

ART. IV.—*The Jurassic Age of the "Jurassic Flora of Oregon"* ;* by F. H. KNOWLTON.

INTRODUCTION.

THE stratigraphic and paleontologic relations of the earlier Mesozoic rocks of the Pacific Coast region, more particularly the Knoxville and related formations, have been the subject of prolonged investigation, and, it may be added, not a little difference of opinion as regards their interpretation. Mr. J. S. Diller, of the U. S. Geological Survey, is especially notable among those who have made this area the subject of study, and to his interest and energy we are principally indebted for the bringing to light of the numerous and often exhaustive collections of fossil plants. To Prof. Lester F. Ward and Prof. Wm. M. Fontaine we are also under obligation for the adequate study, illustration, and publication of these floras, without which they would, doubtless, have long remained unavailable for stratigraphic uses. Although the story told by the floras is seemingly plain and unequivocal, the conclusions of the paleobotanists have not always been given full consideration, and it is the object of the present paper to present this paleobotanical evidence in compact form, together with such stratigraphic and other paleontologic data as may be necessary to make the position clear.†

In November 1908, Mr. Diller published a paper under the title, "Strata containing the Jurassic Flora of Oregon,"‡ the thesis of which he sets forth as follows: "Two fossil floras have been reported from the Mesozoic rocks of California and Oregon, the one Cretaceous and the other Jurassic. With the former the fauna is Cretaceous, but with the latter the fauna has been regarded as a matter of doubt. It is the purpose of this paper to remove the doubt by showing that in parts of Oregon and California the Jurassic flora, is in the 'Myrtle' and Knoxville beds, while elsewhere it extends down to the horizon of the Mariposa, and the general conclusion is reached that for the Pacific Coast the line between the Cretaceous and the Jurassic is the great unconformity at the base of the Knoxville."

The major portion of Mr. Diller's paper is devoted to proof that the Jurassic flora occurs in the Knoxville formation—a

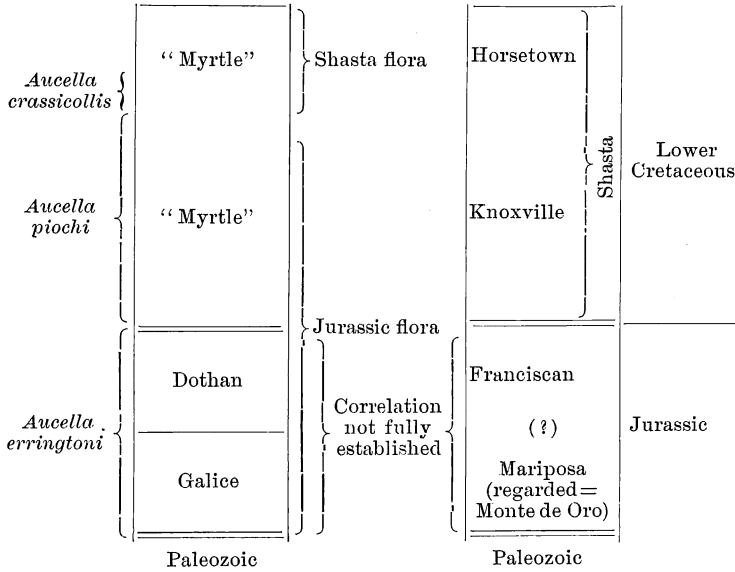
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† The writer labors under the disadvantage of not having seen in the field the several formations here involved, and consequently the discussion is confined mainly to the paleobotanical evidence. The geological data are largely from Diller.

‡ Geol. Soc. Am., Bull., vol. xix, pp. 367-402, 1908.

point conceded by the present writer. It is to the placing of the Jurasso-Cretaceous line at the base of the Knoxville that exception is taken.

Mr. Diller's interpretation of the relations of the several formations concerned in this paper, together with his conclusion regarding the ranges of the floras and the supposedly characteristic invertebrates, is shown in the following diagram, which is taken from his paper (p. 369):



THESIS OF THIS PAPER.

At variance with the conclusions above set forth, it will be shown in the present paper that the so-called "Jurassic flora of Oregon" is everywhere of true Jurassic age, that it is practically never* found in association with the acknowledged Cretaceous flora, and finally, that the line between the Jurassic and the Cretaceous of the region is to be drawn through the upper part of the Knoxville and not at its base.

LOCALITIES OF THE SEVERAL PLANT BEDS

The localities which have afforded the floras are as follows: The "Jurassic flora of Oregon" occurs at three points in Oregon—(1) Thompson Creek and the vicinity of Buck Peak; (2) near Nichols Station on the Southern Pacific railroad, both

* The only possible exceptions are a scrap very doubtfully identified from the area near Riddles, Oregon, and a conifer of no stratigraphic value from California.

in Douglas County; (3) along the forks of Elk River in Curry County. In California there are also three areas: (1) Big Bar and (2) Rattlesnake Creek in the Klamath Mountains, Trinity County, and (3) near Oroville, Butte County, the latter at the western base of the Sierra Nevada.

The Lower Cretaceous flora† is found along Iron Mountain Creek in the vicinity of Riddles, Douglas County, Oregon; at Redding Creek, Tehama County, California, and very extensively along the western side of the Sacramento Valley in Shasta and Tehama counties, California. The Jurassic and Lower Cretaceous floras, although occurring in the same areas, are perfectly distinct and have never been found commingled.

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE
"JURASSIC FLORA OF OREGON."

1. *Thompson Creek, Douglas County, Oregon.*

The beds exposed along Thompson Creek are 1000 feet or more in thickness and dip westward at an angle of about 38°. The lower three-fourths of the section is composed of conglomerates, with small local beds of sandstones and shale, while the upper third is made up of sandstone and shale. Although plant fragments are found at various points in the conglomeratic portion, the principal plant beds are in shaly sandstone about 180 feet below the top of the exposed Mesozoic section. This is one of the richest of the Jurassic plant localities, having furnished 66 species (see pp. 43-45).

As regards the invertebrates found at this locality Mr. Diller says:* "Shells are of exceptional occurrence in the leaf beds. Though carefully sought for, they have rarely been found. A doubtful fragment found with the plant fossils in Thompson Creek was referred to Doctor Stanton, who reported that "the fragment seems to be part of a shell and is probably an Aucella, although there is not enough of it for positive identification."

2. *Buck Peak, Douglas County, Oregon.*

On the northeastern side of Buck Peak, 1,200 feet below the summit, there is an important plant locality which is really embraced in the Thompson Creek area already considered.

* The flora, called in this paper the "Lower Cretaceous Flora," has heretofore been called the "Shasta flora," but since it does not occur throughout the whole of the Shasta series it has seemed best to abandon its use. It may be desirable at some time in the future to give separate names to the portions of the Shasta series containing the Cretaceous and Jurassic floras respectively.

† Geol. Soc. Am., Bull., vol. xix, p. 373, 1908.

At the summit there are found the invertebrates *Aucella Piochi* and *A. crassicollis*, but between the summit and the plant bed, 1,200 feet below, only faint indications of plants have been noted, though according to Mr. Diller "The plant beds at the so-called Todd locality conformably underlie by a few feet only a conglomerate containing indefinite vegetable fragments as well as good specimens of *Aucella Piochii*." From the presence of shells and plants and the lithologic similarity of the intervening beds to those of the Myrtle, the whole is referred to this formation.

The only Jurassic plant in any way determinable that was found in the area and strata usually containing a Lower Cretaceous flora, occurred about 3 miles northeast of Riddles. This was a minute fragment, which was very questionably identified as *Teniopteris oregonensis*, and was found in association with *Aucella Piochii*. If this identification had been positive, or even reasonably certain, it would be the only known instance of the two floras overlapping, but it is altogether too fragmentary to be taken as conclusively affording such evidence.

3. Nichols Station, Douglas County, Oregon.

This is a small area, mainly on Cow Creek, about half a mile north of Nichols Station, and is entirely surrounded by rocks of Eocene age. The beds, only about 200 feet in thickness, are composed of "fine, dark, shaly sandstone or sandy shale." Their relations to the underlying beds cannot be observed, and their reference to the Myrtle was based largely on a single specimen of *Aucella Piochii*, which was in a loose piece of matrix, not certainly found in the plant beds. As a locality for the Jurassic flora, however, it is of the greatest importance, no less than 45 forms having been found here. [See table on pp. 43-45.]

4. Elk River, Curry County, Oregon.

This area, which lies about 40 miles directly southwest of the areas in Douglas County, is of limited extent, ranging along Elk River from near the mouth of Blackberry Creek to the forks of the river and up the North fork for a distance of about a mile and a half; on the South fork the plant beds extend for only 200 yards. The section is about 1000 feet in thickness and is made up of sandy shale, much veined with calcite, "frequent layers of calcareous material, beds of sandstone, and fine conglomerate."

According to Mr. Diller,* "These plant beds are underlain on the South fork by a mass of conglomerate containing in its

*Op. cit., p. 376.

lower part many large pebbles of the greenstone like that on which the conglomerate rests at the base of the 'Myrtle.' No plants were found in the basal conglomerate, though it contained many examples of *Aucella crassicollis*." On this evidence the entire section was regarded as referable to the Myrtle formation.

Since the above quotation was published, in fact during the past summer (1909), Mr. Diller has visited and re-examined the Elk River region of the Port Orford quadrangle, and made the following important observations which he has kindly permitted me to make use of. The plant beds—that is, the beds containing the "Jurassic flora of Oregon"—he now finds to be over 1,200 feet in thickness; they rest conformably on a conglomerate which he regards as the basal member of the Myrtle (Knoxville). This conglomerate contains "multitudes" of *Aucella crassicollis* in the upper portion, while *Aucella Piochii* occurs, though somewhat rare, near the bottom. This conglomerate rests unconformably on a mass of greenstone, which has supplied the pebbles in its basal portion. This greenstone mass, in turn, has cut the underlying crushed and quartz-veined slates and sandstones of the Dothan? which latter contains locally, as identified by Doctor Stanton, *Aucella Piochii* and *Aucella Erringtoni* in association. This distribution of the several species of *Aucella* in this section is very significant, and will be referred to on a later page.

The Elk River area has furnished two considerable collections of fossil plants which together aggregate 20 species [see table on pp. 43-45]. As this entire flora, with the exception of the unnamed specie of *Hausmannia*, is identical with that found in Douglas County, it may be considered as settled that the two areas are of the same age.

This is also the first of the areas thus far considered in which an identifiable invertebrate fauna is found in direct association with the plants. The following list of names is given by Doctor Stanton:*

Spondylus? sp.
Aucella crassicollis Keyserling
Inoceramus ovatus Stanton
Turbo morganensis Stanton
Olcostephanus mutabilis Stanton
Perisphinctes? sp.
Hoplites Hyatti Stanton
Belemnites tehamensis Stanton
Belemnites impressus Gabb
Pinna.

* In Diller, Geol. Soc. Am., Bull., vol. xix, p. 378, 1908.

Doctor Stanton makes the following comment on this fauna: "The collection consists of a number of small lots containing very few specimens, the most abundant and persistent being *Aucella crassicollis* Keyserling, which past experience shows to be characteristic of the upper part of the Knoxville formation and is believed to be confined to the Lower Cretaceous. In several of the lots there are a few ammonites and other fossils that are also Knoxville forms."

The significance of this association of flora and fauna will be considered later.

5. Big Bar, Trinity County, California.

This area, which covers less than two square miles, is on the Trinity River, about twenty miles west of Weaverville, California, and is not less than 150 miles from the areas already considered in Oregon. The entire section of Jurassic rocks in this vicinity does not exceed 200 feet in thickness, and lies on the sharply upturned edges of older, probably Paleozoic strata, and is itself inclined from 20 to 45°. It is composed of soft "gray shales and sandstones, with a small proportion of fine conglomerate," and apparently belongs to the lower part of the Knoxville.

Fossil plants are abundant in this locality, and are scattered irregularly throughout the section, though most numerous in the lower portion. They embrace 20 well-marked species [see table on pp. 43-45] and as stated in the original report, they "prove beyond question that the beds containing them are similar in age to the Jurassic of Oregon, since all but three of the forms (*Onychiopsis* [fruit], *Hausmannia*, and *Pagiophyllum falcatum*) are common to the two areas."

In the same bed with the plants a few shells have been found. Only one of these has been positively determined as *Aucella crassicollis*, the others being unidentified forms of *Pecten*, *Mytilus*, *Cyprina*, and *Unio*, the latter proving that there were alternations of fresh-water and salt-water conditions. These fossils, says Doctor Stanton, "are certainly upper Knoxville and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis*."

6. Rattlesnake Creek, Trinity County, California.

Twenty-five miles south of Big Bar there is another small area of Jurassic plant-bearing beds lying in the drainage of Rattlesnake Creek, $7\frac{1}{2}$ miles southwest of Peanut, Trinity County, California. As at Big Bar, the plant beds rest on the upturned edges of older rocks.

Only three species of plants have been found at this locality: *Cycloptis oregonensis* Font., *Teniopteris vittata* Brongn.,

and *Sequoia Reichenbachii* (Gein.) Heer. The latter species is a form of such wide vertical range that it is of little value in fixing the age of beds in which it may occur, hence its inferential use to prove the beds on Rattlesnake Creek to be of extreme upper Knoxville or lower Horsetown age, where this species has also been found, is not warranted.

Many shells are stated to be present in the same strata with the plants, concerning which Doctor Stanton reports as follows: "Among the fossil plants are two small shells which appear to be young specimens of *Unio*, though they may belong to some marine genus instead."

7. Oroville, Butte County, California.

At this locality Jurassic rocks form an area about 2 miles in length and $2/5$ of a mile in width, on the southern slope of Monte de Oro, about 3 miles northeast of Oroville, Butte County, California. These rocks, to which the local name of the Monte de Oro formation has been given, are composed of "slates, sandstones, and conglomerates in small layers, irregularly interbedded"; they are much disturbed and the true thickness cannot be made out, though thought to be somewhere between 450 and 900 feet.

This area has afforded a rich flora, and was the first to be described of any considered in this paper; it contains 27 species [see table on pp. 43-45]. They are typically Jurassic, and as nearly half were subsequently found to be common to the Douglas County region they are of much importance in settling the Jurassic age of the plant beds in the latter area. Unfortunately the invertebrate collections are not large from the plant beds at Oroville, and comprise new or undeterminable species of the genera *Ostrea*, *Pecten*, *Aucella*?, *Modiola*, *Trigonia*, *Cardium*? and *Belemnites*. Regarding the age as indicated by the *Aucella*? Doctor Stanton says: "If it is really an *Aucella* the age is either Mariposa or Knoxville, more probably the former. The general character of the other forms is suggestive of the older Jurassic faunas of the Taylorsville region, but it must be admitted that there is no definite evidence of this."

STRATIGRAPHIC RELATIONS OF THE BEDS CONTAINING THE LOWER CRETACEOUS FLORA OF OREGON AND CALIFORNIA.

1. Near Riddles, Douglas County, Oregon.

In the vicinity of Riddles, Oregon, and including a small area on Iron Mountain Creek, there is a mass of rocks that has been pretty definitely connected with the upper portion of the Myrtle formation, since it is directly on the strike with that

of the type locality for the Myrtle on Myrtle Creek in the Roseburg quadrangle. These beds contain a small but very important flora of 8 species, as follows:

- Sagenopteris Mantelli?* Schenk
Sagenopteris oregonensis Font.
Sagenopteris nervosa Font.
Angiopteridium strictinerve latifolium Font.
Dioonites Buchianus abietinus Ward.
Nageiopsis latifolia Font.
Populus? *Ricei* Font.
Sapindopsis oregonensis Font.

This flora is identified without hesitation as being of Lower Cretaceous age, or Neocomian. The presence of the species of dicotyledons shows conclusively that it is younger than the "Jurassic flora of Oregon," a fact also proved by the stratigraphic relations and invertebrate fauna. The latter, although stated to be abundant, is not listed by Mr. Diller, though held to be characteristic and proving the correlation between these beds and those containing a similar fauna on the western side of the Sacramento Valley.

The stratigraphic relations between the beds near Riddles which contain the Lower Cretaceous flora, and those to the northwest containing the Jurassic flora, is well set forth by Mr. Diller* in the following statement: "A line of deformation runs northeast and southwest through the region of Nickel Mountain and Dodson Butte. It follows a prominent ridge and appears to mark approximately the limit between the two floras of 'Myrtle formation.' Southeast of it lies the Riddles region and Iron Mountain Creek, where the "Myrtle formation" contains the 'Shasta flora,' while to the northwest of it lie the larger irregular areas of the 'Myrtle,' containing locally on Thompson Creek and Elk River the 'Jurassic flora of Oregon.' At one point the line of deformation is overlapped by the Jurassic flora, where it reaches Cow Creek at Nichols Station. In general, on account of the overlapping 'Myrtle formation,' it may be claimed that the 'Myrtle' containing the Jurassic flora lying northwest of that containing the Shasta flora must be older. So it seems also from the entire absence of any Horsetown fauna on the northwest side of the axis in the same series near the Jurassic flora."

From this exposition it appears very clear that the Myrtle formation may be divisible, at least paleontologically, into two parts, the upper of which is characterized by the presence of a Lower Cretaceous flora and fauna, while the lower is equally marked by the presence of a Jurassic flora. The two floras

* Op. cit., p. 397.

have never been found commingled, but the fauna is occasionally, as at Elk River, also found interbedded with, as well as below, the Jurassic flora, showing that it has a greater vertical range than has usually been accorded to it.

2. *Western Side of the Sacramento Valley in Shasta and Tehama Counties, California.*

This is much the largest and most important of the areas which have afforded the Lower Cretaceous flora. It is found at many localities on the North fork of Cottonwood Creek near the town of Ono, Shasta County, and along the Cold fork and South fork of Cottonwood Creek, as well as near the Post Office of Lowrey and as far south as Paskenta, all in Tehama County. The field relations of this region have been so fully set forth by Professor Ward* and Mr. Diller that it is unnecessary again to go over the matter.

This area is also notable as that which has supplied the major portion of the Knoxville fauna, and since small portions of this fauna were found in association with the Jurassic flora at Elk River, Big Bar, etc., it was assumed by some that the flora of the western side of the Sacramento Valley would present the same associations—that is, prove to be a Jurassic flora—but it very distinctly is not. By combining the floras collected by Professor Ward and studied by Professor Fontaine, with those collected by James Storrs for Mr. Diller and reported on by the writer, we have the following aggregate list of 59 forms, only a single species of which is common to the Jurassic flora. It is distinctly a Lower Cretaceous (Neocomian) flora and finds its closest affinity with the Kootenai of the interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coastal Plain. A further analysis and comparison will be made in later pages.

List of Lower Cretaceous Flora of the Western Side of the Sacramento Valley.

- Dicksonia pachyphylla* Font.
- Thyrsopteris varinervis* Font.
- Cladophlebis parva* Font.
- “ *Browniana* (Dunk.) Sew.
- “ *falcata* Font.
- “ *heterophylla* Font.
- “ *Ungeri* (Dunk.) Ward.
- “ *alata* ? Font.
- Matonidium Althausii* (Dunk.) Ward.
- Gleichenia Nordenskiöldi* Heer.
- “ ? *Gilbert-Thompsoni* Font.

* U. S. Geol. Surv. Mon. 48, p. 211 et seq., 1905.

- Sagenopteris Mantelli* (Dunk.) Sew.
 “ *oregonensis* (Font.) Font.
 “ *elliptica* Font.
 “ *nervosa* Font.
 “ ? sp. Font.
Tæniopteris sp. Kn.
Hausmannia ? *californica* Font.
Angiopteridium canmoreense Dawson ?
 “ *strictinerve* Font.
 “ *strictinerve latifolium* Font.
Oleandra graminæfolia Kn.
Ctenopteris integrifolia Kn.
Ctenis sp. Kn.
Equisetum texense Font.
Dioonites Dunkerianus (Göpp.) Miq.
 “ *Buchianus* (Ett.) Born.
 “ “ *abietinus* Ward.
 “ “ *rarinervis* Font. ?
Nilsonia Stantonii Ward.
 “ *Shaumbergensis* (Dunk.) Nathorst.
 “ *californica* Font.
 “ *sambucensis* Ward.
 “ sp. Kn.
Pterophyllum lowryanum Ward.
Ctenophyllum ? *latifolium* Font. ?
Zamites arcticus Göpp.
 “ *tenuinervis* Font.
Cycadeospermum alifornicum Font.
 “ sp. Kn.
Cephalotaxopsis ramosa Font. ?
 “ *rhytidodes* Ward.
Nageiopsis longifolia Font.
 “ *latifolia* Font.
Abietites ellipticus Font.
 “ *macrocarpus* Font.
 “ sp.
Pinus shastensis Font.
Sequoia Reichenbachii (Gein.) Heer.
 “ *ambigua* Heer.
Sphenolepidium Sternbergianum (Dunk.) Heer.
Saliciphyllum pachyphyllum Font.
 “ *californicum* Font.
Populus ? *Ricei* Font.
Proteaphyllum californicum Font.
Menispermites californicus Font.
Sapindopsis oregonensis Font.
Acaciæphyllum ellipticum Font.
 “ *pachyphyllum* Font.

3. Redding Creek, Trinity County, California.

The final area of beds holding a Lower Cretaceous flora to be considered is the small one on Redding Creek, near Douglas City, Trinity County, California. It is said that the beds at this locality lap over the crest of the Coast Range from the Sacramento Valley, and are of the same age as the beds in the latter area. The flora is a small one, comprising only the following species :

Sagenopteris oregonensis Font.
Sagenopteris elliptica ? Font.
Gleichenia ? *Gilbert-Thompsoni* Font.
Cladophlebis heterophylla Font.
Sequoia Reichenbachii (Gein.) Heer.

These specimens, with the exception of *Cladophlebis heterophylla*, which is known from the Kootenai and lower Potomac, are all reported by Fontaine and the writer from the Lower Cretaceous flora of the localities along the western side of the Sacramento Valley, in direct connection with these beds, as stated above.

The fauna associated with the plants embraces *Pecten operculiformis*, *Trigonia leana*, *Cardium*?, *Corbula*, and *Pleuromya papyracea*, and is regarded by Doctor Stanton as belonging to the lower Horsetown.

TABLE SHOWING LOCAL DISTRIBUTION OF THE JURASSIC FLORA.

As a preliminary to the proper consideration of the Jurassic flora in all its aspects, we may first present a table which gives a complete list of forms known, together with their distribution among the several localities in Oregon and California. The number, or numbers, opposite each species, refer to the localities as follows :

- 1 = Thompson Creek, Oregon.
- 2 = Buck Peak, Oregon.
- 3 = Nichols Station, Oregon.
- 4 = Elk River, Oregon.
- 5 = Big Bar, California.
- 6 = Rattlesnake Creek, California.
- 7 = Oroville, California.

Marchantites erectus (Bean) Sew., 1.
Dicksonia oregonensis Font., 1, 2, 4, 5.
Coniopteris hymenophylloides (Brongn.) Sew., 3, 7.
Thyrsopteris Murrayana (Brongn.) Heer, 1, 3, 4.
Polypodium oregonense Font., 1, 2, 3, 4.
Cladophlebis vaccensis Ward, 1, 2, 3, 4, 5, 7.
 " *haiburnensis* (L. & H.) Br. ? 1.
 " *acutiloba* (Heer) Font., 1, 3.

- Cladophlebis denticulata* Font., 5 ?
 “ *pecopteroides* Font., 2, 4 ?
 “ *sphenopteroides* Font., 5.
 “ *spectabilis* (Heer) Font., 7.
 “ *argutula* (Heer) Font., 7.
 “ *densifolia* Font., 7.
 “ *indica* (O. & M.) Font., 7.
 “ sp., Kn., 5.
Scleropteris oregonensis Font., 3, 5 ?
Ruffordia Göpperti (Dunk.) Sew., 1.
Adiantites Nympharum Heer ? 1, 3.
 “ *orovillensis* Font., 7.
Tæniopteris orovillensis Font., 1, 2, 3, 5, 7.
 “ *major* L. ? & H., 1, 2, 3.
 “ *vittata* Brongn., 1, 2, 3, 5, 6.
 “ ? *oregonensis* Font., 1, 4.
 “ sp., 5.
Macrotæniopteris californica Font., 1, 7.
 “ *nervosa* Font., 7.
Angiopteridium californicum Font., 7.
Sagenopteris Göppertiana Zigno, 1, 2, 4, 7.
 “ *paucifolia* (Phil.) Ward, 1, 2, 3, 4, 5.
 “ *grandifolia* Font., 1, 5.
Danæopsis Storrsii Font., 1.
Didymosorus ? bindrabundensis acutifolius Font., 7.
Hausmannia sp., 4, 5.
Onychiopsis psilotoides (Stokes & Webb) Ward ? 5.
Equisetum ? sp., Font., 1, 3.
Ptilozamites Leckenbyi (Bean) Nath., 3.
Nilsonia orientalis Heer, 1, 2.
 “ “ *minor* Font., 1, 2, 3, 4, 5.
 “ *parvula* (Heer) Font., 1, 2, 3, 4.
 “ *nipponensis* Yokoyama, 1.
 “ *compta* (Phil.) Göpp., 1, 3.
 “ *pterophylloides* Nath., 1, 3.
 “ sp., Kn., 4.
Pterophyllum Nathorsti Schenk, 1, 2, 3.
 “ *contiguum* Schenk, 1, 2, 3.
 “ *æquale* (Brongn.) Nath., 1, 2, 3.
 “ *rajmahalense* Morris, 1, 2, 3.
 “ *minus* Brongn., 1.
Otenis grandifolia Font., 1, 2, 3, 7.
 “ *auriculata* Font., 1?, 7.
 “ *orovillensis* Font., 1, 7.
 “ *sulcicaulis* (Phil.) Ward, 1, 2, 3, 4 ?
Otenophyllum angustifolium Font., 1, 4, 7.
 “ *pachynerve* Font., 3.
 “ *Wardii* Font., 1, 2, 3, 7.
 “ ? n. sp. ? Font., 4.
 “ *densifolium* Font., 7.
 “ *grandifolium Storrsii* Font., 7.

- Podozamites pulchellus* Heer, 1, 2, 3.
 “ *pachyphyllus* Font., 2, 3.
 “ *lanceolatus* L. & H., 1, 2, 3, 7.
 “ “ *latifolius* (Brongn.) Heer, 1, 4, 7.
 “ “ *minor* (Sch.) Heer, 1, 4, 5.
 “ sp., Kn., 4.
 “ ? *pachynervis* Font., 1.
Otozamites oregonensis Font., 4.
Encephalartopsis? *oregonensis* Font., 2.
Cycadeospermum oregonense Font., 1.
 “ *ovatum* Font., 1.
Williamsonia oregonensis Font., 1.
 “ ? sp., Font., 1.
 “ ? sp., Font., 3.
Ginkgo digitata (Brongn.) Heer, 1, 3.
 “ *Huttoni* (Sternb.) Heer, 1, 3.
 “ “ *magnifolia* Font., 1, 2, 3.
 “ *lepida* Heer, 1, 2, 3.
 “ *siberica* Heer, 1, 3.
 “ sp., Font., 1, 3.
Baiera multifida Font., 7.
Phœnicopsis? sp., Font., 1.
Taxites zamioides (Leck.) Sew., 1, 2, 3, 4, 5.
Brachyphyllum mamillare Brongn., 1.
Pagiophyllum Williamsonis (Brongn.) Font., 7.
 “ *fulcatum* Font., 5?
Araucarites sp., Font., 1.
Pinus Nordenskiöldi Heer, 1, 3, 7.
Sequoia Reichenbachi (Gein.) Heer, 6.
Cyclopitys oregonensis Font., 1, 6.
Sphenolepidium oregonense Font., 1, 2, 3, 5.
Samaropsis? *oregonensis* Font., 1.
Leptostrobus? sp., Font., 7.
Yuccites hettangensis Sap., 1, 5?
 Undetermined leaf No. 1, 1.
 “ “ “ 2, 1.
Carpolithus Storrsii Font., 7,
 “ *otallensis* Ward, 1.
 “ *Bucklandii* Will., 1.
 “ *oregonensis* Font., 1, 2.
 “ *elongatus* Font., 1.
 “ *douglasensis* Font., 3.

DISCUSSION OF THE DISTRIBUTION AND AFFINITY OF THE
JURASSIC FLORA.

Aside from furnishing a complete list of the forms thus far known from the Jurassic of Oregon and California, the above table brings out graphically a number of interesting points, perhaps the most important of which is the close interrelation

of the floras of the several areas. Thus, of the 27 species composing the Oroville flora, 12 species occur also in the Douglas County areas. Of the 66 forms found on Thompson Creek, 32 are common to the localities near Nichols Station, and of the 20 forms occurring at Elk River, in Curry County, all but one are common to Douglas County. The close relation between the Oregon areas and that at Big Bar, California, is shown by the fact that all but 3 of its 19 forms are common to the former, and of the 3 species reported from Rattlesnake Creek, 2 are common to the Oregon localities and one to Big Bar. This proves beyond all reasonable doubt that the plant beds of the several localities are identical in age. Whatever is decided regarding any one of them must apply with equal force to all.

We may now proceed to an analysis of the flora to ascertain its bearing on the age of the strata. Of the 100 forms composing the flora 15 are not specifically named and 47 are found in outside areas, mainly beyond the limits of North America, thus leaving 38 species, or considerably less than fifty per cent., as endemic. Of these forms that are peculiar, Professor Fontaine* has well said that "none are incompatible with the conclusion that the age of the strata is Jurassic. On the contrary, so far as they throw any light on the question of age, they indicate that it is Jurassic."†

The value of species new to science and those whose determination is questioned, in attempting to fix the age of the beds containing them lies in their affinities, or close relationship, with species whose position is known. It may be worth while in the present connection to review a number of the peculiar species of this flora to ascertain their relationships. *Cladophlebis vaccensis* is very close to, and indeed was at first identified with, *Asplenium whitbiense tenue* Heer, from the Jurassic of Siberia. *Cladophlebis pecopteroides* is thought by Professor Fontaine to be the Oregon representative of *Pecopteris obtusifolia*, a species of the Yorkshire beds. *Scleropteris oregonensis* is close to *S. Pomelii* Zigno of the Italian Oölite. *Tæniopteris? oregonensis* may be a small, narrow leaf of *T. vittata*, though it has some resemblance to *Cycadites sibiricus* Heer, of the Jurassic of Siberia, which is a *Tæniopteris* rather than a

* U. S. Geol. Surv., Mon. 48, p. 141.

† Mr. Diller has given a portion of this quotation ["so far as they throw any light on the question of age, they indicate that it is Jurassic"] as a full expression of Professor Fontaine's opinion regarding the bearing of the Oregon plants on the question of age. As shown above, this quotation applies only to the new and not specifically named species, while Fontaine's opinions regarding the significance of the positively determined species occur on the two or three succeeding pages of his paper [U. S. Geol. Surv., Mon. 48, pp. 141-145].

Cycadites. *Danaeopsis Storrsii* shows affinity with *D. marantacea* Heer, and *D. Rumpffii* Schimper, two Triassic species, though it is smaller. *Ctenophyllum angustifolium*, as Fontaine points out, is "plainly one of the narrow-leaved Ctenophylla of the type of *Ctenophyllum Braunianum* (Göpp.) Schimper." *Podozamites pachyphyllum* resembles a number of species, but is especially like *Pterophyllum? cteniforme* Nathorst, from the Rhaetic of Sweden. *Williamsonia oregonensis* very much resembles *W. gigas* (Will.) Carruthers, a well-known species of the Jurassic of France and elsewhere. *Taniopteris orovillensis*, the most common fossil plant at Oroville, is very near the plant figured and described by Saporta as *T. tenuinervis* Braunn from the Infralias of France. *Macroteniopteris californica*, which is also a common form at Oroville, is near *T. lata* Oldh. & Morr., of the Rajmahal flora of India. *Angiopteridium californicum* is quite similar to *A. McClellandi* (Oldh. & Morr.) Schimper, from the same locality and horizon as the last.

This comparison could be much further elaborated, but it is perhaps unnecessary.

A COMPARISON OF THE JURASSIC FLORAS OF CALIFORNIA AND OREGON HERE CONSIDERED WITH KNOWN JURASSIC FLORAS OF OTHER PARTS OF THE WORLD.

The Jurassic flora is one of the most widely known and uniformly distributed of any known fossil flora. Reaching its northernmost limit on King Karl's Land, 82° N., and its southernmost extension on Louis Philippe Land, 63° S., it is found entirely round the world in almost every continent and country—North America, Europe, Asia, Australia. Throughout this vast area it is to all intents and purposes practically the same flora. For example, many of the forms discovered on Louis Philippe Land are identical, or closely related, to those of the Oölite of Yorkshire, England, while many forms, identical or closely related, are common between the areas in England, Sweden, France, Italy, Germany, Siberia, China, Japan, India, or North America.

The types of the Jurassic flora are for the most part well marked, and even when only fairly well preserved are capable of very certain identification. When to this is added the fact that in most areas where this flora has been found its position is confirmed by contributory stratigraphic and paleontologic data, the fixation of a similar flora found in a new area is made easy and certain.

It is proposed to compare the flora here under consideration with that of several of the more important of the known Jurassic floras of the world, beginning with that of Eastern

Siberia. At first thought it may seem a far call from California and Oregon to Siberia, but when it is pointed out that there are a number of connecting points at which the Jurassic has been found in western British Columbia, southern and western Alaska, and thence out on the Alaskan peninsula, it is seen that we have here indication of a probable land connection between the continents in Jurassic time.

In 1876 Heer* published his first paper on this flora which included material from Kajamündung and Ust-Bali, Siberia, and the upper Amur River, and Bureja in the Amur. This was supplemented† in 1878 and 1880 by the study of further material from the original localities as well as from the Lena delta, etc. The number of species finally aggregated about 100, many of which have since been identified in widely different parts of the world, the greatest number (16 species) being common to the beds of Yorkshire, England. The age of the Siberian deposits was fixed by Heer as that of the middle Brown Jura (Dogger), which is about the equivalent of the lower Oölite of Yorkshire.

Following is the list of species common to California and Oregon and eastern Siberia:

<i>Cladophlebis argutula</i>	<i>Podozamites lanceolatus minor</i>
<i>Cladophlebis acutiloba</i>	<i>Podozamites lanceolatus latifolius</i>
<i>Cladophlebis spectabilis</i>	<i>Ginkgo digitata</i>
<i>Thyrsopteris Murrayana</i>	<i>Ginkgo Huttoni</i>
<i>Thyrsopteris Maakiana</i>	<i>Ginkgo lepida</i>
<i>Nilsonia orientalis</i>	<i>Ginkgo siberica</i>
<i>Nilsonia parvula</i>	Seeds of <i>Ginkgo</i>
<i>Pterophyllum rajmahalense</i>	<i>Pinus Nordenskiöldi</i>
<i>Podozamites pulchellus</i>	<i>Brachyphyllum mamillare.</i>
<i>Podozamites lanceolatus</i>	

As Professor Fontaine has pointed out, the strata of Oregon and California rival those of eastern Siberia in the development of Ginkgos, and as he says, it is a noteworthy fact that nearly all of the more important forms described by Heer from those beds have similar forms in the Oregon strata. Certain of the forms, notably that known as *Ginkgo digitata*, have a distribution into somewhat later beds, but in these later horizons, such for example as the Kootenai formation, they are smaller and not present in such numbers. In fact the Ginkgos in the Lower Oölite time were immensely developed in the Amur region of Siberia and in the northwestern portion of the

* Beiträge z. Jura-Flora Ostsibiriens u. d. Amurlandes. Mém. Acad. Imp. d. Sci. St. Petersb. (Fl. Foss. Arct., vol. iv, Abt. 2), vol. xxii, pp. 1-122, pls. i-xxxii, 1876.

† Op. cit., vol. xxiv, 1878 (Fl. Foss. Arct., vol. v, Abt. 1), pp. 1-26, pls. i-vii. Op. cit., vol. xxii, 1880 (Fl. Foss. Arct., vol. vi, Abt. 1), pp. 1-34, pls. i-ix.

United States, a profusion of identical forms such as to suggest very forcibly the existence of a former land connection.

At the present point it will be of interest to consider the occurrence of Jurassic plants at various localities in Alaska, the first and in many respects most important being the areas along the west shore of Cook Inlet. In this area Stanton and Martin* have established the Enochkin formation, the upper part of which they regard as the equivalent of the Callovian of European standards. Following German usage, this is considered by these authors as belonging to the upper part of the Middle Jurassic, though according to the prevailing custom of English geologists it belongs to the upper part of the Lower Oölite. The upper two-thirds of the Enochkin formation, which has a total thickness of from 1,500 to 2,500 feet, is especially characterized by the presence of numerous species of Cadoceras, several other genera of ammonites, belemnites, etc. Associated with these shells, often being on the same pieces of matrix, were the following plants:

Cladophlebis denticulata
Ctenis grandifolia
Hausmannia sp.
Dictyophyllum cf. *D. obtusilobum*.

The lower third of the Enochkin formation contains a fauna very different from that of the upper portion. It is characterized by species of Stephæroceras, Sphæroceras, Phylloceras, Lytoceras, etc., the genus Cadoceras being absent, and the most common forms being the several species of Inoceramus described by Eichwald from this region. It is interesting to note that this fauna was originally referred largely, if not wholly, to the Neocomian by Eichwald, and also that several of its species were found to be the same as those from Queen Charlotte Islands, once referred by Whiteaves to the Cretaceous. Associated with the ammonites were the following plants:

Sagenopteris Göppertiana
Pterophyllum rajmahalense
Macrotaeniopteris californica.

It is of importance to note that every one of the five named and positively identified species from the Enochkin formation occurs in the Oroville (Monte de Oro) flora. Several important inferences may be drawn from the intimate relation between the floras of these two areas. Thus, the Mariposa formation, with which the Monte de Oro formation has been identified, is regarded by Stanton as referable to the late Jurassic, but if a

* Geol. Soc. Am., Bull., vol. xvi, p. 397, et seq., 1905.

considerable element of the Oroville flora occurs in Alaska in association with an invertebrate fauna acknowledged to be of Middle Jurassic age, it would seem to follow that the Mariposa is also of similar age. The interpretation of the bearing of the invertebrates on this question must naturally be left to the invertebrate paleontologists, but this much can be said: The plant evidence, as above stated, is distinctly in favor of regarding the Mariposa as much older than "late Jurassic."

Other localities in Alaska are as follows: From Herendeen Bay, in association with shells of *Aucella crassicollis*, we have *Pterophyllum alaskense* Font., a form very closely related to *P. rajmahalense*, in fact hardly to be separated from it. The latter species is one of the most abundant and important of those found in the Oregon locality. Near Nikolai in the Copper River region occurs *Sagenopteris alaskense* Font., which is near *S. Göppertiana* of the lower Oölite of Italy, and which is found also at Thompson Creek, Elk River and Oroville. From the vicinity of Cape Lisburne quite large collections have been obtained. These comprise 14 species which were considered by Fontaine to be of Jurasso-Cretaceous age, but a study of large additional collections since secured, together with a review of much of the original material, has convinced the writer that they are of the same age as the other Alaskan and Pacific Coast plant beds. About half of the Cape Lisburne species are identical with those of Oregon or California. The final locality is between Icy Cape and Wainwright Inlet, some 180 miles northeast of Cape Lisburne. This place has afforded *Podozamites* sp. and *Baiera gracilis*, the latter a species characteristic of the Yorkshire beds.

On account of the larger number of common species, the next area to be compared, although not logically next from a geographical point of view, is Yorkshire, England, which has in common with the California-Oregon region the following:

<i>Marchantites erectus</i>	<i>Pterophyllum minus</i>
<i>Cladophlebis denticulata</i>	<i>Nilsonia compta</i>
<i>Cladophlebis haiburnensis</i>	<i>Podozamites lanceolatus</i>
<i>Coniopteris hymenophylloides?</i>	<i>Ctenis sulcicaulis</i>
<i>Thyrsopteris Murrayana</i>	<i>Cycadeospermum Bucklandii?</i>
<i>Ruffordia Göpperti</i>	<i>Ginkgo digitata</i>
<i>Tæniopteris major</i>	<i>Taxites zamioïdes</i>
<i>Tæniopteris vittata</i>	<i>Brachyphyllum mamillare</i>
<i>Sagenopteris paucifolia</i>	<i>Pagiophyllum Williamsonis.</i>
<i>Ptilozamites Leckenbyi</i>	

The flora of the Yorkshire beds has been made the subject of an exhaustive study by Seward,* published in 1900. The

* Cat. Mesoz. Pl. Brit. Mus., Jurassic Fl., I., Yorkshire Coast.

Jurassic forms a narrow band across England from Yorkshire to Dorsetshire, the plant-bearing beds being especially well represented in the vicinity of East Yorkshire. The area has been a favorite collecting ground for English students for nearly or quite a hundred years, with the result of bringing together a large amount of material. Professor Seward has re-studied such of the old type material as is now available, together with that of more recent date, and as a result has been able to give a very full and satisfactory account of this flora. The age of the Yorkshire plant beds has been very definitely fixed as Lower Oölite.

Certain of the species enumerated in the above list are very characteristic of the Yorkshire flora, such for instance as *Cladophlebis denticulata*, *Thyrsopteris Murrayana*, *Ptilozamites Leckenbyi*, *Nilsonia compta*, *Ctenis sulcicaulis*, *Brachyphyllum mamillare*, *Pagiophyllum Williamsonis*, etc. They are, for the most part, forms not likely to be misidentified, and therefore of especial importance in the present connection.

Jurassic plants are known from a number of localities in France, the more important being Mamers, D'Ethrochey, and Châteauroux, in the departments of Sarthe, Côte d'Or, and Indre, respectively. A considerable number of species are common to these French localities and the English beds just considered, while there are in common with the Pacific Coast at least the following:

Teniopteris vittata
Brachyphyllum mamillare
Ginkgo digitata.

A single species (*Sagenopteris Göppertiana*) has been reported by Zigno from the Lower Oölite of Italy.

It is of interest to note that there are two species—*Pterophyllum contiguum* and *P. Nathorsti*—found in the Oregon beds that have previously been reported only from the Kweitschou beds of China. According to Schenk this horizon cannot be older than Lower Jurassic, and, as Fontaine has stated, since the beds contain *Podozamites lanceolatus* and *Nilsonia compta*, it is most likely that the age is Lower Oölite, certainly not younger. *Pterophyllum æquale* has been noted by Schenk in the Tumulu coal fields of China, in beds of Lower Oölitic age.

In the Kaga strata of Japan, which Yokayama refers to the Lower Oölite, we have *Nilsonia nipponensis*, a species represented by several fairly well preserved examples in the Oregon beds.

There are a few species in the Pacific Coast flora that have heretofore been found only in older beds. Thus, *Pterophyllum rajmahalense* was first found in the Rajmahal series of India, which is held to be of Liassic age, but as this does not differ apparently from Heer's *Pterophyllum sensinovianum* from the Jurassic of Siberia, if Heer's conclusion as to the age of the strata containing it is correct, it appears to have persisted into the Lower Oölite. It is one of the most important and abundant forms at a number of the Oregon localities, occurring literally in hundreds of specimens.

Another species regarded by Fontaine as possibly common to the Rajmahal series is *Cladophlebis indica*, though it is represented by a single example and thus is not of great importance, and the variety of *Didymosaurus bindrabundensis* is but a slight variation from the species as known from these beds; it is also represented by a small fragment only.

The following species are believed to be common to the Rhaetic of Sweden: *Nilsonia pterophylloides* and *Pterophyllum æquale*, while portions of a plant have been identified as *Baiera multifida?* from the older Mesozoic (Rhaetic) of Virginia.

From this it appears that a few of the forms had their origin in older beds and persisted into this stage of the Jurassic, but none of those above enumerated is known to continue into higher horizons.

Having considered those species evidently older, it will be of interest to enumerate those continuing above the Jurassic. The following species have been found in Wealden, Neocomian, or higher beds:

Onychiopsis psilotoides
Ruffordia Göpperti
Podozamites lanceolatus
Ginkgo siberica or *digitata*
Sequoia Reichenbachi.

The species first mentioned, which was doubtfully identified in the beds at Big Bar, is a common species of the English Wealden, and forms suggestive of it, though they have often been given other names, occur in the lower Potomac of Virginia, the Cenomanian of Niederschöna, etc. *Ruffordia Göpperti* is likewise found in the Wealden of England. *Podozamites lanceolatus*, as Professor Fontaine has pointed out, is "probably a much abused type of leaf. It probably is not a species, but rather a type of leaf found in many species which lived in Jurassic times. The original is from the Lower Oölite and the form is probably more characteristic of that period than any other." Leaves that have been identified as

belonging to this species have been found well up in the Cretaceous. *Ginkgo siberica* (or *digitata*) has already been discussed, while *Sequoia Reichenbachi* has been mentioned as the only species common to the Lower Cretaceous flora of California and Oregon. It ranges through the Cretaceous, principally in the upper part.

As has been so often stated, the mere presence of a species in a list is not all that is required to make it of value in fixing age. The plant must be abundant in a flora and characteristic of it. It may be a survivor from an older flora, or the first appearance of a form destined to become a dominant factor in a later horizon. It is for this reason that so much stress has been laid on relative abundance of species in the several parts of this paper, but to bring it out still more forcibly the following may be enumerated as filling such requirements:

Dicksonia oregonensis (close to *D. gracilis* Heer), *Polyopodium oregonense*, *Tæniopteris orovillensis*, *Tæniopteris major*, *Tæniopteris vittata*, *Macrotæniopteris californica*, *Sagenopteris Göppertiana*, *Sagenopteris paucifolia*, *Nilsonia orientalis*, *Nilsonia parvula*, *Pterophyllum Nathorsti*, *Pterophyllum contiguum*, *Pterophyllum æquale*, *Pterophyllum rajmahalense*, *Podozamites lanceolatus*, *Ctenis sulcicarulis*, *Ginkgo digitata*, *Ginkgo Huttoni*, *Ginkgo lepida*, *Ginkgo siberica*, *Taxites zamioïdes*, *Brachyphyllum mamillare*. Certain of these exist literally in hundreds in the beds.

AGE OF THE "JURASSIC FLORA OF OREGON."

Following is Professor Fontaine's* final opinion regarding the age of the beds containing the Jurassic flora: "There can be no doubt, in the opinion of the present writer, that the Yorkshire Lower Oölites, the strata of eastern Siberia and of the Amour, made known by Heer, and the Oregon beds are of the same age. The only question is, What is that age? The investigations of the English geologists would seem to have settled the question for the Yorkshire formation. . . . So far as my knowledge goes, no one has questioned the correctness of the conclusions of the English geologists regarding the age of the Yorkshire strata. That being established as Lower Oölitic would certainly indicate a similar age for the Siberian beds and also for those of Oregon."

The facts that have been presented in the preceding pages regarding relative abundance and world distribution prove beyond any reasonable question that the above statement is correct, and it is confidently asserted that the "Jurassic flora of Oregon" is a true Jurassic flora. This age determination

* U. S. Geol. Surv., Mon. 48, 1905, p. 144.

has been held by the writer for some years; in fact all original as well as subsequent collections have tended to prove it, as they have also the distinctness of the Jurassic and Cretaceous floras of the region. I have, however, ventured to submit the question to Prof. A. G. Nathorst of Stockholm, who is perhaps the greatest living authority on the Jurassic floras of the world. His comment is as follows: "As to the 'Jurassic flora' of Douglas County, Oregon, I can but think that the American paleobotanists are *right* in regarding it as a true Jurassic flora. For even if some of the specific determinations are incorrect, this has no influence on the question of age. *If*, therefore, the *same* flora is found in California, it is naturally also of Jurassic age. In this matter I do not think it possible that there can be more than one opinion prevailing among paleobotanists."

A COMPARISON OF THE JURASSIC AND LOWER CRETACEOUS FLORAS OF THE OREGON-CALIFORNIA AREAS.

If these two floras comprised a small number of species each, it could be argued that lack of identical forms might be corrected by more extensive collections, but fortunately both floras are relatively large, the Jurassic embracing 100 and the Lower Cretaceous 59 forms. Most of the localities have been extensively—even exhaustively—exploited, and the numbers are sufficiently large to bring out the interrelationship if such existed. An examination of the two lists, however, shows that there is only a single species (*Sequoia Reichenbachii*) common to the two, and as this species is of very wide vertical range, it would seem to be settled conclusively that there is no real relationship between the Jurassic and Lower Cretaceous floras. This conclusion is made more positive and significant by the fact that in certain localities, as near Riddles, they occur practically in the same section. That they may yet be found commingled in the same beds is a contingency that seems highly improbable, though that the Jurassic flora may sometime be found in the lower part of the Knoxville of the Sacramento Valley, below the Lower Cretaceous flora and fauna, is quite possible.

It is not within the scope of the present paper to enter into an exhaustive discussion of the Lower Cretaceous flora of California and Oregon beyond the general statement of its obvious affinities. To some extent this has already been done by Professor Fontaine.*

EVIDENCE OF THE INVERTEBRATES.

As stated in the opening paragraphs of this paper, it is not the intention to enter into a critical analysis of the inverte-

* U. S. Geol. Surv., Mon. 48, pp. 270-273, 1905.

brate faunas, as the writer does not feel competent to do this, but simply to point out certain salient facts regarding their distribution and interpretation. In the first place, to mention briefly the invertebrate faunas associated with the Lower Cretaceous flora of California and Oregon, it may be observed that there is no conflict between the two lines of evidence. Thus, near Riddles, Oregon, as Mr. Diller says: "Both fauna and flora agree with the stratigraphy in correlating this area of the 'Myrtle' with the Shasta on the western side of the Sacramento Valley." In the area on Redding Creek, California, the shells are regarded as being of lower Horsetown age, which agrees with the Shasta age of the plants, while concerning the numerous localities on the western side of the Sacramento Valley, the plants and shells are again in accord with the stratigraphy as regards the position and identity of the beds. That they are of Lower Cretaceous age no one appears to question.

Turning now to the areas which have supplied the Jurassic flora, we find that at Thompson Creek the only invertebrate evidence is a fragment that may not even be a shell. At Buck Peak the nearest plant horizon is 1200 feet below the point at the summit where *Aucella crassicollis* is found, though only a short distance below a conglomerate containing *Aucella Piochii*. The only plant found in the intervening beds—and this a mere fragment—occurs near Riddles, also in association with shells of *Aucella Piochii*. From the area near Nichols Station, one of the most important of the plant localities, a single example of *Aucella Piochii* is reported, but it was not found in place and it is not known that it even came from the plant beds, though possibly it did. In the beds at Rattlesnake Creek, the only invertebrate evidence reported is that of "two small shells which appear to be young specimens of *Unio*, though they may belong to some marine genus instead"; obviously they are not of importance in fixing the age.

There remain for consideration but three localities at which a fauna has been found in direct and positive association with the Jurassic flora. First, that at Oroville, California, where the invertebrates, while not abundant or very well preserved, are regarded as "more probably" belonging to the Mariposa, with a suggestion of the resemblance to the older Jurassic faunas of the Taylorsville region. Here again fauna, flora and stratigraphy are in agreement. It finally resolves that Big Bar, California, and Elk River, Oregon, are the only localities at which flora and fauna are apparently not in accord. The only named invertebrate found at the first mentioned locality is *Aucella crassicollis*. Concerning this and the

unamed or unidentifiable forms found with it, Doctor Stanton reports as follows: "The fossils from Big Bar, California, area are certainly upper Knoxville, and hence Lower Cretaceous, as shown by the presence of typical specimens of *Aucella crassicollis*. The other invertebrate fossils from the same area are closely associated stratigraphically with the Ancella, but as they are either undescribed or unidentifiable species, they do not throw any additional light on the question of the age of the beds."

On combining the faunas of Big Bar and Elk River there are found seven named species, of which the most important and characteristic is regarded as *Aucella crassicollis*, which Doctor Stanton says "past experience shows to be characteristic of the upper part of the Knoxville formation, and is believed to be confined to the Lower Cretaceous."

The new facts regarding the distribution of the several species of *Aucella* in the section at Elk River, which resulted from Mr. Diller's re-examination of the area during the past summer and which has already been briefly alluded to [p. 37], is of much significance in the present connection. From this evidence it appears that not only is the principal horizon for *Aucella crassicollis* in the basal member of the Knoxville and beneath that of the Jurassic plant beds, but *Aucella Piochii*, supposed to characterize the lower portion of the Knoxville—indeed so occurring in the Elk River section—has been found in the underlying slates of probable Dothan age in association with *Aucella Erringtoni*, which is a typical Mariposa species! The wide vertical range here shown for *Aucella crassicollis* and *A. Piochii* would certainly seem to disqualify them as diagnostic or key fossils.

The interpretation that is to be given the Knoxville fauna as a whole may now be considered, and it requires only a brief review of the literature to show that the invertebrate paleontologists are not in agreement among themselves as to what this shall be. Thus, Doctor Stanton* regards the entire fauna of the Knoxville formation as of Neocomian age. After reviewing the differences of opinion regarding the age of certain Russian beds, he continues: "It is evident, then, that even if it were possible to refer the Knoxville to definite horizons of the Russian *Aucella* beds, its age might still be questioned. One important fact that should be borne in mind is that structurally and faunally, so far as known, the Knoxville is a unit. It is true that there is a gradual change in the fauna from the lower to the upper beds, but there is no distinct break that would justify the reference of one portion to the Jurassic and another to the Cretaceous. There are some elements of the

*U. S. Geol. Surv., Bull. 133, p. 30, 1895.

fauna, such as *Belemnites tehamænsis*, *Hoplites Storrsii*, and some of the Turbinidæ, that resemble European Upper Jurassic types. *Aucella Piochii* belongs to the same general type as *A. mosquensis*, which has usually been referred to the Jurassic, and it is somewhat closely related to the Aucellæ of the Mariposa beds; but Professor Pavlow informs me that Aucellæ very similar to *A. mosquensis* occur in the Neocomian of Russia also. These resemblances are not considered of sufficient importance to counterbalance the evidence of the Cretaceous age of the entire series. Some Jurassic elements are naturally to be expected in the Lower Neocomian, and it is well known that in Europe several species of ammonites pass up from the Jurassic to the lowest Cretaceous beds."

On the other hand, Prof. A. P. Pavlow,* the distinguished Russian geologist and paleontologist, in reviewing the Knoxville species of *Aucella*, takes issue with Doctor Stanton as to the age of the beds. He says: "I share perfectly the opinion of Diller and Stanton that the different parts of the Knoxville series contains each its own *Aucella* fauna, which becomes modified gradually. But I cannot share the opinion that all the Knoxville ought to be referred to the Cretaceous system. At least in that which concerns its lower part characterized by *Aucella Gabbi* (*Aucella Piochii* type) I do not find data sufficient to take this side, since the *Aucella* beds speak more in favor of placing these lower beds in the Portlandian, or perhaps in the Aquilonian (though for this last there are only a few indications). The upper part of the series, which is the larger (2000 feet), offers an *Aucella* fauna of the character of the Lower Cretaceous."

If this view be accepted—and it may be added that it corresponds well with the plant evidence—the Knoxville will be divided into two parts, of which only the upper (2000'±) will be Cretaceous, while the remainder (18,000') of the great section will be relegated to the Jurassic. Professor Pavlow was of course unaware of the fact that the two species of *Aucella* (*A. Piochii* and *A. crassicollis*) overlap in range to the extent just shown at Elk River and elsewhere, and the deciding factor in drawing the Jurassic-Cretaceous line may well be the floras.

Another one to write upon the subject is Dr. Emil Haug† of Paris, who, after enumerating a number of Knoxville forms, which he says "have for a long time been parallelized with the Neocomian of Europe," proceeds as follows: "However, the work of Mr. Stanton contains also several *Hoplites*, described as new species, but which are close neighbors of species of the

* Nuov. Mém. Soc. Impér. Nat. Moscow, vol. xvii, p. 83, 1907.

† Bull. Geol. Soc. France (3), vol. xxvi, p. 226, 1898.

horizon of Stramberg, some among them being even very probably identical with these last. There can be no doubt that the lower part of the "Knoxville beds" corresponds to the upper Portlandian of the Mediterranean region."

This view is even more revolutionary than that of Professor Pavlow, since if the genus *Hoplites*, as represented in the Knoxville, is taken as the gauge of Jurassic age, it will carry with it practically the entire Knoxville fauna, which is found in direct association with one or the other of the five species recognized in this genus.

More recently still Prof. James Perrin Smith, in an article on "Salient Events in the Geologic History of California,"* has expressed his conviction, based on invertebrate as well as stratigraphic evidence, that the line between Jurassic and Cretaceous shall be drawn through the Knoxville and not at its base. He says: "After this mountain-making epoch near the close of the Jurassic, the sea again encroached on the uplifted area, and the Knoxville sediments were laid down on the western border of the Coast Range. The lower Knoxville beds contain a fauna closely related to that of the Mariposa, still with Jurassic types of *Aucella*, and with the same poverty of other animals. But the upper Knoxville beds, while still retaining reminiscences of the Boreal Region in *Aucella* and a few other forms, show a preponderance of life characteristic of more favorable conditions. *Aucellas* of more northerly habit mingle with cephalopods that did not belong in the Boreal Region, and on the nearby land cycads abounded. The line between Jurassic and Cretaceous should be drawn, not at the beginning of the Knoxville but between the lower and upper Knoxville beds; the former belonging to the Portland and Aquilonian, while the latter belong to the Neocomian."

Enough has been presented to show that there is more or less difference of opinion regarding the bearing of the invertebrates of the Knoxville on the question of age.

RELATIONS BETWEEN MYRTLE AND KNOXVILLE.

The Myrtle formation takes its name from what is regarded as its typical exposures along Myrtle Creek, Oregon, in the Roseburg quadrangle. In this general area the maximum thickness of the Myrtle formation is estimated by Mr. Diller to be about 6000 feet. It is separated on paleontological grounds into two portions, the later (upper) of which from its contained invertebrate fauna was correlated with the Horse-town of California, while the earlier (basal) portion was correlated with the Knoxville on the basis of the presence of certain invertebrates but especially *Aucella crassicollis* and

* Science, N. S., vol. xxx, pp. 347, 348, Sept. 10, 1909.

Aucella Piochii. The first mentioned species of *Aucella*, Mr. Diller says,* “is characteristic of the later portion of the *Aucella*-bearing beds immediately adjoining the Horsetown beds. In California these forms are found in the Knoxville beds, which lie below and are older than the Horsetown beds.”

In his latest published words on the relations of the Myrtle formation Mr. Diller continues as follows:† “At the base of the ‘Myrtle formation’ in Oregon there is an important unconformity and overlap. The successively newer, overlying strata of the ‘Myrtle’ in general lap over further and further inland beyond the limit of the older strata of the same series, just as the members of the Shasta series do in California. Furthermore, the lower portion and greater part of the ‘Myrtle formation’ is characterized by a fauna in large measure identical with that of the Knoxville beds, while the top part contains a fauna closely related to that of the Horsetown beds. There is good reason, therefore, for regarding the Shasta series of California and the ‘Myrtle formation’ of Oregon as equivalent.”

To this statement there is but one conclusion possible, namely—that Mr. Diller regards the Myrtle as a whole as the equivalent of the Shasta as a whole, the latter naturally including both Knoxville and Horsetown. As the newer part of the “Myrtle formation” corresponds to the Horsetown, so the earlier part corresponds to the Knoxville. That this earlier portion of the Myrtle really corresponds to the whole of the Knoxville is shown, as at Elk River, Thompson Creek, etc., by the presence in it of a Jurassic flora, and *Aucella Piochii*, which latter is held to characterize the lower Knoxville. On the other hand, from the presence of *Aucella crassicolis* in association with the Jurassic plants in this earlier portion of the Myrtle, the whole of this portion is held by some to be equivalent to the upper part of the Knoxville just below the Horsetown—in other words, that there is nothing in the Myrtle section corresponding to the middle and lower portions of the great Knoxville section. This view would seem to involve some paleontologic, as well as stratigraphic, difficulties or anomalies. First—If the lower portion of the Myrtle corresponds only to the upper part of the Knoxville, then it is hardly correct to say that the Myrtle as a whole is the equivalent of the Shasta as a whole. Second—As already pointed out, Louderbach, on structural and lithologic grounds, regards the lower portion of the Myrtle as referable to the Franciscan of California. To correlate this with the upper part of the Knoxville would certainly do violence to this view. Third—

* Roseburg folio, No. 48, p. 2, 1898.

† Geol. Soc. Am., Bull., vol. xix, p. 396, 1908.

A choice must be made between the evidence afforded by the two species of *Aucella*, since these are regarded as the most important and characteristic of the invertebrates. If *Aucella crassicollis* is selected, then this portion of the Myrtle will be upper Knoxville; if *Aucella Piochii* is followed, this portion may be lower Knoxville. In this connection it is to be remembered that in certain sections of the Myrtle—such, for instance, as that at Elk River—*Aucella crassicollis* occurs above, commingled with, as well as below, the Jurassic plants, while here or in nearby areas *Aucella Piochii* is found also below, with and above the plants.

In view of these conflicting alternatives it seems to the writer that the plants, being thoroughly consistent, afford the better criteria, and on their evidence the earlier portion of the Myrtle is regarded as representing the Jurassic portion of the Knoxville as a whole. If this be true, and it is believed to be, then *Aucella crassicollis* ranged from near the base of the Knoxville (Myrtle) to near its top.

As affording a possible confirmation of the position above assigned the Myrtle on the basis of the plants, a word may be said regarding a comparison of the depositional conditions under which the Myrtle and Knoxville were laid down. It needs but a glance at the geological folios involving the areas covered by the Myrtle formation (Port Orford, Coos Bay and Roseburg quadrangles) to show that during Myrtle time there was a broad bay, or estuary, opening on the west to the Pacific ocean, and extending northeast as far at least as the middle of the Roseburg quadrangle. In the Sacramento valley in Knoxville time there was similarly a bay opening on the south and extending northward between the Coast Range and the Sierra Nevada. In both areas there was a progressive subsidence and decided overlap. In the Myrtle area this extended northeast and was most marked in the Riddles area. In the Sacramento Valley it of course proceeded northward, first the Knoxville, then Horsetown, and finally Chico, resting successively on older rocks. So far as known to the writer there is no *a priori* reason why these two bays may not have been practically synchronous. It will probably never be possible to settle this point stratigraphically, since it is highly improbable that these were at first, if indeed ever, connected on the present land mass.

That the Myrtle formation, as thus far made known, corresponds only to the upper part of the Knoxville, while the still earlier lower portions are concealed beneath the sea, or may yet be found in some unexplored portion of Oregon, is to beg the question.

RELATIONS BETWEEN KNOXVILLE AND MARIPOSA.

The evidence that has been presented regarding the Jurassic flora and its distribution obviously has a bearing on the relations between the Knoxville and the Mariposa. As is well known, Dr. C. A. White held that the Knoxville and Mariposa were contemporaneous, at least in part, a view fully accepted by Doctor Becker, though not generally agreed to by subsequent workers in this field. The two formations have never been found in contact, nor are they likely to be, since one (Mariposa) is found on the western slope of the Sierra Nevada in central California, and the other (Knoxville) on the opposite side of the Sacramento Valley, mainly against the eastern slope of the Coast Range. A strong point of agreement is shown by the abundance of Aucellæ in both, though they are not now admitted to belong to a single species, as Doctor White believed. Doctor Stanton states that "the faunas, though not large, are entirely distinct, and that of the Mariposa includes several forms of ammonites that are characteristic of late Jurassic the world over, while that of the upper part of the Knoxville contains an equally characteristic array of Cretaceous forms." It is not surprising that there should be a marked difference between the fauna of the Mariposa and the *upper part* of the Knoxville, but when the comparison is made with the lower Knoxville, according to Prof. James Perrin Smith, it shows "a fauna closely related to that of the Mariposa, still with Jurassic types of Aucella." As a matter of fact practically the entire Knoxville fauna, with the exception of Aucella, has come from the upper 3,000 feet of beds, that is the beds within this distance of the upper range of *Aucella crassicollis*, which is fixed as the point separating Knoxville from Horsetown. As thus delimited it comprises a sufficiently distinct faunal group (the Paskenta division of Anderson), but its extension to include the underlying 17,000± feet of beds which contain exceedingly few of the Knoxville species other than Aucella, is seemingly without adequate support.

Be this as it may, the relation, if it exists, is through the flora of the Monte de Oro formation near Oroville, which "on geographic and structural as well as lithologic and economic grounds" has been correlated with the Mariposa. The Oroville flora, as already shown, binds it inseparably with the other Jurassic plant-bearing areas in California and Oregon, and as pointed out on p. 49, the finding of five characteristic Oroville plants in the Middle Jurassic of the Cook Inlet region is certainly a strong indication that the Mariposa (Monte de Oro) is not the latest Jurassic.

The intense folding, vulcanism and partial metamorphism of the Mariposa is held to be a strong indication of its greater age as compared with the Knoxville, where there has been comparatively little folding or other alteration; yet even this should apparently be accepted with a measure of caution, since it is by no means clear that the various students who have worked in this field have always given the same limits to the Knoxville. Thus the Dillard area of Oregon seems to be more or less of an exception. In this area the rocks have undergone silicification and veining similar to that of the Mariposa, and on these lithologic as well as other grounds are regarded by Louderbach as identical with the Franciscan of California, which is almost certainly the approximate equivalent of the Mariposa, if not indeed below it. However, from the presence in the rocks of the Dillard area of two species of *Aucella* (*A. Piochii* and *A. crassicollis*), Diller considers them referable to the Myrtle (Knoxville). But since the shells occur in calcareous pebbles in a conglomerate it is possible that they were derived from an earlier *Aucella*-bearing horizon, though it is but fair to state that Diller concludes that they may be concretions rather than true rolled pebbles.

RELATIONS BETWEEN DOTHAN AND MARIPOSA.

In the Oregon areas here considered the Jurassic plant beds are unconformably underlain in many places by rocks to which the name Dothan formation has been given, and these in turn have been tentatively correlated with the Franciscan of California. The Dothan rocks, chiefly sandstones with some slates, which have been more or less silicified and veined, are characterized by the presence of *Aucella Erringtoni*, a species found also in the Mariposa. The only plant thus far noted in the Dothan was found on Catching Creek, about six miles southwest of Riddles, and was identified as probably the upper part of a leaf of *Pterophyllum*, such, for example, as *P. æquale* (Brongn.) Nath. Although this is so fragmentary as to be of little value in fixing the age, it is nevertheless a suggestion that if a flora could be developed in these beds, it would more than likely bring out a similarity to that of the Oroville (Monte de Oro) flora.

THE LINE BETWEEN THE JURASSIC AND THE CRETACEOUS.

It has been held on structural and stratigraphic grounds, that in this area the line between Jurassic and Cretaceous should be drawn at the base of the Knoxville. However, the paleobotanical evidence that has been presented in this paper shows that, notwithstanding the unconformable relations existing between the Knoxville and underlying beds, this is not a

natural line of delimitation. According to the plants the major portion of the great Knoxville section was deposited in Jurassic time, and the line should be drawn through the upper Knoxville at the highest point (about 2000 \pm feet below the summit) at which the Jurassic flora occurs. This point corresponds very nearly with the upper limit of the range of *Aucella Piochii*, which is acknowledged to be of Jurassic type, and, as already shown, extends down into the horizon of the Mariposa. It is true that this places the line at a point where there is no evidence of a break in the sedimentation, but it is a very decided paleontological break, and is exactly similar in character to that relied upon to separate Knoxville from Horsetown in the same section. Although the Knoxville is of such great thickness (20,000 feet), it is not probable that it required a very long time, geologically speaking, for its deposition.

SUMMARY.

1. The Lower Mesozoic strata of Oregon and California have afforded two floras, one of which is Cretaceous and the other Jurassic. These two floras, although sometimes occurring practically in the same section, have not been found commingling.

2. The Cretaceous flora ranges from the extreme upper part of the Knoxville formation through the Horsetown formation. It embraces about 60 species of plants and is regarded as being of Lower Cretaceous (Neocomian) age. It finds its closest affinity with the Kootenai of the Interior region, the Trinity of Texas, and the lower Potomac of the Atlantic Coast.

3. Associated with the Lower Cretaceous flora is an invertebrate fauna regarded as being of Neocomian age, the plants and invertebrates thus being in agreement.

4. The Jurassic flora, which has been called the "Jurassic flora of Oregon," ranges from beds which have been referred to the Mariposa formation, through the major portion of the Knoxville formation. It includes 100 species and finds its close affinity with the Lower Oölite floras of known position in other parts of the world. It is beyond question a true Jurassic flora.

5. Associated with the Jurassic flora is a meager, often poorly preserved, invertebrate fauna of only seven species, including the two supposedly characteristic species of *Aucella* (*A. crassicollis* and *A. Piochii*). This fauna, with the exception of *Aucella Piochii*, is the same as that found in association with the Lower Cretaceous flora, and it is on account of this association that the Jurassic plant beds have been referred by some invertebrate paleontologists to the Cretaceous.

6. The age of the beds containing the "Jurassic flora of Oregon" thus hinges on the relative strength of the evidence afforded by the flora as compared with that of the associated fauna. It has been shown in this paper that of a total of 100 species of plants, 47 species are known also from known Jurassic of other, often widely separated, parts of the world. Only one of these 100 species has been found in the Lower Cretaceous beds of the region. The total Knoxville fauna comprises 77 forms of invertebrates, only 7 named species of which have been found associated with the Jurassic plants. Of these 7 species of invertebrates, only a single species has been found outside the limits of the Oregon-California area, and it has been further shown that the invertebrate paleontologists are not in accord among themselves as to the interpretation to be given the age determination of the fauna. The conclusion is reached that the plants, being thoroughly consistent, afford the better criteria, and the beds are regarded as unquestionably of Jurassic age.

7. From the paleobotanical evidence which has been presented it follows that in this portion of the Pacific Coast region the line between the Jurassic and Cretaceous is to be drawn through the upper part of the Knoxville formation, and not at its base. This line is fixed by the upper limit of the Jurassic flora.