

Porenchyma: Abundant vasicentric several cells wide forming a narrow halo around vessels or vessel groups. Also aliform with short wings. Sometimes confluent between two or three pores. Terminal parenchyma rather sporadic in a 3- to 4-seriate somewhat discontinuous line including or associated with a zone of small pores.

Fibers: Libriform. Rounded in transverse section. Thick walled. Not aligned radially but arranged in wide tracts between rays.

Rays: Medium. Visible without lens on cross-section. Approximately 5 per mm. Conspicuous on radial forming a cherry-like fleck. Slightly undulate around larger vessels. Homogeneous. Mostly 4 to 6 cells wide. 30 to 40 cells high. Also sparse 1- to 2-seriate rays a few cells high.

Intercellular canals: Vertical traumatic gum ducts arranged in tangential rows. Fairly frequent.

Affinities and Discussion

The genus Acacia today includes more than 400 species of trees and shrubs widely distributed over the tropics and subtropics of both hemispheres. Of these, more than 300 are native to Australia and the South Pacific islands. Native acacias nearest to the Crook County collecting area are those in the southwestern United States and Mexico.

While the fossil Acacia described here reflects closely the typical structural details of the living woods of this genus, to which it clearly belongs, assignment to a particular species is more difficult to establish -- particularly in the absence of such helpful diagnostic plant parts as leaves or seed-pods. Among the species of live woods available for comparison, its structure most closely approximates that of A. arabica, with which it is virtually identical in all major features. Minor differences include: fewer pores in the fossil wood (4 to 12 per sq. mm. in the fossil species and 5 to 15 per sq. mm. in A. arabica); somewhat smaller pore size in the fossil species; and fewer vessels containing gum deposits in the fossil species. (Obscuring by mineral stains as well as abnormalities of preservation might account for this apparent difference to some degree.)

A. arabica is indigenous to India, Arabia, and North Africa. It cannot withstand freezing temperatures but can adapt to a variety of environments, including lake and river banks as well as flood plains with repeated and prolonged periods of inundation.

New Fossil Species?

Further comparisons with additional specimens of living Acacia may prove beyond doubt that the Clarno fossil species has its closest affinity with A. arabica. The minor anatomical differences noted could then provide the basis for separating the fossil species from the closely similar living A. arabica and for the establishment of a new fossil species of the genus Acacia.

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AN EXTINCT EVODIA WOOD FROM OREGON

By Irene Gregory*

Introduction

During the early Eocene in Oregon, approximately 35 million years ago, a relatively level lowland reached from the base of the Blue Mountains in northeastern Oregon to the Pacific Ocean, which at that time extended into western Oregon. Since the Coast and Cascade Ranges had yet to develop, the entire area was influenced by ocean currents and had a subtropical climate largely free from frost.

Fossil plant remains in the Eocene Clarno Formation indicate the area to have been forested with many kinds of broad-leaf evergreen trees that today also are typical of such subtropical climates. Among them were magnolia, palm, Cedrela, Persea (avocado), Ficus (fig), Sabal (palmetto), Anona, and Meliosma. Since Eocene time, as a result of climatic changes, many of these trees have become extinct as natives in this hemisphere.

The genus Evodia can be included among trees which were native to Oregon during Eocene times but which are extinct in the western hemisphere.

A group of petrified woods collected from the Eocene Clarno Formation includes specimens identified as Evodia. Well-preserved and undistorted by earth pressures, the specimens have retained the finest anatomical details, so the diagnostic features necessary for identification are virtually as definitive as those in living wood (Figure 1).

Character and Distribution of Living Evodia

Evodia belongs to the family Rutaceae, a large group of shrubs and trees (with a few herbs) whose members occur throughout the world, primarily in subtropical and tropical areas. Their woods are characterized by small

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* Mrs. J.M. Gregory is a paleobotanist specializing in fossil wood anatomy.

(often minute) to medium vessels, typically grouped in multiples (often radial strings) and having a distinct oblique arrangement. Most are dense and hard Evodia, which is light and soft, is aberrant among rutaceous woods.

As a living wood today, the genus Evodia includes approximately 45 species of trees and shrubs, most of which are aromatic. Their range is restricted to an area reaching from Madagascar through India and Malaya to the Polynesian Islands and Australia.

Several different timber species of Evodia are harvested, especially in Malaya, for use in making tea boxes, looms, posts, matches, and other such articles. E. micrococca of Australia (called White Evodia or Silver sycamore) is a fine-textured white wood valued for cabinetwork. Some species of Evodia have wood so bitter that no insect will attack it; thus it is valued for its durability. One Chinese species, the Bee-bee Tree (E. danielii), has been introduced in North America as a decorative garden tree. Blooming profusely in mid-summer with large eight-inch clusters of flowers, it has been named for its particular attraction to bees.

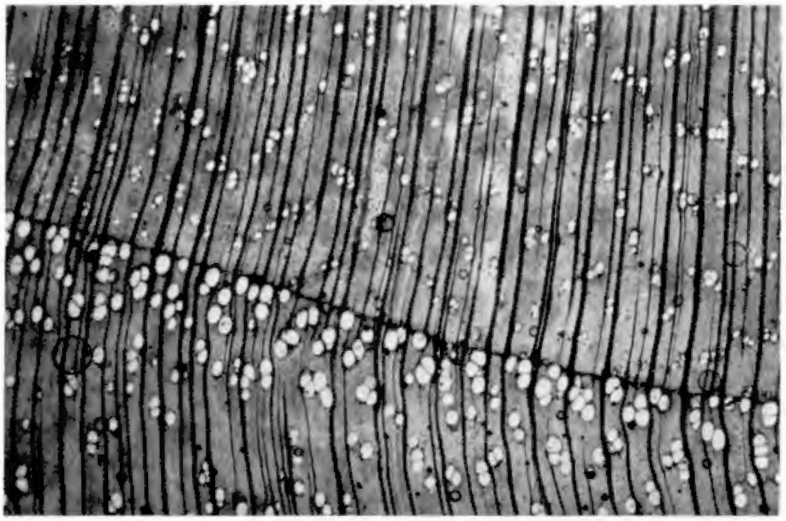
Records of Fossil Evodia

Reports of Evodia in the fossil record are few. Evodioxylon oweni (Carruthers) is reported from the Miocene and Cretaceous of eastern Africa (Chiarugi, 1933). Leaves of a fossil species, E. miosinica Hu and Chaney, are reported from the Miocene Shangwang flora of Shantung, China; the compound leaves (seven to 12 leaflets) show a marked resemblance to those of E. danielii described by Chaney and Hu (1940). Another list of plant fossils from the Miocene of Oregon includes a specimen tentatively identified as Evodia wood, although its anatomy is not described (Eubanks, 1966).

Geologic Background

The central Oregon locality in which the Evodia specimens occur has been mapped as Clarno Formation (Waters, 1968). The Clarno Formation has been described as composed almost entirely of andesitic volcanic material - chiefly lavas, mudflows, breccias, and tuffs, including some water-laid sediments. The formation overlies older marine rocks of Paleozoic and Mesozoic age. The Clarno sediments contain abundant fossil plant remains, mainly subtropical in nature, occuring in lenses of volcanic ash that accumulated in shallow lake bottoms and small ponds, either by direct ash falls or by erosion and redeposition of such material.

The somewhat orderly stratification of specimens in the Evodia locality indicates that the material may represent such a lake-bottom accumulation. The wood specimens, closely packed in the volcanic tuff, are highly silicified, with well-preserved cell structure and wood grain.



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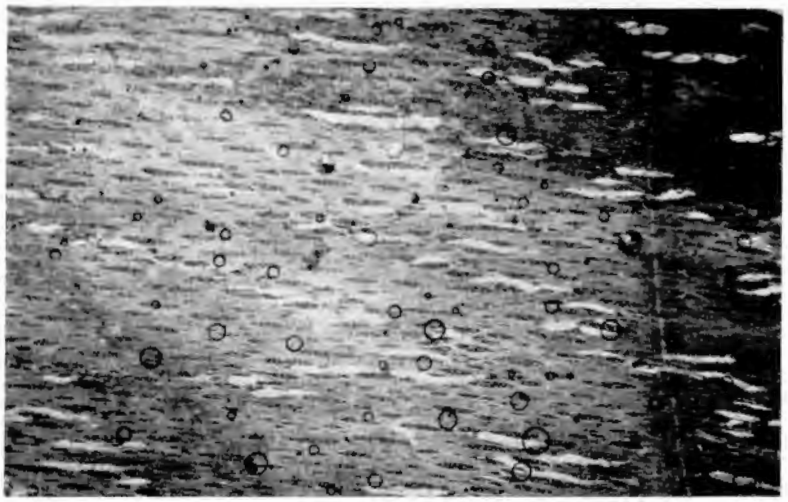

B

Figure 1. Photomicrographs of thin sections cut from fossil Evodia of Oregon.

A. Transverse section.
B. Tangential section.

Systematic Description

Family: Rutaceae
Genus: Evodia Forst.
Evodia gadijirian nov. sp.

Figure 1, A and B

Growth rings: Present; distinct to the naked eye. Marked by a uniseriate row of larger early-wood pores and thin but definite line of terminal parenchyma.

Vessels: Medium-sized to very small in the late wood. Open, with rare inclusions of gum. Solitary, but chiefly in radial rows of two or three, which at times are aligned tangentially. Rarely in nests of five to 12. Early-wood vessels are more numerous, more closely spaced, and larger, with a somewhat ring-porous arrangement. Up to 14 per millimeter. Vessel segments are thin walled, long. Perforations simple; oblique. Tyloses not observed.

Parenchyma: (A) Terminal; distinct to eye, forming a sharply-defined four- to eight-seriate line along which the single row of early-wood vessels of the next ring are aligned; thin-walled. (B) Paratracheal; one to two cells wide between vessels and between vessels and rays where they are contiguous. Rarely several cells grouped in the space between vessels. Frequently very small globules of gum are present; here, as in other parts of the wood, the gum has not taken on the coloration of the minerals in the host rock, but rather remains its natural amber color.

Fibers: Non-libriform, coarse, thin-walled; wide lumen. Not aligned in rows, but arranged to fill in large areas between rays and vessels.

Rays: Not distinct to naked eye. Very variable in size. 1- to 8-seriate, heterogeneous; up to 26 cells and 550 microns high. Small globules of gum are present.

Affinities

The minute anatomical details of the fossil Evodia wood closely resemble those of the living woods of this genus. Species correlation is more difficult to make; but because of the excellent preservation of the fossil wood structure, we can see its close comparison with E. fraxinifolia, extant in the eastern Himalayas and northern Burma.

Minor differences in the anatomy of the two woods are observed. These provide the basis for separating the fossil species from the living Evodia for the establishment of a proposed new fossil species, E. gadijirian.

Differences include:

A. Notably larger vessel nests in the fossil species.
   Vessel nests: Up to 12 per nest in fossil species.
   Up to several only in living E. fraxinifolia.

B. Rays up to twice as tall in the fossil species.
   Rays: Up to 550 microns high in the fossil species.
   Up to 225 microns high in the living E. fraxinifolia.

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WORM-BORED POPLAR FROM THE EOCENE OF OREGON

By Irene Gregory*

That faithful, true-to-life detail may be retained during the process of petrification is shown by the photographs on the opposite page. The beautifully preserved and undisturbed chips of wood filling this worm burrow were formed in a poplar tree living about 40 million years ago during the Eocene in Oregon. The specimen (much enlarged) is of the genus Populus in the willow family (Salicaceae).

The worm tunnel was made by an insect larva of the flat-headed borer type of today. Its strong mandibles enabled it to carve out from the living poplar wood the typical crescent-shaped chips pictured "floating" in the clear chalcedony that was deposited in the borrow during petrification by silica-bearing ground waters.

The process of petrification of wood is not yet well understood, but, by this means, original cell structure is retained through some mineral (commonly silica) infiltrating the plant tissues. The nearly perfect preservation of detail that can result provides one of our most accurate tools for fossil-wood research.

In the specimen illustrated, structural features appear as clearly as in living wood, and minute anatomical details are retained in even the smallest chips carved out by the borer.

Some of the typical anatomical features of poplar wood preserved in this fossil specimen include growth rings delineated by somewhat larger vessels at the beginning of each ring; vessels small and in short radial rows of two to several; rays fine and close; and parenchyma limited to terminal.

As with many Tertiary woods of the Pacific Northwest, the over-all aspect of this specimen more clearly resembles Asiatic Populus of today than it does our living North American members of this genus. The living forests of Asia seem to have retained their Tertiary character, not only in the kinds of trees present but also in the anatomy and general aspect of their woods.

The specimen pictured is one of an assemblage of silicified Eocene woods occurring in an outcrop of the Clarno Formation in Crook County, Oregon. Woods from this area are being collected and studied by the author.

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*Mrs. J. M. Gregory is a paleobotanist and an authority on fossil wood anatomy.

Photomicrographs of silicified poplar wood showing tunnel and chips made by a wood borer during the Eocene Epoch. Upper picture 2.5 X enlargement; lower picture (portion of upper) 35 X enlargement. (Specimen preparation by Fred Roner and photography by Thomas J. Bones.)

See page opposite for story.

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PLANT FOSSILS IN THE CLARNO FORMATION, OREGON

By

Herbert L. Hergert*

Introduction

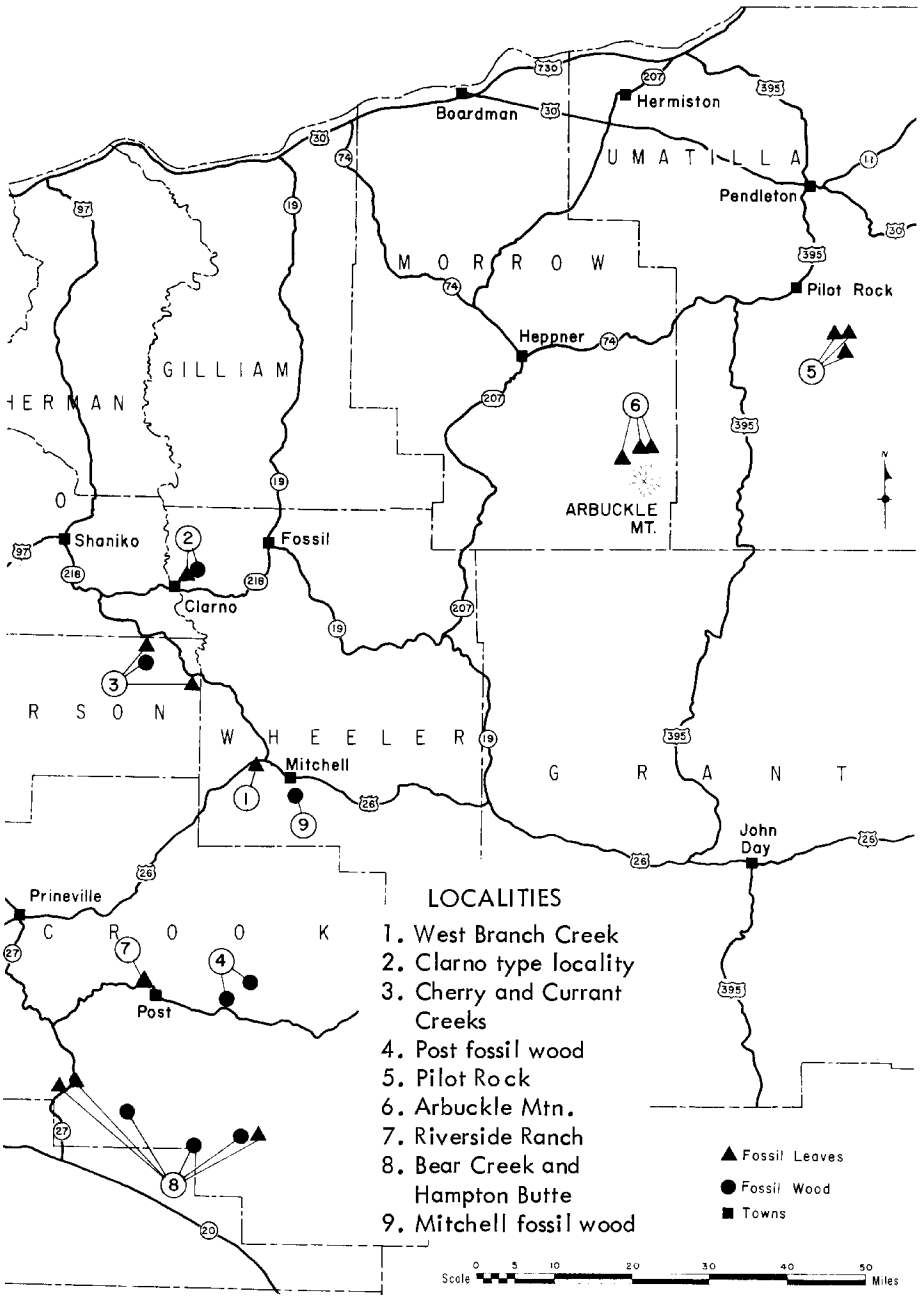
The Clarno Formation was originally described by Merriam (1901) from outcrops at Mitchell and Clarno's Ferry, Oregon. Since that time the formation has been found to be very widely distributed throughout central Oregon (Wilkinson, 1959). It is composed of an unknown thickness of volcanic rocks and interfingering terrestrial sediments which contain a newly discovered vertebrate fauna and an abundance of fossil plant remains.

Wilkinson (1959) and Taylor (1960) describe several distinctive rock types that make up the Clarno Formation. Of special importance are the beds of tuff ranging from coarse gritty tuffaceous sandstones to fine-grained tuffaceous shales, some of which are water-laid and contain fossil leaves. Another important unit in which plant remains are found is composed of volcanic conglomerates and breccias of mud-flow origin. Associated with the conglomerates and breccias are andesite and basalt flows. Welded tuffs occur at several horizons. Plugs, dikes, and sills of andesite, rhyolite, and dacite are characteristic of the Clarno Formation and are topographically expressed on the landscape as prominent buttes and ridges.

The range in age of the Clarno Formation has not been determined with certainty. In the few places where its base is observed, it lies unconformably on Cretaceous deposits, and it is overlain unconformably by the upper Oligocene-lower Miocene John Day Formation.

Up until recently, writers have generally favored a middle to upper Eocene age for the Clarno Formation, the assignment being based almost entirely an fossils found in the vicinity of the type locality at Clarno's Ferry. Thus, R. A. Scott (1954) in his excellent monograph on the fossil nuts and fruits occurring $1\frac{1}{2}$ miles east of Clarno's Ferry, suggests an age

*Olympic Research Division, Rayonier, Inc., Shelton, Washington. Dr. Hergert holds a PhD degree in Chemistry and a minor in Paleobotany from Oregon State College, 1954.



FOSSIL PLANT LOCALITIES IN THE CLARNO FORMATION, OREGON

somewhat older than upper Eocene. Until recently, animal fossils were thought to be of such rare occurrence in the formation that Stirton (1944) used a single tooth, presumably belonging to the genus Hyrachyus, to establish a middle Eocene age for the Clarno Formation. Recently an extensive deposit of animal fossils near the type locality was discovered by the late A. W. Hancock and is being studied by J. A. Shotwell of the University of Oregon. Preliminary work suggests an upper Eocene or, possibly, lower Oligocene age for these fossils, but the stratigraphic relationship of the vertebrate bed to the plant locality is problematical (Taylor, 1960).

Plant fossils have been found at many other places in the Clarno Formation in addition to those occurring at the type locality (see accompanying map). Comparison clearly shows the non-contemporaneity of many of the florules and suggests that the age of the Clarno Formation is of an appreciably greater range than that proposed by many previous authors. Since some of these localities have not been described in detail in the literature previously, it would seem to be of value to summarize our present state of knowledge of the Clarno flora. Descriptions of the localities are presented below in the order of decreasing age of the flora. Numbers refer to locality numbers on the map.

Clarno Flora Localities

West Branch Creek Locality:

Most of the generalizations in the more recent literature concerning the Clarno flora are based on the leaf remains found on West Branch Creek in Wheeler County. Howard (1955) has suggested that the best collecting areas are in tuffaceous and shaly sediments in secs. 20, 29, and 30, T. 11 S., R. 21 E. The notable fossils from West Branch Creek are the large multilobed leaves of Platanophyllum angustiloba which is thought to be an ancestor of the modern sycamore. The author considers this species to be characteristic of middle to upper Eocene floras in Oregon. Chaney (cited in Scott, 1954) has furnished the following list of genera from this locality, but complete results of his study have not been published.

Astronium	Celastrus	Nectandra	Ficus
Rhus	Alchornia	Vitus	Alangiophyllum
Catalpa	Casearia	Persea	Platanophyllum
Cordia	Cinnamomum	Abuta	Gouania
			Meliosma

It may be noted that the indicated composition of the flora from this locality differs appreciably from that present at Pilot Rock (described elsewhere in this report). The West Branch Creek flora is considered to be the oldest in the Clarno Formation.

M. Pabst (1948) has studied the ferns from this locality and identified the following species:

Lygodium kaulfussii	Lastrea (Goniopteris) fischeri
Anemia elongata	Salpichlaena anceps
Dennstaedtia	Woodwardia latiloba
Pteris? sp.	Hemitelia pinnata
Dryopteris sp.	

A close correlation with species of the Paleocene of the Rocky Mountains was indicated, and a middle to upper Eocene age was suggested for the West Branch Creek flora.

Clarno type locality:

One and one-half miles east of Clarno's Ferry (SE$\frac{1}{4}$ sec. 27, T. 7 S., R. 19 E.), Wheeler County, near the type locality of the Clarno Formation is a remarkable occurrence of fossil fruits and seeds. These fossils have been described by Scott (1954), Scott and Barghoorn (1955), as previously noted, and correlated with flora of the Ypresian (upper lower Eocene) London clay. The specimens were assigned to eight genera, the most common fossil being a small walnut (Juglans clarnensis). Leaf impressions are also present in rocks at this locality but are of more limited occurrence. Chaney (1936) has noted the presence of a cycad, provisionally assigned to the genus Dioon, at this locality. Further description of the fossil leaves at this locality are wanting in the literature, however.

In addition to fruits, nuts, and leaves, silicified wood may also be found in this area. Some of this wood contains representations of fungi, two species having been described by Scott (1955). In the same paper, Scott indicated that he had identified more than 25 species of fossil wood from this locality, but they were not described.

The author has also collected fossil wood from this area. Palm, walnut (Juglans), Cinnamomum, sycamore, (Platanus), and wood from several other as yet unidentified genera are present. Significantly, gymnosperm wood was absent. This locality is probably one of the few plant fossil localities in the entire world that offers the opportunity of correlating species identifications from fruits, wood, and leaves of a plant. The age of this locality is considered to be middle upper Eocene.

Cherry Creek and Currant Creek localities:

The first fossil plants studied in the Clarno Formation were obtained from two localities in Jefferson County, Cherry Creek (T. 10 S., R. 19 E.) and Currant Creek (T. 9 S., R. 18 E.), the exact geographical locations of which are not precisely described in the literature. Collections from these localities were first studied by Newberry (1883, 1898), and Lesquereux (1883) and subsequently by Knowlton (1902). Although the determinations

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SOME TYPICAL FOSSIL LEAVES
FROM THE CLARNO FORMATION, OREGON

1. Sabalites eocenica (Lesa) Dorf - PALM
2. Magnolia leei Knowlton - MAGNOLIA
3. Laurophyllum merrilli Chaney and Sanborn - LAUREL
4. Cryptocarya eocenica, new species - PECAN
5. Litsea oregonensis, new species - CHINESE CHERRY
6. Persea praelingue Sanborn - AVOCADO

(All specimens approximately one-half natural size)

are mainly of historical interest, and undoubtedly require revision in the light of newer work, they are included here for comparison with the lists of fossils from other Clarno localities.

Cherry Creek

Lygodium kaulfussii	Cercis tenuinervis
Allantodiopsis erosa	Magnolia culveri
Equisetum oregonense	Cinnamomum dilleri
Salix schimperi	Rhamnus cleburni
Juglans rugosa	Platanus basilobata
Juglans? bendirei	Diospyros alaskana
Hicoria? oregoniana	Phyllites wascoensis
Quercus furcinervis americana	Phyllites sp.

Currant Creek

Pteris pseudopinnaeformis
Goniopteris lesquereuxi
Equisetum oregonense

More recently, Arnold (1952) has described the remains of a silicified tree fern, Osmundites chandleri, from this same general area. This striking fossil was found 9½ miles east and 3 miles north of the small town of Ashwood (T. 9 S., R. 18 E.), on or near the east-west line separating sections 15 and 22. This same area yields scattered remains of silicified wood, none of which have been described in the literature, and stems of a fern provisionally referable to the genus Eorhachis.

Post fossil wood locality:

On the Clarno surface, north and east of Post in Crook County, considerable silicified plant remains may be found. Arnold (1945, 1952) has described a fern stem, Osmundites oregonensis, which is closely related to the fern stems obtained near Currant Creek. The locality is in the northwestern corner of sec. 27, T. 16 S., R. 20 E., 8 miles due east of Post on a small tributary of Crooked River, known locally as Lost Creek, that flows into it from the north.

The author has obtained silicified wood from two areas, one of which is 8 miles due east of Post and the other 3 miles north of the first. Neither of these yielded any coniferous woods in contrast to the Mitchell and Hampton Butte fossil wood localities (see below). Seventeen species have been differentiated, but only a few have been identified with any certainty. The predominant fossil is a sycamore (Platanus), similar to but not identical with any living sycamore with which the author is acquainted. Palm wood and roots, Quercus (one specimen only), and a wide-rayed wood apparently

referable to Cryptocarya are notable. Other genera provisionally identified were Juglans (identical with that occurring at Clarno's Ferry), Vitus, Rhamnus, Magnolia, Ocotea, and Nyssa. Several woods, though not identified as to genera, appear to be identical with specimens obtained from the type locality. It is concluded that the fossil-bearing stratum in this area is slightly younger than that at Clarno's Ferry, or upper Eocene.

Pilot Rock localities:

The most extensively studied flora, outside of the type locality, is that obtained from two locations on East Birch Creek about 10 miles southeast of the town of Pilot Rock in Umatilla County. Leaf impressions (see illustrations) were obtained from a variably textured sandstone dipping 26° due east. The basal beds are an unfossiliferous white tuff, while the sediments are unconformably overlain by northwesterly dipping Columbia River Basalt (middle Miocene). Extensive collections were made by students of the late Dr. Ethel Sanborn of Oregon State College from the NE$\frac{1}{4}$ sec. 7, T. 2 S., R. 33 E., and the SW$\frac{1}{4}$ sec. 12, T. 2 S., R. 32 E. Notes left by Dr. Sanborn and subsequent studies by the author show the presence of the plants listed on the following page.

The only published reference to the composition of the flora at this locality is that of G. M. Hogenson (1957), who includes a third location in the NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 31, T. 2 S., R. 33 E. He reports determinations of 7 species made by R. W. Brown of the U.S. Geological Survey, which are in general agreement with those reported here. From the composition of this flora, the age of the locality is considered to be intermediate between that of the Comstock and Goshen floras of Western Oregon, namely lower Oligocene, and younger than that of the type locality at Clarno's Ferry.

Arbuckle Mountain localities:

A group of Clarno Formation localities yielding abundant remains of palms (Sabalites) occurs in the vicinity of Arbuckle Mountain in Morrow County about 20 miles southeast of Heppner. Two small collections, numbered PF61 and PF62 in the Department museum, include Magnolia sp., Sabalites eocenica, Salix?, and Laurophyllum. Fossils from PF61 were collected in 1945 by C. O. Clark on the headwaters of Johnson Creek, a tributary of Butter Creek, near the divide with Willow Creek in sec. 19, T. 4 S., R. 29 E. Fossils from PF62 are probably from the same general area, but exact location is not available.

Another location known as the Arbuckle Mountain locality, briefly mentioned by Chaney (1948), was discovered by J. E. Allen (1947) during a coal survey for the department. His notes describe the location as being 1$\frac{1}{2}$ miles northwest of Arbuckle Mountain at the junction of the Heppner-Ukiah road with the Arbuckle corral road in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 19, T. 4 S., R. 29 E., 24 miles southeast of Heppner. Fossil leaves were picked up, over a distance of several hundred feet, from a shaly bed in sandstone

which crosses the road junction. It is possible that this locality is the same as PF62.

Allen also mentions that leaf imprints occur in sandstone and shale beds associated with the coal at three mines in the vicinity of the Arbuckle Mountain locality. These are: mine No. 1 in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 20 and mine No. 3 in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 19, both in T. 4 S., R. 29 E., and at mine No. 7 in the NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 34, T. 4 S., R. 28 E.

Allen's mine No. 7 (Willow Creek prospects) was described previously by Mendenhall (1909) af the U. S. Geological Survey, who submitted specimens of fossil plants to F. H. Knowlton for determination. Knowlton reported the following species which he regarded as "upper Clarna" ar upper Eocene:

Monocotyledonous plant ("unknown ta me")
Glyptostrobus cf. G. europaeus Heer
Quercus consimilis? Newberry
Populus sp.?

Hogenson (1957) collected fossil leaves in the Arbuckle Mountain area from "a shale bed underlying massive sandstone bed which forms a ridge top" in the NE$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 20, T. 4 S., R. 29 E. The fossils fram this this location were identified by R. W. Brown as follows:

Aneimia sp.	Quercus banksiaefolia Newberry
Glyptostrobus dakotensis Brown	Magnolia sp.
Sabalites sp.	Carpites verrucosus Lesquereux

Numerous other dicotyledonous leaves

Although the fossils from the Arbuckle Mountain localities have nat been studied completely, it seems likely that they are contemporaneous with the Pilot Rock flora.

Riverside Ranch locality:

A small assemblage of leaf fassils, closely related in composition to those obtained from Cherry Creek, has been described by Chaney (1927). They were obtained on the Riverside Ranch, 34 miles up the Crooked River from Prineville, "one-half mile north of the highway on the west bank of Wickieup Creek" in Crook County. Although only 5 species were characterized (Pinus sp., Quercus furcinervis americana, Sassafras sp., Platanus cf. nobilis, and Rhamnus cleburni), they hold considerable significance. It is questionable if any of these species are present in the Clarno's Ferry, West Branch Creek, or Pilot Rock collections. It appears that this locality is lower to middle Oligocene in age.

Pilot Rock Plant Fossils

Species identified

Cinnamomum acrodromum
Platanus aceroides
Glyptostrobus dakotensis
Equisetum oregonensis
Laurus princeps
Ocotea eocernua
Sabalites eocenica*
Cordia rotunda
Ilex oregona
Siparuna ovalis
Siparuna standleyi
Callichlamys zeteki
Mallotus oregonensis
Magnolia leei*
Ficus goshensis
Persea praelingue*
Anona prereticulata
Laurophyllum merrilli*
Ficus quisamburgii
Magnolia reticulata
Magnolia californica
Goniopteris lesquereuxi
Allantodiopsis erosa
Asimina eotriloba

New species recognized

Tetracera prescandens
Cryptocarya eocenica*
Litsea oregonensis*

Specimens identified only as to genera

Thuites sp.
Ficus cf. F. hispada Linne
Oreodaphne sp.
Calyptranthes cf. C. arbutifolia C. and S.
Nectandra cf. N. presanguinea, C. and S.
Ocotea sp.
Aralia (Platanophyllum)
Rhamnus cf. R. pseudogoldianus Hollick
Credneria sp.
Aristolochia cf. A. mexicana C. and S.
Cryptocarya sp.
Dillenia sp.

* Species illustrated.

Bear Creek and Hampton Butte localities:

A number of authors (Mote, 1939; Bowman, 1940; Lowry, 1940; and others) have suggested division of the Clarno Formation in southern Crook County into a lower and upper member on lithologic grounds. A younger age for an upper division seems also to be justified on the basis of plant fossil differences. Two fossil leaf localities near the junction of the road in the upper Bear Creek Valley (secs. 9 and 17, T. 18 S., R. 17 E.) are mentioned by Lowry (1940). A few specimens from this locality were present in collections at Oregon State College. Although the collection is meager and preservation is only fair, the following could be identified: Thuites sp. Knowlton, Pinus knowltoni, Cercidiphyllum crenatum, Quercus clarnensis, Carpinus grandis, Ostrya oregoniana, Platanus sp., Alnus (?) sp., and Pteris sp. Many of these occur in the Bridge Creek flora (John Day Formation) (Chaney 1927, 1952) and it is possible that these localities might be more properly referred to the John Day because of this.

A few miles to the southeast may be found extensive deposits of fossil wood. These have a composition which is closely related to that of the previously mentioned leaf locality, but which also contains a few subtropical species not present in the John Day. The best collecting appears to be in the Hampton Butte area in sec. 36, T. 19 S., R. 19 E., 12 miles north of the Bend-Burns highway. The silicified wood in this area is frequently colored in green or carnelian shades and therefore is highly prized by hobbyists. Approximately three-fourths of the specimens collected by the author in this area were coniferous, half of these being a species of pine similar to that occurring in the John Day Formation, but definitely not identical. Cypress and Taxodium (bald cypress) or Sequoia (redwood) also appeared to be present. Of the angiosperms, more than half were a Quercus of the live-oak type. Eleven other genera were distinguished, including Cinnamomum, Magnolia, Ocotea, and Platanus. Palm, tree ferns, Juglans, and most other Clarno type-locality genera were absent.

Specimens of fossil wood were also collected at Lowry's (1940) petrified wood locality (SW corner sec. 8, T. 19 S., R. 18 E.). This locality yielded only conifers (Pinus and Taxodium or Sequoia) and sycamore (Platanus), but there is little question about its contemporaneity with the Hampton Butte locality because of the distinctive coloring of the specimens. Bowman (1940) reported the presence of three fossil leaf horizons in the valley of the south fork of Camp Creek (T. 19 S., R. 21 E.), but preservation was poor and only Platanus and Equisetum could be identified. All of the wood studied was either in situ or traceable to its original source.

Mitchell fossil wood locality:

Silicified wood, similar in appearance and composition to that obtained from the Hampton Butte and Bear Creek areas, may be found $1\frac{1}{2}$ miles south of Mitchell in sec. 15, T. 12 S., R. 21 E., on the east side of Nelson Creek. The locality was discovered by Howard (1955) and

mapped as upper Clarno. The wood has been eroded from tuffs and breccias reminiscent of Lowry's and Bowman's "Upper Clarno" member of the Clarno Formation. More than half of the specimens from this area are pine, identical with that found in the vicinity of Hampton Butte. Of the 12 or more angiosperms found at this locality, at least 6 are also identical with those at Hampton Butte. Insufficient work has been done to characterize them completely, but there is little doubt that the flora from both this and the Hampton Butte locality are much more closely related to the subsequent John Day flora than the earlier Clarno type flora. A middle to upper Oligocene age for these localities appears to be justified on the basis of the present evidence.

Conclusion

An examination of the plant fossils from 9 groups of Clarno Formation localities in Central Oregon shows such a diversity of composition that it must be concluded that this formation was laid down over a considerable period of time. Best estimates on the basis of floral evidence suggest a range from middle-upper Eocene to middle-upper Oligocene. This conclusion also coincides with that of some of the more recent lithologic studies (Wilkinson personal communication).

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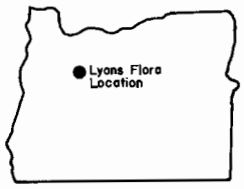
THE OLIGOCENE LYONS FLORA OF NORTHWESTERN OREGON

Herb Meyer
Student, Portland State University

The purpose of this study of the Lyons flora is to determine the age and paleoecology of the flora through the examination and identification of the fossil plant species of the flora.



The plant fossils comprising the Lyons flora were collected from a locality in the upper Thomas Creek area, 5 miles southeast of the town of Lyons, Oregon.

Geologic Occurrence

The beds from which the Lyons flora was obtained are part of the Little Butte Volcanic Series of Oligocene and early Miocene age described by Peck and others (1964). Stratigraphically below the fossil deposit, the Little Butte Volcanic Series is characterized by a pumiceous tuff-breccia which contains blocks and fragments of a volcanic flow rock. This exposure, the base of which is not exposed, underlies the fossil deposit for a thickness of more than 400 feet.

The deposit containing the fossil leaves is composed of a thinly laminated tuffaceous material which has been silicifed to varying degrees. These beds may have been deposited in a shallow, quiet body of water. Lacustrine deposition is suggested by the stratification of the beds, the abundant presence of fossil leaves, and the presence of one water plant in the fossil record.

Composition of the Lyons Flora

Twenty-four identified fossil plants represent the Lyons flora as it is known at this point in the study. Twelve have been identified to species and twelve have been identified only to genus (Table 1).

Ed. note: Herb Meyer was an OMSI student research worker and a winner in the 1972 Westinghouse Science Talent Search.

Table 1. Systematic list of species

GYMNOSPERMAE

GINKGOALES
- GINKGOACEAE
  - *Ginkgo biloba* L.

CONIFERALES
- PINACEAE
  - *Abies* sp.
- TAXODIACEAE
  - *Cunninghamia chaneyi* Lakhanpal
  - *Metasequoia occidentalis* (Newberry) Chaney
  - *Sequoia affinis* Lesquereux
- CUPRESSACEAE
  - *Chamaecyparis* sp.

ANGIOSPERMAE

GLUMIFLORAE
- CYPERACEAE
  - aff. *Cyperacites* sp.

JUGLANDALES
- JUGLANDACEAE
  - *Pterocarya mixta* (Knowlton) Brown

FAGALES
- BETULACEAE
  - *Alnus* sp. 1
  - *Alnus* sp. 2
- FAGACEAE
  - *Castanopsis longifolius* Lakhanpal

ROSALES
- SAXIFRAGACEAE
  - *Hydrangea* sp.
- HAMAMELIDACEAE
  - *Exbucklandia oregonensis* (Chaney) Brown

ANGIOSPERMAE, continued

ROSALES, continued
- PLATANACEAE
  - *Platanus condoni* (Newberry) Knowlton
- ROSACEAE
  - *Rosa hilliae* Lesquereux

SAPINDALES
- ACERACEAE
  - *Acer* sp.
- SABIACEAE
  - *Meliosma* sp.

MALVALES
- TILIACEAE
  - *Tilia* sp.

MYRTIFLORAE
- NYSSACEAE
  - *Nyssa* sp.
- ALANGIACEAE
  - *Alangium thomae* (Chaney and Sanborn) Lakhanpal

ERICALES
- CLETHRACEAE
  - Clethra sp.

CONTORTAE
- OLEACEAE
  - *Fraxinus* sp.
- GENTIANACEAE
  - *Nymphoides circularis* (Chaney) Brown

TUBIFLORAE
- VERBENACEAE
  - *Holmskioldia speirii* (Lesquereux) MacGinitie

Growth habit

The following conclusions regarding the growth habit of the Lyons species have been made through comparisons with the similar living species.

Trees

Ginkgo biloba	Exbucklandia oregonensis
Abies sp.	Platanus condoni
Cunninghamia chaneyi	Acer sp.
Metasequoia occidentalis	Tilia sp.
Sequoia affinis	Nyssa sp.
Chamaecyparis sp.	Fraxinus sp.
Castanopsis longifolius	

Low Trees and Shrubs

Pterocarya mixta	Meliosma sp.
Alnus sp. 1	Alangium thomae
Alnus sp. 2	Clethra sp.
Rosa hilliae	

Vines

Hydrangea sp.	Holmskioldia speirii

Herbs

aff. Cyperacites sp.	Nymphoides circularis (aquatic)

Although this information would seem to indicate that trees comprised most of the vegetation, it should be considered that this type of vegetation is more readily preserved in the fossil record. The larger stature of trees and the greater quantity of their leaves would, as discussed by Lakhanpal (1958), increase the probability of their preservation.

Paleoecology

The interpretations of the paleoecology of the Lyons flora are based upon comparisons with the similar living species and their climatic distribution and upon the analysis of physiognomic leaf characters.

Distribution of similar living species

Table 2 shows the similar living species of the Lyons plants identified to species and the geographical distribution of each. Those plants known only to genus have not been included since most of them have widespread geographical distribution.

The following species, as judged by their similar living species, were typically subtropical: Ginkgo biloba, Castanopsis longifolius, Exbucklandia oregonensis, Platanus condoni, Alangium thomae, and Holmskioldia speirii.

Typically temperate species include the following: Metasequoia occidentalis, Sequoia affinis, Pterocarya mixta, and Rosa hilliae. Cunninghamia chaneyi is both subtropical and temperate. Many genera not included in Table 2 (i.e., Abies, Chamaecyparis, Alnus, Acer, Tilia, and Fraxinus) are predominantly temperate plants, while Meliosma is predominantly subtropical.

Analysis of leaf characters

Certain physiognomic characters of the leaves present information which can be used as an indication of the paleoclimatic conditions under which a flora lived. The analysis of such characters for several floras are shown in Table 3, by percentage.

The length of the leaves has been measured and recorded in two categories: those 10 cm and under and those over 10 cm. Marginal characteristics have been distinguished as entire or non-entire. Entire includes those leaves with no regular indentations along the margin, whereas non-entire includes margins which are lobed, toothed, or have other regular indentations. The occurrence of an abrupt, elongate apex confirms the presence of a dripping point. The texture of the leaves of a species has been determined either as thick or thin.

Large leaves are frequently predominant in the tropical and subtropical floras; smaller leaves occur more frequently in the cooler floras. Leaves with entire margins are typical of climates that are physiologically arid for the plant during part or all of its growing season (i.e., tropical, non-humid

Table 2. Distribution of similar living species

Fossil species	Living species	East Asian	American East	American West
Ginkgo biloba	G. biloba	X		
Cunninghamia chaneyi	C. lanceolata	X		
Metasequoia occidentalis	M. Glyptostroboides	X		
Sequoia affinis	S. sempervirens			X
Pterocarya mixta	P. paliurus	X		
Castanopsis longifolius	Castanopsis spp.	X		
Exbucklandia oregonensis	E. populnea	X		
Platanus condoni	Platanus spp.		X	X
Rosa hilliae	R. palustris		X	
Alangium thomae	A. chinense	X		
Holmskioldia speirii	H. sanguinea	X		
	Total	8	2	2

Table 3. Percentage of leaf characters

Flora	Length		Margin		Dripping point		Texture	
	over 10 cm	under 10 cm	entire	non-entire	present	absent	thick	thin
Lyons	35	65	40	60	10	90	30	70
Bridge Creek	30	70	25	75	10	90	55	45
Muir Woods modern forest	27	73	23	77	9	91	64	36
Scio	33	67	33	67	33	67	44	56
Goshen	53	47	61	39	47	53	98	2
Panama modern forest	56	44	88	12	76	24	98	2

temperate, and arctic climates). Leaves with non-entire margins are more characteristic of humid climates which are not physiologically arid for the plant. Dripping points are usually present only in the large, entire margined leaves of tropical and subtropical floras. Leaves with thick textures are also typical of tropical and subtropical species.

Comparisons with the other floras in Table 3 indicate that the Lyons flora is unlike the subtropical Goshen flora and the more tropical Panama modern forest. A closer similarity to the temperate Bridge Creek and Muir Woods floras is apparent. The Lyons species are quite similar to the Scio species in size, textural, and marginal characteristics. The Scio flora is apparently a semi-subtropical coastal flora, although it has few species in common with the Lyons flora.

Paleoecological conditions of the Lyons flora

The comparison with modern species and the analysis of leaf characters indicate that the Lyons flora contained plants which were both subtropical and temperate, although the temperate species were predominant. Since the Lyons flora grew near the margin of the Oligocene sea, the occurrence of both subtropical and temperate species in the flora can be attributed to the moderate climatic conditions which resulted from the influence of a marine climate. Under such moderate conditions, subtropical species which were typical in the Eocene and early Oligocene floras had survived into the middle Oligocene.

The Lyons flora probably represents a forest which grew near a coastal environment which had a warm temperate climate with mild, moderate temperatures.

Age and Correlation of the Flora

The Tertiary of western North America experienced a climatic cooling trend as this period progressed. Eocene and early Oligocene floras contain typically tropical or subtropical plants. Beginning in the middle Oligocene and continuing through the middle Miocene, climatic changes gave rise to temperate hardwood-conifer forests. Cool temperate floras became

Table 4. Distribution of Lyons species in other Tertiary floras

	Oligocene							Miocene				Plio-cene
	Early		Middle				Late	Early	Middle		Late	Early
Fossil species	Comstock	Florissant	Goshen	Scio	Rujada	Bridge Creek	Weaverville	Eagle Creek	Latah	Mascall	Stinking Water	Troutdale
Ginkgo biloba								X	X	X		
Cunninghamia chaneyi					X							
Metasequoia occidentalis				X	X	X	X					
Sequoia affinis		X			X							
Pterocarya mixta					X				X	X	X	
Castanopsis longifolius					X							
Exbucklandia oregonensis					X	X		X	X			
Platanus condoni					X	X						
Rosa hilliae		X				X						
Alangium thomae			X	X	X	X						
Nymphoides circularis						X						
Holmskioldia speirii		X	X			X						
Species in flora	0	3	2	2	8	7	1	2	3	2	1	0
Species in sub-epoch	3		11				1	2	3		1	0

Table 5. Distribution of Lyons genera in other Tertiary floras

Fossil genera	Oligocene							Miocene				Plio-cene
	Early		Middle				Late	Early	Middle		Late	Early
	Comstock	Florissant	Goshen	Scio	Rujada	Bridge Creek	Weaverville	Eagle Creek	Latah	Mascall	Stinking Water	Troutdale
Abies		X			X	X				X	X	
Chamaecyparis		X										X
Alnus					X	X		X	X	X	X	X
Hydrangea		X	X			X	X		X	X	X	
Acer		X				X		X	X	X	X	X
Meliosma			X									
Tilia		X				X	X	X	X			
Nyssa						X	X	X	X	X		
Clethra												
Fraxinus				X	X	X				X		X
Genera in flora	0	5	2	1	3	7	3	4	5	6	4	4
Genera in sub-epoch	5		8				3	4	7		4	4

predominant by the Pliocene. As these climatic changes occurred, the plant species, and often genera, would change accordingly. Therefore, the plant species from any one sub-epoch ore somewhat distinctive from those of any other.

The age of the Lyons flora is based upon comparisons made with the distribution of the same plant species in other Tertiary floras, as shown in the correlation charts (Tables 4 and 5). It is most probable that the age of the Lyons flora is equivalent to the age of those floras which contain the largest number of species in common with it.

Table 4 shows the distribution of the Lyons plants identified to species; Table 5 shows the distribution of the plants identified only to genus. Those plants known to species are most useful for age determination, whereas those known to genus actually reveal little information about age. This is due to the fact that many of the genera are widely distributed throughout the Tertiary epochs, while species are more limited to a single epoch or sub-epoch.

The table showing the distribution of plants identified to genus is included primarily to show their distribution in other floras.

The correlation of those twelve plants identified to species (Table 4) indicates a close resemblance to middle Oligocene floras. Representation of Lyons species in the subtropical early Oligocene floras is less prominent. Cool temperate floras that are younger than late Oligocene age also show little similarity to the Lyons flora. Resemblance to the middle Oligocene Bridge Creek and Rujada floras of Oregon on the basis of species is noteworthy. The Lyons plants bear eleven species in common to the floras of this sub-epoch; seven species are common to the Bridge Creek flora and eight are common to the Rujada flora. This evidence would indicate that the Lyons flora is of middle Oligocene age.

As pointed out, generic comparisons have a limited value when used in age determination. However, the information from Table 5 confirms the placement of the Lyons flora in the middle Oligocene to Miocene group. The abundance of genera in common with the early and middle Miocene floras does not contradict the middle Oligocene placement of the Lyons flora; many of the Oligocene genera survived into the early and middle Miocene.

Holmskioldia speirii, a species abundant in the Lyons flora, is not known regionally in floras younger than middle Oligocene age. It can, therefore, be used as an indication of pre-late Oligocene age in a flora. Accordingly, its presence in the Lyons flora confirms the pre-late Oligocene age of the flora.

The close resemblance of the Lyons flora to the Bridge Creek and Rujada floras and the pre-late Oligocene age indicated by Holmskioldia speirii indicate that the age of the Lyons flora is middle Oligocene.

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Explanation of plates

PLATE I.

Figure 1. Ginkgo biloba L.
Figure 2. Cunninghamia chaneyi Lakhanpal
Figure 3. Metasequoia occidentalis (Newberry) Chaney
Figure 4. Sequoia affinis Lesquereux
Figures 5, 6. Pterocarya mixta (Knowlton) Brown
Figure 7. Hydrangea sp.

PLATE II.

Figure 1. Castanopsis longifolius Lakhanpal
Figure 2. Alnus sp. 2
Figure 3. Alnus sp. 1
Figure 4. Alnus "cones"
Figure 5. Chamaecyparis sp.
Figures 6, 7. Exbucklandia oregonensis (Chaney) Brown

PLATE III.

Figure 1. Platanus condoni (Newberry) Knowlton (Reduced X 2/3)
Figure 2. Rosa hilliae Lesquereux
Figures 3, 4. Holmskioldia speirii (Lesquereux) MacGinitie

PLATE IV.

Figure 1. Meliosma sp.
Figure 2. Tilia sp.
Figure 3. Nyssa sp.
Figure 4. Fraxinus sp.
Figure 5. Acer sp.

PLATE V.

Figures 1, 3. Alangium thomae (Chaney and Sanborn) Lakhanpal
Figure 2. Clethra sp.
Figure 4. Nymphoides circularis (Chaney) Brown

All figures are natural size unless otherwise noted.

PLATE I

fig. 1

fig. 2

fig. 3

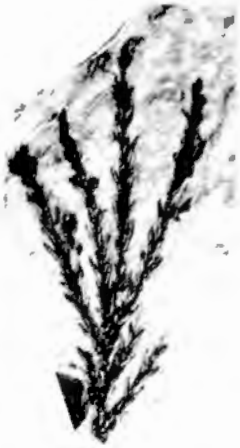

fig. 4

fig. 5

fig. 6

fig. 7

PLATE II

fig. 1

fig. 2

fig. 3

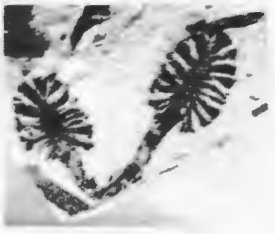

fig. 4

fig. 5

fig. 6

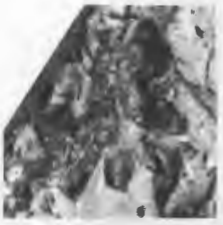

fig. 7

PLATE III

fig. 2

fig. 3

fig. 4

PLATE IV

fig. 1

fig. 2

fig. 3

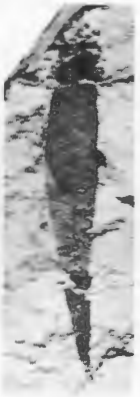

fig. 4

fig. 5

PLATE V

fig. 1

fig. 2

fig. 3

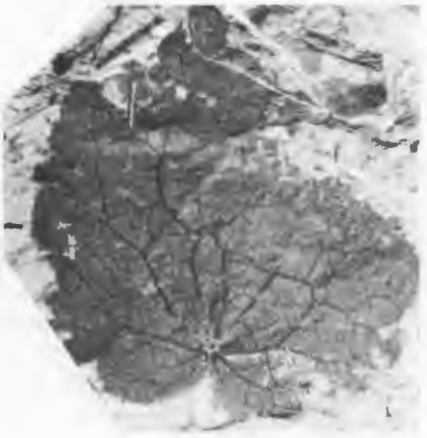

fig. 4

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PRELIMINARY REPORT ON FOSSIL FRUITS AND SEEDS FROM THE MAMMAL QUARRY OF THE CLARNO FORMATION, OREGON

By Thomas M. McKee*

The Department encourages students of geology and paleontology to submit original articles of scientific merit for publication in The ORE BIN. This paper by Thomas M. McKee on the fossil fruits and seeds from the Mammal Quarry site in the Clarno Formation is a noteworthy example of what a young person with aptitude, motivation, and guidance can achieve.

Tom McKee, a recent graduate of Jefferson High School in Portland, has been keenly interested in paleobotany since elementary school days. He is a member of the Oregon Museum of Science and Industry Student Research Center and is on the paleontology research team at Camp Hancock. His work on fossil fruits and seeds from the Mammal Quarry won him a number of state and national awards, including one in the Westinghouse National Science Talent Search. This report, originally printed in mimeograph form by the OMSI Student Research Center, is published here with only slight alterations. --- Ed.

Introduction

During the summer of 1969 the author was a member of the Vertebrate Paleontology Research Team of the Oregon Museum of Science and Industry. This team consisted of eight high school students and a field director. The team's objective was to recover vertebrate fossils from the Clarno Formation Mammal Quarry near Clarno, Oregon. It was evident from previous excavations that abundant fossil plant material was located in the middle and lower units of the quarry. Therefore it was decided to collect and study the fossil fruits and seeds associated with the

* Oregon Museum of Science and Industry Student Research Center, Portland, Oregon

vertebrate fossils, allowing a more complete reconstruction of the paleoecology of the Clarno Mammal Quarry site and a detailed analysis of the depositional environment.

This paper is a preliminary report on the fossil seeds and nuts so far collected and studied by the author. He expects to continue his research on plant material at the Clarno Mammal Quarry site and extend his studies to adjacent areas.

Geologic Occurrence

The Clarno Mammal Quarry (OMSI Loc. No. ONT-1) is located about 2 miles east of Clarno, Oregon, in the NE¼ sec. 27, T. 7 S., R. 9 E., in the Clarno quadrangle, Wheeler County. The quarry is in the Clarno Formation, which is widely exposed throughout central Oregon. R. L. Hay (1963, p. 201) states that "The Clarno Formation consists largely of lava flows and volcanic breccias, but volcanic conglomerates and sandstone, claystones and vitric tuffs are common in some places. The various lithologic units interfinger laterally and no units have been found which are sufficiently widespread to subdivide the formation over a distance of more than ten miles. The full thickness of the formation is about 5000 feet...."

In the area of the Clarno Mammal Quarry, the Clarno Formation consists of interbedded mudflows and tuffs and andesitic lavas that have been altered both hydrothermally and by weathering. The upper limit of the Clarno Formation is a subject of debate, but it is usually accepted that the lower member of the overlying John Day Formation (upper Oligocene) was deposited on the surface of the eroded Clarno Formation. Well-core data from the vicinity of the Clarno Mammal Quarry show that the Clarno Formation rests unconformably on Cretaceous marine sediments (figure 1).

Previous Work

The Clarno Formation was considered to be upper Eocene by Merriam (1901) in his original description of the formation. This age determination was based on the analysis of fossil leaf remains from the Clarno Formation by Knowlton, who published his findings in 1902. Chaney (1952) considered the Clarno Formation as middle and upper Eocene, also based on fossil leaf remains. Scott (1954) described the fossil flora of the Nut Beds of the Clarno Formation and stated that "The affinities of the fruits and seeds substantiate the Eocene age of the Clarno Formation and suggest, but do not confirm, that it is older than upper Eocene." Mellett (1969) describes a partial skull of Hemipsalodon grandis, a large Pterodon-like hyaenodontid from the Clarno Mammal Quarry. Mellett states that Hemipsalodon is stratigraphically limited to the early Oligocene. Bruce Hansen of the University of California, Berkeley, who is working on the Clarno vertebrate fauna, states (oral communication, 1969) that the two prepared brontothere

ERA	Period	Epoch	Millions of years ago	Series	Formation
CENOZOIC	Quaternary	Pleistocene			Alluvium
					Erosion
			2 - 3		Rattlesnake Fm.
	Tertiary	Pliocene		upper	
				middle	Erosion
				lower	Mascall Fm.
			12		
		Miocene		upper	Columbia River Basalt
				middle	Erosion
				lower	John Day Fm.
			26		
		Oligocene		upper	
				middle	Erosion
				lower	Clarno Fm.
			38		
		Eocene		upper	
				middle	Erosion
				lower	
			54		
MESOZOIC	Cretaceous				Undifferentiated marine sediments
			136		

Figure 1. Generalized geologic time chart showing age relationship of the Clarno Formation.

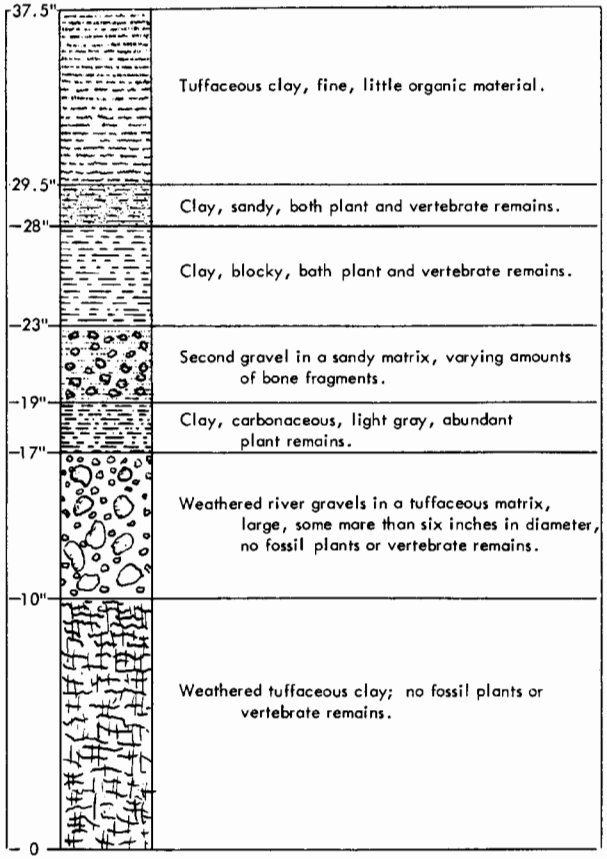

Figure 2. Measured section of the Clarno Mammal Quarry.

mandibles collected from the Clarno Mammal Quarry during 1969 seem to be of species limited to the Oligocene (figure 1).

Stratigraphic Relationships

An occurrence of fossil plant remains known as the Clarno Nut Beds (Scott, 1954) is found approximately half a mile southwest of the Clarno Mammal Quarry. Stratigraphically above the Nut Beds is a deposit known locally as Red Hill. This deposit consists of a clay soil weathered from tuffaceous sand and volcanic dust (Taylor, 1960).

Taylor ran a series of tests on the red tuffs at Red Hill and on the tuff that occurs at the Clarno Mammal Quarry. He found that the two tuffs are texturally similar. The Clarno ignimbrite caps both the Red Hill and the Clarno Mammal Quarry tuffs. This seems to place the Clarno Mammal Quarry in the same clay stratum as the red tuff which occurs at Red Hill. Based on the textural similarity and the fact that the Clarno ignimbrite caps both deposits, the author assumes that the Clarno Mammal Quarry was deposited at the same time as the tuffs of Red Hill. Therefore, the Clarno Nut Beds, which occur stratigraphically below Red Hill, are older in age than the Clarno Mammal Quarry, although the difference may be very slight.

Age

A potassium-argon date of 34.5 million years was determined for the Clarno Nut Beds by Evernden, Curtis, and James (1964). The assumption then can be made that the Clarno Mammal Quarry is younger than 34.5 million years. Placement of the quarry in the early Oligocene agrees with the suggested assignments to early Oligocene age based on vertebrate remains from the Clarno Mammal Quarry by both Mellett (1969) and Hansen (oral communication, 1969).

Stratigraphy at the Clarno Mammal Quarry

The Clarno Mammal Quarry occurs in a large slump block of tuffaceous clays that appears to have moved down slope about 40 feet from its original position. Capping the clays is the Clarno ignimbrite which is used as the marker bed for the displaced sediments. To the east of the main quarry and about 40 feet above the fossil-bearing level of the main quarry is a smaller mammal deposit. The beds at this second deposit probably represent part of the main quarry beds not displaced by slumping.

On the basis of limited excavation, the general stratigraphy of the deposit shows distinctly stratified sediments dipping 12° northwest and striking N. 30° E. (figure 2). The sediments at the bottom of the excavation appear to be a highly weathered tuffaceous clay. Resting on this clay is a deposit consisting of highly weathered river gravels composed of chert

and tuffaceous cobbles in a tuffaceous matrix. The larger cobbles in this unit are more than 6 inches in diameter. Lying on the river gravels is a carbonaceous unit of very fine, light-gray clay containing abundant plant remains. Directly above this carbonaceous unit is a second gravel in a sandy matrix which contains varying amounts of bone fragments. Resting on the second gravel is a deposit of blocky clay containing both vertebrate and plant remains. The blocky clay underlies a thin unit of sandy clay containing both plant and vertebrate remains. The top unit in the excavation consists of a fine tuffaceous clay containing little organic material.

Floral Composition

Of the 204 specimens of fossil fruits and seeds recovered from the Clarno Mammal Quarry, 39 have been identified. The unidentified material is so poorly preserved that identification is either unreliable or impossible. All identified specimens belong to the Phylum SPERMATOPHYTA, Class ANGIOSPERMAE, Subclass DICOTYLEDONAE. Four families and six genera are represented in the identified flora, with three identified to the species level.

Systematic List

Phylum: SPERMATOPHYTA
- Class: ANGIOSPERMAE
  - Subclass: DICOTYLEDONAE
    - Family: JUGLANDACEAE
      - Genus: JUGLANS Linnaeus
        - *Juglans clarnensis* Scott
    - Family: MENISPERMACEAE
      - Section: TINOSPOREAE Diels
        - Genus: ODONTOCARYOIDEA Scott
          - *Odontocaryoidea nodulosa* Scott
      - Subsection: COCULINAE
        - Genus: DIPLOCLISIA
          - *Diploclisia* sp.
    - Family: ICACINACEAE
      - Section: PHYTOCRENEAE Engler
        - Genus: PALAEOPHYTOCRENE
          - *Palaeophytocrene* cf. *P. foveolata* (Reid & Chandler)
    - Family: VITACEAE
      - Genus: VITIS (THURNBERG) Linnaeus
        - *Vitis* sp.
      - Genus: TETRASTIGMA Planchon
        - *Tetrastigma* sp.

The genus DIPLOCLISIA is the most abundant plant represented in the Clarno Mammal Quarry flora with 31 specimens having been recovered. Second in abundance is the species Odontocaryoidea nodulosa with three specimens (figure 3).

Species	No. of specimens
Juglans clarnensis	1
Odontocaryoidea nodulosa	3
Diploclisia sp.	31
Palaeophytocrene cf. P. foveolata	2
Vitis sp.	1
Tetrastigma sp.	1
Total	39

Figure 3. Numerical data.

Systematic Relationships

Phylum: SPERMATOPHYTA

Class: ANGIOSPERMAE

Subclass: DICOTYLEDONAE

Family: JUGLANDACEAE

Genus: JUGLANS Linnaeus

Juglans clarnensis Scott

(Plate 1, figures 1-2)

Specimen: OMSI No. PB-1.

Discussion: One specimen of this species was found, consisting of a lateral half of the cotyledon. The specimen is a cast that is slightly compressed, distorting the two lateral halves of the primary embryo lobes. The surface of the lobes is smooth. Length: 11 mm.; width in the plane of dehiscence is distorted; thickness (at right angles to plane of dehiscence) 11 mm.

Family: MENISPERMACEAE

Section: TINOSPOREAE Diels

Genus: ODONTOCARYOIDEA Scott

Odontocaryoidea nodulosa Scott

(Plate 1, figures 5-6)

Specimen: OMSI No. PB-31.

Discussion: Three specimens of this species were recovered. All are locule casts with a carbonaceous cover which appears to have been the exocarp. The specimens have been slightly compressed. The locule cast is elongate, length: 22-28 mm.; width: 5 mm.; thickness: undeterminable owing to compression; and deeply boat shaped. The apical end is pointed, the shoulder region slopes, and the basal end is blunt with a small median projection. The dorsal side is smooth, with a slight median ridge marking the suture. The ventral side is concave.

Family: MENISPERMACEAE

Section: TINOSPOREAE Diels

Subsection: COCULINAE

Genus: DIPLOCLISIA Miers

Diploclisia sp.

(Plate 1, figures 3-4)

Specimen: OMSI No. PB-6.

Discussion: This genus has the largest representation in the Clarno Mammal Quarry flora, with 31 specimens consisting of both locule casts and

impressions. Most of the specimens show the flattened interface of one valve of the endocarp in the plane of dehiscence. This view shows the horseshoe-shaped ring of about 22 large tubercles with corresponding hollows between them, surrounding a slightly elevated flat surface. The walls of the specimen appear to consist of radially directed coarse fibers and are thick with a pronounced ridge extending completely around the horseshoe-shaped ring. Length: 9-11 mm.; width in plane of dehiscence: 5-7 mm.; thickness: undeterminable owing to compression.

Family: ICACINACEAE

Section: PHYTOCRENEAE Engler

Genus: PALAEOPHYTOCRENE Reid & Chandler

Palaeophytocrene cf. P. foveolata Reid & Chandler

(Plate 2, figures 3, 4, 4a)

Specimen: OMSI No. PB-37.

Discussion: Two incomplete locule casts of this species were recovered from the Clarno Mammal Quarry. Their estimated length is 14-16 mm.; width 7-9 mm.; and the thickness indeterminable. There are approximately 7-8 surface pits lengthwise and 5-6 pits across the width. These incomplete specimens compare favorably with the species Palaeophytocrene foveolata.

Family: VITACEAE

Genus: VITIS (Thurnberg) Linnaeus

Vitus sp.

(Plate 2, figures 5-6)

Specimen: OMSI No. PB-39.

Discussion: One complete seed of this genus was recovered from the Clarno Mammal Quarry. The seed is split into two parts along the raphe ridge and is distorted by compression. It is obovoid with smooth contours sharply pointed at the apex and rounded at the base. Length of seed: 3 mm.; width 2.3 mm.; thickness: undeterminable. The specimen has been compared at the Oregon Museum of Science and Industry to No. 984 of the

Hancock collection from the Clarno Nut Beds.

The Clarno Mammal Quarry specimen does not appear to represent the London Clay species Vitis pygmaea. The London Clay species, Vitis pygmaea, differs from this specimen in the appearance of the apex, which is highly stipitate in Vitis pygmaea but smooth in the Clarno specimen. Moreover, the raphe ridge of the Clarno specimen extends onto the apex, but not in the London Clay species; and the ventral infolds are much narrower in the London Clay species.

Family: VITACEAE

Genus: TETRASTIGMA Planchon

Tetrastigma sp.

(Plate 2, figures 7, 8, 8a)

Specimen: OMSI No. PB-40.

Discussion: One complete seed of this genus was recovered. The seed is ovate and is ornamented with prominent radial lobes separated by deep furrows. The raphe ridge extends the length of the ventral face. Length: 5 mm.; width: 3.5 mm.; thickness: undeterminable.

ANGIOSPERM

INCERTAE SEDIS

(Plate 2, figures 1-2)

Specimen: OMSI No. PB-34.

The specimens consist of three much compressed fruiting heads which are only partially intact, preventing identification. Diameter of globular fruiting heads is 18-22 mm.

Relation of Living and Fossil Floras

Present-day distributions of the modern equivalent genera of the fossil plant remains so far identified in the Clarno Mammal Quarry flora have habitats ranging from cool-temperate to exclusively tropical (see figure 4). However, the majority of the identified fossil genera (4 of 6) have modern equivalents living in subtropical to tropical habitats.

Fossil Genus	Nearest modern equivalent	Habitat
Juglans	Juglans	Tropical to cool temperate
Odontocaryoidea	Odontocarya	Lowland tropical
Diploclisia	Diploclisia	Tropical to sub-tropical
Palaeophytocrene	Phytocrene	Lowland tropical
Vitis	Vitis	Tropical to cool temperate
Tetrastigma	Tetrastigma	Subtropical and lowland tropical

Figure 4. Present-day distribution of the nearest modern equivalent genera.

The nearest modern equivalents to identified fossil genera of the Clarno Mammal Quarry have a wide geographical distribution ranging from Canada to many tropical areas in the Old World. A majority of the modern equivalents (5 of 6) are found in India and Ceylon (figure 5).

The Clarno Mammal Quarry fruit and seed genera are found in several other Tertiary floras in the New and Old Worlds. The Clarno Nut Beds correlate best with the Clarno Mammal Quarry by having all six genera present. The lower Eocene London Clay Flora of England comes next, with four out of six genera represented (figure 6).

Summary

This report is preliminary to further collecting and study at both the Clarno Mammal Quarry and the Clarno Nut Beds.

Based on the information previously discussed, the author concludes that the Clarno Mammal Quarry is younger than the Clarno Nut Beds, and probably early Oligocene in age. This assignment agrees with age determinations of vertebrate remains from the Clarno Mammal Quarry.

The 39 identified specimens indicate the presence of a tropical to subtropical climate at the site of the Clarno Mammal Quarry during early Oligocene time. Based on the limited flora identified, the composition of the Clarno Mammal Quarry flora appears to be essentially the same as the flora found in the Clarno Nut Beds.

EXPLANATION OF PLATE I

Juglans clarnensis Scott - Page 122

Fig. 1. OMSI No. PB-1. The lateral half of the cotyledon. The specimen has been compressed, distorting the two lateral halves of the primary embryo lobes. 3 X

Fig. 2. Drawing showing the loteral half of the cotyledon and the correct position of the two lateral halves of the primary embryo lobes. 3 X

Diploclisia sp. - Page 123

Fig. 3. Drawing showing the horseshoe-shaped furrow enclosing the plug. 3 X

Fig. 4. OMSI No. PB-6. The flattened interface of one valve of the endocarp showing the horseshoe-shaped ring of tubercles and corresponding hollows. 7.5 X

Odontocaryoidea nodulosa Scott - Page 123

Fig. 5. OMSI No. PB-31. Dorsal side showing a slight median ridge marking the suture. 3 X

Fig. 6. Same, ventral side concave, showing the pointed apical end, blunt basal end with a small median projection, and the sloping shoulder region. 3 X

EXPLANATION OF PLATE II

Incertae sedis - Page 125

Fig. 1. OMSI No. PB-36. Fruiting head partially intoct, showing awns. 3 X

Fig. 2. OMSI No. PB-34, the same. 3 X

Palaeophytocrene cf. P. foveolata - Page 124

Fig. 3. OMSI No. PB-37. Incomplete locule cast, showing surface pits. 3 X

Fig. 4. OMSI No. PB-38, the same. 6 X

Fig. 4a. Drawing showing external shape of complete locule cast in relationship to fig. 4. 3 X

Vitis sp. - Page 124

Fig. 5. OMSI No. PB-39. One-half of the obovoid seed, split down the raphe ridge. 3 X

Fig. 6. The same. Other half of the seed in matrix. 9 X

Tetrastigma sp. - Page 125

Fig. 7. OMSI No. PB-40. Impression of seed in matrix. 6 X

Fig. 8. The same. Obovate seed showing its ornamentation with prominent radial lobes separated by deep furrows and the raphe ridge which extends the length of the ventral face. 6 X

Fig. 8a. Drawing of fig. 8, emphasizing the radial lobes and deep furrows and the prominent raphe ridge. 3 X

PLATE I

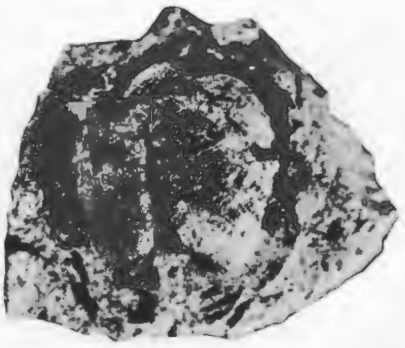

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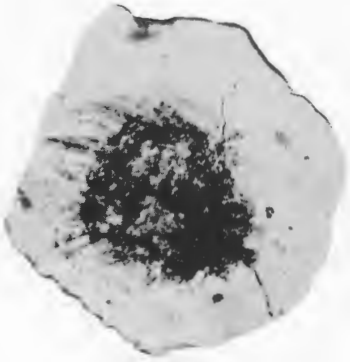
PLATE II



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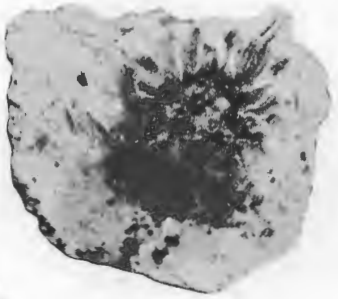

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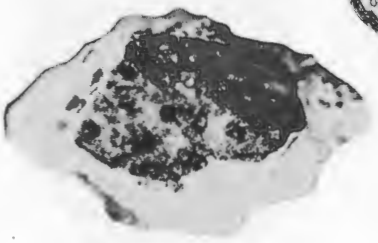

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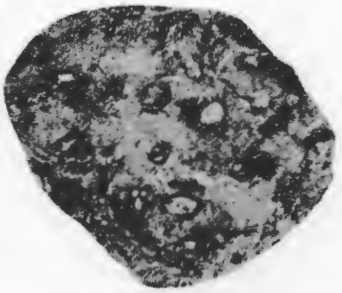

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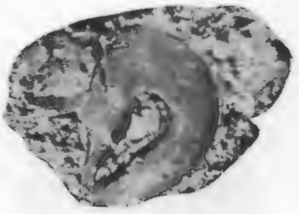

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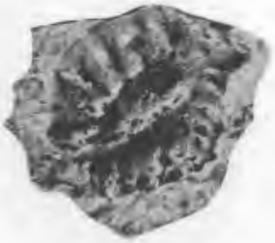

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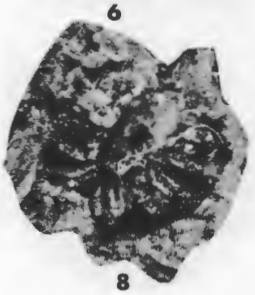

8

Fossil genus	Nearest modern equivalent	CANADA	UNITED STATES	MEXICO AND CENTRAL AMERICA	HIMALAYAS	JAPAN AND NORTH CHINA	SOUTH CHINA AND BURMA	INDIA AND CEYLON	FURTHER INDIA	MALAY PENINSULA	MALAY ISLANDS	TROPICAL AFRICA	PHILIPPINES
Juglans	Juglans	X	X	X	X	X		X					
Odontocaryoidea	Odontocarya			X									
Diploclisia	Diploclisia						X	X		X	X		
Palaeophytocrene	Phytocrene							X	X	X			X
Vitis	Vitis		X	X	X	X	X	X	X	X	X	X	X
Tetrastigma	Tetrastigma				X		X	X	X	X	X		X

Figure 5. Geographical distribution of the nearest modern equivalents of the Clarno Mammal Quarry fruit and seed genera.

Genera	Clarno Nut Beds	Chalk bluffs	London Clay	Lower Bagshot	Bournemouth
Juglans	X				
Odontocaryoidea	X		X		
Diploclisia	X				
Palaeophytocrene	X	X	X		
Vitis	X		X	X	X
Tetrastigma	X		X		

Figure 6. Occurrence of Clarno Mammal Quarry fruit and seed genera in other Tertiary floras.

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FRESHWATER FISH REMAINS FROM THE CLARNO FORMATION OCHOCO MOUNTAINS OF NORTH-CENTRAL OREGON

By Ted M. Cavender
Museum of Zoology, University of Michigan

Introduction

Recent collecting at exposures of carbonaceous shale in the Clarno Formation west of Mitchell, Oregon has produced a small quantity of fragmentary fish material representing an undescribed fauna. The fossils were found in the Ochoco Mountains along U.S. Highway 26 where it crosses the mountains near Ochoco Summit. The fossil-bearing site in the black shales is named the Ochoco Pass locality and the fish remains described herein are referred to the Ochoco Pass local fauna. Although this fauna, at present, is a small one, it holds considerable interest from two standpoints. First, it is on older Tertiary fish fauna of later age than the famous middle Eocene Green River fauna, but earlier than the more numerous middle Tertiary fish faunas of western North America. Second, the fossils may help to shed some light on the depositional environment of the Ochoco Pass black shales. The shales at one time or another have been regarded as marine sediments (Pigg, 1961, p. 61).

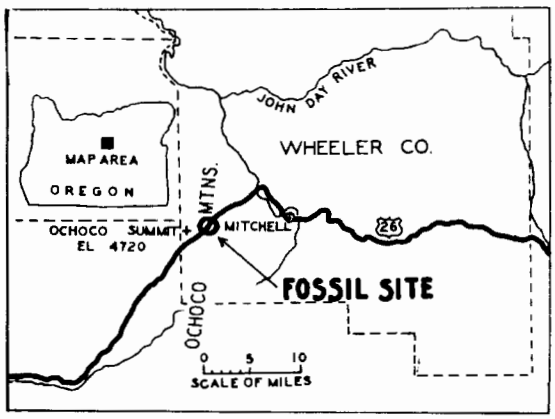

Figure 1. Map showing location of the Ochoco Pass locality.

This paper is intended as an initial systematic account of the fish remains at the Ochoco Pass locality. At present, the known fossil fish material is so scant and poorly preserved that only tentative identifications are possible. Considerable effort has been made to compare the Ochoco Pass fossils with pertinent forms previously described from early to middle Tertiary deposits in North America, and with similar Recent forms.

Of the Ochoco Pass specimens I have studied, one of the first to be collected and recognized as fish was loaned to me by its collector, Margaret Steere, geologist for the State of Oregon Department of Geology and Mineral Industries. The bulk of

material and some of the best specimens were collected during several visits to the locality in 1963 and 1966 by Lee Jenkins of Hood River, Oregon. I am very grateful to the latter for his considerable contribution to this project. Other specimens were collected in August 1966 by a field party consisting of Michael Uhtoff, Michael Lappé, Lee Jenkins, and the author.

Location and Geology

All of the fossil fish material came from a deep road cut on U.S. Highway 26, 13.5 miles west of Mitchell, in the W$\frac{1}{2}$ sec. 17, T. 12 S., R. 20 E., Wheeler County, Oregon. This road cut is approximately 2.7 miles northeast of Ochoco Summit. The fossil site is indicated on the map (fig. 1). Good exposures of carbonaceous shale occur in the vertical cuts on both sides of the road. The fossils were found on slabs of shale pried loose from the walls in the bosal 10 feet of the road cut (fig. 2).

The geology in the vicinity of the fossil fish locality is summarized by the Oregon Department of Geology and Mineral Industries os follows:

> The Ochoco Pass locality is underlain by the Clarno Formation, which is widely distributed throughout central Oregon. According to Wilkinson (1959), the formation is composed largely of terrestrial volcanic rocks having similar lithalogies from place to place but representing variable times of deposition. Of particular importance in the Clarno are lenses of tuffaceous sediments containing fossil plants and a mammalian fauna. The formation rests unconformably on Cretaceous marine beds in the vicinity of Mitchell and is unconformably overlain by the John Day Formation of late Oligocene to early Miocene age. This relationship, in addition to fossil studies and several potassium-argon dates, places the age of the Clarno as Eocene to early Oligocene.
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> In respect to the stratigraphic horizon occupied by the fossil fish described in this paper, the particular shale bed is in the lowest of three Clarno units mapped by Swarbrick (1953) in an unpublished master's thesis on the geology of this area. Swarbrick (p. 36-44) writes: "Unit 1 of the Clarno Formation cansists of extensive andesitic mudflows, volcanic flow breccia, and localized leaf-bearing tuffs and tuffoceous sediments. The sediments include interbedded tuffaceous, carbonaceous shale and sandstone, overlain by tuffaceous volcanic cobble conglomerate."
>
> "Total thickness of unit 1 is about 2100 feet of which 600 feet are tuffaceous sediments and 1500 are volcanic breccia and andesitic mudflow."
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> The younger Clarno rocks in the area mapped by Swarbrick cansist of unit 2, basaltic flows and flow breccia; and unit 3, local dacite flows.

Preservation of Fossils

Most of the fossils are disarticulated fish bones and scales, some of which are fragmented. The bone is usually in the form of a thin, carbonaceaus film, but typically a full imprint of the bone is preserved. The very fine surrounding sediment is pitch black to dark gray and much compacted, forming dense shale layers that fracture conchoidally. Some of the rock resembles a mudstone. Smooth fracture (shear) planes also are apparent at angles to the bedding planes. The shale layers are so broken that only small pieces could be removed from the outcrop.

Figure 2. Above: Road cut, Ochoco Pass locality. Individuals approximately opposite site of fish beds; looking northeast. Below: Closeup showing fish-scale horizon where individuals are working.

Methods of Study

The specimens were prepared for study by removing the carbonized bone. Latex casts were then made from the resulting imprints. This technique produces a fairly good duplication of the original bone. Ammonium chloride was used to highlight surface features on the casts which were stained black by means of India ink mixed with the liquid latex. Photographs were made of the casts using a 35-mm Miranda single-lens reflex camera, bellows attachment and 50-mm Soligor lens, incandescent lighting or electronic flash, and Plus-X film.

I have made full use of the osteological collections of the University of Michigan Museum of Zoology (UMMZ) for making comparisons with the various fossil fish bones. The abbreviation "SL" means standard length, which is the distance from the most anterior part of a fish's snout to the base of its caudal fin.

The scale terminology is that of Lagler (1947). Except where stated, the Ochoco Pass fossils are housed in the University of Michigan Museum of Paleontology (UMMP). Comparative fossil material studied is housed in the Harvard Museum of Comparative Zoology (MCZ), the American Museum of Natural History (AMNH), the United States National Museum (USNM), and the National Museum of Canada (NMC).

Paleontological Descriptions

Amiidae (bowfins)
cf. Amia Linnaeus
Plate I, 7. Plate II, 2 and 3.

Material -- 15 isolated scales, most of them complete; the largest is 16 mm, the smallest is 6 mm long.

Remarks -- Among the scales of the living freshwater fishes of North America, those of Amia calva are very distinctive (Lagler, 1947). Scales of fossil Amia, including those from the Ochoco Pass locality, differ very little from the scales of the Recent bowfin. Amia or amiid scales are known from freshwater deposits extending, in age, through much of the Tertiary of western North America. These deposits include the Eocene Bridger Formation, Wyoming (Cope, 1884), Eocene Green River shales (Yale Peabody Museum No. 3009), Eocene Horsefly River beds of British Columbia (NMC collections), Oligocene Florissant Lake Beds, Colorado (Cope, 1884), Oligocene Ruby shales, Montana (UMMP collections), and Oligocene Grant shales, Montana (UMMP collections). For the age determinations applied to the last three fossil-bearing deposits, I have referred to the following authors: MacGinitie (1953) -Florissant Lake Beds; Becker (1961) - Ruby shales; and Becker (1962) - Grant shales.

Hiodontidae (mooneyes)
cf. Hiodon Leseur
Plate I, 8 and 9. Plate II, 9.

Material -- several isolated scales.

Remarks -- The existence of a hiodontid in the Ochoco Pass fauna is based on identification of scales alone. The scales illustrated here, when compared with those of

Hiodon tergisus and Hiodon alosoides, show no marked differences. The scale of Hiodon possesses around 10 to 15 basal radii, the lateral basal corners are strong, the focus is apical in position and transversely ovoid in shope, the circuli are very fine, and a few faint, incomplete radii are usually observable in the apical field. Most Hiodon scales are not symmetrical but have one side longer then the other. Some of the fossil scales show this character, also.

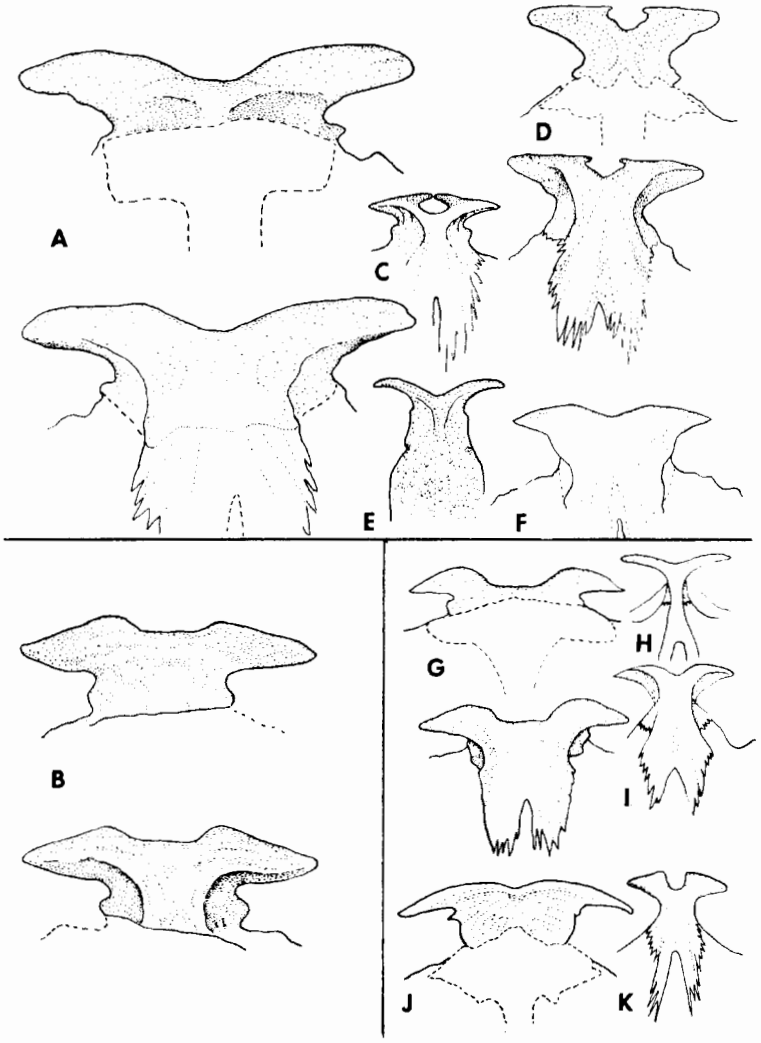
Siluriformes (catfishes)
Family: indeterminate
Plate IV, 1-3

Materials -- a nearly complete supraethmoid, broken left cleithrum, and a complete (right?) pelvic bone.

Remarks --The bones in question are not readily assignable to any New or Old World catfish family. Catfish in general have a number of very characteristic skeletal elements, two of which are the supraethmoid of the skull and the cleithrum of the pectoral girdle. Unfortunately, in this case, where the supraethmoid and cleithrum are disarticulated and broken, taxonomic determination even to family is exceedingly difficult or impossible. Tilak (1963b) found that the complete pectoral girdle is a useful systematic character at the family level in siluriforms and the same appears to be true of the ethmoid region. Figure 3 gives a general idea of the form of the supraethmoid in a few fossil and Recent catfishes. A shallow and braad anterior notch in the supraethmoid is found in many siluriforms, usually where the premaxillary supporting processes are well developed. The deeper, partly enclosed, notch of Ictalurus (Ictaluridae) (fig. 3D) is repeated in Mystus planiceps (Bagridae), (fig. 3C).

The catfish supraethmoid from the Ochoco Pass locality (fig. 3B; plate IV, 1) has the broad, shallow notch in the anterior margin. In this character, it resembles somewhat the ictalurid Pyladictis olivaris, and, among the North American fossils, "Ameiurus" primaevus Eastman (1917), fig. 3F, and "Rhineastes" sp. (MCZ 8500, fig. 3A). Dorsally, the supraethmoid is constricted between the nasal capsules into a fairly narrow bridge connecting the premaxillary supporting processes to the frontals. This ethmoid bridge is excavated at each side, forming the mesial walls of the nasal capsules as in Ictalurus. It should be noted for comparative purposes that, posteriorly, the supraethmoid in Ictalurus cavers, in part, the anterior extension of the brain case into the ethmoid region (Starks, 1926). Tilak (1965) stated that such an anterior cranial cavity is characteristic of most siluriforms with the main exception of the Ariidae. The anterior portion of the supraethmoid consists of the processes (mentioned above) which are large and directed laterally. To these are attached, ventrally, the premaxillary tooth plates. In the possession of a constriction between the nasal capsules in combination with lateral excavation, the Ochoco Pass supraethmoid resembles that of Ictalurus furcatus (fig. 3D) and a number of Old World catfishes. "Ameiurus" primaevus does not have this constriction and "Rhineastes" sp. (MCZ 8500) shows only a slight indication of such. Underneath the constriction, the Ochoco Pass supraethmoid (mesethmoid) is expanded into a broad oval plate of bone that forms a seat for the head of the vomer and also sutures, posteriorly, with the anterior end of the parasphenoid. Rhamdia (Pimelodidae) does not have such a noticeable expansion of the supraethmoid, nor do the ariids, Arius (Galeichthys) and Potamarius. The ventral supraethmoid plate is well defined in ictalurids.

The Ochoco Pass cleithrum (plate IV, 3) consists only of the middle portion of



the bone; both the anterior and dorsal extensions are missing. There is a strong humeral process. Large confluent ridges cover the lateral surface of the cleithrum.

Of particular importance is the single pelvic bone. Although it resembles that of a number of the Old World catfishes of Europe and Asia (fig. 4), it can be distinguished from the pelvic bones of the Recent North American ictalurids. The characters I have stressed in a comparison of pelvic bones from a limited number of species belonging to seven catfish families are the presence (however weak) of an ossified posterior ischial process (Weitzman, 1962) -- also found in other Ostariophysi:

Figure 3. Comparison of siluroid supraethmoids, fossil and Recent (dorsal aspect except where stated): A. "Rhineastes" sp. MCZ 8 500, Eocene Bridger Basin, Wyo., ventral aspect above, dorsal aspect below, X1.4. B. Indet. UMMP V56361, Ochoco Pass locality, Oregon, ventral aspect above, dorsal below, X2.2. C. Mystus planiceps (Bagridae) UMMZ 15568 5, SL 205mm, Sumatra, X1.2. D. Ictalurus furcatus (Ictaluridae) UMMZ 169031-S, SL 327 mm, Mo., ventral aspect above, dorsal below, X1.5. E. Clarius lazera (Claridae) UMMZ 169015-S, SL 189mm, Egypt, X2.7. F. "Ameiurus"primaevus? AMNH 9499, Eocene Green River Formation, Wyo., X1.8. G. Parasilurus asotus (Siluridae) uncat. spec. (J-66), SL 405mm, Japan, ventral aspect above, dorsal below, X1.4. H. Rhamdia guatemalensis (Pimelodidae) UMMZ 178542-S, Mexico, X1.5. I. Pelteobagrus nudiceps (Bagridae) UMMZ 183856-S, SL 167mm, Japan, X2.4. J. Pangasius micronemus (Schilbeidae) UMMZ 186691-S, SL 315mm, Thailand, ventral aspect, X1.4. K. Arius felis (Ariidae), UMMZ 179147-S, SL 192mm, Fla., Gulf of Mex., X1.3.

Characidae, Cyprinidae, Catostomidae -- and the form and relative proportions of the posterior margin. Those catfishes that typically have six or close to six pelvic rays in each fin (five of the seven families: Bagridae, Schilbeidae, Pimelodidae, Ariidae, Clariidae [Regan, 1911]) possess a short, nearly straight articular surface along the posterior margin for seating the pelvic fin rays. Those catfishes with typically more than seven pelvic rays in each fin (Ictaluridae and Siluridae: Silurus, Parasilurus, Kryptopterus, Wallagonia) possess wide, somewhat rounded, posterior margins, that are uninterrupted by notches and do not give rise to any kind of ossified projection at their postero-mesial corners. Although not illustrated, the Plotosidae, an Old World, largely marine, family can also be placed in this category. Except for these last three families, and possibly some of the Eocene Green River forms, all the others included in this comparison (along with the Ochoco Pass catfish) have pelvic bones with ossified ischial processes variously developed. Not enough Recent specimens have been examined to determine whether the rounded posterior margin and lack of an ossified ischial process are correlated with a high number of pelvic fin rays or reflect an anatomical specialization of the pelvic region associated with reproduction (or both may be linked together). Use of the pelvic fins by species of ictalurids in tending their eggs has been described by Breder (1935). Similarity in pelvic structure may indicate a genetic relationship (Tilak, 1963a, has allied the Siluridae to the Plotosidae). The number of rays is known to vary within some currently defined family groups, for example, from 5 to 8 in both the Bagridae and Pimelodidae, 6 to 14 in the Siluridae, and also within a genus, for example, 6 in Pangasius larnaudii, 8 in Pangasius micronemus.

The Ochoco Pass pelvic bone appears to have the short posterior (articulating) margin for seating the pelvic fin rays. Thus it is unlike the typical ictalurid condition.

Catostomidae (suckers)
Gen. and sp. indet.
Plate III, 4-7.

Material -- a small right opercle, right quadrate, fragment of a pharyngeal arch, left interopercle, incomplete basioccipital, and numerous scales.

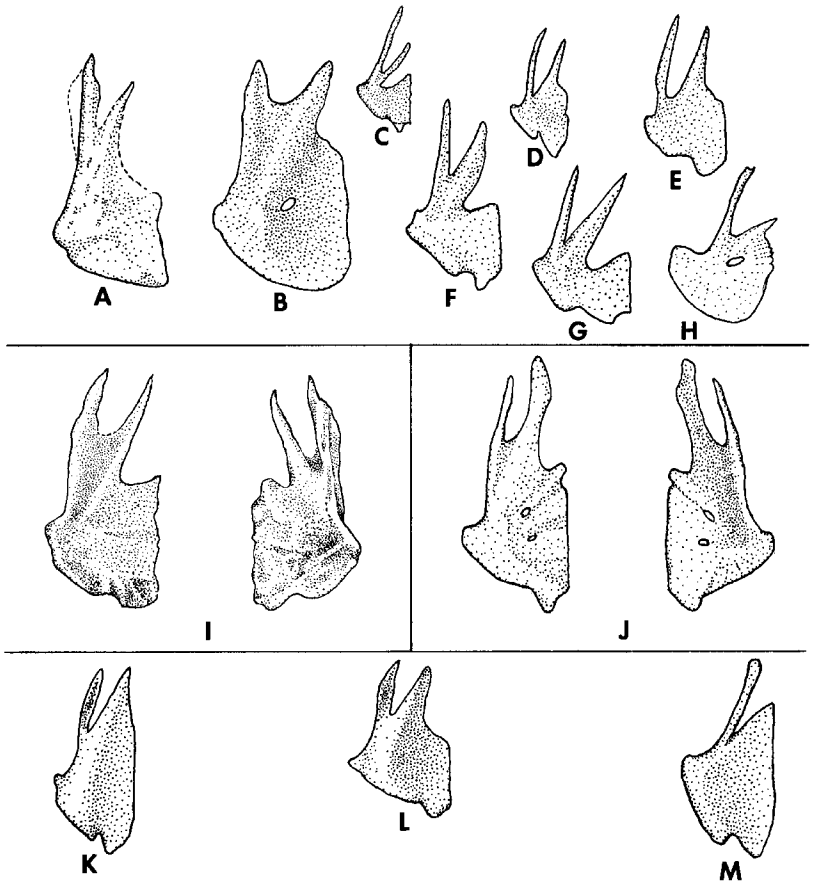


Figure 4. Comparison of siluroid right pelvic bones, ventral aspect except where stated: A. Undescribed species, AMNH 6888, SL 143mm, Eocene Green River Fm., Wyo. X4. B. Ictalurus punctatus (Ictaluridae) UMMZ 186239-S, SL 370mm, Va., X1.5. C. Clarias lazera (Claridae) UMMZ 166654, SL 159mm, Egypt X1.6. D. Rhamdia guatemalensis (Pimelodidae) UMMZ 184738-S, SL 173mm, Mexico, X1.3. E. Arius felis (Ariidae) UMMZ 179147-S, SL 192mm, Fla., X1.3. F. Pelteobagrus nudiceps (Bagridae) UMMZ 183855, SL 112mm, China, X2.8. G. Mystus planiceps (Bagridae) UMMZ 155685, SL 205mm, Sumatra, X1.6. H. Parasilurus asotus (Siluridae) uncat. spec. (J66-), SL 405mm, Japan, X1.6. I. Indet. UMMP V56360, Ochoco Pass locality, Ore., ventral aspect to left, dorsal to right, X3. J. Pangasius micronemus (Schilbeidae) UMMZ 186691-S, SL 315mm, Thailand, ventral aspect left, dorsal to right, X1.4. K. Bagroides macropterus (Bagridae) UMMZ 186765, SL 163mm, Thailand, X2. L. Leiocassis siamensis (Bagridae) UMMZ 186722, SL 80mm, Thailand, X3. M. Pseudopimelodus zungaro (Pimelodidae) UMMZ 66312, SL 123 mm, Bolivia, X2.

cf. Amyzon Cope
Plate I, 1,4; Plate II, 1; Plate III, 1-3.

Referred material -- left opercle, left frontal, right dentary, scales.

Remarks -- Study of the scales indicates that more than one kind of sucker is represented in the collection. Scales (plate I, 1,4; plate II, 1) are typical of the "Amyzon type" and can be duplicated in the numerous Amyzon scales from the Oligocene Grant lake shales of Montana (UMMP collections). This type of scale, from the flank region of the body, is characterized by width as great as or greater than the length, the focus is typically basal in position, there are as much as a dozen fine basal radii, strong primary radii in the apical field (with more numerous and weaker secondary radii in older scales), well-defined lateral basal corners that are marked interiorly by the shape of the circuli, and numerous fine circuli (ridges) that thicken slightly, are more widely spaced, and become fluted in the apical field*. The Amyzon scale differs from scales of all Recent catostomids in the above combination of characters and is particularly distinctive in its basally positioned focus. In this latter feature, it agrees with scales of some of the Old World cyprinids -- especially certain species of Leuciscus.

A second type of sucker scale (plate I, 5,6; plate II, 4) represented in the Ochoco Pass locality resembles the "Amyzon type" except that it is (1) proportionally not as deep as long, (2) has a more centrally positioned focus, (3) the basal radii are more numerous, and (4) the lateral basal corners are not as well defined, some being almost rounded. Besides the scales, a left opercle (plate III, 2) appears to belong to the genus Amyzon and resembles some of the opercles found with Amyzon remains from the Oligocene Florissant Formation, Colorado, and from the Grant lake shales, Montana. The dentary (plate III, 3) resembles that of Amyzon brevipinne (Lambe, 1906) and the frontal is close to that of a second deeper bodied Amyzon species, illustrated (but misidentified as Amyzon commune Cope) by Lambe (1906) from the Horsefly River locality, British Columbia. Figure 5 compares the Ochoco Pass frontal with frontals of Amyzon and some Recent catostomids. In general, these frontals fall into two groups. One has a projecting postorbital process and notch in the orbital rim to seat the supraorbital bone; this group contains Amyzon, Ictiobus, and Carpiodes. The other group has no projecting postorbital process of the frontal, no supraorbital bone, and the orbital rim nearly parallels the midline of the skull. Catostomus, Moxostoma, Erimyzon and Hypentelium form the second group. Cycleptus, Myxocyprinus and Minytrema are somewhat intermediate since they have a supraorbital, but no well-developed postorbital process on the frontal.

Discussion

The three identified fish families present in the Ochoco Pass fauna: Amiidae, Hiodontidae, and Catostomidae, as well as an included (but as yet unidentified) catfish family, are, to my knowledge, not known together in any other Eocene or Oligocene fish fauna from western North America. A fossil mooneye is unknown from the

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* Fragments of this same type of sucker scale, or one very similar to it, were collected and sent to me by Lee Jenkins from an outcrop of leaf-bearing mudstone on Gray Butte in Jefferson County, Oregon.

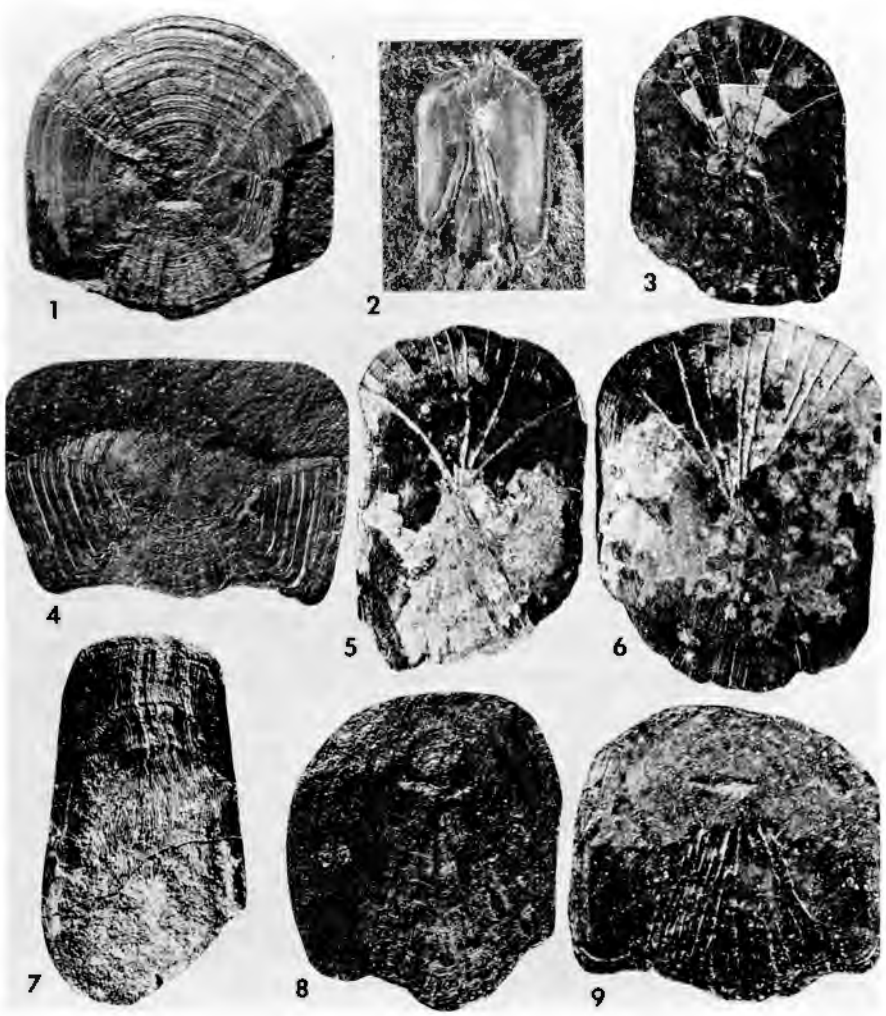

Plate I. Isolated scales from Ochoco Pass locality, Ore.: 1) regenerated catostomid scale, cf. Amyzon, UMMP V 56350, X5. 2) Indet. scale, possibly a hiodontid, UMMP V56374, X2. 3) regenerated catostomid scale, Oregon Dept. Geology and Mineral Industries, X3.5. 4) catostomid scale, apical field missing, cf. Amyzon UMMP V56347, X4.4. 5) catostomid scale, Oregon Dept. Geol. and Min. Ind., X4.4. 6) catostomid scale, Oregon Dept. Geol. and Min. Ind., X4.6. 7) regenerated amiid scale, cf. Amia UMMP V56363, X4. 8) hiodontid scale, cf. Hiodon UMMP V56368, X5.9. 9) hiodontid scale, cf. Hiodon, UMMP V56370, X7.8.

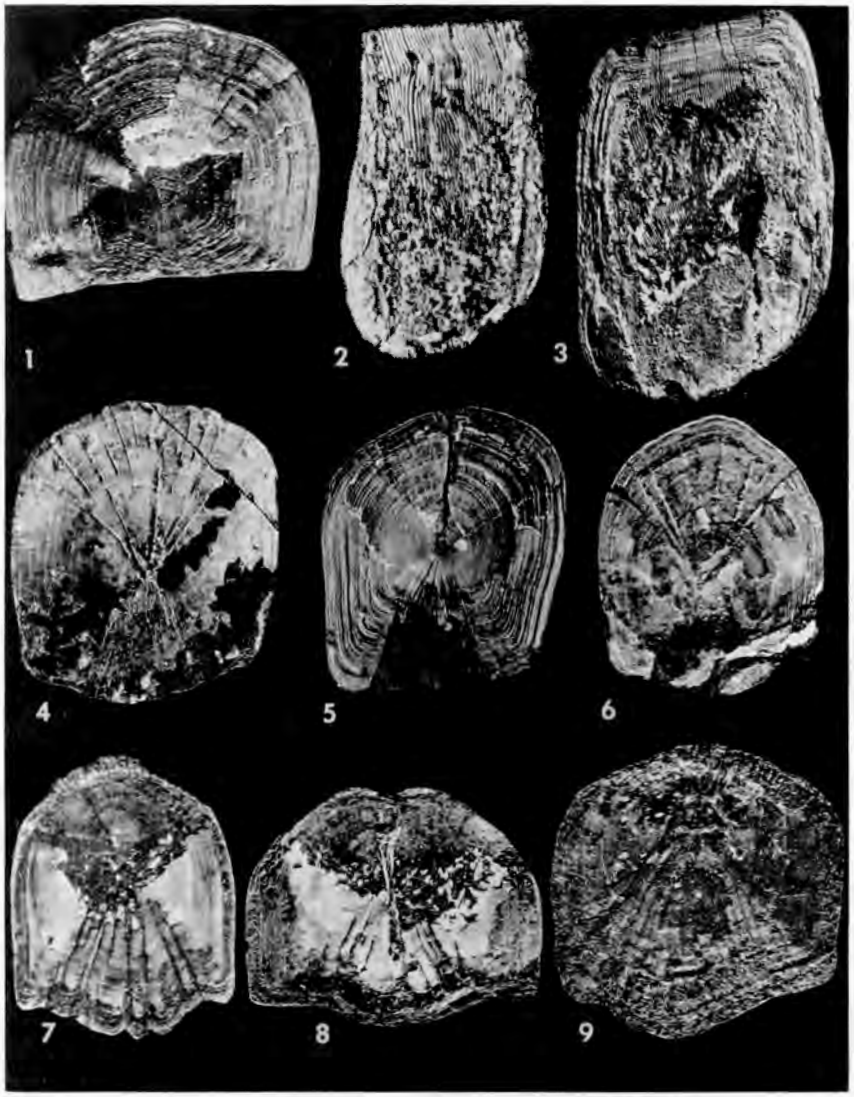

Plate II. Isolated scales from Ochoco Pass locality, Ore.: 1) catostomid scale, cf. Amyzon UMMP V56358, X4.3. 2) regenerated amiid scale, cf. Amia, UMMP V56364, X8.2. 3) regenerated amiid scale, cf. Amia, UMMP V56366, X3.8. 4) catostomid scale, Oregon Dept. Geol. and Min. Ind., X3.8. 5) catostomid scale, UMMP V56357, X4. 6) catostomid scale, cf. Amyzon, UMMP V56351, X6.6. 7) Indet. scale, possibly a hiodontid, UMMP V 56375, X6.5. 8) Indet. lateral line scale, possibly a hiodontid, UMMP V56371, X5.5. 9) hiodontid scale, cf. Hiodon, UMMP V56369, X6.


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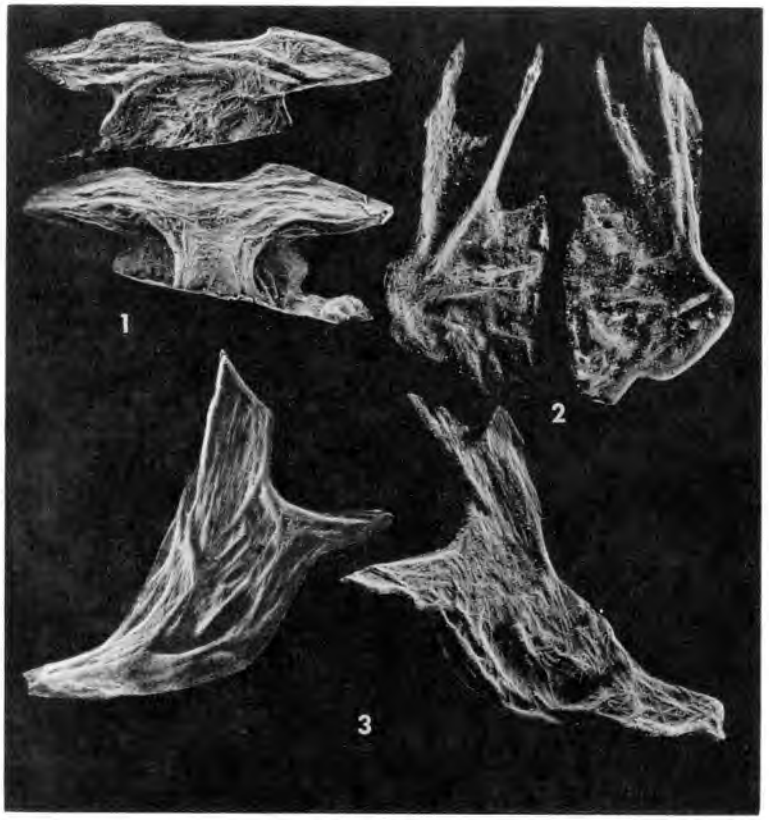

Plate III. Isolated catostomid skull elements from Ochoco Pass locality, Ore. 1) left frontal, ventral aspect, cf. Amyzon, UMMP V56341, X2.7 2) left opercle, cf. Amyzon, UMMP V56346, X1.5. 3) right dentary, cf. Amyzon, UMMP V56345, X3.8. 4) right quadrate, mesial aspect, gen. and sp. indet., UMMP V56354, X2.9. 5) incomplete basioccipital, gen. and sp. indet., UMMP V56356, X3.2. 6) right opercle, mesial aspect, gen. and sp. indet., UMMP V56344, X3. 7) parasphenoid, gen. and sp. indet., UMMP V56343, X3.8. 8) left interopercle, gen. and sp. indet. UMMP V56355, X3.9.

Plate IV. Isolated siluroid skeletal elements from Ochoco Pass locality, Ore. 1) supraethmoid, ventral aspect above, dorsal below, UMMP V56361, X2.7. 2) right pelvic bone, ventral aspect to left, dorsal to right, UMMP V56360, X4.5. 3) left incomplete cleithrum, lateral aspect at left, mesial at right, UMMP V56362, X3.2. (above)

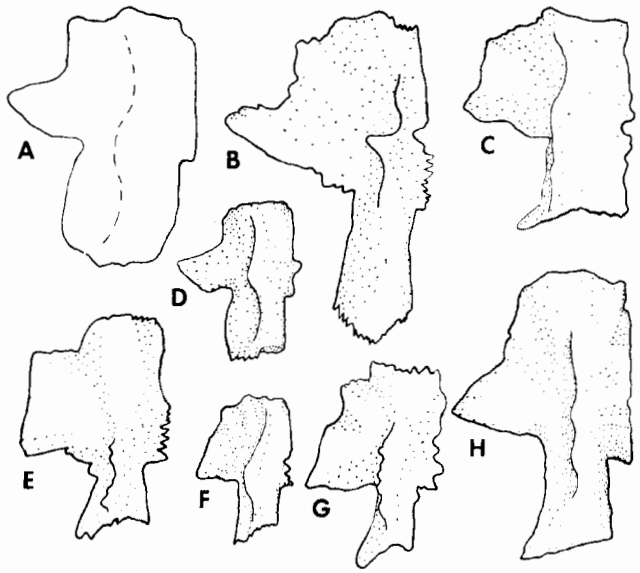

Figure 5. Comparison of catostomid left frontal bones, dorsal aspect. A. cf. Amyzon, UMMP V56341, Ochoco Pass locality, Oregon, X1.7. B. Ictiobus bubalus, uncat. spec., Texas, est. SL350mm, X1.5. C. Cycleptus elongatus, UMMZ 176973-S, SL 404mm, Texas, X1.5. D. Amyzon sp., NMC 1686, est. SL 185mm, Eocene Horsefly R. locality, Brit. Col. X1.8. E. Catostomus commersoni, UMMZ 160983, SL 135mm, Ky., X1.8. F. Myxocyprinus asiaticus, AMNH 11629, SL 59mm, China, X5.4. G. Minytrema melanops, UMMZ 179906, SL 206mm, Ky., X1.5. H. Amyzon, sp., USNM 4085 and 5508, est. SL 190mm, Oligocene, Florissant, Colo., X2.2.

Green River Formation or from the Florissant Lake Beds, although the other three families have been reported from the latter. Suckers are unknown in the Green River shales. At the Eocene Horsefly River locality in British Columbia and the Oligocene lake shales near Grant, Montana, a fossil mooneye has been found along with suckers and a bowfin. Catfish have not been discovered at these two localities as yet. The Eocene Horsefly River hiodontid may be equivalent to Eohiodon rosei from the Tranquille beds at Kamloops Lake, British Columbia (Cavender, 1966).

As more collecting is done at the Ochoco Pass locality, new elements in the fish fauna will probably appear. One of the scales (UMMP V56373) that has not been identified suggests that a cyprinid might have been present. Determination is difficult because Amyzon scales early in development can look similar to it. This scale is very small (4mm long) with a basal focus, no visible basal radii, about a dozen apical radii (5 of which are primary) and the scale has lateral basal corners. It resembles scales of Richardsonius balteatus. The oldest North American cyprinids now known are from the basal part (Bridge Creek flora horizon) of the John Day Formation in Oregon. A potassium-argon date of this stratigraphic horizon has been determined as 31.1 million years (Evernden and others, 1964).

Three of the above families mentioned, the Amiidae, Hiodontidae, and Catostomidae, are considered by Darlington (1957) as primary freshwater groups which are today restricted to fresh water and apparently have been thus confined through much or all of their evolutionary history. Since the catfish has not been definitely assigned to a specific family, it does not provide substantial evidence for a freshwater habitat, although catfishes today live predominantly in fresh water. Some members of the marine catfish family, Ariidae, do inhabit the lower parts of freshwater streams along the tropical coasts of Central America (Miller, 1966). Skeletal evidence, however, does not indicate that the Ochoco Pass catfish(es) is an ariid. A more probable affinity is with the Bagridae or Ictaluridae, both freshwater families according to Darlington (1957). Freshwater catfishes have a fossil record throughout most of the Cenozoic in western North America (John Lundberg, oral communication, 1967), and when this record is compared with that of some of the other freshwater families, it stands out as a fairly good one. Eocene catfish fossils representing a number of different families have been reported from Europe, Africa, Asia, South America, and (Oligocene) Australia, as well as North America (Romer, 1966). It is apparent that by early Tertiary time, the evolutionary history of siluroids was already quite complicated.

The fossil hiodontid scales from the Ochoco Pass locality vary from 3mm to 7mm in length. In Recent Hiodon, a similar size range can be found an very small to large juveniles up to 200 mm SL. Two living species, Hiodon tergisus and H. alosoides, and an extinct middle Eocene species, Eohiodon rosei, mentioned above (also the undescribed hiodontid species from the Grant lake shales, Montana), make up this family which is endemic to North America. The Hiodontidae have no close living relatives; they are relict fishes, survivors of an early stage of teleost evolution.

Potassium-argon dates from Eocene sediments in British Columbia containing the oldest known North American Catostomidae range from 45 to 49 million years (Rouse and Mathews, 1961). Suckers appear to be one of the major components both in numbers and species (except in the Green River fauna as stated above) of the early to middle Cenozoic freshwater faunas of western North America. The Eocene and Oligocene species known from complete specimens possess a long dorsal fin and seem to belong to or have a close relationship with the extinct genus Amyzon.

Of the four groups of fishes known in the Ochoco Pass fauna, only one, the Catostomidae, lives in the same area today. Hiodontids, catfishes and bowfins are not native to the Columbia River Basin (Miller, 1959). Catfish, however, are known from the Pliocene-Pleistocene "Idaho Lake" fauna, Columbia and Snake River drainage (Miller, 1965; Miller and Smith, 1967).

Fossil remains other than fish scales and bones occasionally are found at the Ochoco Pass locality. Various plant fragments occur as imprints on the shale slabs. One piece shows a single, broken beetle wing.

Since some of the scales are fragmented and all the bones are disarticulated, transportation of the remains may have taken place before burial. Stream carry into a quiet body of water which had a highly organic mud bottom is a possibility. However, partial ta almost complete decomposition of dead fish (along with a large amount of plant material) near or on a lake bottom is perhaps a better explanation for this type of preservation. The evidence gathered from this study of the fish remains indicates that the Ochoco fish occupied, in life, a freshwater habitat.

Acknowledgments

I am indebted to Bobb Schaeffer, American Museum of Natural History, David

Dunkle, United States National Museum, Dale Russell, National Museum of Canada, and Bryan Patterson, Harvard Museum of Comparative Zoology, for the loan of fossil specimens referred to in this study; to Claude Hibbard for making available facilities in the University of Michigan Museum of Paleontology; to the State of Oregon Department of Geology and Mineral Industries for the geological information given in this paper; to Lee Jenkins for help rendered on various field aspects of this study; to John Lundberg, University of Michigan, for offering his knowledge of catfish osteology, both fossil and Recent; and to Robert R. Miller, who read the manuscript.

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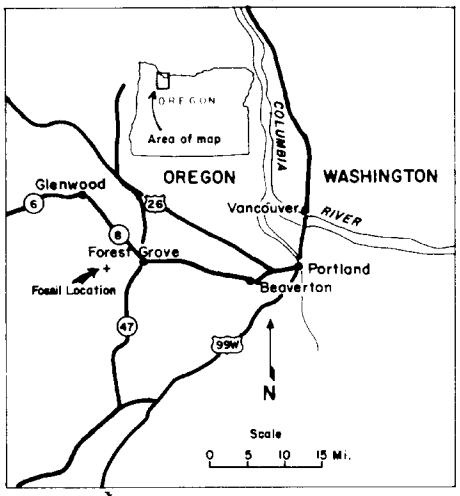
A LARGE FOSSIL SAND SHARK OF THE GENUS ODONTASPIS FROM OREGON

By Shelton P. Applegate*

An association of numerous preserved hard parts of a single fossil shark are only rarely encountered in the Cenozoic marine beds. Therefore, we were quite excited when a package arrived from the Oregon Department of Geology and Mineral Industries which contained not only fossil invertebrates and fish scales but remains which from their similar size and close occurrence musthave come from a single individual shark. The fossils in question were collected by geologists with the Oregon Department who also provided the geologic summary quoted below. Acknowledgment is made to the following members of the Museum staff: to Anita Daugherty for her assistance in editing the manuscript, to Pearl Hanback for the fine illustrations, and to Dorothea Barger for typing the manuscript.



The fossils occurred in a blackish gray marine shale associated with small pelecypods and gastropods. A few plant fragments were also present, as well as a number of bony fish scales and a pair of fish-ear bones (otoliths). In cross section some of the sediment showed foraminifera.

The following description of the fossil site was provided by the Oregon Department of Geology and Mineral Industries:

"The locality is in the bedof Scoggin Creek about 40 miles by road west of Portland and about 5 airline miles southwest of Forest Grove (see index map). The rocks containing the fossil shark remains belong to the Yamhill Formation, which crops out in a north-trending belt about a mile wide. Here the formation is composed of about 2000 feet of siltstone and thin-bedded black shale which weathers to a yellowish color. The beds dip to the southeast from 7° to 15° and are well exposed in the

*Associate Curator, Vertebrate Paleontology, Los Angeles County Museum of Natural History.

creek bed at time of low water.

"The sediments have been dated as late Eocene from microfauna by W. W. Rau (written communication, 1962), who states that the foraminiferal assemblage is diagnostic of the Narizian stage of Mallory, A-2 zone of Laiming, and typical of that found at the type locality of the Yamhill Formation along Mill Creek about 30 miles to the south.

"The Yamhill Formation lies between older Eocene marine sediments and associated volcanic rocks that make up the Coast Range to the west and sandstone of the Spencer Formation of later Eocene age to the east."

Since the conditions for preserving vertebrate fossils must have been excellent, the abundance of this material gives us promise of finding other interesting vertebrate remains. Such a find as this is probably another indication of the rich undescribed fossil marine fish fauna that occurs along the Pacific Northwest. If more of these fossils are collected and described, we will know a great deal more about the history and distribution of fossil fishes.

The shark material consists of 22 vertebrae, one of which is shown in figure 3B. There are numerous patches of hollow cubes of calcified cartilage which form a mosaic (figure 3A is a sketch of such a patch in place); each cube is called a tessera. In living sharks these cubes make up the skull (chondocranium), jaws, and gill and fin supports (Applegate, 1967). Fossil tesserae are more often than not dissolved by ground water or at least detached, so that they are either missing or overlooked. The tesserae in this specimen appear to be similar to those which occur in the living sand-shark genus Odontaspis. The vertebrae in cross section (figure 3C) are of the typical lamnoid type, showing radial supports with branching similar to what is found in Recent Odontaspis. The illustrated vertebra is from the caudal region. Figure 1 shows a typical member of this genus Odontaspis taurus.

The most important part of these fossil remains is a single tooth (figures 2, A & B). By comparing this with those teeth in Recent sand-shark jaws, a method which I have discussed elsewhere (Applegate, 1965), it becomes apparent that the tooth is a second lower right anterior, or the

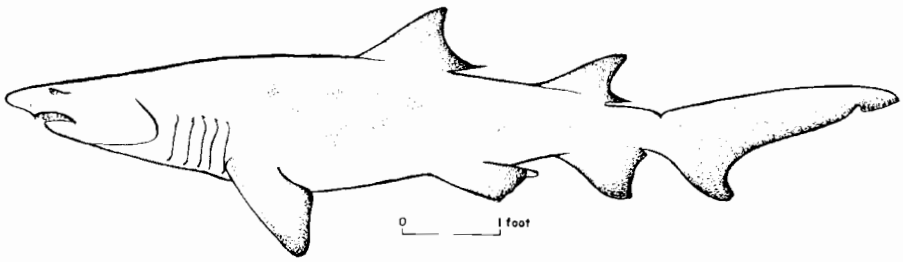


Figure 1. Drawings of the Recent Odontaspis taurus, which is related to the nine-foot Oregon sand shark.

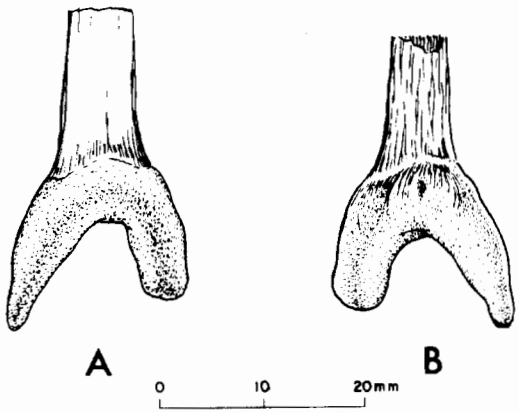


Figure 2. Two views of the shark tooth.

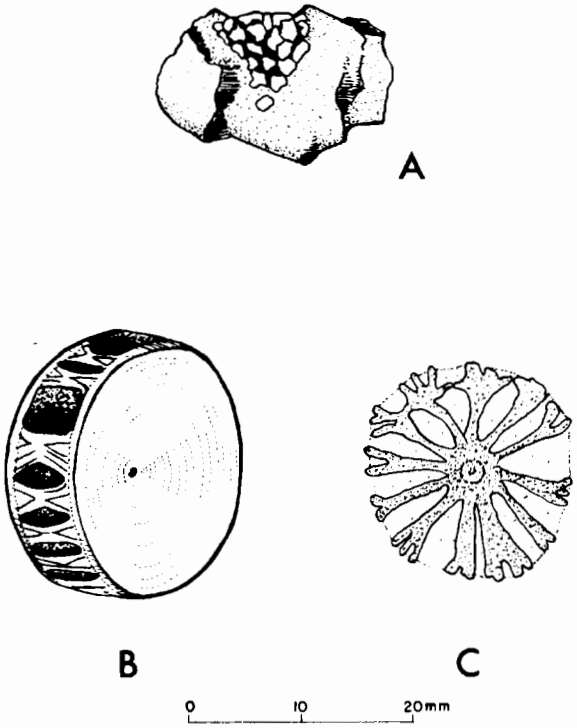


Figure 3. Vertebrae and cartilage of the sand shark.

third tooth from the center line. The greatest width of the tooth base is 17 mm. The height of the tooth is 28 mm., to which must be added a good portion of what is missing. A similar tooth from a female sand shark, (No. 12) (Applegate, 1965), had the following measurements: width 17 mm., height 34 mm. The total length of this shark was 273 cm., or approximately nine feet. The fossil shark might be assumed to have had a similar length.

On the inner surface of the crown the tooth has definite razed lines or striations (fig. 2). There is a tendency for some of these striations to be faint. Some branch, and others join together. Such striations are known from only a few species of fossil sand sharks.

Undoubted fossil odontaspids are known from the Cretaceous to the present. The Cretaceous genus Scapanorhynchus, related to the Recent deep-sea goblin shark Mitsukurina, has very strong, straight, well-defined striations on the inner crown surface; at least two species in Scapanorhynchus are close to Odontaspis, a situation that needs further investigation by the establishment of artificial tooth sets as suggested by Applegate, 1965. In the Paleocene at least three species of small odontaspids with striae occur: Odontaspis substriata substriata, Odontaspis substriata atlasi, and Odontaspis whitei. All three species have been found in the Midway near Fort Benton, Ark., L.A.C.M. Locality 6510. O. whitei and substriata are also known from the Paleocene of Africa, and from the beds that range from Thanetian to upper Ypresian age in Africa we find O. substriata atlasi. According to White, another species Odontaspis striata (his O. macrota striata) is characteristic of the early Eocene of England, while the most recent recognized striated species O. macrota is more characteristic of the late Eocene. Probably O. whitei or O. substriata is the ancestor of O. striata which in turn gives rise to O. macrota. The teeth of the Paleocene species are quite small, averaging around one-half inch or less in total length; those of O. macrota and O. striata are longer, more than one inch. Those of O. macrota are said to be the longer and thicker of the two. This general type of tooth occurs also in the Miocene, and is here interpreted as being from O. macrota. I believe that the Oregon tooth is also referable to O. macrota.

It is of special interest that the Recent sand shark Odontaspis taurus shows occasional striations on its crown. Since the O. macrota type of tooth is close in many ways to those of O. taurus, it may be the ancestor of this modern form.

Fossil teeth of the O. macrota-O. striata type are known from Europe, Russia, Africa, New Zealand, and North America. They have been taken at the L.A.C.M. Locality 2024 called "Pipehill," in Baja California (Tepatate Formation, thought to be late Paleocene). Another example from the Pacific Coast is known from Trabuco Canyon, Orange County, Cal., where it was found in the topsoil: its age is not known, but it is probably Eocene or lower Miocene. A few small teeth of this complex are known from L.A.-C.M. Locality 1649, Tejon Formation, in the Santa Ynez Mountains, Cal.

In the eastern United States, Odontaspis cf. macrota is known from Miocene beds at New Bern, N.C.; near Charleston, S.C.; and near Wallmeyer Fish Camp, Va. Any or all of these teeth could represent reworking from underlying Eocene sediments.

The genus Odontaspis is rare in typical West Coast Miocene beds and the few that are known are referable to the O. ferox type. The only living sand shark in the eastern Pacific is Odontaspis ferox, reported by Daugherty (1964) on the basis of two specimens taken off California. This species is also represented in the L.A.C.M. collection by the jaw of a third specimen purchased by Mr. Donald Cocke in La Paz, Baja California. O. ferox is a deepwater shark with almost world-wide distribution in temperate waters, though most commonly taken in the Mediterranean. The tooth crowns of this shark are smooth, and the teeth quite different in shape and number of lateral denticles from the Oregon specimen.

If we may assume that O. macrota was the ancestor of O. taurus, it may have occupied a similar niche. The modern taurus is a comparatively sluggish fish-eating shark, capable of short bursts of speed. It is a bottom dweller, occurring in very shallow water from about 1 to 15 fathoms. It is known from the eastern United States, Brazil, Europe and the Mediterranean, South Africa, and perhaps Australia. Recently, the possibility of its occurring in Japan has been brought to my attention by Mr. Toru Taniuchi; yet there is no record of its having ever been taken in the eastern Pacific. If O. macrota had a similar distribution to that of O. taurus and similar teeth, and was the ancestor of taurus, we can at least theorize similar habits. The Pacific Eocene forms may have inhabited ancient shallows and bays which were lost during later mountain building. The fact that these coastal sharks seem to shun the tropics or very cold water plus the presence of the Isthmus of Panama may be what has kept the eastern Pacific free of this species since the Miocene. Certainly as we discover more fossils, our knowledge of these interesting sharks will become clearer. One should keep in mind that fossil fishes can tell us a great deal about past climates, currents, continental outlines, and the evolution of life.

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FOSSIL SHARKS IN OREGON

Bruce J. Welton*

Approximately 21 species of sharks, skates, and rays are either indigenous to or occasionally visit the Oregon coast. The Blue Shark Prionace glauca, Soup-fin Shark Galeorhinus zyopterus, and the Dog-fish Shark Squalus acanthias commonly inhabit our coastal waters. These 21 species are represented by 16 genera, of which 10 genera are known from the fossil record in Oregon. The most common genus encountered is the Dog-fish Shark Squalus.

The sharks, skates, and rays, (all members of the Elasmobranchii) have a fossil record extending back into the Devonian period, but many major groups became extinct before or during the Mesozoic. A rapid expansion in the number of new forms before the close of the Mesozoic gave rise to practically all the Holocene families living today. Paleozoic shark remains are not known from Oregon, but teeth of the Cretaceous genus Scapanorhynchus have been collected from the Hudspeth Formation near Mitchell, Oregon.

Recent work has shown that elasmobranch teeth occur in abundance west of the Cascades in marine Tertiary strata ranging in age from late Eocene to middle Miocene (Figures 1 and 2).

All members of the Elasmobranchii possess a cartilaginous endoskeleton which deteriorates rapidly upon death and is only rarely preserved in the fossil record. Only under exceptional conditions of preservation, usually in a highly reducing environment, will cranial or postcranial elements be fossilized. The hard outer enamel of all sharks teeth enables them to resist weathering and transportation prior to deposition. Considering this fact and also the fact that tooth progression and replacement in the elasmobranchs is a perpetual process which continually contributes teeth to nearby sediments, it is no wonder that teeth constitute almost 100 percent of all the shark material found in Oregon.

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* Student, Department of Earth Sciences, Portland State University

Previous Work

Although elasmobranch faunas from the Tertiary of Oregon have never received extensive taxonomic treatment, their existence has, however, been noted by early workers, dating as far back as the mid-1800's. In 1849, J. D. Dana explored the Astoria Formation in search of vertebrates and was one of the first to recognize shark remains from Oregon.

Packard (1940), in describing a leatherback turtle, Psephophorus(?) oregonensis, commented on the occurrence of sharks teeth in the Astoria Formation at the mouth of Spencer Creek. Packard (1947) again noted the presence of sharks teeth in the Astoria Formation, but unfortunately this material was never described.

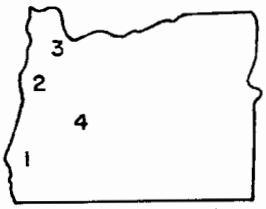
Steere, in a series of papers describing fossil collecting localities from the Tertiary marine sediments of western Oregon, mentions the occurrence of sharks teeth from the Cowlitz Formation (1957) and again in a later publication (1958, p. 58) states that "a few shark teeth have been collected from Oligocene marine sandstones of the Eugene Formation."

Sands of the Spencer Formation west of Monmouth, Oregon, have yielded an unusually high concentration of shark and ray teeth of late Eocene age. Schlicker (1962, p. 174) noted this concentration, stating that "Sharks teeth are abundant in a roadcut near the Luckiamute River just north of Helmick Park on U.S. Highway 99-W."

The first shark remains from Oregon to receive taxonomic treatment were collected from Scoggins Creek by members of the Oregon Department of Geology and Mineral Industries in 1967. Twenty-two vertebrae, one anterior tooth, and a few patches of calcified cartilage were collected from a well-bedded, fine-grained dark mudstone in the Yamhill Formation of Eocene Age. All of the specimens were forwarded for identification to Shelton P. Applegate, Associate Curator of Vertebrate Paleontology at the Los Angeles County Museum of Natural History. Shortly thereafter, an article appeared in The ORE BIN (Applegate, 1968) describing the dentition and skeletal elements as belonging to an Eocene Sand Shark Odontaspis macrota.

Hickman (1969, p. 104) described the occurrence of two sharks teeth in the Eugene Formation, south of Salem, Oregon. In her discussion she states, "Sharks teeth are occaionally found in the Eugene Formation. The teeth represent two major groups of sharks. The single cusps are typical of the modern galeoid type of shark (Hickman, 1969, pl. 14, fig. 12) and the saw-like teeth typical of the primitive hexanchoid genus Hexanchus (Notidanus) (Hickman, 1969, pl. 14, fig. 13). Both of these groups are abundantly represented by teeth in Tertiary marine deposits, although they are not well known from the Pacific Coast."

Specimens of the hexanchid sharks, Notorhynchus and Hexanchus, are relatively abundant in beds of lower Tertiary age in Oregon. Sharks of the genus Notorhynchus are known from sediments of Eocene and Oligocene



Locality map for stratigraphic sections

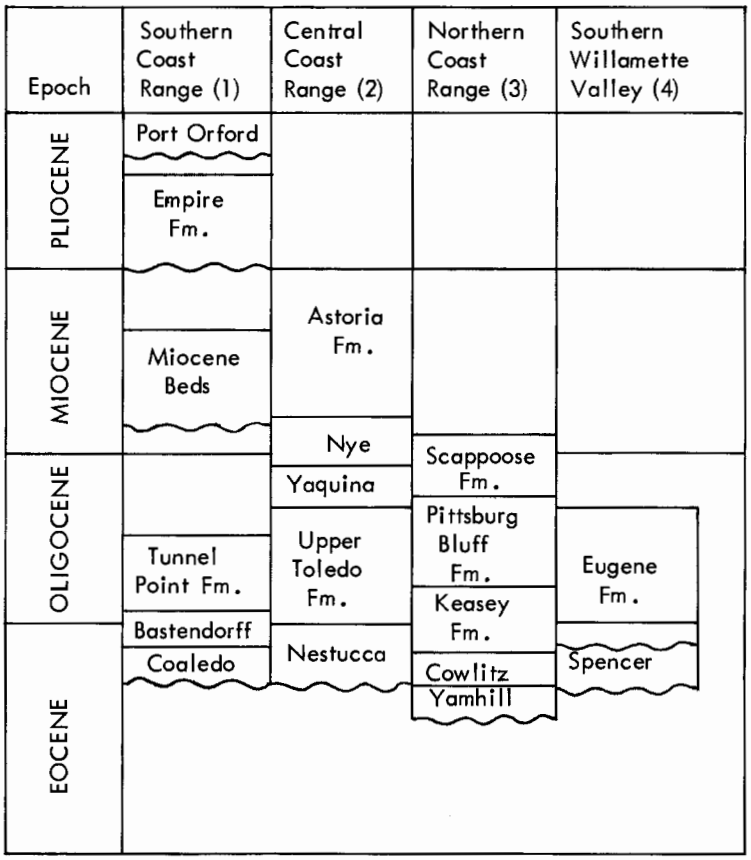


Figure 1. Correlation chart for geologic formations of western Oregon. Adapted from J. D. Beaulieu, 1971, p. 63.

age in northwestern Oregon, and early and middle Miocene beds of the central Oregon Coast Range have yielded teeth of the Six-gilled Shark Hexanchus. The first North American occurrence of the genus Heptranchias is represented by a single tooth collected from the Keasey Formation at Mist, Oregon.

Occurrence

Fine-grained black Cretaceous mudstones of the Hudspeth Formation crop out along numerous small exposures north of Mitchell in east-central Oregon. These sediments have yielded three teeth, the only Mesozoic shark teeth known at this time from Oregon. One of the teeth may be tentatively assigned to the common Cretaceous genus Scapanorhynchus. A more thorough search of these rocks will undoubtedly reveal an abundance of material.

Five upper Eocene formations in western Oregon have yielded elasmobranch remains, representing over 75 percent of all the Tertiary shark material known from Oregon.

The Yamhill Formation, cropping out along stream beds in Scoggins Valley, west of Forest Grove, Oregon, has yielded a disarticulated skeleton of the Eocene Sand Shark, Odontaspis macrota (Pl. 1, 3a, b) (Applegate, 1968). In association with this skeleton are five teeth of a yet undescribed species of echinorhinid or Spiney Shark (personal communication from Shelton P. Applegate). Apparently these teeth represent normal tooth loss during post-mortem scavenging by the Spiney Shark.

Coarse sandstones and fine-grained mudstones of the Coaledo Formation, exposed from Yokam Point south to Shore Acres State Park below Charleston, yield many teeth, usually included in biostromes of clastic shell material. Over 700 shark and ray teeth have been recovered from sediments at Shore Acres State Park. This assemblage is characterized by Odontaspis macrota, Squalus, and the Eagle Ray Myliobatis (Pl. 1, 8a, b, c). The abundance of myliobatid teeth at this locality far exceeds any other area in Oregon.

Sands of the Spencer Formation at Helmick Hill, 9 miles west of Monmouth, Oregon contain a single discontinuous lens of weathered limonite-stained pebbles and sharks teeth, not exceeding a foot in thickness. Disaggregation and screening of these sediments has yielded over 2,000 teeth, of which 95 percent belong to the Sand Shark Odontaspis macrota. Teeth of Squalus, Myliobatis, Isurus, the Angel Shark Squatina, and the Horn Shark Heterodontus (Pl. 1, 4c) are encountered.

Transport prior to deposition at the Helmick Hill locality has destroyed the roots and severely abraded most of the teeth. Weathering and leaching by groundwater have also contributed to tooth destruction. Lateral edges and crown points on most teeth are smooth and rounded, and lateral denticles have been broken off most of the odontaspids. Only by the shear abundance of teeth is it possible to find a few specimens which still exhibit morphologic

Sharks	Yamhill Fm.	Coaledo Fm.	Cowlitz Fm.	Spencer Fm.	Nestucca Fm.	Keasey Fm.	Pittsburg Bluff Fm.	Scappoose Fm.	Nye Mudstone	Astoria Fm.	Miocene Beds at Cape Blanco
Carcharodon				X		X				X	
Centrophorus						X					
Centroscymnus							X				
Echinorhinus	X										
Galeocerdo				X	X					X	
Galeorhinus		X									
Heptranchias						X					
Heterodontus		X		X							
Hexanchus									X	X	
Isurus		X	X	X	X	X			X	X	
Lamna		X	X	X	X	X			X	?	
Notorhynchus						X	X				
Odontaspis	X	X	X	X	X	X	X		X		
Pristiophorus			X			X	X		X		
Scyliorhinus		X									
Sphyrna				X							
Squalus		X	X	X	X		X		X		X
Squatina		X	X	X		X	X	X	X		
Rays											
Myliobatis		X	X	X					X	X	
Raja					X		X		X		
Rhinoptera		X									

Figure 2. Checklist of Tertiary Elasmobranchii from Oregon.

features suitable for description and identification. Unfortunately, less frequently occurring forms are usually quite abraded and classification beyond the generic level may be impossible for many. The probability also exists that these teeth were reworked from older underlying sediments.

Explanation of Plate 1

1. Notorhynchus sp. Agassiz (Seven-gilled Shark), Pittsburg Bluff Formation, Oligocene, lower left lateral tooth. X 2, PSU 13-17.

2. Hexanchus sp. Rafinesque (Six-gilled Shark), Nye Mudstone, lower lateral tooth. X 1.8, Taylor collection, Portland, Oregon.

3. Odontaspis macrota Agassiz (Sand Shark), Yamhill Formation, second lower right anterior tooth; a. lingual view, b. lateral view. X 1.5, PSU 13-24.

4. Heterodontus sp. Blainv. (Horn Shark), lateral pavement teeth, a. lateral view, b. dorsal view, both collected from the Quimper Sandstone, Washington; c. dorsal view of tooth collected from Spencer Formation, Oregon. X 2.5, PSU 13-18 and PSU 13-19.

5. Squatina sp. Valmont (Angel Shark), Nye Mudstone, a. Lateral view, b. labial view. X 1.7, PSU 13-23.

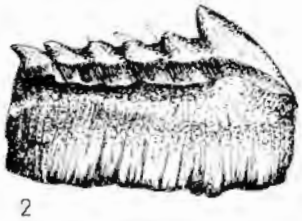
6. Pristiophorus sp. Muller and Henle (Saw Shark), Pittsburg Bluff Formation, rostral spine. X 1.7, PSU 13-22.

7. Squalus sp. Linne (Dog-fish Shark), Pittsburg Bluff Formation. X 4.2, PSU 13-21.

8. Myliobatis sp. Cuvier (Eagle Ray), Coaledo Formation, pavement tooth, medial row, a. ventral view showing roots, b. lateral view, c. dorsal view. X 2.2, PSU 13-20.

PLATE 1

1



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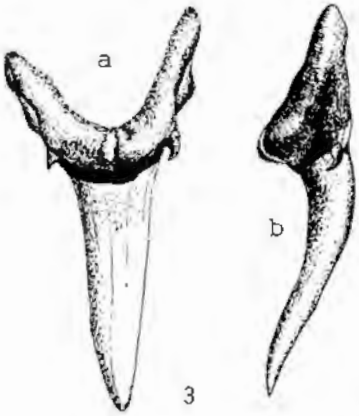

a

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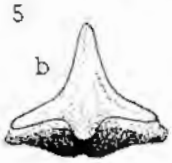

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Glauconitic green sands of the Nestucca Formation at Toledo yield fair to poorly preserved teeth of the Mako Shark Isurus, the Tiger Shark Galeocerdo, and what appears to be small teeth of the skate Raja. Mammalian bone fragments and teleost remains have also been found.

A well-known Tertiary crinoid locality at Mist, Oregon has contributed a number of smaller sharks from sediments of the Keasey Formation of late Eocene to early Oligocene age. Aside from such forms as Squatina, Odontaspis, the Seven-gilled Shark Notorhynchus, and Centrophorus, a new species of Seven-gilled Shark Heptranchias is being described from this locality by the author. Elsewhere the Keasey sediments have yielded a large and well-preserved tooth of the White Shark Carcharodon, Saw Shark Pristiophorus, and the Mako Shark Isurus.

Coquina-like concretionary biostromes of clastic shell material which crop out along roadcuts in the lower sections of the Pittsburg Bluff Formation yield numerous teeth of a small squalid shark Centroscymnus and not uncommonly teeth of Raja, Squatina, Odontaspis, Squalus, Pristiophorus (Pl. 1, 6), and Notorhynchus (Pl. 1, 1). These genera, plus several additional forms, collectively constitute the most diverse assemblage yet known from the middle Oligocene of Oregon.

Younger Oligo-Miocene sands of the Scappoose Formation, which conformably overlies the Pittsburg Bluff Formation, have produced teleost teeth and a fragmentary tooth crown of Squatina.

Underlying the Astoria Formation at Newport and south toward Seal Rock are found sediments of early Miocene age which are assigned to the Nye Mudstone. A Six-gilled Shark Hexanchus (Pl. 1, 2), Squalus (Pl. 1, 7), Pristiophorus, Squatina (Pl. 1, 5a, b), Odontaspis, and Isurus are found. This constitutes the only assemblage of early Miocene sharks yet known from Oregon.

The Miocene Astoria Formation has extensive exposure along the Oregon coast north of Newport, yet it has yielded only a few sharks teeth. This is quite surprising in light of the great abundance of teeth found in sediments of equivalent age from California and the Atlantic Coast of the United States. The assemblage at this time consists of the following: Carcharodon megalodon, Hexanchus, Myliobatis, Isurus planus?, and Galeocerdo cf. aduncas. In addition, Dr. E. M. Baldwin of the University of Oregon Department of Geology has in his possession a large tooth belonging to a Mako Shark, Isurus hastalis. This tooth was collected from sediments which were dredged up in Coos Bay and presumably are Miocene in age. Two Squalus teeth have also been collected from late Miocene sandstones immediately south of Cape Blanco, Oregon.

To my knowledge, teeth of sharks or rays have not yet been collected from Pliocene or Pleistocene sediments in Oregon. This is not to say that they do not exist but only that very little attention has been directed towards searching for shark teeth in these sediments.

Discussion

It is difficult to identify unassociated fossil sharks teeth; to do so requires a thorough understanding of the variability of tooth morphology among species of modern sharks and rays. Teeth may be individually examined for the presence or absence of the following general features: crown and root shape; position of nutrient canals; serrations on the crown and denticles; number of lateral denticles; tooth size; and flexures in the crown. Any number of these characteristics may require critical examination in order to segregate teeth of different species.

Variations in tooth morphology may be observed within the jaws of almost any modern shark or ray. Teeth of a single species may differ in the upper and lower jaw or laterally in a single tooth row. Tooth variation also occurs as a result of age and sexual dimorphism. In order to establish valid taxa when working with unassociated fossil teeth, it is necessary to construct entire tooth sets which define the total range of variation within the species. This technique has proven to be useful for the interpretation of large faunas in California and is presently being applied to Oregon sharks and rays.

The paucity of some of the faunas previously described is for the most part apparent rather than real. It is due to the nature and conditions of deposition of the sediments and does not accurately represent the characteristics of the actual biotic community. The physical conditions of sedimentation and biologically limiting factors in the environment directly influence the resultant fossil assemblage. Where active transport or agitation of sediments occurs during deposition, organic remains may be subjected to severe abrasion, often resulting in the accumulation of clastic shell debris and total destruction of all softer parts. Sorting of teeth may occur as a result of strong current action, and post-depositional leaching by ground water can destroy tooth dentine. The latter best describes the conditions which must have existed during the formation of the Helmick Hill shark tooth bed. Only rarely do Oregon localities yield nontransported shark material. However, excellent undisturbed faunas have been obtained from a few outcrops of the Coaledo, Nestucca, and Keasey Formations.

Summary

The purpose of this paper is to give some account of the fossil shark faunas of Oregon. This has been, at best, only introductory to the more than 5,000 specimens now being studied by the author. Many of the genera are listed in Figure 2, but species determinations have not yet been completed. In most instances, more than one species exists for each genus listed. Newly developed localities are continuing to yield more material, and it is hoped that each of the faunas mentioned herein will be treated in full at a later date.

Acknowledgments

Special thanks are expressed to Dr. Shelton P. Applegate, Los Angeles County Museum of Natural History, for the opportunity to study specimens of sharks at the Museum and for his assistance in the verification of the Oregon material.

I am also grateful to David Taylor of Portland, Oregon, the Oregon Museum of Science and Industry, and the State Department of Geology and Mineral Industries for making their collections of Tertiary sharks teeth available for this study.

Thanks are given to Dr. R. E. Thoms, Brian Gannon, Dr. Ronald Wolff, Margaret Steere, and Frank Kistner, who kindly read and criticized the manuscript. Photographic equipment was loaned by Larry Chitwood, and the manuscript was typed by Chris Lewis.

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OREGON EOCENE DECAPOD CRUSTACEA

By W. N. Orr and M. A. Kooser
Department of Geology, University of Oregon

Introduction

Although they are locally ubiquitous, fossilized crabs are seldom common in the Tertiary fossil record of the Pacific Northwest. Literature on this invertebrate group for the same area is limited to a few papers describing individual new species or faunal lists which include an occasional note on decapods. The most authoritative compendium at present on the fossil crabs of the west coast was produced by Mary J. Rathbun in 1926.

The present paper is to describe a particularly well-preserved assemblage of middle Eocene crabs found in association with a diverse invertebrate community in exposures of the Umpqua Formation in southwest Oregon.

Location

Collections described here were obtained from exposures of the Umpqua Formation in road cuts along road 3406 adjacent to Snout Creek in the N$\frac{1}{2}$, SW$\frac{1}{4}$ sec. 9, T. 34 S., R. 11 W., between 2.5 and 3 miles east of Agness, Oregon (fig. 1). Most of the exposures along this road were found to be fossiliferous but the best single locality (U. of O. Locality no. 2594) is 3 miles east of Agness in the cut on the south side of the road. These sediments have been mapped and described by several authors but undoubtedly the most recent and continuing efforts in the area are by Baldwin (1961, 1963, 1964, 1965). According to that author [(1965) and oral communication], sediments in the area under study are from an interval in the upper half of the Umpqua Formation. Locally the sediments along Snout Creek dip gently to the west and are part of a syncline plunging to the northeast. The Umpqua Formation in the immediate vicinity consists of black to grey calcareous siltstones that weather yellow and tan upon oxidation of the iron content. Within the siltstone, calcareous concretions from 1 cm up to 10 cm are common and it is in these concretions that the best preserved invertebrate specimens are to be found. Calcite-filled fractures and small-scale slickensides within the siltstone suggest considerable movement and deformation of the sediments after consolidation.

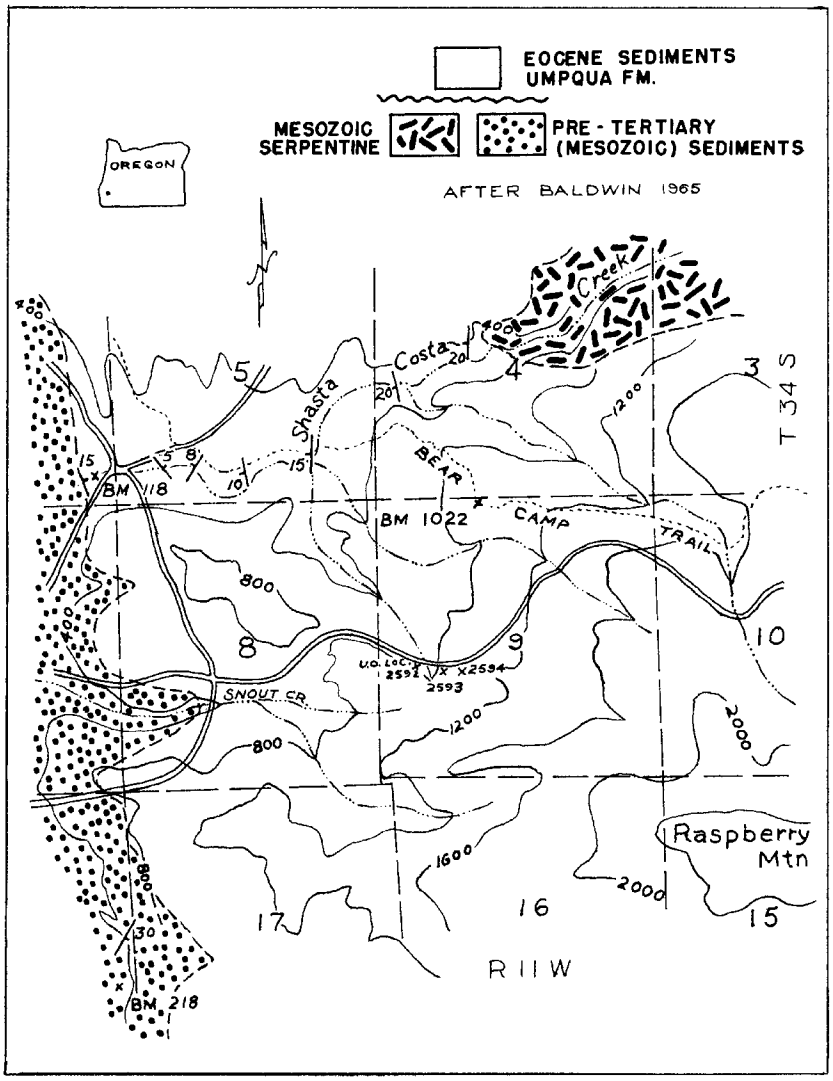


Figure 1. Geologic sketch map showing location of Univ. of Oreg. Mus. of Nat. Hist. Localities 2592, 2593, 2594. Geology from Baldwin [(1965) and oral communication].

Fossil Assemblage

Crabs

Fossilized crabs from these sediments are assigned to three genera and species including Raninoides washburnei Rathbun, Plagiolophus weaveri Rathbun and Cancer sp. The latter species is indeterminant and may be a new, as yet unnamed taxon.

By far the commonest species of crab recovered at any of the collecting sites was Plagiolophus weaveri. (figure 5A-I) This species is characterized by three prominent spines on the anterior periphery of the carapace and the large forward projecting orbits. Many of the living Pacific Coast crabs related to this species (family Goneplacidae) are burrowing types found in the mud flats of shallow bays and inlets. More than fifty complete carapaces of P. weaveri were recovered as well as several fragments sufficiently large for identification. This moderate number of whole specimens permits a simple analysis of growth in this species by plotting the width of the carapace against the length (fig. 2). With this type of graphic presentation, we are able to see that the ratio of width to length in the smallest individuals is very near one to one. Young adult specimens have a ratio of four to three whereas in mature adults the ratio is around three to two. A growth pattern of this type where the width increases at a more rapid rate than the length is not uncommon in decapods and is an expression of the rapid expansion of the branchial areas enclosing the gills within the lateral portions of the carapace. Males may be distinguished from females in this species by the slightly wider abdomenal segments in females (fig. 5E & 5F). The observed ratio of males to females in the P. weaveri population was around four to one. Plagiolophus weaveri has been reported by Rathbun (1926) from several Eocene localities in California. Many of the specimens of P. weaveri represented in this study were complete articulated specimens. This was particularly true of specimens preserved in concretions. The frequency of whole specimens here suggests that these organisms were buried in a quiet or low-energy environment in the Eocene ocean. Another explanation for their outstanding preservation as fossils might lie in their habitat as borrowing organisms.

Somewhat less common at these localities was the species Raninoides washburnei Rathbun (fig. 4D, E, G). This species belongs to a family (Raninidae) of crabs that once lived along the north Pacific Coast. At present they are more representative of tropical to subtropical waters from Mexico to Panama (Rathbun 1926). Although no articulated specimens of R. washburnei were recovered, we were fortunate enough to extract a small specimen on which the sternum plates are displayed (fig. 3C, 4F). R. washburnei is characterized by the coarse punctations on the carapace, the outward projecting lateral spine off the ovate carapace and the broad bispinous outer orbital spine. Specimens of Raninoides washburnei have been reported (Rathbun 1926) from Oligocene sediments near Eugene, Oregon as well as

from middle Eocene sediments exposed in Douglas County, Oregon.

The final decapod species recovered from the southwest Oregon locality has been assigned to the genus Cancer because of subelliptical carapace outline, small orbits and the rows of five tooth-like spines on the anterior lateral margins (fig. 4H, I). Only a very few specimens assignable to this taxon were recovered and most were fragments. The difficulty of assigning even whole specimens to a recognized species, however, suggests that they may belong to a new species. The genus Cancer is commonly represented by several species in the Tertiary fossil record of the Pacific Northwest (Nations 1969) and is known from rocks dating from the Paleocene to the Holocene.

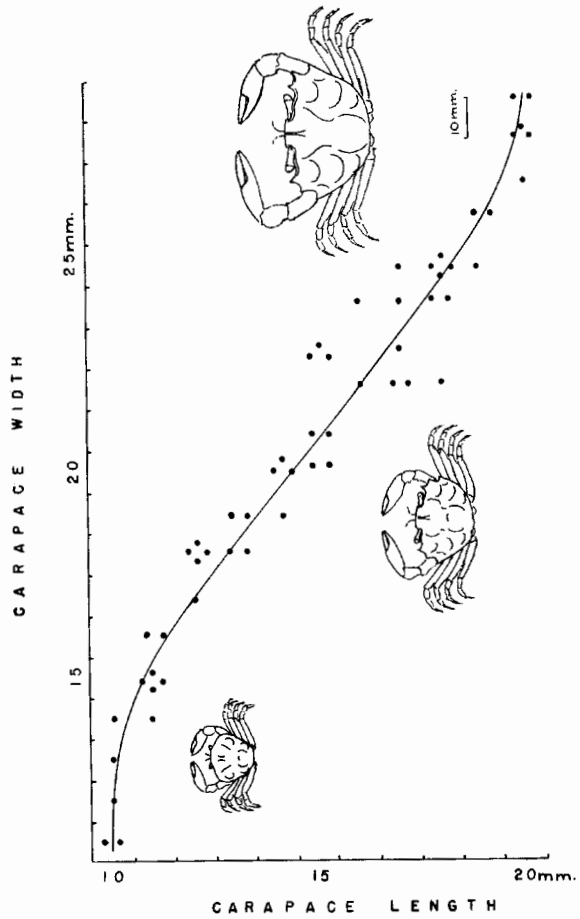


Figure 2. Length/ width distribution in the species Plagiolophus weaveri Rathbun.

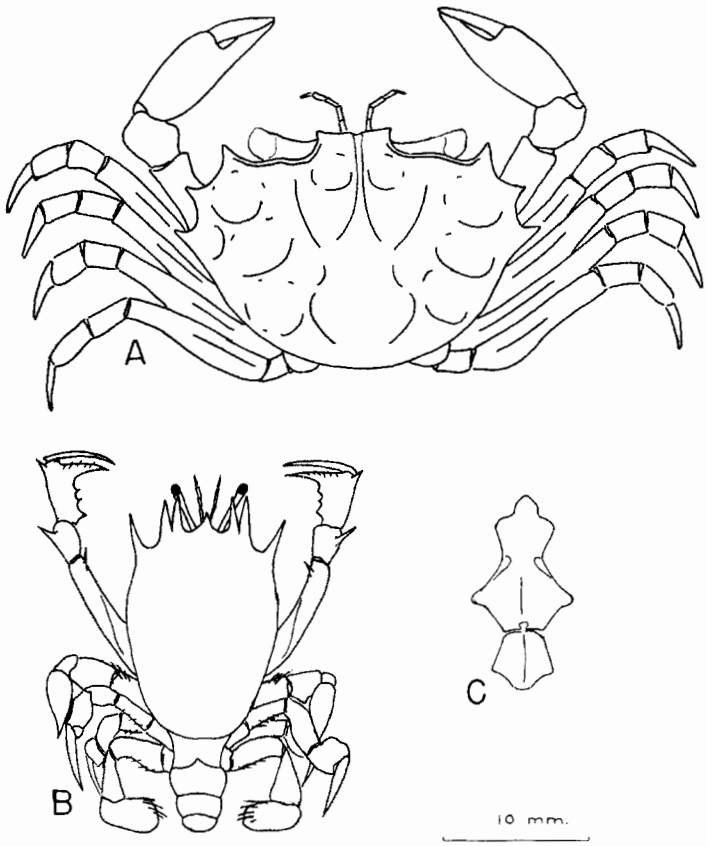


Figure 3. Reconstruction of Plagiolophus weaveri Rathbun (3A) and Raninoides washburnei Rathbun (3B), Sternum of Raninoides washburnei Rathbun (first and second segments and episternum) (3C). Details of reconstructed legs here as well as those on figure 2 are not precise (particularly those of R. washburnei) and are primarily to show the proportions of the carapace with respect to the entire body.

Echinoderms

Several specimens of irregular echinoids were recovered at the localities. Most of the specimens were small (2 cm dia. or less) and were considerably distorted. The specimens are characterized by well-defined, depressed

SPECIES LIST

MOLLUSCA

Pelecypods

Acila decisa (Conrad)

Anomia mcgoniglensis Hanna

Crassatella cf. uvasana mathewsoni (Gabb)

Glycimeris fresnoensis Dickerson

Nuculana gabbi (Gabb)

Ostrea sp.

Solena (Eosolen) cf. coosensis Turner

Tellina soledadensis Hanna

Gastropods

Fusinus merriami Dickerson

Homalopoma wattsi (Dickerson)

Mitra cretacea Gabb

Olivella mathewsoni umpquaensis Turner

Siphonalia cf. bicarinata Dickerson

Turritella buwaldana coosensis Merriam

Volutocorbis oregonensis Turner

Scaphopods

Dentalina sp.

FORAMINIFERA

Bathysiphon eocenica Cushman & Hanna

Dentalina jacksonensis (Cushman & Applin)

Haplophragmoides cf. scitulum (Brady)

Haplophragmoides obliquicameratus Marks

Haplophragmoides sp.

Lenticulina sp.

Lenticulina theta Cole

Marginulina subbulata Hantken

Nodosaria pyrula D'Orbigny

Pseudoglandulina ovata Cushman & Applin

Rhabdammina eocenica Cushman & Hanna

Robulus alato-limbatus Gumbel

Spiroplectammina richardi Martin

Textularia sp.

Trochammina sp.

EXPLANATION FOR FIGURES 4 AND 5

Figure 4. A, B, C, Chela and leg segments of Plagiolophus weoveri Rothbun

A University of Oregon Museum of Naturol History hypotype No. 28220 Length 25 mm Loc. No. 2594

B U.O.M.N.H. No. 28221 Length 23 mm Loc. No. 2594

C U.O.M.N.H. No. 28222 Length 25 mm Loc. No. 2594

D, E, G, Raninoides washburnei Rathbun, carapaces

D U.O.M.N.H. No. 28223 Length 33 mm Loc. No. 2594

E U.O.M.N.H. No. 29224 Length 36 mm Loc. No. 2594

G U.O.M.N.H. No. 29225 Length 22 mm Loc. No. 2594

F Raninoides washburnei Rathbun, sternum (first and second segments and episternum) U.O.M.N.H. No. 28226 Length 19 mm Loc. No. 2594

H, I Cancer sp. ventral (H) and dorsal (I) views of male carapace U.O.M.N.H. No. 28227 Length 26 mm Loc. No. 2594

Figure 5. All specimens Plagiolophus weaveri Rathbun

A Juvenile, dorsal view of carapace U.O.M.N.H. No. 28228 Length 10 mm Loc. No. 2594

B Abdomen of small male U.O.M.N.H. No. 28229 Width 15 mm Loc. No. 2594

C Young adult, dorsal view of carapace U.O.M.N.H. No. 28230 Width 14 mm Loc. No. 2594

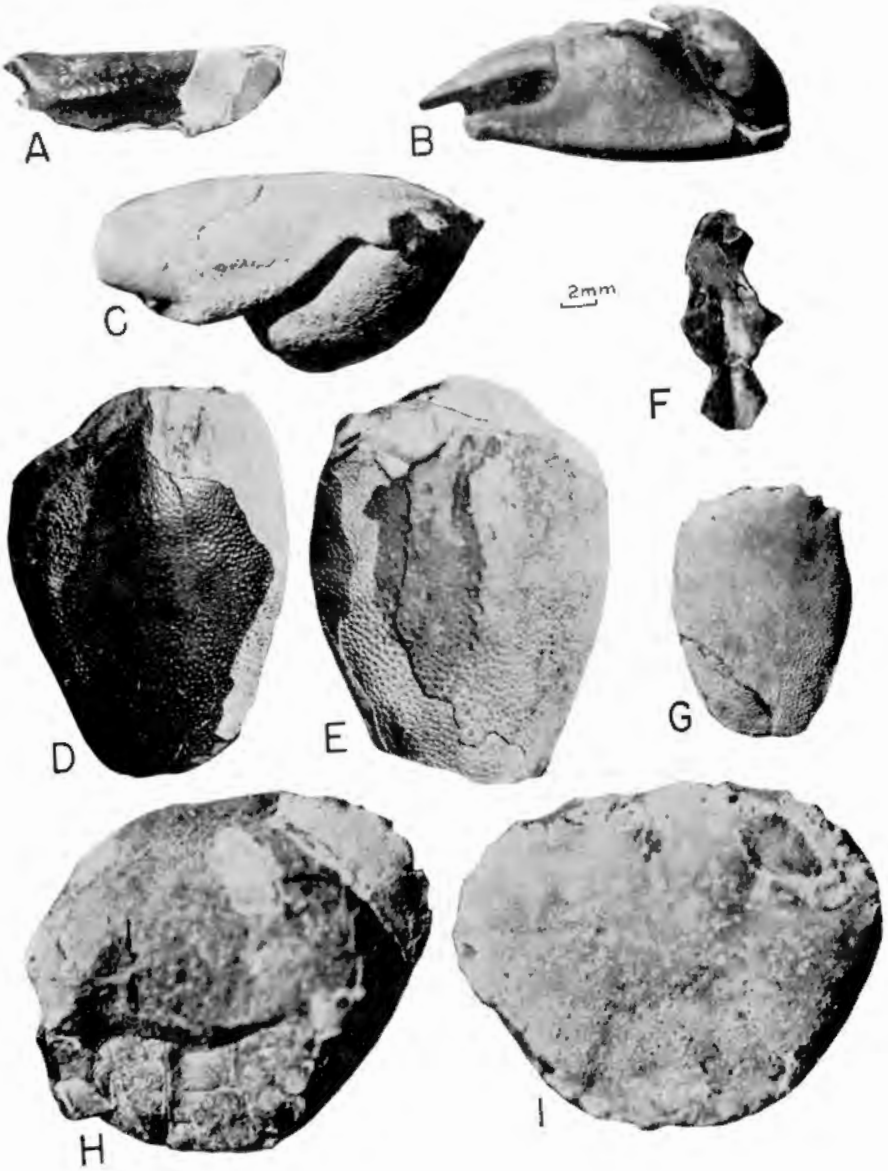
D Mature adult, dorsal view of carapace U.O.M.N.H. No. 28231 Width 24 mm Loc. No. 2594

F Mature male, ventral view of carapace U.O.M.N.H. No. 28232 Width 28 mm Loc. No. 2594

E, G Posterior and dorsal views of carapace of a mature female U.O.M.N.H. No. 28233 Width 25 mm Loc. No. 2594

H Mature adult, dorsal view of carapace U.O.M.N.H. No. 28234 Width 28 mm Loc. No. 2594

I Adult male ventral view of carapace U.O.M.N.H. No. 28235 Width 20 mm Loc. No. 2594


A
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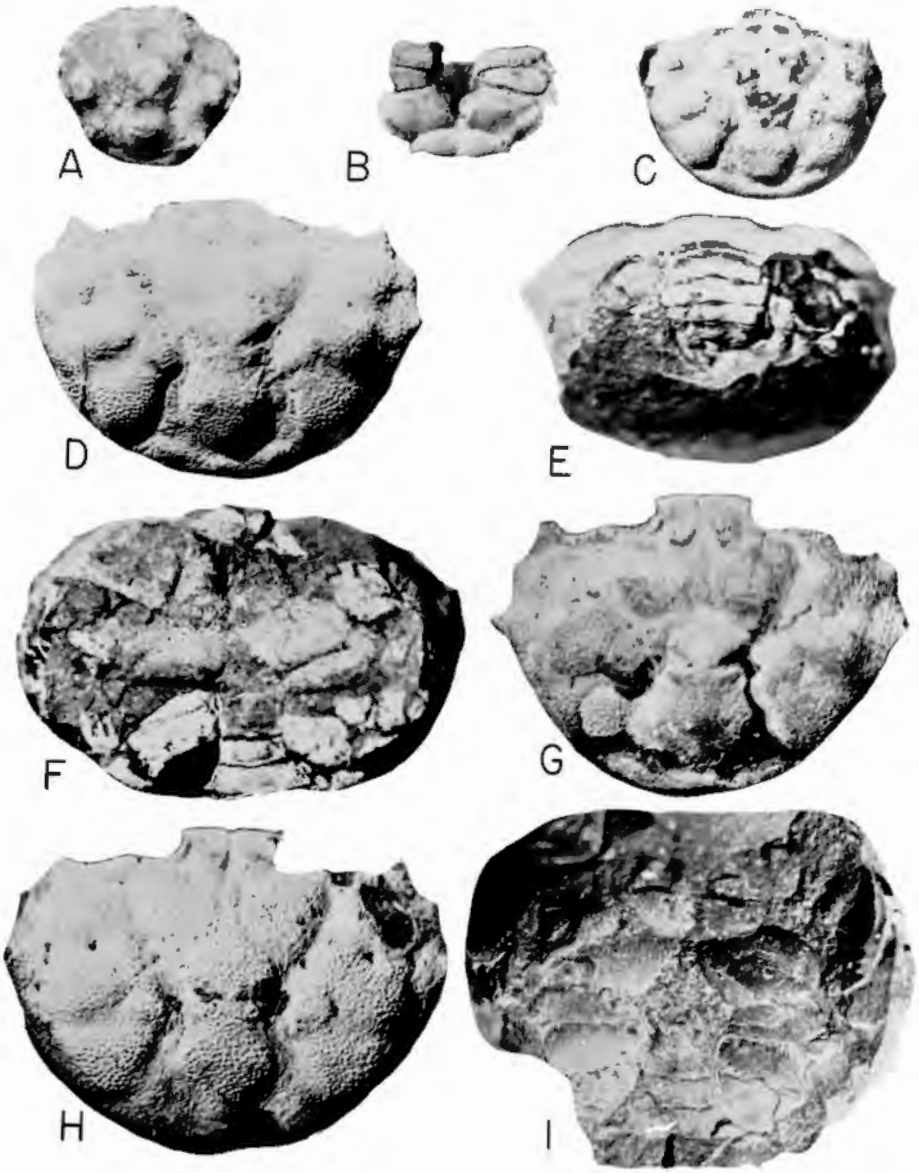
A
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ambulacral areas divided by sharp ridges. Because of the distortion it was not possible to immediately identify these organisms. Echinoid spines from both sand dollar and urchin types of echinoids were among the more common components of the biogeneous portion of the sediments.

Molluscs

Associated with the decapods at every locality was a diverse and well-preserved molluscan fauna. The fauna is made up of nearly equal numbers of gastropods and pelecypods and a very few, small scaphopod specimens (see species list). All of the molluscan species identified have been previously reported from Eocene rocks by Turner (1938) and Thoms (1964). Upon initial examination it was noticed that almost every molluscan specimen recovered was remarkably small. As a working hypothesis, the possibility that we were collecting a dwarf or depauperate fauna was considered. After some time was spent preparing the fauna, however, the large number of broken fragments of larger pelecypods and gastropods led us to the conclusion that the "dwarfism" phenomena was largely a post-consolidation deformation product. Larger specimens of molluscs may then have been more easily fragmented than the smaller, compact, geometrically competent specimens. It is possible that this phenomena may have had a similar effect on the decapods.

Protozoa

The protozoa are represented in the Umpqua sediments here by several species and most specimens are well preserved. In addition to the smaller calcareous and arenaceous foraminifera (list below), several perfect specimens of the larger foraminifera Pseudophragmina psila Woodring were recovered. This species has been reported by Thoms (1964) in both of his "Upper" and "Lower" Umpqua members. Despite the fact that several species of smaller foraminifera were identified it is difficult to assign a definitive correlation for the sediments other than middle Eocene. Most of the calcareous species are of the family Lagenidae whereas the remainder are characterized by an arenaceous test. The latter group is abundant even today in shallow bays and estuaries. The apparent lack of other families of foraminifera , particularly the planktonic Globigerinidae, further implies (but does not necessarily confirm) a shallow-water origin for the sediments and faunas under consideration here. Like many shallow-water forms, the foraminifera listed here tend to be stratigraphically long ranging. This may be due to a true longevity of the species involved or to the lack of sufficient distinguishable morphology on their relatively simple tests making them difficult to subdivide into evolutionary series. Most of these species range through several Eocene foraminiferal stages (Mallory 1959) and it is impossible to restrict the fauna to a shorter interval than the Ulatisian to Bulitian stages.

The presence of Haplophragmoides obliquicameratus Marks suggests the Narisian stage, as it is known only from that stage in California (Mallory 1959). Thoms (1964), however, has indicated that this species probably has a longer stratigraphic range in Oregon than in California on the basis of his study of Umpqua biostratigraphy. Thoms (1965) further correlates sediments from what is apparently the same stratigraphic interval with the late Ulatisian to late Penutian stages of Mallory (1959). Stratigraphic evidence presented by Baldwin [(1965) and oral communication] largely corroborates Thoms' (1964) correlation.

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THE TRACE FOSSIL TISOA IN WASHINGTON AND OREGON

Robert W. Frey* and John G. Cowles**

Introduction

Recently we described and interpreted some specimens of the trace fossil Tisoa from the Tertiary of Washington (Frey and Cowles, 1969), the first reported occurrence of this fossil burrow in North America. Specimens were collected near Megler, Washington, along a bluff facing the Columbia River (Figure 1); the fossils weathered out of the Lincoln Creek Formation. Distinct variations in trace fossil morphology were observed, representing differences in behavior of the animals responsible for the burrows.

Figure 1. The Megler locality, Pacific County, Washington. (On Columbia River, approximately 400 feet east of boundary between sections 8 and 9, T. 9 N., R. 9 W.)

* University of Georgia Department of Geology, Athens 30601
** Route 1, Box 96, Rainier, Oregon 97048

Tisoa has since been identified at various other places in Washington, but until very recently all of our attempts to locate specimens in Oregon opposite the Megler locality had failed. The fossil is now known from the Astoria Formation (early Miocene).

Considering the potential environmental, paleoecological, and paleontological significance of trace fossils generally (Frey, 1970, 1971), further searches should be undertaken in Oregon and Washington, aimed at documenting variations in, and the stratigraphic and facies distributions of, this fossil burrow.

Characteristics of Tisoa

Megler specimens of Tisoa typically consist of two parallel tubes contained within elongate calcareous concretions (Figure 2A, B), which are thus very similar to specimens reported from other countries (Häntzschel, 1962, Figure 137.4; 1965). The concretions collected by us are of assorted sizes but are invariably less than 15 cm in length and 7 cm in diameter. The enclosed tubes are generally 1 to 1.4 cm in diameter, and they run the full length of the host concretion; distances between adjacent tubes range from 2.5 to 7 mm (Frey and Cowles, 1969, Figure 1). Individual tubes are commonly lined with diagenetic pyrite, and the pairs of tubes may also be encircled by a thin layer of pyrite (Figure 3C, D). These tubes, evidently remaining open for a time during deposition of Lincoln Creek sediments, were eventually filled with a variety of detrital and diagenetic minerals.

Actually, rare specimens from Megler show that the "normal" twin tubes are in reality fragments of the upper part of a single U-shaped tube (Figure 3A), conceivably as much as a meter in original length (Häntzschel, 1962, p. W218). U-shaped fragments are less common now than "normal" specimens because (1) the break-up of the original structure produced more fragments of the upper part than of the basal part (Figure 4C), and (2) the basal part may have been less well constructed by the burrowing animal originally (Frey and Cowles, 1969, p. 19).

Rare Megler specimens also show that the tubes are not invariably straight (Figure 4A) and that the twin tubes may branch into additional pairs of tubes (Figure 4B). Furthermore, single-tube varieties of Tisoa are fairly common at this locality (Figure 2C); although these are identical to "normal" specimens in all other respects, no evidence for an original second tube has been observed.

Peculiarly, many of the tisoans observed at various places in Washington, other than Megler, consist predominantly of the single-tube variety, and at some localities the "normal" twin tubes are apparently very rare. Weldon W. Rau (1968, personal communication) wrote us that:

> "Although we frequently find concretions with a single tube of some sort in the middle, I do not recall ever seeing any like your specimens with the double tube. Those I have

enclosed (by mail) are not particularly good specimens but are a sample from outcrops where I saw hundreds and possibly thousands. They were all oriented with the long axis normal to bedding. They range from a few inches up to passibly 8 inches in length. They all seem ta have evidence of a crude tube thraugh the middle."

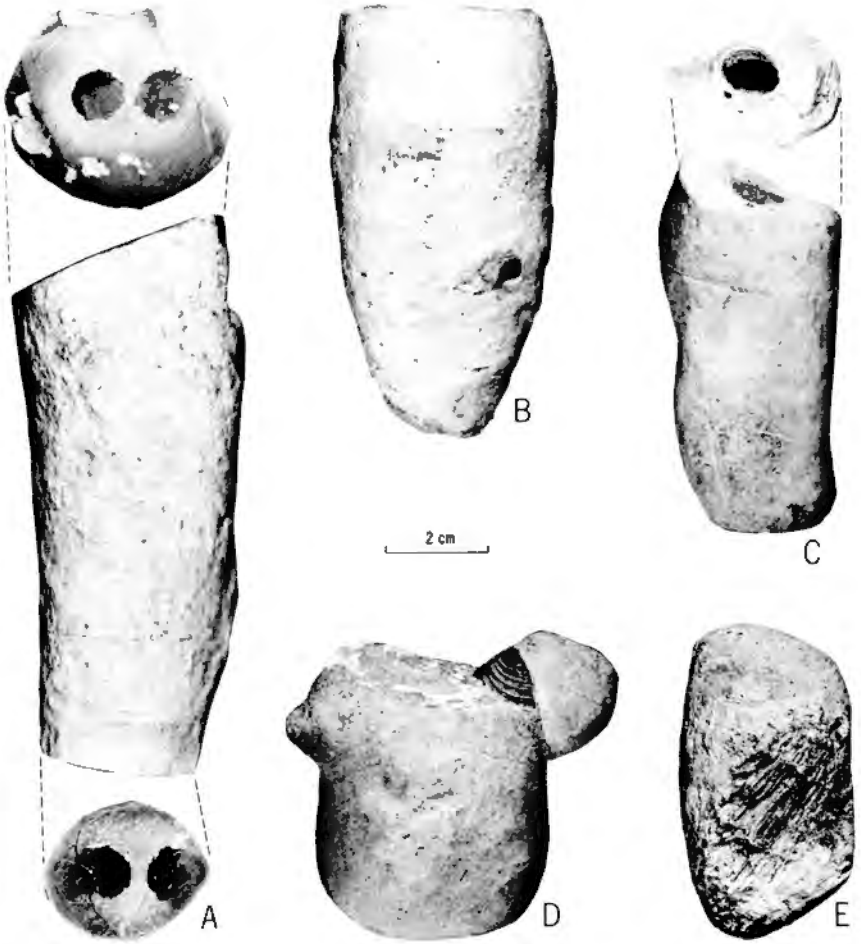

Figure 2. Tisoans from Megler. A,B. Typical double-tube specimens. C. Typical single-tube specimen. D. Bivolve Lucinoma cf. L. ocutilineota (Conrad) embedded in tisoan concretion. E. Fish fin on side of tisoan concretion.

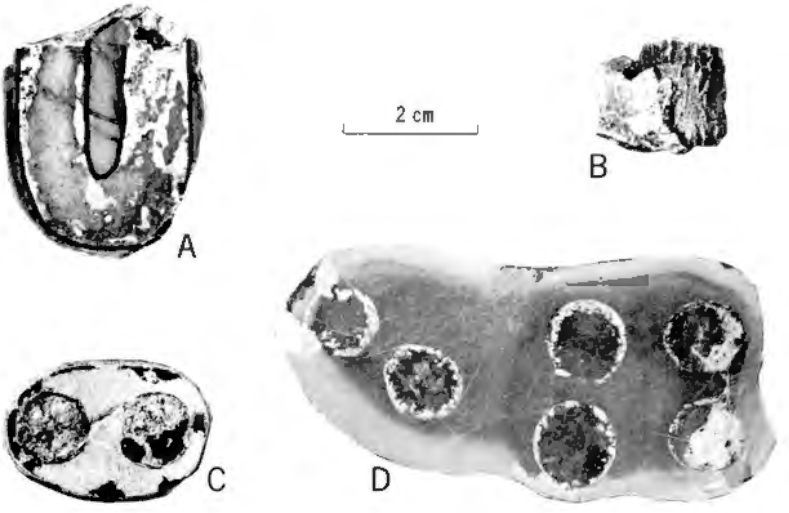

Figure 3. Tisoans from Megler. A. Longitudinal section through U-shaped tube (outlined in ink). B. Longitudinal view of tube fragment, mostly weathered out of its concretion, showing scratch marks. C. Transverse view of tisoan having pyrite concentrations around tubes and circumference of concretion. D. Transverse section through concretion containing three pairs of tubes, each lined with pyrite (cf. Figure 4B).

The morphological variations and interrelationships among local and regional assemblages of Tisoa thus clearly need additional study. Such work may eventually show that the genus is too broadly conceived and that it could realistically be split into two genera, although we would certainly discourage taxonomic splitting if possible (see Frey, 1971, p. 103-104).

Interpretation of Tisoa

The wall linings seen in many tisoan tubes suggest that the burrowing animal reinforced its domicile with organic secretions, which later reacted biogeochemically and thus helped concentrate secondary minerals such as pyrite (see Frey, 1971, p. 101-102). These alterations and the formation of enveloping concretions took place early in diagenesis, as suggested by a nearly intact fish fin and a closely articulated clam found embedded in tisoan concretions (Figure 2D, E); otherwise, bioturbation and other sedimentary and diagenetic processes probably would have disarticulated and scattered these fossil remains.

On the basis of morphology, requisite behavior, and the presence of small scratch marks on certain burrow walls (Figure 3B), we interpret Tisoa

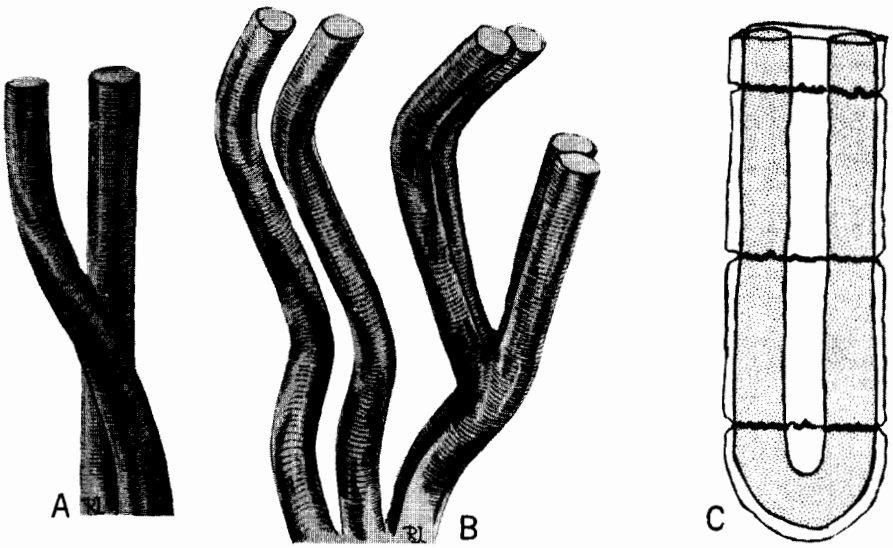

Figure 4. Reconstructions of Megler tisoans. A. Spiraled tubes. B. Branched tubes (cf. Figure 3D). C. Hypothetical specimen illustrating how several short, double-tube tisoans may be derived from a single long, U-shaped tube.

as the dwelling burrow of a shrimp- or amphipod-like arthropod (Frey and Cowles, 1969, p. 20). None of our burrow specimens contain arthropod remains, and virtually none of the fossil arthropods reported by Weaver (1942) are likely candidates; yet arthropod remains are rarely found even in well-documented Holocene and fossil arthropod burrows (Bromley, 1967, p. 170-172).

A possible exception among invertebrates reported by Weaver are such decapods as Callianassa knapptonensis (Rathbun, 1926, p. 112-113, Pl. 38, Figure 4), collected from the Oligocene near Megler. By analogy with the Holocene shrimp C. californiensis (Warme, 1967), C. knapptonensis conceivably could have constructed tisoan burrows having smooth exteriors, rather than the more popularly known knobby exteriors of Holocene C. major burrows and Ophiomorpha (Weimer and Hoyt, 1964). Callianassa californiensis does not, of course, make U-shaped burrows having closely appressed limbs, but certain other features of the burrow are somewhat comparable.

Overall, the burrowing habits reflected by Megler tisoans are more like that of the Holocene amphipod Corophium volutator (see Häntzschel, 1939), although the tisoan organism must have been substantially larger in size.

Distribution of Tisoa

Tisoa was previously known only from foreign localities, including the Oligocene of Tunisia, Cretaceous of Russia, and Jurassic of France and Madagascar (Häntzschel, 1962, p. W218). Hartmut U. Wiedemann (1970, personal communication) informed us that he has also observed the trace fossil in Jurassic marls near Aalen, Württenberg, Germany. Specimens from all of these localities consist predominantly of the twin-tube variety.

We have collected additional specimens southeast of Megler, especially on the western slope of K M Mountain, half a mile or more below the summit, along U.S. Highway 101. Weldon W. Rau (1968, 1971, personal communications) notes having seen Tisoa-like concretions in several other places, including the structures mentioned in his report on the Quinault Formation (Rau, 1970, p. 10). We examined a few of his specimens and found them extremely similar to those from Megler. Specimens from all of these localities consist mostly (or perhaps wholly) of the single-tube variety however.

In contrast, we have not personally located any unequivocal tisoans in Oregon. On the Oregon side of the Columbia we collected certain of the fossils and other concretions associated with Tisoa at Megler but no unmistakable evidence of Tisoa itself. Recently, however, Sam Boggs of the University of Oregon informed us (1971, personal communication) that he has collected a few specimens from an area along Youngs River near Astoria; we examined some of these specimens (from the Astoria Formation) and indeed found them to be single- and double-tube varieties of Tisoa, the latter being rare.

We strongly suspect that continued searching will eventually yield many additional specimens from Oregon, which will help establish further the morphological variation and overall distribution of this trace fossil in the Pacific Northwest.

Conclusions

Additional observations on the morphology and distribution of Tisoa are needed. Primary consideration should be given to the documentation of behavioral, biostratigraphic, and facies relationships of the different varieties of this trace fossil in Oregon and Washington. Only with this kind of information at hand can the full paleontological and environmental significance of Tisoa be evaluated.

Acknowledgments

We are grateful to Weldon W. Rau, Washington Department of Natural Resources, Ewart M. Baldwin, University of Oregon, and Richard E.

Thoms, Portland State University, for their comments and suggestions concerning this manuscript, and to Sam Boggs, University of Oregon, for sending us specimens of Tisoa collected by him in Oregon.

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FOSSIL BIGHORN SHEEP FROM LAKE COUNTY, OREGON

Richard E. Thoms* and Harold Cramer Smith**

In the first week of October, 1972, Roy Collier, a bulldozer operator for the MC ranch at Adel, Oregon, bulldozed up a skull from the gravels near the mouth of Twentymile Creek. The locality is in the South Warner Valley, Lake County, Oregon, in the NW$\frac{1}{4}$, sec. 19, T. 40 S., R. 24 E., W. B. & M. Subsequent examination of the skull indicated that it represents a specimen of Ovis catclawensis Hibbard and Wright, an extinct Pleistocene species of bighorn sheep known only from the Great Basin. A "battered cobble" of basalt, possibly representing human occupation of the stream bank or its vicinity, was found in association with the skull.

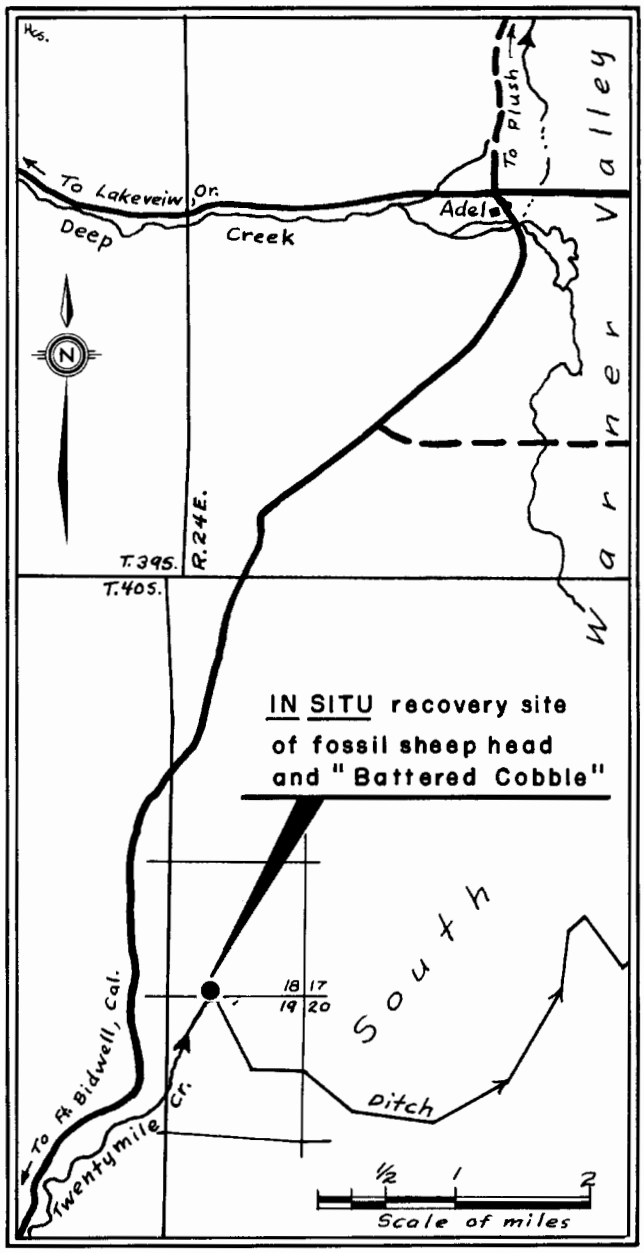
Previous Studies on Fossil and Living Bighorn Sheep From North America

For a thorough treatment of the various studies which have been made on the descriptions, distributional patterns, and evolution of fossil and recent bighorn sheep in North America, the reader is referred to the paper by Stokes and Condie (1961). The following section, a review of the historical record of bighorn sheep in the Oregon country, is offered for the reader to better understand the rugged and limited conditions under which the modern analog of Ovis catclawensis now survives in a portion of the Great Basin.

Historical Record of Bighorn Sheep (Ovis canadensis) in the Oregon Country

The story of the decline of bighorn sheep in Oregon parallels the decline of other wilderness species that could not compete with the coming of the white man and his "civilization."

*Chairman and Associate Professor of Geology, Department of Earth Sciences, Portland State University
**Wildlife artist, Information and Education Department, State of Oregon Game Commission


To Lakeview, Or.
Deep Creek
Adel
To Plush
Warner Valley
N
T.39S.
R.24E.
T.40S.
IN SITU recovery site
of fossil sheep head
and "Battered Cobble"
South Ditch
18 17
19 20
To Ft. Bidwell, Cal.
Twentymile Cr.
1/2 1 2
Scale of miles

The bighorn is strictly a wilderness animal, intolerant of heavy hunting and competition with domestic livestock, elk, and deer. At one time much more numerous than today, bighorn sheep were widespread over the West wherever rugged terrain provided desired habitat. As the white man turned livestock onto accessible ranges and extensively hunted the bighorns, they retreated to the most inaccessible, wildest, and highest peaks of the Rockies and to the deserts of the Southwest. All this happened quickly in the last half of the 1800's.

Distribution in North America

Two distinct species of wild mountain sheep evolved in North America since Pleistocene times, according to Cowan (1940). They are the thinhorn sheep (*Ovis dalli*) with three races or subspecies, and the bighorn sheep (*Ovis canadensis*) with five races.

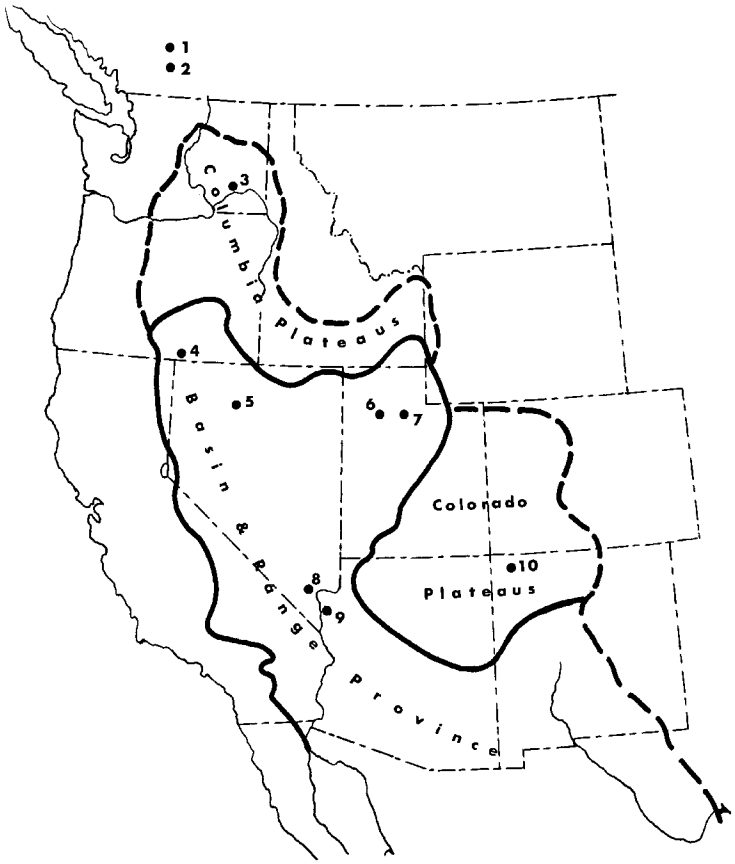
Distribution in Oregon

Two types of bighorns were originally native to Oregon: the California bighorn (also called the rimrock or lava beds bighorn), and the Rocky Mountain bighorn. Bighorns generally have more massive, close, heavier horns than do the northern thinhorns, with usually blunt, broomed tips as compared to the sharper, wider spread point of the Dall and Stone sheep. The Rocky Mountain bighorn, "Emah-ki-kini" of the Blackfeet Indians, held to the relatively small area of the northeast corner of the state, including the Wallowas and part of the Blue Mountains. Old timers reported the Rocky Mountain bighorn as far south as the Strawberry Mountains in Grant County and over to the high breaks along the Snake River Canyon. U.S. Forest Service reports indicate a remnant of these sheep as late as 1933 in the high Wallowas.

The California bighorn ("Tsnoon" of the Warm Springs Indians, and "Quoipa" of the Piutes) ranged from the Cascades east through central and southeastern Oregon. Early explorers such as Peter Skene Ogden gave accounts of the lava beds sheep near the Deschutes River in the area south of The Dalles, which is still known as the "Mutton Mountains." From locales such as this, the sheep ranged eastward through Hart Mountain and the Steens Mountains to Idaho and Nevada. One authentic report places these sheep as far southwest as the Siskiyou Mountains along the California-Oregon border.

Survival

Several theories are advanced as to the cause of the extinction of this species in Oregon. Schnabel in 1916 wrote that disease in the winter of 1884-1885 killed most of the sheep in the desert country. However,



FOSSIL BIGHORN SHEEP SITES REPORTED IN WESTERN NORTH AMERICA

LEGEND FOR NUMBERED SITES

1. Two remains in Alaska-Kowak clays
2. Canada - Last Chance Creek - Yukon Territory
3. Washtucna Lake (Old Washington Lake) - Franklin County, Washington
4. Mouth Twentymile Creek, Lake County, Oregon
5. Willow Creek Canyon - near Winnemucca, Nevada
6. Danger Cave, Utah
7. Hardman Gravel Pits - Salt Lake City, Utah
8. Gypsum Cave, Nevada
9. Catclaw Cave, Mohave County, Arizona
10. River gravels near Bloomfield, New Mexico

parasites from domestic sheep appear to be the greatest decimating factor. Huge flocks of domestic sheep covering much of the high desert range near and after the turn of the century contaminated nearly all parts of both summer and winter range. The scab mite supposedly caused loss of hair and undercoat so that the wild sheep perished from exposure during the winter. This theory is questioned by some authorities. In 1914, a Mr. Tillford of Fort Klamath stated that close grazing of bighorn winter range by domestic flocks resulted in heavy winter die-off in the winter of 1879-1880. Other eastern Oregon rangers corroborated the starvation theory.

In Oregon, the Steens and Hart Mountains appeared to be the last stronghold of the California bighorns. The last records of wild sheep in these areas was an account, by Goldman, of one or two rams seen on Hart Mountain in 1912. By 1916 the California bighorn had disappeared from the state.

In 1939, a group of Lakeview sportsmen, with the aid of the U. S. Biological Survey, released 23 Rocky Mountain bighorns on Hart Mountain. This transplant was unsuccessful.

In 1954, the Oregon Game Commission, in cooperation with the British Columbia Game Department, trapped 20 sheep in British Columbia and released them in Oregon. Again the Hart Mountain area was chosen as a good site. They were released into a 34-acre pen and held there while a 600-acre holding pen was constructed on the west face of Hart Mountain. The large pen was started in March, 1955, and completed in July of that year. It consisted of over $4\frac{1}{2}$ miles of fence constructed under adverse conditions and on very difficult terrain.

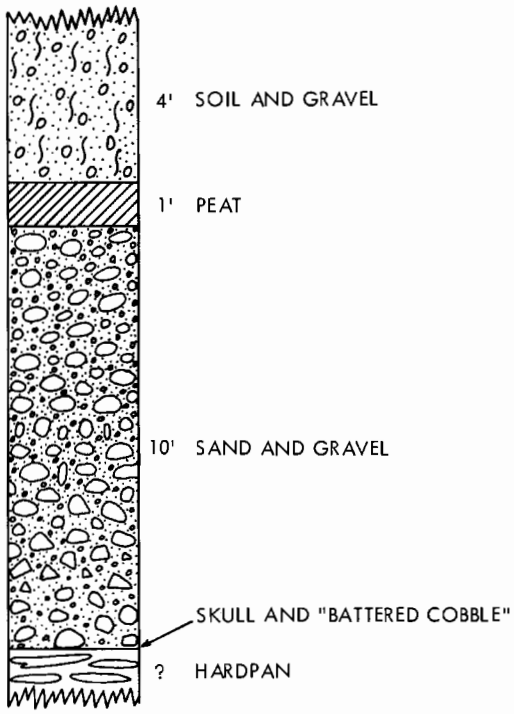
The sheep quickly adapted to life in the 600-acre pen. The first release from the pen was made in June, 1957, when 18 sheep were allowed to escape from the pen at the west face of the mountain. Since that time a few sheep have liberated themselves by breaking through the fence. An attempt has been made each year to tally as many sheep as possible both inside and outside of the pen. By 1960, the known population was over 64 animals, including animals both in and out of the enclosure. In 1960 four sheep were caught and moved to Steens Mountain, a distance of about 70 airline miles, and in 1961 an additional seven sheep were moved to that site.

In November of 1965, 17 sheep were transplanted from the Hart Mountain herd to the Owyhee Canyon country. In 1971, 21 Hart Mountain sheep were released in the Strawberry Mountains area south and east of John Day and Prairie City. Also in 1971, 40 sheep from Jasper National Park were released on two different sites in the Snake River country, 20 head below Hells Canyon Dam, and 20 head on the lower Lostine River. To date, some of the transplants have been sufficiently successful to allow limited permit hunting.

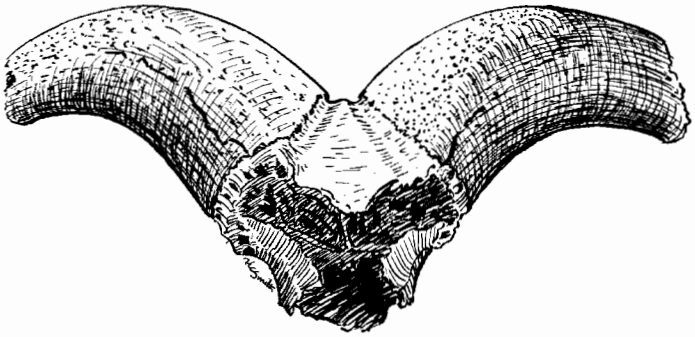
Stratigraphy

The skull and "battered cobble" were found about 5 feet apart on the south side of the creek bed, lying on the hardpan layer beneath the oldest deposit of sand and gravel exposed in the bed of Twentymile Creek. The sand and gravel was previously about 8 to 10 feet thick, but was partially cleared away about 10 years ago. The bed of Twentymile Creek is artificially altered by continual construction of revetments and digging in the channel for agricultural purposes. Thus, the specimens were covered by only about 4 feet of the deposit. They were obviously associated with the sand and gravel and not with the hardpan. A layer of peat, about 1 foot thick, overlies the sand and gravel, and this in turn is covered by about 4 feet of mixed soil and gravel.

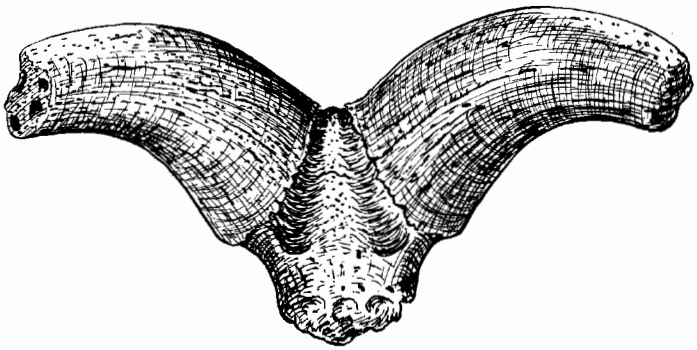
Across the channel on the north side, about 5 to 10 yards from the bank, is a promontory where the wind has blown away the soil in places, exposing numerous artifacts. This may represent an old campsite, and thus a human origin for the "battered cobble" is made more probable.



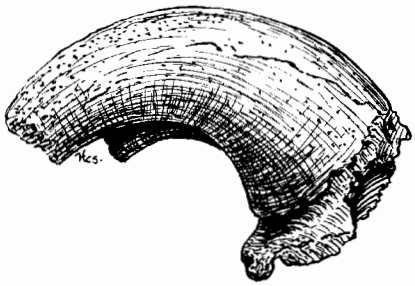
Stratigraphic column at discovery site (Adel, Oregon)



Front View



Rear View



Side View

Three views of partial skull and attached horns of Ovis catclawensis from Adel, Oregon.

Description and Comparison of the Adel Specimen

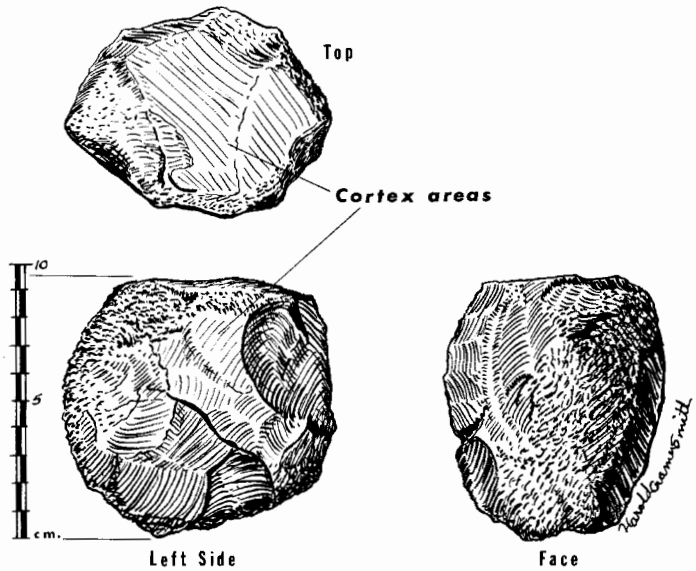
The accompanying table summarizes the measurements which could be made on the specimen, a partial skull with attached horn cores. These measurements compare favorably with those made by Stokes and Condie (1961) on fourteen specimens of Ovis catclawensis from several localities in the Great Basin. However, the partial nature of the Adel specimen permitted only one of Stokes and Condie's "most significant measurements" -- the maximum core circumference -- to be compared. Comparison of illustrations from Stokes and Condie with the specimen shows many similar features. In addition, comparison of the Adel specimen with specimens and measurements of the modern Ovis canadensis canadensis and Ovis canadensis californiana do not warrant inclusion in either of these subspecies. The Adel specimen possesses the robust features of a mature male, with the fused condition of cranial sutures characteristic of an individual of 10 years or more in age.

Horn core and skull measurements of the Adel specimen

Maximum diameter at base of horn cores:	left	116 mm
	right	115 mm
Minimum length of horn cores:	left	179 mm
	right	179 mm
Circumference of horn cores at base:	left	336 mm
	right	337 mm
Minimum angle between horn cores:	90°	

Conclusions

The discovery of the Adel specimen extends the known range of Ovis catclawensis into the northwestern-most part of the Great Basin. Although a precise date for the locality has not yet been established, all heretofore known occurrences of this species are Pleistocene, and the majority of these are from the Alpine Formation of the Bonneville Lake basin. The association of skull and "battered cobble" in proximity to a living site suggests that Ovis catclawensis was contemporaneous with early man in at least part of its stratigraphic range. This association, as well as the geographic distance of the find from those of the Bonneville basin, should spur interest in this fascinating part of Oregon's Pleistocene record.



"BATTERED COBBLE"

Possible artifact from mouth of Twentymile Creek in South Warner Valley. (Found in association with sheep skull.)

Description: Approximately cobble size, some cortex* (20%) remains, both areas of cortex on opposite ends of object.

Appears to have been battered over 60% of surface, quite a number of hinge-flake scars visible in one area. Spalls and other flake scars over much of remainder of surface. Little indication of mechanical transportation subsequent to manufacture is present. It was apparently deposited at site of find or nearby. An in situ circumstance is indicated.

Conclusion: Quite high probability that this object represents human (cultural?) modification, but it is not a standard artifact form. Other associations and data needed to confirm. I would call it a "battered cobble."

Dr. Tom Newman
Department of Anthropology
Portland State University

*Natural, unflaked surface of the basalt cobble

Acknowledgments

The assistance of several persons who have aided in the preparation of this report is hereby acknowledged. First of all, Roy Collier, of Adel, Oregon, whose sharp eye and steady hand first brought the specimen to light and whose generous loan of the specimen made its careful study possible. Next, Dr. Tom Newman of the Department of Anthropology, Portland State University, who analysed the "battered cobble;" and finally, David Taylor, who made the measurements of the skull in the Earth Sciences Museum, Portland State University.

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FOSSIL LOCALITIES

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May 1957

FOSSIL LOCALITIES OF THE SUNSET HIGHWAY AREA, OREGON

By Margaret L. Steere*

Introduction

The Sunset Highway area in western Columbia and Washington Counties, Oregon, is famous for its abundant marine fossils of Oligocene age. This fossiliferous area lies about 35 miles northwest of Portland and extends from Mist at the north end to Forest Grove at the south. Outcrops yielding fossils are numerous, and most exposures of sedimentary rock, hard enough to have resisted weathering, reveal at least a few fossils. The localities described on the following pages, and shown with corresponding numbers on the accompanying map, are easily reached by road. Sunset Highway (US 26) bisects the area and surfaced roads lead north and south from it.

Geologic Setting

During most of the period from late Eocene until the end of Oligocene time, some 30 to 50 million years ago, northwest Oregon was covered by an arm of the sea in which molluscs and other marine invertebrates were exceedingly numerous. Streams eroding the adjacent lands brought in mud, sand, and volcanic ash which settled in layers on the floor of the sea. As the floor gradually subsided, thousands of feet of sediments accumulated. Shells of the animals living on the sea bottom, or washed up along the margins, were buried and preserved as fossils in the sedimentary rocks.

Some time after the close of the Oligocene period, the land was uplifted permanently from the sea and the sedimentary rocks were warped into gentle folds and then deeply eroded. Today these tilted fossil-bearing strata are exposed in steep banks along streams and in roadcuts and quarries.

The oldest fossiliferous sediments in the area belong to the Cowlitz Formation (upper Eocene), which in the region of the Cowlitz River, Washington, reaches a thickness of nearly 8,000 feet. In Oregon, the Cowlitz Formation is less extensive and consists largely of conglomerates and sand-

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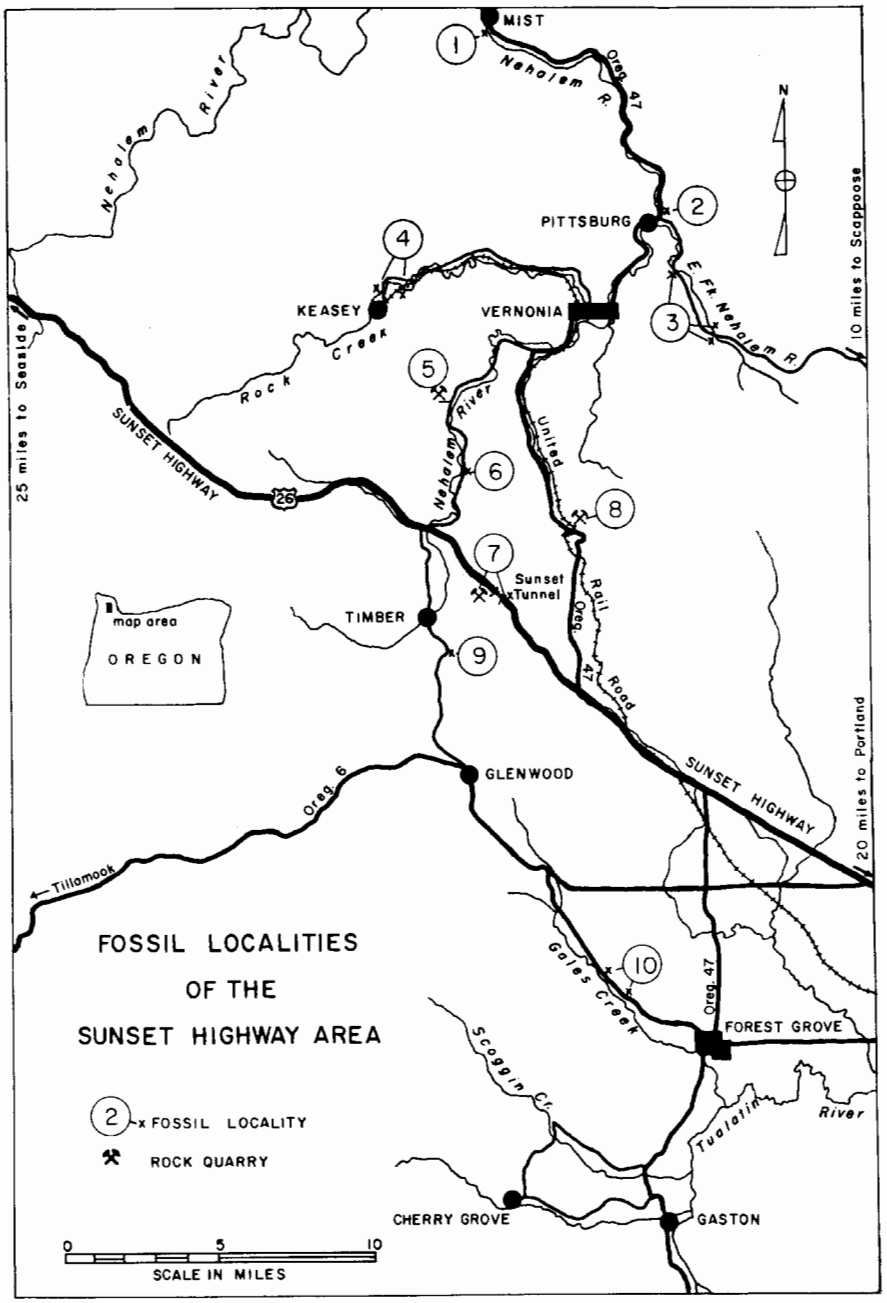
* Geologist, State of Oregon Department of Geology and Mineral Industries.


MIST
Nehalem R.
Oreg. 47
Nehalem River
PITTSBURG
E. Ft. Nehalem R.
10 miles to Scappoose
KEASEY
VERNONIA
Rock Creek
Ft. Nehalem River
United
25 miles to Seaside
SUNSET HIGHWAY
26
Sunset Tunnel
Rail Road
Oreg. 47
map area
OREGON
TIMBER
GLENWOOD
Oreg. 6
SUNSET HIGHWAY
20 miles to Portland
Tillamook
FOSSIL LOCALITIES
OF THE
SUNSET HIGHWAY AREA
Gales Creek
Oreg. 47
FOREST GROVE
Scoggin Cr.
Tualatin River
x FOSSIL LOCALITY
ROCK QUARRY
CHERRY GROVE
GASTON
0
5
10
SCALE IN MILES

stones deposited near the shore of the Eocene sea. These rocks crop out irregularly along the western side of the Sunset Highway area, where they overlie or interfinger with volcanic rocks of the Coast Range. Some outcrops of the Cowlitz Formation contain marine shells (Locality 5) and others show fossil plant remains.

Overlying the Eocene sediments are the highly fossiliferous Oligocene marine formations. Most noteworthy of these, as far as abundance and variety of fossils is concerned, are the Keasey and Pittsburg Bluff Formations (named after Keasey and Pittsburg in Columbia County where the formations were first studied). The Keasey Formation, which is the older of the two, is about 2,000 feet thick. It is, for the most part, a massive tuffaceous mudstone which is gray on fresh exposure but turns soft and yellowish when exposed to the weather. It crops out between Keasey and Vernonia, and continues in a wide band trending north and south through the center of the map area. Fossils are found in most unweathered outcrops (Localities 1, 4, 6, 7, 8, 9, 10) and include many new species, some recently described by Hickman (1976).

The Pittsburg Bluff Formation is a massive sandstone about 800 feet thick containing richly fossiliferous layers. It is exposed in various places from the bluffs along the Nehalem River north of Pittsburg to outcrops along Sunset Highway east of the tunnel. It is most fossiliferous in the vicinity of Pittsburg (Localities 2 and 3) where the fossils are typical of a nearshore or shallow-water fauna. Layers of plant remains, carbonaceous material, and coal are characteristic of the Pittsburg Bluff Formation.

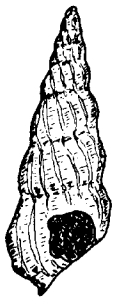
Both the Keasey and the Pittsburg Bluff Formations contain hard limy concretions ranging from the size of a baseball to 3 or more feet in diameter. These concretions are difficult to break open, but are usually worth the trouble as most have something of interest inside, such as the carapace of a crab or a beautifully preserved shell.

Fossil Localities

1. Mist crinoid locality

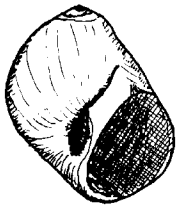
An unusual crinoid zone in the Keasey Formation is located in a high bluff on the west side of the Nehalem River 0.3 mile south of the junction of Oregon highways 47 and 202 in Mist. The outcrop is plainly visible from Highway 47. To reach it, cross the Nehalem River on the Burn Road bridge just south of Mist and walk upstream several hundred feet along the west bank of the river to the bluff and then a short distance along the base of the bluff at the water's edge. The whole bluff is composed of gray fine-grained tuffaceous siltstone of the Keasey Formation. Since the crinoid zone is only a few feet above the river at low-water stage, it can be reached only in late summer.

Crinoids, popularly known as sea lilies, resemble plants but are actually marine animals of the echinoderm family. Fossil crinoids of Tertiary age have been found in only a few places in the world, and nearly complete specimens,

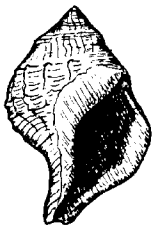


EPITONIUM

EXILIA



POLINICES

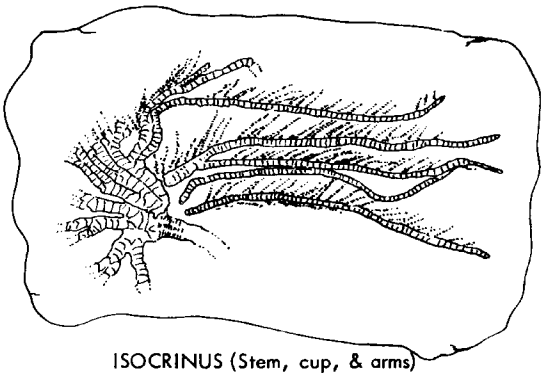


BRUCLARKIA

MOLOPOPHORUS

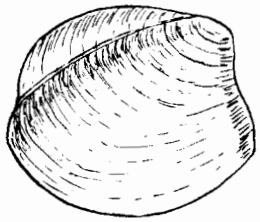
CANCELLARIA

SHARK TOOTH

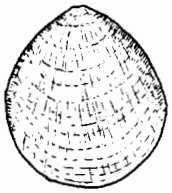


ISOCRINUS (Stem, cup, & arms)

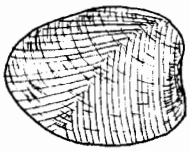
SOME TYPICAL FOSSILS OF THE SUNSET HIGHWAY AREA
(Approximate natural size)



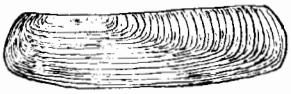
THYASIRA



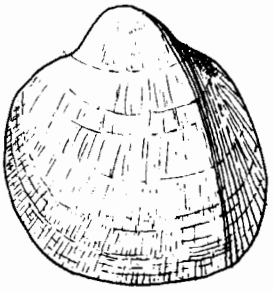
GLYCYMERIS



ACILA



SOLEN

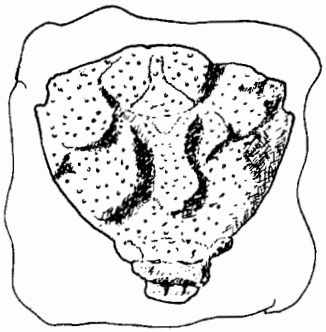


DELECTOPECTEN

NUCULANA

NEMOCARDIUM

DENTALIUM



ZANTHOPSIS (Carapace)

SOME TYPICAL FOSSILS OF THE SUNSET HIGHWAY AREA

(Approximate natural size)

including stem, cup, and branching arms, such as occur at the Mist locality, are especially rare (Moore and Vokes, 1953). This remarkable deposit should be treated with great respect, and care taken not to cause unnecessary destruction of the bed. Other fossils found with the crinoids include spiny echinoderms (sea urchins) corals, shark teeth, and various molluscs.

2. Pittsburg locality

The sandstone bluffs along the Nehalem River near the town of Pittsburg in Columbia County are the type locality for the Pittsburg Bluff Formation of Oligocene age. The formation is well exposed a short distance north of Pittsburg in roadcuts along State Highway 47, especially at 0.2 mile north of the Scappoose road junction. At this location the massive sandstone contains narrow bands thickly crowded with gastropods.

3. East Fork Nehalem River localities

Richly fossiliferous zones in the Pittsburg Bluff Formation crop out in the bluffs of the East Fork Nehalem River. The best exposures are in roadcuts along the Pittsburg-Scappoose road and the Crown Zellerbach logging road, both of which follow the East Fork valley. Fossils occur in hard concretionary masses; some are so well preserved that even the mother-of-pearl is still present. Elsewhere in the formation the rock softens so rapidly on exposure that the fossils quickly disintegrate.

The most easily accessible outcrop is a cut on the Scappoose road 2.7 miles east of Hwy. 47. The fossils are in a hard zone near road level.

A second locality, once highly productive, is on the north wall of the valley, 1 mile west of the Railroad Trestle Wayside sign at Scaponia Park. The outcrop is on the old railroad grade, now overgrown by trees, about 30 feet above the elevation of the Crown Zellerbach logging road.

A third locality is a roadside outcrop on the Crown Zellerbach logging road approximately 1.6 miles east of the Railroad Trestle Wayside sign. Rare isopods, associated with plant fossil material, were found here in 1964 by Sam Mercer of Rainier. Weathering of the outcrop may have destroyed the fossils.

4. Rock Creek locality

The original collecting area for Keasey fossils, the type locality for the Keasey Formation of Oligocene age, is in the banks of Rock Creek between Vernonia and Keasey (a former logging railroad station). The locality is largely of historical interest today because the Keasey Formation is now exposed elsewhere in less weathered and more accessible places. To reach the locality from Vernonia, follow Rock Creek road 8.8 miles to the third highway bridge over Rock Creek. Fossils can be found near water level in the low bank of the creek.

5. Rocky Point quarry locality

A county-owned quarry in Eocene basalt is situated just off the Timber-Vernonia road 6.5 miles southwest of Vernonia (or 5.8 miles north of Sunset Highway at the Timber-Vernonia junction). An access road 1/8 mile long leads to the small quarry. Overlying the basalt is a bed of pebble conglomerate of the Cowlitz Formation containing Eocene marine fossils. Pelecypods, brachiopods, hexacorals, and shark teeth have been found at this locality.

6. Nehalem River locality

A fossiliferous outcrop of the Keasey Formation occurs in a prominent cut along the Nehalem River on the east side of the road from Timber to Vernonia, 3.0 miles north of the junction with Sunset Highway. The locality is about 3 miles south of Locality 5. Large pelecypods of the genus *Thyasira* are found at this outcrop.

7. Lite-Rock quarry

The Keasey Formation is exposed in the Lite-Rock quarry at the west end of the Sunset Tunnel on Sunset Highway. Many well preserved pelecypods, gastropods, dentalium, crabs, and other varieties of fossils have been found in the gray, tuffaceous mudstone and in base-ball size concretions. (This quarry was closed to visitors at latest inquiry, October 1976).

8. Railroad trestle quarry locality

The Keasey Formation is exposed in a quarry above Hwy. 47 at the east end of a high, curving, railroad trestle. The location, not visible from the highway, is 6.4 miles north of Sunset Highway and 8.5 miles south of Vernonia. A road (closed to cars) leads uphill to the quarry; parking space is available at the bottom. Well-preserved fossil shells, similar to those at the Lite-Rock quarry, can be collected at this site.

9. Timber locality

The Keasey Formation crops out in a prominent roadcut at a sharp bend in the Timber-Glenwood road. The locality is 1.3 miles south of the railroad crossing at Timber and 5.2 miles north of Glenwood. Well-preserved fossils have been found here in the past.

10. Gales Creek locality

Two roadcuts on Hwy. 6 along the north side of Gales Creek valley expose the Keasey Formation. The roadcuts are $3\frac{1}{2}$ and 5 miles west of Forest Grove. Although both outcrops are weathered, a few fossils can be found in the harder sandstone layers. Concretions are fairly numerous, and some contain fossil crabs.

Fossils to Look For

Hundreds of species of fossil shells have been collected from the Sunset Highway area and identified by paleontologists, and there are many new fossil species that have never been described. A few of the fossils typical of the area are illustrated here. Molluscs, chiefly pelecypods (clams) and gastropods (snails), make up the majority of the large fauna, but other types of marine fossils such as shark teeth, crabs, and crinoids (sea lilies) are also represented. Plant remains in the form of woody material and poorly preserved leaves are locally present. Names of some of the fossils commonly found in the Cowlitz, Keasey, and Pittsburg Bluff Formations, together with those less common but of special interest, are listed below. For a more complete list of species see the references cited at the end of this report.

Cowlitz Formation (upper Eocene)

Pelecypods:
- Acila decisa (Conrad)
- Glycymeris eocenica (Weaver)
- Ostrea griesensis Effinger
- Volsella cowlitzensis (Weaver and Palmer)

Plant remains

Gastropods:
- Exilia dickersoni (Weaver)
- Ficopsis cowlitzensis (Weaver)
- Polinices nuciformis (Gabb)
- Siphonalia sopenahensis (Weaver)

Brachiopods

Shark teeth

Keasey Formation (lower Oligocene)

Pelecypods:
- Acila nehalemensis Hanna
- Delectopecten (new species)
- Nemocardium weaveri (Anderson and Martin)
- Nuculana (new species)
- Thyasira disjuncta (Gabb)
- Yoldia chehalisensis (Arnold)

Teredo (in wood)

Glass sponge

Scaphopods (Dentalia)

Corals

Crinoids:
- Isocrinus oregonensis Moore and Vokes
- Isocrinus nehalemensis Moore and Vokes

Gastropods:
- Cancellaria (new species)
- Epitonium keaseyense Durham
- Exilia lincolnensis Weaver
- Gemmula bentsonae Durham
- Polinices (new species)
- Scaphander stewarti Durham

Echinoderms (sea urchins)
- Salenia sp.

Crustacea (crabs):
- Zanthopsis vulgaris Rathbun
- Eumorphocorystes naselensis Rathbun

Pittsburg Bluff Formation (middle Oligocene)

Pelecypods:
- Acila shumardi (Dall)
- Nuculana washingtonensis (Weaver)
- Macrocallista pittsburgensis (Dall)
- Spisula pittsburgensis Clark
- Solen townsendensis Clark
- Tellina pittsburgensis Clark
- Thracia condoni Dall

Gastropods:
- Bruclarkia columbiana (Anderson and Martin)
- Molopophorous gabbi Dall
- Perse pittsburgensis Durham
- Polinices washingtonensis (Weaver)

Isopod

Plant remains

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FOSSIL LOCALITIES OF THE EUGENE AREA, OREGON

Margaret L. Steere*

Introduction

The Eugene area became known for its fossils through Dr. Thomas Condon, first Professor of Geology at the University of Oregon, who began collecting there in the 1870's. Since that time, many species of fossils have been discovered and identified, and both the University of Oregon and Oregon State University have important collections in their museums. Many of the fossils came from basement excavations for campus buildings.

Typical fossils of the Eugene area are sea shells and leaf imprints. They occur in interfingering marine and terrestrial strata that were deposited from late Eocene to late Oligocene time (40 to 25 million years ago). These fossiliferous beds now crop out in the hills of the Eugene area and all dip gently eastward as the result of regional folding. A recent study by Hickman (1969) describes and illustrates the Eugene molluscan fossils.

Geologic History

During the time that the Eocene and Oligocene fossil beds were being deposited, most of northwestern Oregon lay beneath a warm shallow sea whose southeastern shoreline ran approximately through the Eugene area (Lowry, 1947). Marine invertebrate animals lived in great numbers on the sea floor, while semitropical forests grew along the coast. Because the sea level fluctuated considerably, the Eugene area was at times under water and receiving marine sediments, and at times above sea level and receiving terrestrial sediments. For this reason both fossil shells and fossil plants are found in close proximity in the rock strata.

The oldest fossil-bearing rocks in the Eugene area are brown tuffaceous marine sandstones and shales of late Eocene age, named the "Spencer Formation" after typical outcrops near the mouth of Spencer Creek. The Spencer Formation was laid down on the sea floor as layers of sand and mud which incorporated the shells of marine animals living there. It attained a thickness of several thousand feet. Today these fossiliferous beds are exposed in

*Geologist, State of Oregon Department of Geology and Mineral Industries.

Richardson Butte and other hills along the western edge of the Eugene area (Locality 1). The formation can be traced northward along a narrow belt into the Corvallis area and southward toward Comstock; east of this outcrop belt it dips beneoth younger strata.

Near the close of Eocene time, regional uplift caused the sea to retreat temporarily from the Eugene area. The new land surface began to receive thick deposits of ash, tuff, breccia, and other volcanic materials, some of which was reworked and redeposited by streams. Luxuriant forests, at first subtropical, grew on the slopes of volcanoes and in the valleys between them. Fossil wood, leaves, seeds, and flowers are found today in lenses of fine-grained sediments marking sites of ancient ponds where plant remains from surrounding forests became buried in mud and ash (Localities 6 and 7). Several ages of forests are represented in the Eugene and adjacent areas, and two have been described in detail by paleobatanists Ralph Chaney and Ethel Sanborn (see Bibliography). These are the late Eocene Camstock flora southwest of Cottage Grove and the Oligocene Goshen flora (Locality 7).

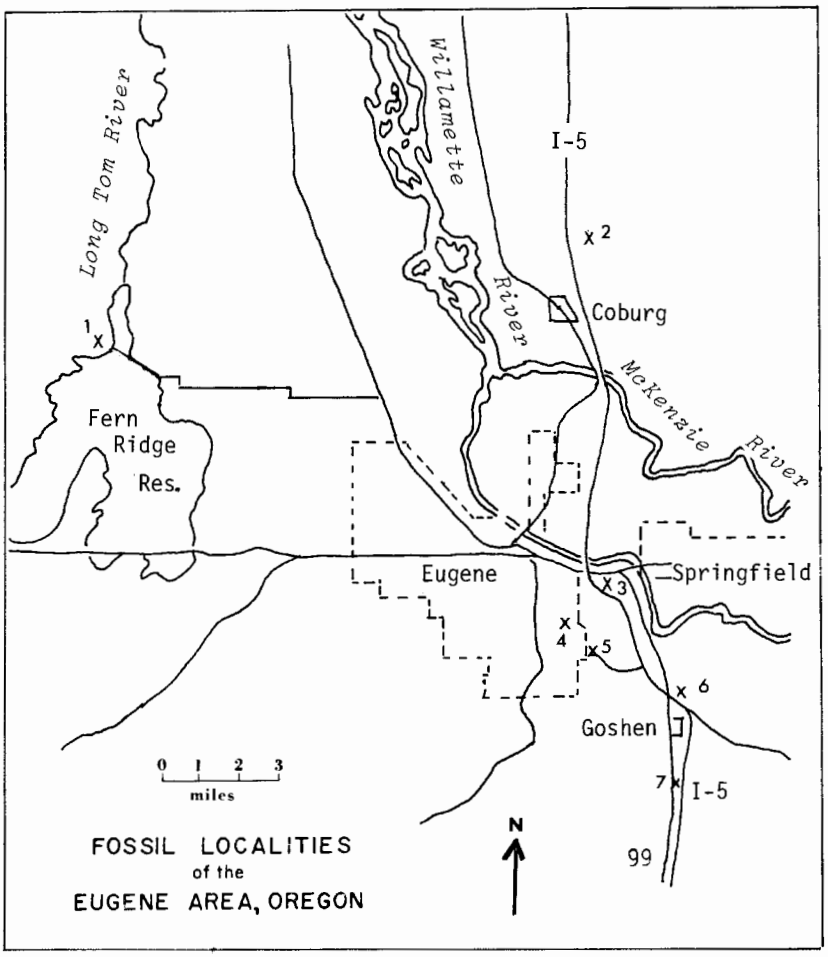
In middle Oligocene time, the sea again invaded the Eugene area. It filled what is now the Willamette Valley trough, and a tangue of it temporarily extended nearly to Cottage Grove. An abundant invertebrate fauna, composed chiefly of mallusks and crabs, lived an the floor of this sea and were buried in the sands and muds brought in by streams. Thus was formed the gray, tuffaceous and highly fossiliferous sandstones of the Eugene Formation. As the sea floor subsided, the formation became extremely thick. According to Vokes, Snavely, and Meyers (1951), who mapped the Eugene area in considerable detail, the Eugene Formation may be as much as 15,000 feet thick.

The fossiliferous Eugene Formation is exposed taday at many places in and about Eugene (Localities 2 to 5). It can be traced southward toward Cottage Grove, where it interfingers with the Fisher Formation. It can also be traced northward along the Coburg Hills and into the Salem area. Its equivalent farther to the north is the Pittsburg Bluff Formation.

Withdrawal of the Oligocene sea from the Willamette Valley some 30 million years ago marked the end of marine deposition in the Eugene area. In Miocene time, the Spencer, Fisher, and Eugene Formations were intruded by lavas which in places spread out over the strata as extensive flows. The prominent topographic features such as Skinner Butte, Spencer Butte, and Judkins Point are erosional remnants of these resistant volcanic rocks. During more recent geologic epochs, the Willamette River and its tributaries have carved wide valleys in the older rocks and have developed extensive flood plains underlain by thick deposits of alluvium. Occasionally an excavation in this alluvial material reveals bones and teeth of now extinct mammals that lived in this region at the close of the Ice Age.

Where to Find Fossils

Some of the fossil localities listed in the original (1958) version of this report are no longer in existence and some of the others are deeply weathered or are on private property. Those known to have been destroyed by construction of buildings, streets, and highways are omitted here, and a few others are added. Any new excavation exposing unweathered sedimentary rock in the Eugene area is a good place to look for fossils. Hickman (1969) lists 15 accessible fossil-bearing outcrops of the Eugene Formation.



1. Fern Ridge dam

Marine fossils are abundant and well preserved in buff-colored sandstone of the Spencer Formation cropping out on Richardson Butte at the west end of Fern Ridge dam. The locality is on the barren hillside at the extreme southeast end of the Butte and above a road leading north from the west end of the dam. The fossils occur at various elevations on the side of the hill. As many as 25 different species of mollusks of Eocene age have been reported from this locality.

2. Lenon Hill

Marine fossils have been collected in the past from outcrops of the Eugene Formation on Lenon Hill northeast of Coburg. Highway I-5 passes close to the west end of Lenon Hill, but no access road is available at that point. To reach the locality, start at Coburg and go north on the Brownsville road about 2 miles. Turn right (east) on road that crosses I-5 and drive to east end of Lenon Hill. The Hill is composed of the Eugene Formation. Beds containing Crepidulas, Spisulas, and other Oligocene mollusks crop out about halfway up the steep south and west slopes.

3. Railroad cut near Sears Warehouse

Marine fossils occur in the steep bluff along the Southern Pacific Railroad about a quarter of a mile east of the Sears Warehouse. The locality lies east of I-5 and is reached via Judkins Road. Sandstone of the Eugene Formation exposed in the railroad cut has yielded a large number of fossils in the past.

4. Amazon Creek

Molds and casts of fossil shells occur in outcrops of the Eugene Formation along Amazon Creek. The locality is in the city limits south of 19th Ave.

5. Agate Street and 30th Ave.

Fossils can be found in a roadcut on 30th Ave. near Agate Street on the east edge of the city. The fossils occur as molds and casts in weathered sandstone of the Eugene Formation.

6. North Goshen leaf locality

Many large, well-preserved leaves were formerly collected from a roadcut in a small hill of thin-bedded, dark gray shale at the north edge of Goshen. The locality is at the intersection of I-5 and Oreg. Hwy. 58. Fossil leaves were in the form of black carbonaceous films and imprints; rare salamander and insect imprints were also found. According to R. E. Brown (see Vokes and others, 1951, in bibliography) this flora is younger than the true "Goshen flora" and probably late Oligocene in age. Most of the small hill has been removed for highway construction; the remainder is deeply weathered.

7. South Goshen leaf locality

This leaf locality is one of the sites of the "Goshen flora," a large suite of fossil plant remains of lower to middle Oligocene age occurring in lenses of whitish tuff within the Fisher Formation. The Goshen flora is described by Chaney and Sanborn (see bibliography). This locality is at a roadcut through a small hill on old Highway 99 beneath an overpass 1.75 miles south of Goshen. The outcrop has been partly destroyed by recent highway construction, but fossil leaves can still be found in the bed of whitish tuff at road level.

Fossils to Look For

Marine fossils: Mollusks are by far the most abundant of the invertebrate marine fossils of the Eugene area. They include pelecypods (clam-like shells), gastropods (snail-like shells), and scaphopods (tooth shells). The Spencer and Eugene Formations each carry a distinctive assemblage of mollusks, with more than 20 species of pelecypods and nearly as many species of gastropods. Fossil barnacles, sea worms, echinoids, and crabs, although not as numerous as the mollusks, are not uncommon in the Eugene Formation.

Plant fossils: Fossil leaves, wood, and occasional flowers, fruits, and seeds, occur locally in the Eugene area. The fossil plants so far recognized in the map area include two ages of Oligocene floras. The older flora (Goshen flora) contains meliosma, magnolia, fig, and other semitropical plants. The younger flora contains plants characteristic of a more temperate climate such as pine, oak, maple, and sassafras.

Vertebrates: Occasionally teeth and fragments of elephant tusks are found in the Pleistocene silts along Spencer Creek and in the Willamette Valley. Such finds are rare and new locations are unpredictable, consequently no localities are described in this report. Several fossil salamanders and a few insect imprints have been discovered at the north Goshen leaf locality (Locality 6) in black shales of late Oligocene age. Shark teeth have been collected from Oligocene marine sandstones of the Eugene Formation.

Vertebrate Fossils

Pleistocene elephant:
* *Elephas columbi*
(jaw and grinding teeth)

Oligocene salamander:
* *Palaeotaricha oligocenica*

Oligocene shark tooth:
Odontaspis sp.

* Illustrated

Marine Fossils

Spencer formation (Eocene)

Pelecypods:
- Acila decisa Conrad
- Ostrea idriaensis Gabb
- Brachidontes cowlitzensis (Weaver and Palmer)
- Macrocallista conradiana (Gabb)
- Tellina cowlitzensis Weaver
- * Spisula packardi Dickerson
- * Venericardia hornii Weaver and Palmer
- * Pitar eocenica (Weaver and Palmer)

Gastropods:
- Polinices nuciformis (Gabb)
- Siphonalia sopenahensis (Weaver)
- Perse sinuata (Gabb)
- * Turritella uvasana Conrad

Scaphopod:
- * Dentalium stramineum Gabb

Eugene formation (Oligocene)

Pelecypods:
- * Acila shumardi (Dall)
- * Thracia condoni Dall
- Loxocardium eugenense (Clark)
- * Pitar dalli (Weaver)
- Tellina eugenia Dall
- Spisula eugenense (Clark)
- * Solen eugenensis Clark

Gastropods:
- * Epitonium condoni Dall
- * Polinices secta (Gabb)
- * Crepidula ungana Dall
- Bruclarkia fulleri Durham
- Molopophorus dalli Anderson and Martin

Scaphopod:
- * Dentalium

Echinoid

Barnacle:
- Balanus

Sea worm:
- Teredo

Crabs:
- * Raninoides eugenensis Rathbun
- Zanthopsis (several species)
- * Callianasa oregonensis Dana

Plant Fossils

South Goshen flora (Early Oligocene)

- Ocotea eocernua Chaney and Sanborn
- * Meliosma goshenensis Chaney and Sanborn
- Ilex oregona Chaney and Sanborn
- Magnolia reticulata Chaney and Sanborn
- Cupania packardi Chaney and Sanborn
- * Ficus goshenensis Chaney and Sanborn
- Tetracera oregona Chaney and Sanborn

North Goshen flora (Late Oligocene)

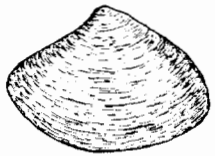
- * Pinus latahensis Berry
- * Quercus consimilis Newberry
- * Hydrangea bendirei (Ward) Knowlton
- Acer glabroides Brown
- Platanus dissecta Lesqueureux
- * Cinnamomum dilleri Knowlton
- Sassafras sp.

* Illustrated

EOCENE FOSSILS FROM THE SPENCER FORMATION

Venericardia homii

Pitar eocenica

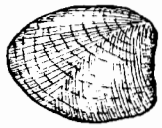


Spisula packardi

Turritella uvasana

Dentalium

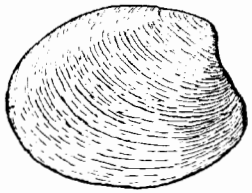
OLIGOCENE FOSSILS FROM THE EUGENE FORMATION



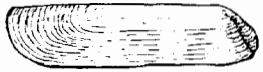
Acila shumardi

Thracia condoni

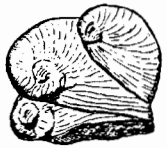
Epitonium condoni



Pitar dalli



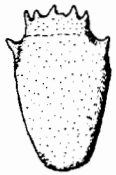
Solen eugenensis



Crepidula ungana

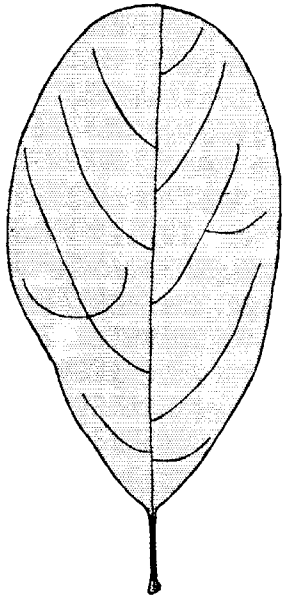
Polinices secta

Raninoides eugenensis (crab claw)

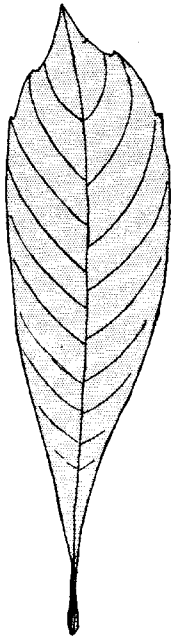


Callianasa oregonensis (crab shell)

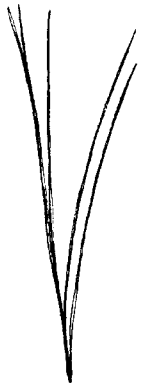
FOSSIL PLANTS



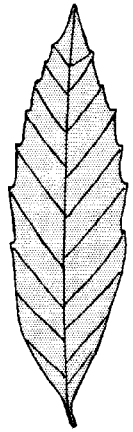
Ficus goshenensis (fig)



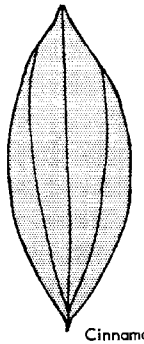
Meliosma goshenensis



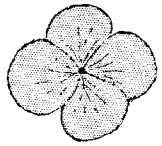
Pinus latahensis (pine)



Quercus consimilis (oak)



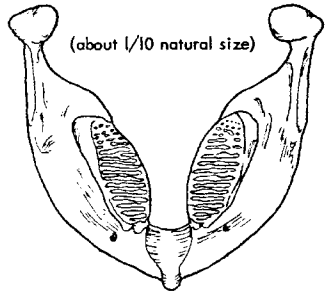
Cinnamomum dilleri (cinnamon)



Hydrangea flower

FOSSIL VERTEBRATES

Oligocene salamander



Pleistocene elephant (jaw and grinding teeth)

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FOSSIL LOCALITIES OF THE SALEM-DALLAS AREA

By Margaret L. Steere*

Location

The Salem-Dallas area lies in the center of the Willamette Valley in Polk and Marion Counties (see accompanying map). Within this orea there are a number of scattered rock outcrops where fossils have been found. The 12 locolities described in this report are easily reached by paved highways or good secondary roads.

Geologic History

Thousands of feet of fossiliferous marine strata underlie the Salem-Dallas area. These rocks were deposited in seas that covered most of western Oregon during Eocene and Oligocene times. The beds have been tilted eastward; thus the older rocks (Eocene) crop out along the western side of the area in the vicinity of Dallas while to the east the overlapping younger rocks (Oligocene) crop out in the vicinity of Salem.

Eocene formations

The earliest fossil record in the area goes back about 50 million years to the time when submarine volcanoes were exceedingly active on the floor of the Eocene sea. Some of the volcanoes must have emerged as islands that supported plant life. A thick series of basaltic lava flows and pyroclastic rocks accumulated around the volcanic centers together with interbeds of sediments containing shells of marine animals. Today these uplifted rocks, known as the Siletz River Volcanics, form the core of the Coast Range west of Dallas.

Local pockets of limestone and limy sediments occur within or overlie the volcanic rocks. One such limestone deposit occurs south of Dallas (Localities 9 and 10) and smaller ones near Ellendale (Locality 11) and near Buell (Locality 12). Geologists are not in agreement on the relative

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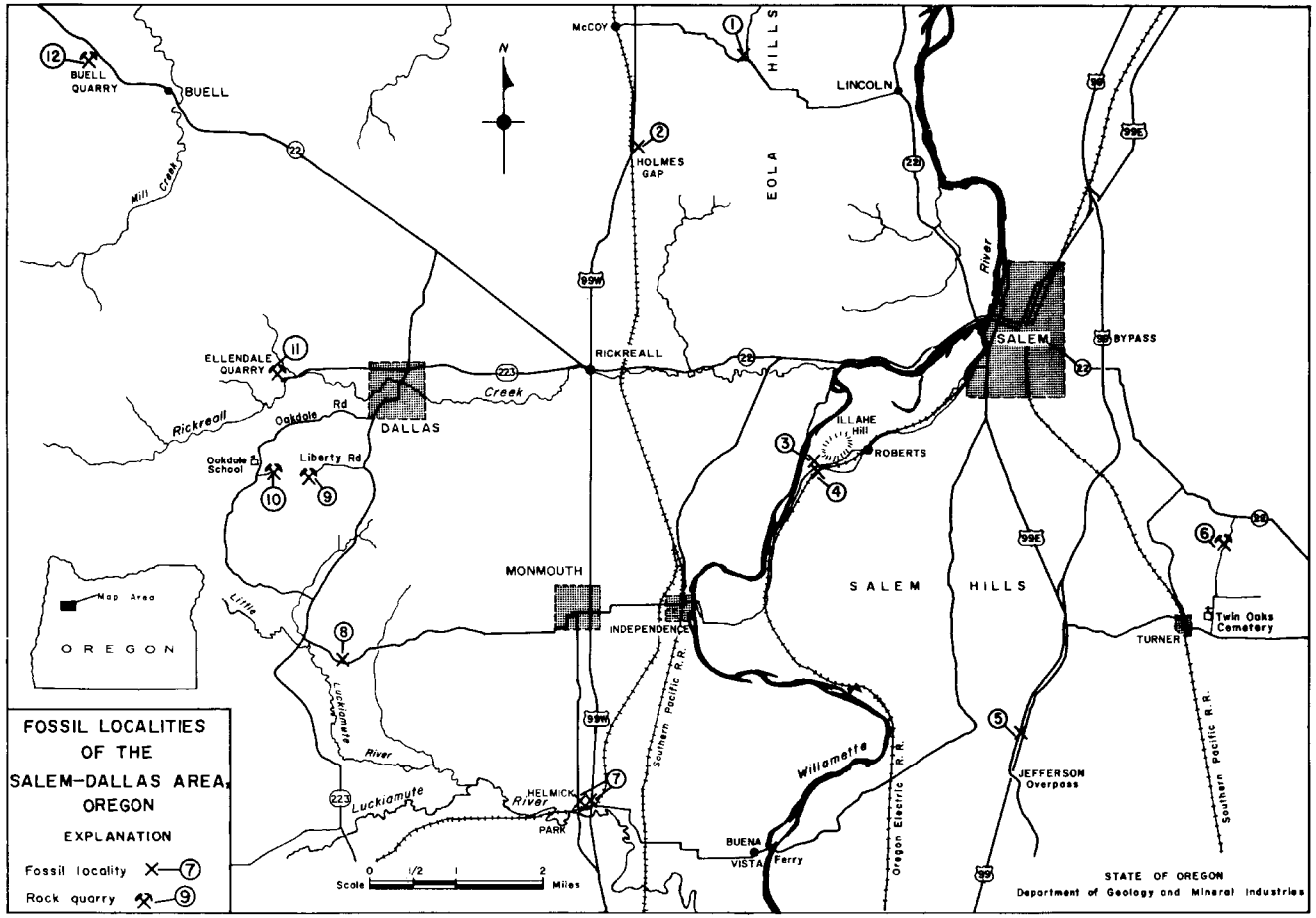
* Geologist, State of Oregon Department of Geology and Mineral Industries.


FOSSIL LOCALITIES OF THE SALEM-DALLAS AREA, OREGON
EXPLANATION
Fossil locality
Rock quarry
Map Area
OREGON
Scale 0 1/2 1 2 Miles
STATE OF OREGON
Department of Geology and Mineral Industries
N
McCOY
LINCOLN
EOLA HILLS
HOLMES GAP
BUELL
BUELL QUARRY
Mill Creek
ELLENDALE QUARRY
Rickreall Creek
Oakdale Rd
DALLAS
Oakdale School
Liberty Rd
RICKREALL
SALEM
BYPASS
River
ILLAHE Hill
ROBERTS
MONMOUTH
INDEPENDENCE
Little Luckiamute River
Luckiamute River
HELMICK PARK
Southern Pacific R.R.
Willamette River
BUENA VISTA Ferry
Oregon Electric R.R.
SALEM HILLS
JEFFERSON Overpass
TURNER
Twin Oaks Cemetery
Southern Pacific R.R.

ages of these limy beds except that the fossils are all of Eocene age. Among the fossils reported (see bibliography at end of this article), are a rare gastropod "Pleurotomaria", oysters and other mollusks, brachiopods, bryozoa, nautilus, foraminifera, crabs, shark teeth, and fossil plants.

After submarine volcanic activity had diminished, many hundreds of feet of Eocene sandstones and siltstones were laid down over the lavas in the Dallas region. These rocks (Tyee and Yamhill Formations) now crop out in the foothills of the Coast Range west of Dallas.

Between Dallas and the Willamette River is an area of late Eocene marine strata composed mainly of thin-bedded micaceous siltstones and shales containing occasional hard, massive layers. These beds are called the Nestucca Formation north of Dallas and the Helmick beds south of Monmouth. The beds extend southward into the Corvallis and Eugene areas, where they are known as the Spencer Formation. In fresh outcrops the rocks are gray and contain many marine fossils, including shark teeth and mollusks. On exposure to the weather, however, the thin-bedded material turns rusty brown and disintegrates (Localities 7 and 8).

Oligocene formations

Early in Oligocene time, about 40 million years ago, the sea again invaded western Oregon. Massive beds of fossiliferous siltstones known as the Keasey Formation accumulated on the sea floor. The type locality for these deposits is in the Sunset Highway area northwest of Portland where the beds contain a great variety and abundance of fossil shells. In the Willamette Valley, the extent of the Keasey Formation is not well known due to scarcity of outcrops, but where found the beds contain a characteristic Keasey fauna.

By middle Oligocene time, the slowly rising Coast Range began to form a highland or row of islands to the west of the Salem-Dallas area. In the gradually subsiding basin of the Willamette Valley region, there accumulated several thousand feet of tuffaceous sandstones containing an abundance of shallow-water marine shells. Today these sandy, buff-colored beds, known as the Eugene Formation, are widely distributed in the Willamette Valley. Although the name "Illahe Formation," was given to beds in the Salem area by Mundorff in 1939, the name "Eugene Formation", is now preferred. The Eugene Formation contains a variety of pelecypods and gastropods (Localities 1 to 6).

Miocene to Holocene (Recent) formations

Uplift of the land some time in late Oligocene or early Miocene caused the sea to retreat permanently from the Salem-Dallas area. The middle Miocene epoch was a time of major volcanism. Basaltic lava flows, known as the Stayton Lavas and contemporaneous with the great Columbia River Basalt extrusions, blanketed the marine formations in the Salem area. Since Miocene time, the Willamette River and its tributaries have carved

wide valleys in the volcanic and sedimentary rocks. Remnants of the basalt flows can be seen capping the Salem and Eola hills, while the underlying fossiliferous sandstones of the Eugene Formation crop out beneath. Prolonged chemical weathering of the Stayton Lavas has altered the basalt to clay and bauxite, which may be recognized by its red color.

For the past 10,000 years or more the Willamette River and its tributaries have been depositing a thick cover of sand, silt, and mud over the broad Willamette Valley. Occasionally fossil bones and teeth are found in these sediments in river banks and excavations. Elephant, mastodon, ground sloth, and camel are a few of the strange inhabitants of the Salem area at the close of the Ice Age whose fossil remains have been discovered. Because the location of such fossils is unpredictable, no localities are described in this report.

Where to Look for Fossils

The places to look for fossils in the Salem-Dallas area are where sedimentary beds are either recently exposed or sufficiently well cemented to have resisted many years of weathering. Favorable localities may be man-made excavations such as quarries and road cuts, or they may be natural outcrops on hillsides and along the banks of streams. The following 12 localities are good places to find fossils, but be sure to ask for permission to enter private property.

1.* Eola Hills locality

Fossil beds of the Eugene Formation crop out beneath Stayton Lavas in a number of places in the Eola Hills. The locality described here is near the top of the divide on the road that crosses Eola Hills from McCoy to Lincoln. To reach the locality, start at Rickreall, go north on U.S. 99W toward Amity for 8 miles to the Lincoln road. Turn right and go east 3 miles to road junction at top of hill. A hard, fossiliferous layer of the Eugene Formation crops out at road level just west of the junction. Various other outcrops in the vicinity are reported to expose fossils.

2. Holmes Gap locality

Holmes Gap is the narrows between the hills where U.S. Highway 99 W crosses the Southern Pacific railroad 5 miles north of Rickreall. Coarse, dark-gray fossiliferous sandstone crops out in two places in a pasture on the east side of the highway about 0.2 mile northeast of the railroad crossing. One outcrop is on the bank of a shallow gully about 200 feet west of a farmhouse. The other outcrop is on the side of a small ravine in

* Numbers refer to localities on index map.

the steep bluff near the highway. This coarse sandstone contains a variety of well-preserved shells of middle Oligocene age and may represent the base of the Eugene Formation. Typical fossils are the pelecypods Acila and Pitar, and the gastropods Bruclarkia and Molopophorus.

3. Illahe Hill locality

Fossils are numerous in a weathered exposure of the Eugene Formation at the south end of Illahe Hill about 5 miles southwest of Salem. To reach the locality, follow South River Road to Roberts and continue 1.4 miles. The outcrop is at the base of the hill about 500 feet north of the road. The entire hill is composed of the Eugene Formation. Fossils at Illahe Hill are similar to those directly across the road at Finzer Station (Locality 4). The two localities were probably continuous strata before being separated by erosion.

4. Finzer Station locality

Fossils are abundant at Finzer Station on the Oregon Electric railroad 5 miles southwest of Salem. This locality is a deep railroad cut through a hill directly across the road (South River Road) from the Illahe Hill locality (Locality 3). To reach it climb up to the tracks at the railroad overpass and walk along railroad for about 100 feet. Here the Eugene sandstone of Oligocene age forms the vertical walls on each side of the tracks. Fossil casts, particularly pelecypods, are exceedingly abundant. The sandstone weathers rapidly and fossils are well preserved only when freshly exposed. Fossils also occur in a hard limy lens. Some of the typical genera are: the pelecypods Solen, Spisula, Yoldia, and Nuculana, and the gastropod Bruclarkia.

5. Frontage Road locality

Chalky-white mollusks in gray sandstone and siltstone are abundant in a road cut on Frontage Road about 10 miles south of Salem. To reach the locality from Salem, drive south about 11 miles to the Jefferson overpass. Turn right (west) onto Frontage Road and drive back toward the north (parallel to I-5) for 1 mile to road cut. The Eugene Formation of Oligocene age is exposed here, dipping northeastward under the Stayton Lavas. Although the original shells are still preserved, they quickly disintegrate on exposure to the air, leaving internal casts in the rock. The locality is about 3.5 miles south of the junction of U.S. 99 through Salem and the By-pass (I-5).

6. Turner quarry locality

From center of Turner (about 9 miles southeast of Salem), go east on county road ½ mile to Oaks Cemetery road. Turn left (north) and go north on Oaks Cemetery road toward Witzel for 2.3 miles to old, shallow quarry and dump on west side of road. The quarry exposes well-cemented

brown tuffaceous sandstone of the Eugene Formation of Oligocene age in which casts and molds of Spisula and other pelecypods are well preserved. An upper quarry a short distance to the west exposes the overlying Stayton Lavas of Miocene age.

7. Helmick Hill locality

U. S. Highway 99 W makes a long deep cut through the north bank of the Luckiamute River 4.5 miles south of Monmouth. The cut exposes northward-dipping Helmick beds of late Eocene age. This exposure is similar to the cut through Helmick Hill on old Highway 99 W a third of a mile due west. The new highway cut is not as deeply weathered as the old one and fossils can still be found in the more indurated layers. Among the fossils that have been collected from these cuts in the past are the pelecypods Spisula, Tellina, and Volsella, and the gastropods Ampullina and Acrilla. Numerous shark teeth have also been found.

8. Cooper Hollow road locality

A road cut in a low bank on the Cooper Hollow road about 5 miles south of Dallas exposes upper Eocene sediments that are presumably a continuation of the Helmick beds. The outcrop is on the north side of the highway where the highway rises up out of the Luckiamute Valley, 1.2 miles east of State Highway 223 (Kings Valley road). When the Cooper Hollow road was under construction, a number of kinds of fossil mollusks similar to those at Helmick Hill were collected from the freshly exposed dark-gray shale. Weathering has since obscured much of the outcrop, but a few fossils can still be found. They are generally fairly well preserved and can be combed out of the soft shale.

9. Polk County Lime quarry

The Polk County Lime quarry is about 1 mile east of the Oregon Portland Cement quarry in an extension of the same limestone deposit. It may be reached from the Dallas Court House by following State Highway 223 south for 2.2 miles to Liberty Road and continuing west on Liberty Road 1.5 miles to the quarry. Fossils of Eocene age, particularly Ostrea, are numerous in certain horizons.

10. Oregon Portland Cement quarry

The Oregon Portland Cement Company has a large quarry in a deposit of massive gray limestone southwest of Dallas. The quarry may be reached from the Dallas Court House by following State Highway 223 for 1.0 mile south to the intersection with Oakdale Road. Turn west on Oakdale Road and go 3.7 miles to quarry sign and private road. The quarry is in the bottom of a valley 0.3 mile east of Oakdale Road. Fossils are of Eocene age and are fairly numerous in certain horizons at this locality.

EOCENE FOSSILS

Limestone Beds

Pelecypods:

- Barbatia cf. B. cowlitzensis (Weaver and Palmer)
- Lima sp.
- Ostrea sp.
- Pecten cf. P. interradiatus Gabb
- Spondylus carlosensis Anderson
- Crassatellites dalli Weaver
- Pitar cf. P. dalli (Weaver)

Gastropods;

- Acmaea n. sp.
- Calyptraea sp. indet.
- Turritella andersoni cf. subsp. susanae Merriam
- Pleurotomaria sp. indet.

Brachiopods:

- Terebratulina (several species)

Bryozoa

Foraminifera

- Discocyclina sp. (large disk-shaped foram)

Crustacea:

- Raninoides oregonensis Rathbun

Cephalopods:

- Nautilus (several species)

Echinoderms (sea urchins):

- Spatangus tapinus Schenck

Shark teeth

Fossil plants:

- Cinnamomum
- Ferns
- Pine cones

EOCENE FOSSILS (cont'd)

Helmick Beds
(Spencer Formation)

Pelecypods:
- Spisula (several species)
- Tellina (several species)
- Nuculana gabbi (Gabb)
- Volsella cowlitzensis (Weaver and Palmer)
- Acila decisa (Conrad)

Gastropods:
- Ampullina andersoni (Dickerson)
- Acrilla aragoensis (Turner)
- Ficopsis cowlitzensis (Weaver)
- Exilia cf. E. dickersoni (Weaver)

Scaphopods:
- Dentalium sp.

Foraminifera

Shark teeth

Plant fragments

OLIGOCENE FOSSILS

Eugene (Illahe) Formation

Pelecypods:
- Acila shumardi (Dall)
- Solen sp.
- Pitar oregonensis (Conrad)
- Nuculana washingtonensis (Weaver)
- Spisula pittsburgensis Clark
- Yoldia oregona (Shumard)
- Tellina eugenia Dall

Gastropods:
- Polinices cf. P. washingtonensis (Weaver)
- Perse sp. indet.
- Crepidula sp. indet.
- Molopophorus dalli Anderson and Martin
- Bruclarkia columbiana (Anderson and Martin)
- Ficus modestus (Conrad)

Among those found are the crab Raninoides, pelecypods, a large species of nautilus, shartk teeth, sea urchins, foraminifera, leaf imprints, and pine cones.

11. Ellendale quarry

Fossils of Eocene age have been found in the Ellendale basalt quarry. The quarry is on Ellendale road, 3.0 miles west of the junction in north Dallas with State Highway 223. Basaltic rock of the Siletz River Volcanics comprises most of the material in the quarry, but a sedimentary bed of grit containing many broken fossil shells is exposed over a fairly wide area near the top of the quarry and is easily accessible from the south side of the hill into which the quarry is dug. Among the fossils that have been found are the gastropods Calyptraea, Turritella, and the rare Pleurotomaria; the pelecypods Barbatia, Ostrea, and Pecten; several kinds of brachiopods; and bryozoa.

12. Buell limestone quarry locality

Fossils of Eocene age are abundant in the Buell limestone quarry 2 miles west of Buell on State Highway 22. The entrance to the quarry is marked by a sign at a gate on the south side of the highway. The quarry (not operating at present) is visible about 1/8 mile to the southwest in the bottom of a valley. A layer of coquina composed of shells and shell fragments contains Ostrea, Lima, and other mollusks. Overlying this layer is a bed of black basaltic grit containing large round foraminifera (easily seen without a hand lens) and brachiopods.

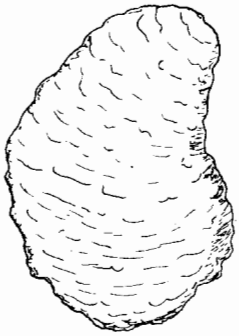
Fossils To Look For

Pelecypods and gastropods are the most abundant and the most varied fossils in the marine formations of the Salem-Dallas area. Other marine animals reported from these formations are scaphopods, brachiopods, cephalopods, echinoids, corals, bryozoa, foraminifera, crabs, and shark teeth. Fragments of poorly preserved leaves and wood are abundant in the Eocene strata.

Once in a while bones and teeth of fossil mammals, particularly mastodons, are found in the Pleistocene and Recent sediments of the Willamette Valley.

The names of some of the characteristic fossils of the Eocene and Oligocene marine formations in the Salem-Dallas area are listed below, and many additional fossils are listed in publications cited at the end of this report.

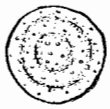
SOME TYPICAL EOCENE FOSSILS OF THE SALEM-DALLAS AREA



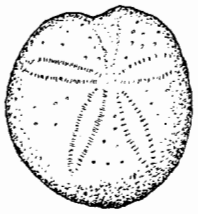
Ostrea
(Pelecypod)
$\frac{1}{2}$ x

Volsella
(Pelecypod)

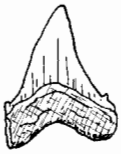
Terebratulina
(Brachiopod)



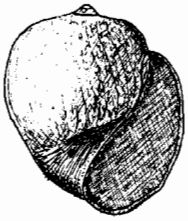
Discocylina
(Foraminifera)
10 x



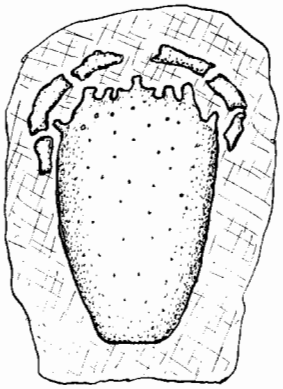
Spatangus
(Sea urchin)



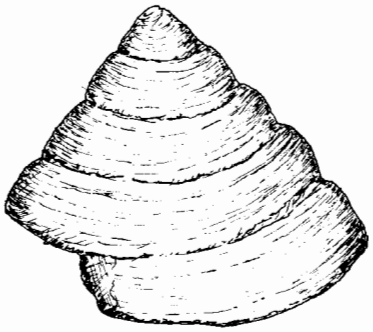
Shark tooth



Ampullina
(Gastropod)

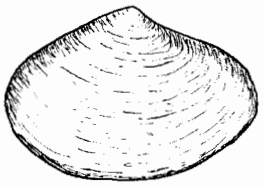


Crab

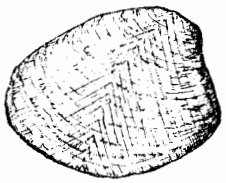


Pleurotomaria
(Gastropod)
$\frac{1}{4}$ x

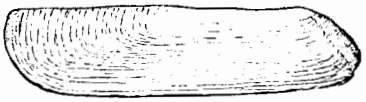
SOME TYPICAL OLIGOCENE FOSSILS OF THE SALEM-DALLAS AREA



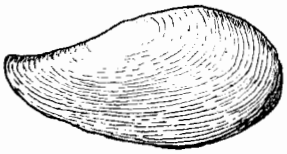
Spisula
(Pelecypod)



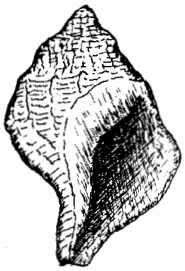
Acila
(Pelecypod)



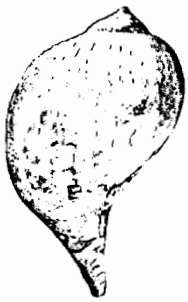
Solen
(Pelecypod)
$\frac{1}{2}$ x



Yoldia
(Pelecypod)



Bruclarkia
(Gastrapod)



Ficus
(Gastropod)

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FOSSIL LOCALITIES OF LINCOLN COUNTY BEACHES, OREGON

By Margaret L. Steere*

Geologic Picture

Many fossils occur in the old marine sediments which form cliffs behind the beaches of Lincoln County, Oregon. Particularly fossiliferous is the Astoria Formation, which crops out almost continuously along the coast from the town of Lincoln Beach south to Yaquina Bay. Its areal distribution is shown as the shaded portion on the accompanying map, and in this long, narrow strip fossils may be found in unweathered road cuts as well as along the beach cliffs.

The Astoria Formation is composed chiefly of blue-gray sandstones and shales that were deposited during middle Miocene time, about 20 million years ago, when the shore line of the sea was somewhat east of its present position. The name "Astoria Formation" is applied to these Miocene sediments in Lincoln County because of their similarity to the type Astoria Formation at Astoria in Clatsop County, Oregon.

Shells of mollusks (see accompanying sketches) are concentrated in great numbers in certain layers of the Astoria sediments. Scattered through the formation are many large, ball-like concretions which when split open, expose masses of fossil shells. Occasionally concretions are found that contain the fossil bones of whales and sea lions.

Overlying the Astoria Formation in many places along the coast are thick deposits of brown and yellow dune sands of Pleistocene or Recent origin. These nonfossiliferous sands are readily distinguished from the older sandstone by their distinctive yellowish color and general lack of consolidation.

Two other fossil-bearing formations, older than the Astoria, crop out along the shore of Yaquina Bay. They include the gray Nye Mudstone of early Miocene age and the yellow, iron-stained sandstones of the Yaquina Formation of late Oligocene age. Fossil shells are scarce in the Nye Mudstone but are numerous in the Yaquina Formation. The Yaquina Formation also contains fossil plant fragments and coal.

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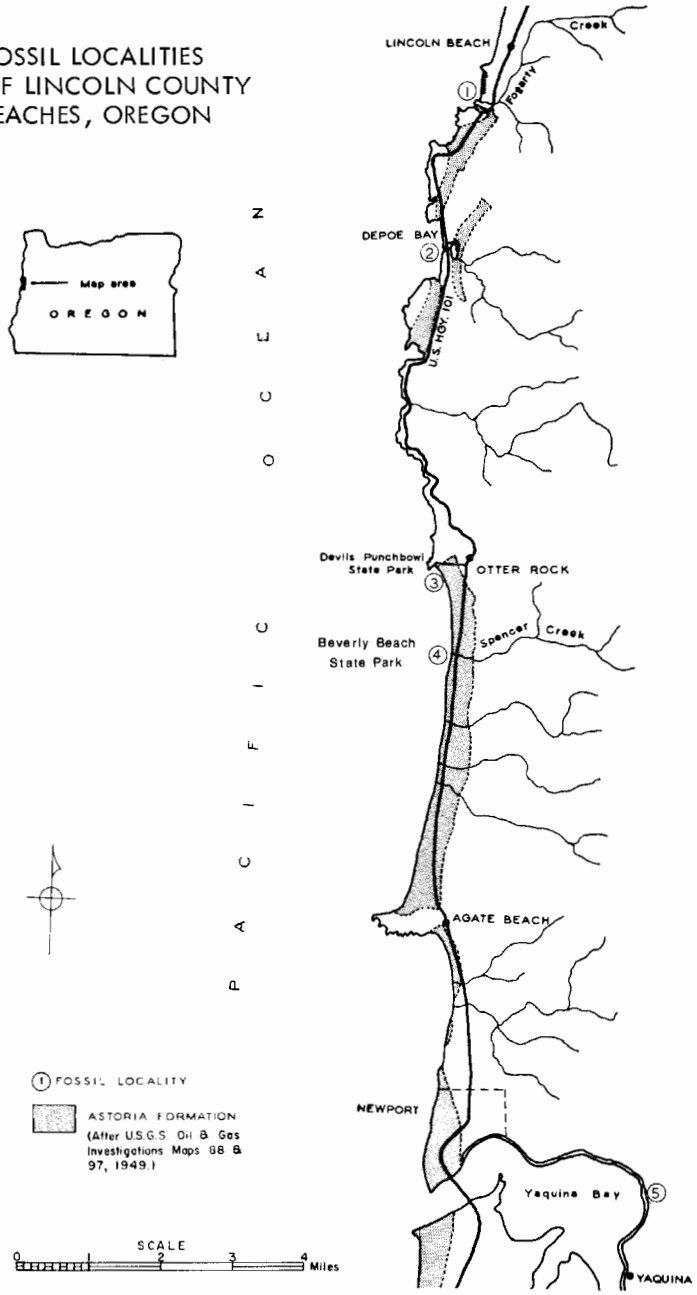
* Geologist, State of Oregon Department of Geology and Mineral Industries

FOSSIL LOCALITIES
OF LINCOLN COUNTY
BEACHES, OREGON



Fossil Localities

Five of the best places to find fossils along the Lincoln County beaches are described below and their locations shown on the accompanying map:

1. Fogarty Creek State Park

   U.S. Highway 101 crosses Fogarty Creek 1.0 mile south of the Lincoln Beach Post Office. There is a parking space and picnic area on the east side of the highway, and a trail leads under the bridge directly out to the beach. Fossils and concretions containing fossils can be found in the Astoria Formation, which forms the cliffs along the beach both north and south of the creek.

2. Depoe Bay

   The fossiliferous Astoria Formation crops out in the high cliff at the north end of the small inner bay, east of the highway bridge. The locality is easily reached by way of a road which follows around the north end of this bay to the Coast Guard Station at water level. The base of the cliff can be reached at low tide.

3. Otter Rock

   Fossils can be found in the sea cliffs below Devils Punch Bowl State Park, which is 0.4 mile west of the highway at Otter Rock. A good foot trail leads down to the beach from the southeast corner of the park. Buff-colored sandstone, which forms the high cliffs of the point, yields a few fossils. The blue-gray Astoria Formation, containing only a few fossils at this particular locality, crops out at the foot of the trail and is continuous, and locally very fossiliferous, as far as Yaquina Head, 5 miles to the south.

4. Beverly Beach State Park

   Many well-preserved fossils and concretions containing fossils can be found in the low sea cliffs at Beverly Beach State Park. The park is on Spencer Creek 6 miles south of Depoe Bay. Camping, picnic, and parking areas lie east of the highway, and from them a trail leads under Spencer Creek bridge and out to the beach. The sea cliffs here and for the next 4 miles south

are composed of fossiliferous Astoria sandstone; this same rock is sometimes exposed on the floor of the beach, especially during the winter when storms sweep away the sand. Various turnouts along U.S. Highway 101 south of Beverly Beach State Park also provide access to the beach area and fossil beds.

5. Yaquina Bay

Road cuts in cliffs along the north shore of Yaquina Bay expose thin beds of Nye Mudstone with thicker layers of very hard, light-colored concretions. Fish scales and vertebrae and small mollusks can be found in the mudstone in a series of outcrops along the Yaquina Bay road between 1 and 2 miles east of Newport.

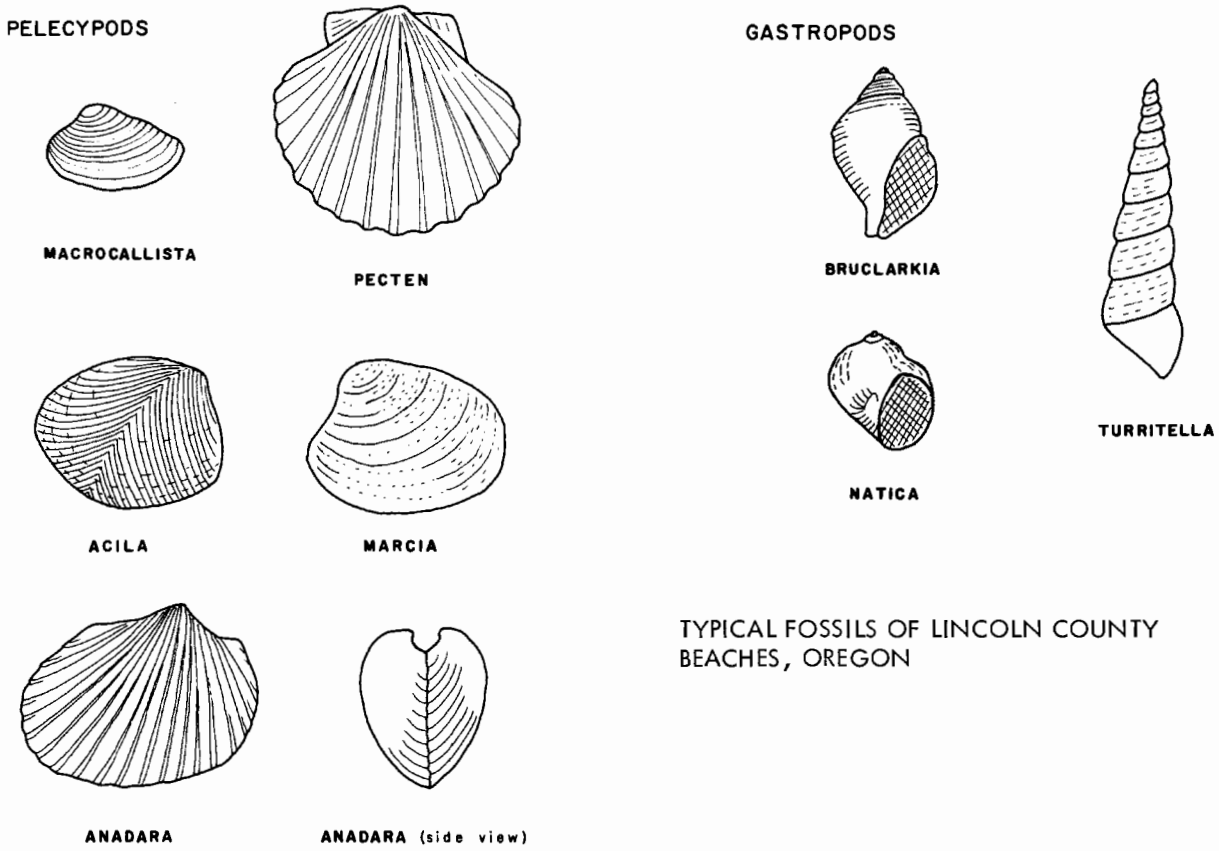
At the east end of Yaquina Bay, beginning about 4 miles from Newport, fossil mollusks are numerous in certain places in yellow sandstone of the Yaquina Formation. An outcrop just north of the Yaquina store has been productive in the past. A road cut 1.7 miles beyond the store, at river light No. 25, contains fossil leaf imprints in westward dipping cream-colored sandstone. An underlying carbonaceous layer of shale contains fossil wood.

Names of the Fossils

When a paleontologist discovers a new fossil, he gives it three names, two of which are Greek or Latin, the third his own name. For instance, a certain mollusk which is very abundant along the Lincoln County beaches has been named "Anadara devincta Conrad." The first name, Anadara, is the genus, denoting a group of fossils all members of which look something alike. Next comes the species name, devincta, which differentiates the fossil from all others of that genus. And last is the name of the paleontologist himself -- in this case, Conrad. After a description of the species has been published, the name is adopted internationally.

The amateur fossil hunter will find that it is very difficult to tell one species from another, but that it is fairly easy to identify the genus of a well-preserved specimen by carefully comparing it to pictures and descriptions in the literature.

Fossils which are found in greatest abundance along the Lincoln County beaches are the mollusks. Mollusks are a large family of animals having protective shells, the most common types being pelecypods and gastropods. These two important groups are easily differentiated: pelecypods have two shells and resemble clams; gastropods have one coiled shell and



TYPICAL FOSSILS OF LINCOLN COUNTY BEACHES, OREGON

resemble snails. At least 60 species of fossil mollusks (pelecypods and gastropods in approximately equal numbers) have been found in the Astoria Formation in Lincoln County and more than half that number in the Yaquina Formation. All of these species have been described and most of them illustrated in the literature (see bibliography).

The names listed below represent only a few of the many species of pelecypods and gastropods characteristic of the Astoria and Yaquina Formations. Some of these fossils are shown in the accompanying sketches.

Astoria Formation	Yaquina Formation
Pelecypods:	Pelecypods:
Acila conradi Meek	*Acila shumardi* Dall
Anadara devincta Conrad	*Nemocardium lincolnensis* Weaver
Marcia angustifrons (Conrad)	*Macrocallista pittsburgensis* Dall
Pecten propatulus Conrad	*Thracia condoni* Dall
Gastropods:	Gastropods:
Bruclarkia oregonensis (Conrad)	*Bruclarkia columbiana* (Anderson and Martin)
Ficus modestus Conrad	*Fusinus lincolnensis* Weaver
Natica oregonensis (Conrad)	*Calyptraea mammillaris* Broderip
Turritella oregonensis Conrad	

For many years fossil hunters, both amateur and professional, have been finding fossil bones of marine mammals in the outcrops of the Astoria Formation along the Lincoln County beaches. Most of the bones have been identified as belonging to pinnipeds (seals and walruses), cetaceans (whales), and sirenians (sea cows). The majority of the finds have been separate parts of skeletons, such as skulls, jaw bones, and vertebrae. More rarely is an entire skeleton discovered. The best preserved specimens are generally found in the hard sandstone concretions. Among the mammals identified from the Astoria Formation are the following:

Sirenians (sea cows)
- *Desmostylus cymatias* Hannibal
- *Desmostylus hesperus* Marsh (extinct species)

Pinnipeds (seals and walruses)
Desmatophoca oregonensis Condon

Cetaceans (whales)
Cophocetus oregonensis Packard and Kellogg

Remains of other vertebrate dwellers in the Miocene sea, which have been found in the Astoria Formation, include a very large turtle skull, fish vertebrae, and shark teeth.

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FOSSIL LOCALITIES IN THE COOS BAY AREA, OREGON

By Margaret L. Steere
Geologist, State Department of Geology and Mineral Industries

Introduction

Fossil shells are abundant in the sedimentary rocks of the Coos Bay area. Good fossil specimens are most likely to be found where sedimentary rocks are freshly exposed, such as in recent unweathered road cuts or at the base of cliffs along the coast and the bay where wave action is constantly uncovering new material. Ten easily accessible fossil localities are described in the following text and their location shown on the accompanying map. Localities along the water's edge can generally be reached only at low tide.

Geologic Picture

The Coos Bay area is underlain by a very thick sequence of sediments, chiefly of Eocene age, laid down millions of years ago in the environment of a fluctuating sea where deposition was in part marine and in part continental.

The sediments were later folded into a large, basin-like trough having lesser folds within its general structure. Even though these folded rocks have long since been beveled by erosion, the ancient structure is still apparent, especially along the coast between Cape Arago State Park and Yokam Point where the upturned edges of the harder strata crop out in parallel ridges.

Within the sequence of sediments in the Coos Bay area, a number of formations have been recognized and named, but the most extensive is the Coaledo Formation of Eocene age, which is believed to be at least 6,000 feet thick. It crops out in many places in the area and in some sections has an abundance of fossil marine shells. The Coaledo Formation contains,

also, plant remains in the wide-spread coal beds, but the identity of the plants has been largely lost and consequently the coal beds do not usually make good fossil hunting grounds.

Overlying the truncated folds of the older strata is a deposit of thick-bedded, brown sandstone called the Empire Formation. This formation is limited to the South Slough basin and represents a local inundation of the sea during Pliocene time. Within the Empire sandstone is a local lens of fossil conglomerate, called the Coos Conglomerate, composed of myriads of shells cemented together. This very fossiliferous lens crops out at the water's edge near Fossil Point, about half way between Empire and Charleston. Besides a great variety of fossil shells, the Empire Formation has yielded a number of bones of Pliocene marine mammals.

Descriptions of Fossil Localities*

1. Cape Arago State Park. Cape Arago State Park is on the coastal headland southwest of Coos Bay, about 15 miles from U.S. Highway 101, and is reached from either North Bend or Coos Bay via Empire and Charleston on a good, surfaced road. At the park, trails lead down the cliffs to the narrow beaches at the base of the three coves (South, Middle, and North). The bedrock which forms the cliffs is the Coaledo sandstone of Eocene age. At Middle Cove, large boulders filled with Eocene fossils lie along the beach. In these boulders and in the outcropping Coaledo sandstone and conglomerate exposed at low tide, one can find many species of gastropods and pelecypods and, occasionally, fossilized crabs and sand dollars. Fossil crabs are generally inside hard, limy concretions.

2. Sunset Bay. Sunset Bay is $2\frac{1}{2}$ miles by road northeast of Arago State Park, or 11 miles from Highway 101. The road skirts the landward end of the bay, and a parking area is situated close to the water's edge. At low tide fossil shells can be easily found in the steep Coaledo sandstone cliffs which form the north and south walls of the bay.

3. Yokam Point. Yokam Point, sometimes called Mussel Reef, is a promontory at the west end of Bastendorff Beach, about 1 mile east of Sunset Bay and 10 miles from Highway 101. At this locality, the Coaledo beds are almost vertical, and the more resistant sandstone layers jut out into the ocean as reefs containing highly fossiliferous lenses. The road passes close to the point, and at low tide the reefs can be reached from various trails leading down to the beach.

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* Numbers correspond to locality numbers on map.

4. Fossil Point. Fossil Point, a well-known pioneer landmark, juts out from the east shore of Coos Bay, 1.6 miles by road north of the east end of the South Slough bridge, or 3.2 miles south of the right-angle turn in the highway at Empire.

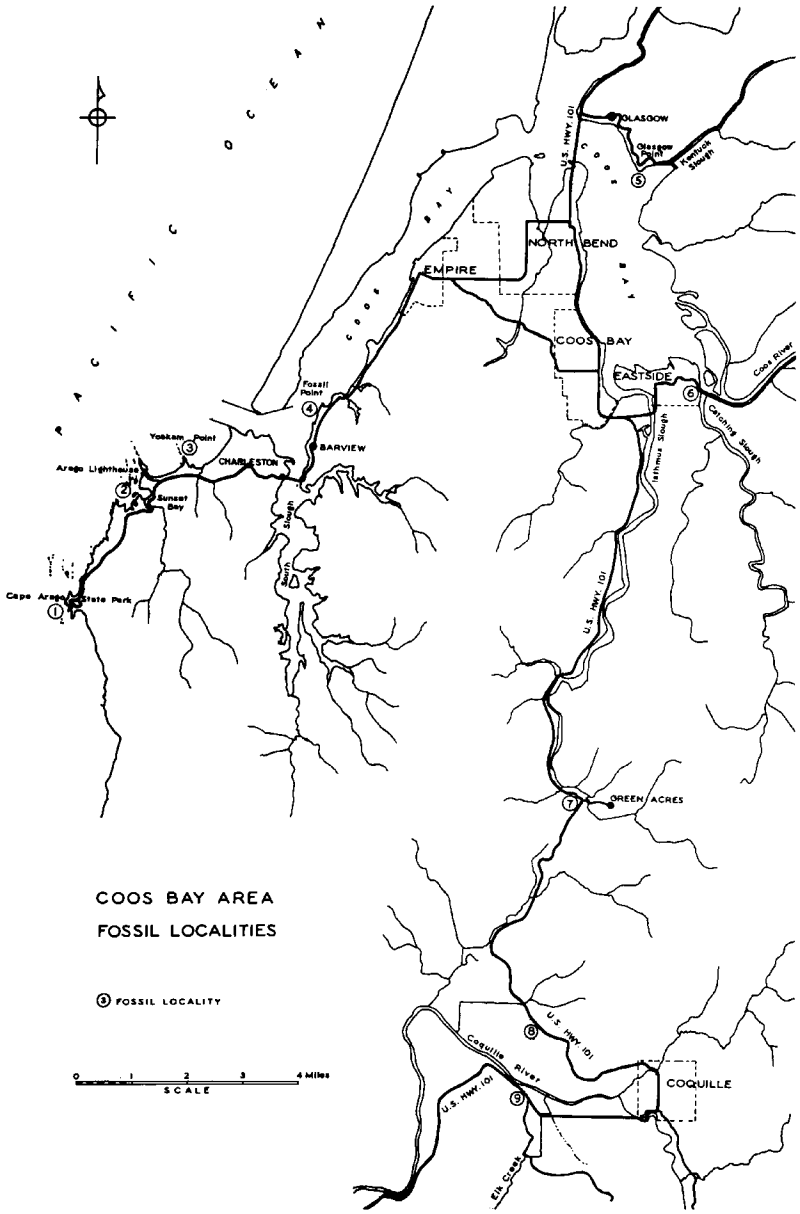
Fossil Point is composed of massive, brown sandstone of the Empire Formation. Many species of Pliocene mollusks occur in the sandstone, but of particular prominence are the large and well-preserved pectens. Skulls and other bones of Pliocene whales and sea lions are sometimes found here. The Empire sandstone forms a continuous ledge which may be followed at low tide along the shore for about half a mile to the south. The ledge terminates in a deep-water recess the south wall of which is formed by the Coos Conglomerate that projects into the bay. Fossil shells in this conglomerate are so numerous and so firmly cemented together that extraction of single specimens is difficult.

The locality is not so easily accessible as in the past, for the narrow strip of land between the highway and the shore is now largely private property. The outcrop of Coos Conglomerate may be reached at low tide by following the beach north from the east end of the South Slough bridge for a distance of about 1 mile. Fossil Point may be reached at low tide from the small bay at the north end of the point where the highway comes close to the water's edge, 3.1 miles south of the right-angle turn of the highway in Empire.

5. Glasgow Point. Glasgow Point is a headland across the bay from North Bend and southeast of the town of Glasgow. It is reached from the north end of the Coos Bay bridge by following a surfaced road east through Glasgow for 2.5 miles to the edge of Kentuck Slough. From here one can walk back along the shore for about $\frac{1}{4}$ mile to Glasgow Point and continue northwest for a short distance along the base of the high cliff. Large sandstone boulders of the Coaledo Formation lie along the shore beneath the cliff from which they originally came. Many of the boulders contain layers packed with well-preserved fossils such as the corkscrew gastropod *Turritella* and numerous pelecypods.

6. Catching Slough. A fossiliferous zone in the Coaledo Formation is exposed in the cliff beside the Coos River road near the west end of the bridge which crosses the mouth of Catching Slough. The locality is 1.0 mile east of the right-angle turn of the highway in Eastside. Small Eocene fossil shells occur in narrow bands in the bedrock of the cliff.

7. Green Acres. Locality 7 near Green Acres and Locality 8 near China Creek are only two of a number of fossiliferous exposures of the Coaledo Formation in road cuts through hills along U.S. Highway 101 between Coos Bay and Coquille. Cuts through soft rock are weathered and slumped, but those through harder strata expose vertical sections of sandstone and


PACIFIC OCEAN
COOS BAY
GLASGOW
Glasgow Point
Kentuck Slough
U.S. HWY. 101
NORTH BEND
EMPIRE
COOS BAY
EASTSIDE
Coos River
Catching Slough
Millicoma Slough
Fossil Point
BARVIEW
CHARLESTON
Yoakam Point
Arago Lighthouse
Sunset Bay
Cape Arago State Park
Bath Slough
GREEN ACRES
Coquille River
COQUILLE
Elk Creek
COOS BAY AREA
FOSSIL LOCALITIES
FOSSIL LOCALITY
0 1 2 3 4 Miles
SCALE

shales, many of which are fossil bearing.

The Green Acres locality is on Highway 101 near the sign pointing east to Green Acres, 8 miles south of the junction in Bunker Hill of Highway 101 and the Coos River Road. A large road cut in the hillside beside the highway exposes several thick bands of fossil shells in gray Coaledo shale.

8. China Creek. The locality is a long roadcut in a low hill just east of China Creek. It is 5.3 miles southeast of the Green Acres locality and 3.5 miles northwest of the junction in Coquille of U.S. Highway 101 and State Highway 42. In the cut, shales and sandstones of the Coaledo Formation dip at a low angle to the west. Eocene fossils occur in thin bands at several horizons.

9. Fat Elk Road. A thick section of dense gray shale in the Coaledo Formation crops out on the south side of Highway 101, 0.1 mile west of the intersection of Fat Elk Road, and 2.5 miles west of the bridge which crosses the Coquille River at Coquille. Fossils are abundant but break easily. This rock was quarried and used to build up the shoulders of the highway between Fat Elk Creek and Coquille, and the large blocks of rock on either side of the highway in this section contain many fossils.

10. North End of Causeway. The Coaledo Formation crops out in road cuts in the headland at the north end of the new causeway leading from Coos Bay bridge across Haynes Inlet. As this portion of the highway was not completed at the time the field investigations were made, this locality was not visited by the writer, but it is likely that fossils are present in the fresh exposures of shale at this locality.

Fossils to Look For

Pelecypods (clam shells) and gastropods (snail shells) are the most abundant of the marine invertebrates in the Coos Bay area and occur in great variety; there are about 35 species of each in the Coaledo Formation and about 50 species of each in the Empire Formation. Other marine invertebrates, such as scaphopods (tooth shells), echinoids (sand dollars), and crustaceans (crabs), are not as common and are limited to one or two species each.

Vertebrate animals also lived in the Eocene and Pliocene seas. Fossilized fish vertebrae and shark teeth of Eocene age are sometimes found in the Coaledo beds. In the Empire Formation, fossil bones of Pliocene marine mammals are not uncommon. The skull of an immense sea lion (*Pontolis magnus* True) was discovered many years ago near Fossil Point by a resident of Empire, and since that time a number of bones of unidentified species of sea lions and whales have been found in the Pliocene sandstone.

Names, descriptions, and illustrations of the fossils characteristic of

the various sedimentary formations in the Coos Bay area are given by Dall, Howe, Turner, Weaver, and others (see bibliography).

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