ART. XXI.—*The Flora of the Great Falls Coal Field, Montana;* by J. S. NEWBERRY. (With Plate XIV.)

IN the School of Mines Quarterly for 1887, I published a brief description of the coal basin which underlies the country about the Great Falls of the Missouri in Montana, and I am now able to add some facts of more than usual geological interest to those before known in regard to this coal field.

The Great Falls coal basin lies on the north slope of the Belt and Highwood Mountains; the strata all dipping toward the north. These mountains are subordinate folds of the Rocky Mountain system and are each composed of a granitic Archæan nucleus, locally overlain by a great thickness of Cambrian rocks which are best seen about Sulphur Springs. This formation must be at least 10,000 feet in thickness, and it underlies the surface from a point fifteen miles north of Sulphur Springs to near Townsend on the south. Splendid exposures of the same group are seen in Prickly Pear Cañon on the road from Helena to Great Falls. They consist of numerous alternations of thin bands of fine grained sandstone and argillaceous shale, generally metamorphosed into quartzite and slate. Near Sulphur Springs is an outcrop of limestone converted into marble. The prevailing color of the rocks of this group is gray at the surface, darker below. No distinct fossils were found in the slate though particles of carbonaceous matter abound everywhere. A shaly sandstone which apparently overlies all the series described is largely made up of Primordial trilobites.

On the summit and the north slope of the Belt mountains the Archæan granite nucleus is overlain by Potsdam sandstone full of *Scolithus* and casts of sea-weeds. There are here numerous large dykes of rhyolite which cut the granite and sandstone.

Succeeding the Potsdam sandstone is a great mass of Paleozoic limestone, sometimes blue, but mainly of a cream color, which has been cut by the streams draining northward into most picturesque cañons and valleys of which the sides are set with buttes imitating castles, fortresses, churches, etc., combining to form scenery equally attractive to the tourist and geologist. In the limestones are found both Silurian and Carboniferous fossils. North of the mountains the limestones are unconformably overlain by a series of sandstones, shales and fresh water limestones which include one large and several smaller seams of coal. These dip toward the north and are soon covered with a great and continuous sheet of glacial drift

that for the most part conceals the coal-bearing rocks and obscures the extent and outlines of the basin. The Missouri River has cut through the drift and exposed for many miles a series of pinkish sandstones which form the falls.

The age of this Great Falls coal basin was for a long time in doubt. Dr. Hayden first visited the locality, but found no fossils, and his experience was repeated by Dr. C. A. White and myself; although the exposures are ample on Sand Coulée and Belt Creek where the main coal has been extensively mined for years. Casts of stems and branches of trees are abundant in the sandstones, and the miners reported the occurrence of impressions of ferns in the shales over the coal, but after the most careful and thorough search nothing of the kind was found. The coal itself is of fairly good quality, the thicker seam consisting of several benches, of which the lower one, two and a half feet in thickness, makes a very good coke, and the whole will furnish an excellent steam coal for locomotives or stationary engines, will serve well as a household fuel, and is destined to be of great economic importance to the people who shall congregate in this prairie region.

Subsequent to my return from Great Falls, Mr. J. J. Hill, the president of the Chicago, St. Paul and Manitoba Railroad, in whose interests I made an examination of the coal basin, sent to me a slab of sandstone covered with Unios. This, as was to be expected, proved the fresh water character of the deposits, but the impressions were too ill defined to permit accurate, specific determination, and therefore threw no light upon their age. When the railroad along the north side of the Missouri, constructed with such unexampled rapidity by Mr. Hill, reached Great Falls, a cutting near the town passed through shales in which were numerous lenticular nodules of iron ore. Each of these contained a fern frond, a cycad leaf or a twig of a conifer. Some of them were collected by Mr. R. S. Williams of Great Falls, by whom they were sent to Professor Dana at New Haven. He submitted them to me for examination and I found that without exception they were species that had been described by Sir William Dawson from his Kootanie group [Lower Cretaceous] of Canada, or by Professor Heer from the Kome group of Greenland. These included *Sequoia Smittiana* Heer; *S. gracilis* Heer; *Zamites acutipennis* Heer; *Z. Montana* Dawson, etc. More recently Mr. Williams has sent to me a larger collection of fossil plants consisting mostly of ferns, from a different stratum in the Great Falls group. On opening the box I thought I identified a number of these with species described by Professor W. M. Fontaine from the Potomac group in Maryland and Virginia. But that there might be no mistake on a subject of such geo-

logical importance, I forwarded specimens of each species to Professor Fontaine asking that he would compare them with his Potomac fossils and decide upon their identity or difference. His letter in reply is so interesting that I herewith append a copy of it.

UNIVERSITY OF VIRGINIA, Oct. 15, 1890.

DR. J. S. NEWBERRY—

Dear Sir:—I have examined the plant fossils that you obtained from Great Falls, Montana, and sent to me for comparison with the fossils of the Potomac formation.

I find them to be as follows:

1. *Thyrsopteris rarinervis* F.
2. A plant near to *Podozamites distantinervis* F.
3. *Cladophlebis parva* F.
4. *Sequoia Reichenbachi* H.
5. *Pecopteris Browniana* F.
6. *Aspidium Fredericksburgense* F.
7. *Sphenolepidium Virginicum* F.
8. A plant allied to *Thyrsopteris brevifolia* F.
9. A plant near to *Cladophlebis distans* F.
10. *Thyrsopteris insignis* F.
11. *Carpolithus Virginiensis* F.
12. A plant near to *Cycadiospermum rotundatum* F.
13. *Pecopteris microdonta* F.
14. *Thyrsopteris brevipennis* F.
15. A plant near *Cladophlebis constricta* F.

The above named identities and resemblances are found on comparing the plants sent, with fossils of the Potomac formation described in Monograph XV of the publications of the U. S. Geological Survey.

The forms that I enumerate as "near" to named Potomac fossils, I hesitate to identify with them on account of the small amount or poor preservation of the material in hand available for comparison.

It should be stated that No. 9, which in foliage shows a facies like *Cladophlebis distans* has a fructification like that of some Aspidia and if identical with the Potomac plant this fact would remove it from the genus *Cladophlebis*.

Yours truly, W. M. FONTAINE.

The above identifications prove conclusively the general identity of the geological horizons of the Potomac group, the Great Falls group, the Kootanie group of Canada and the Kome group of Greenland, and confirm the view advocated by Professor Fontaine and myself that the Potomac group is Lower Cretaceous and not Jurassic.

Professor L. F. Ward in his review of the Potomac flora, (this Journal,) leaves the question of the age of the Potomac

group in doubt, but his opinion seems rather to incline to a Jurassic date. Professor O. C. Marsh considers the Potomac group Upper Jurassic, because he has obtained from it a number of reptilian remains of decided Jurassic affinities, but he tells me there are no species which he can identify with those of the Jurassic system, and we have been hitherto with little or no information about the vertebrate fauna of the Lower Cretaceous rocks of North America; so we need not be surprised to find it exhibiting marked Jurassic affinities. As pointed out by Professor Marsh the low grade and Mesozoic character of the mammalian fauna of the upper member of the Cretaceous system, the Laramie, would without other evidence lead to the conclusion that it was much older than it really is.

Professor Fontaine makes the Potomac group about the geological equivalent of the Wealden of Europe, but for the reason that it contains eighty known species of angiosperms out of a total number of three hundred and seventy-five, I am inclined to regard it as newer rather than older than the Wealden. The fossil plants of the Jurassic have been collected in large numbers and in many countries, but nowhere has a dicotyledonous plant been found in that formation, nor has an angiosperm been discovered in the Wealden of England or on the continent of Europe. The plants of the Wealden have been fully described by Dunker, Schenk and others, but all the species known are cycads, conifers or ferns. I recently had an opportunity, through the kindness of M. Dollo, of examining the plants found with the Iguanodons at Bernissart, and among them all there was not a trace of an angiosperm. This does not absolutely prove that the Potomac group is of more modern date than the Wealden, because the progress of plant life has been, as we know, somewhat unlike in different parts of the world, and the angiosperms may have begun their existence on the North American continent sooner than elsewhere, but it seems hardly possible that eighty or more species of arborescent angiosperms should have flourished on this continent before they had put in an appearance in the vegetation of the Old World. We may at least say that Professor Fontaine is fully justified in his conclusion that the Potomac is not older than the Wealden.

The relations of the Potomac to the Amboy flora are of special interest; the two formations are consecutive members of the Cretaceous system and the "variegated marls" of Fontaine or the "alternate sands and clays" of Uhler may be regarded as the southern extension of the Amboy clay group. Yet a long interval of time must have separated the epochs of the two formations, since the floras are so entirely different. Only a beginning has yet been made in the exploration of the

flora of the Amboy clays and yet we have obtained from them more than one hundred and fifty species. Probably when as much time shall have been given to the collection of plants from the Amboy clays as has been devoted to the collection of Potomac plants, the number of species will be as large, and better comparisons can then be made between the two floras, but it is evident that they are widely different. From the Amboy clays we have now taken about one hundred and fifty species of plants; of these more than one hundred, or a large majority, are angiosperms, whereas of three hundred and seventy-five species taken from the Potomac group only eighty are dicotyledonous. Besides this, it is doubtful whether any species yet found is common to the two formations.

The flora of the Amboy clays is most nearly allied to that of the Dakota group in the far west and the Atane group of Greenland, while one or two species are apparently identical with some taken from the Kome or Lower Cretaceous group. We may therefore fix the horizon of the Amboy clays with absolute certainty at Middle Cretaceous. With equal certainty we can assert that the Potomac, the Kootanie and the Kome groups represent perhaps distinct but closely related epochs of the Neocomian or Lower Cretaceous of the Old World.

As these determinations have for the most part been made from fossil plants, we must wait for the discovery of plants in the Cretaceous beds of Queen Charlotte's Island and the Shasta group of California before we can accurately correlate them with the Lower Cretaceous strata of Central North America. For this region the history of the Cretaceous age can already be written with a good degree of fullness and its more important incidents are as follows.

During the first half of the Cretaceous age the greater part of the continent of North America was out of water and therefore suffering erosion and receiving no deposition. During this interval a broad, circumscribed and almost inland sea occupied the place of the Gulf of Mexico, and the adjoining shores of South America, Mexico and Texas. In this sea marine deposits were forming which are the equivalents of the Lower Greensand or Neocomian. In time they attained in Chihuahua a thickness of not less than 4,000 feet and represent at least one-half of the Cretaceous age. During this time the area of the plains was out of water and toward the north bore on its surface lakes and marshes where the Great Falls and Kootanie groups were deposited. Beds of coal of considerable thickness and now of great importance were formed in these marshes. Up to the present time we have gathered thirty or forty species of the plants which from their debris formed the

peat that has now become coal. So far we have found among the remains of these plants not a single dicotyledonous leaf, but judging from the flora of the Potomac group and that of the Kome beds which have so many species in common with the Kootanie and Great Falls deposits, we may expect in the future to find a few angiosperms, the remains of the pioneers and advanced guard of the great army which here mingled with the cycads and conifers, and soon, through some inscrutable influence, mostly superseded them.

After the Kootanie epoch the eastern half of the North American continent was depressed and the sea gradually rose upon it, moving inwards, spreading a sheet of sea beach as far as it extended [the Dakota sandstone] and ultimately covering with 2,000 feet or more of marine sediments [the Colorado group] all the great depressed area lying between the Cumberland and Canadian highlands and the Wasatch.

The third great period of the Cretaceous age was the gradual emergence of this portion of the continent from the sea and the formation of the Laramie group with its great series of coal beds, its abundant land flora and its horned Dinosaurs. This closes the history of the Cretaceous age in North America.

The record which we have of the plant life of the continent during this long and varied interval is of special interest because we can reproduce the topography of the continent and in imagination clothe all its highlands with the successive phases of vegetation which we have disinterred in such abundance from the lacustrine and estuary deposits of its different epochs. The first Cretaceous forests were composed chiefly of cycads and conifers, showing great variety, because this was a part of their golden age. With these were numerous ferns more nearly allied to those of the present day than those of the Trias or Jura, several of the genera, as *Gleichenia*, *Asplenium* and *Aspidium*, continuing to the present day. This was the Kootanie epoch or that of the Great Falls coal basin, perhaps synchronous with, but more likely a little anterior to the Potomac epoch, in as much as we have found no angiosperms in the Kootanie flora.

Then came the Potomac group with a wonderful variety of conifers and cycads and with about one-fourth of its species angiosperms. Later still the epoch of the Amboy clays and Dakota sandstones when two-thirds to three-fourths of the species were angiosperms, but no palms had yet appeared.

Finally came the Laramie epoch, when the cycads and conifers constituted not more than one-tenth of the flora and the botanical aspects of the vegetation were essentially those of today, only palms were numerous as far north as the Canadian line, and the temperature was a little higher than at present.

List of Potomac species occurring elsewhere.

Equisetum Lyelli Mant., Wealden, Germany.
Pecopteris socialis?* Heer, Atane, Greenland.
Pecopteris Browniana Dunk., Wealden, Germany.
Sphenopteris Mantelli Brongn., Wealden, Germany.
Aspidium Oerstedi?* Heer, Atane, Greenland.
Aspidium Dunkeri Schimp., Wealden, Germany.
Gleichenia Nordenskioldi Heer, Kome, Greenland.
Dioonites Buchianus Schimp., Wealden, Germany.
Sequoia Reichenbachi Heer, Cretaceous [general].
Sequoia subulata Heer, Kome, Greenland.
Sequoia ambigua Heer, Kome, Greenland.
Sequoia rigida Heer, Kome, Greenland.
Sphenolepidium Kurrianum Heer, Wealden, Germany.
Sphenolepidium Sternbergianum Heer, Wealden, Germany.

Potomac Plants in Great Falls Group.

Sphenolepidium Virginicum F.
Carpolithus Virginiensis F.
Thyrsopteris rarinervis F.
Aspidium Fredericksburgense F.
Thyrsopteris insignis F.
Thyrsopteris brevipennis F.
Sequoia Reichenbachi Heer.
Pecopteris Browniana Dunk.
Cladophlebis distans F.
Pecopteris microdonta F.
Thyrsopteris brevifolia F.
Cladophlebis parva F.
Cladophlebis constricta F.

Great Falls Plants in Kootanie Group, Canada.

Sequoia Smittiana Heer.
Zamites Montana Dawson.
Zamites acutipennis, Heer.

Great Falls Plants in Kome Group, Greenland.

Sequoia Smittiana Heer.
Oleandra arctica Heer.
Zamites acutipennis Heer.
Zamites borealis Heer.
Sequoia Reichenbachi Heer.
Sequoia gracilis Heer.

* The materials on which Prof. Fontaine based the identification of these species are insufficient for satisfactory comparison; and while it is not impossible that the life of one or more species may have stretched over all the interval between the beginning and end of the Cretaceous age, stronger evidence of this fact than any we yet have must be furnished before we can consider it as established.

Since the above notes were written I have received, through the kindness of Mr. Williams, another collection of fossil plants from Great Falls. With several species before mentioned, it includes some which seem to be new, and of which brief descriptions are given below.

Chiropteris Williamsii, n. sp.

Pl. XIV, fig. 10, 11.

Fronds orbicular, oblong or lobed, two to four inches in diameter; petiolate, margins entire, nervation radiate, dichotomously forked and somewhat reticulated.

Of this remarkable fern I have many specimens, but none quite complete. At first sight they suggest the fronds of *Doleropteris* of the Coal Measures, but in that genus the nerves are fasciculate and divide by separation of the bundles and not by forking, and they never anastomose. In some specimens of the plant before us the nerves are buried in the parenchyma, showing that the consistence was thick and leathery; in others, perhaps more macerated, the nerves appear very distinct and rather coarse. A single small specimen shows a distinct stipe at the base.

This plant I have included in the genus *Chiropteris* with much hesitation, for it differs from the type species in having an orbicular or elliptical frond which is generally simple, though sometimes lobed, while in *C. Kurriana*, the type, the frond is flabellate and deeply lobed, almost palmate, thus approaching *Sagenopteris*, but in that genus the frond is distinctly palmate, the divisions being lanceolate, though springing from a common base. The nervation too of *Sagenopteris* is much more closely reticulated. In these respects the two genera would seem to be distinct. The nervation of our plant is essentially that of *Chiropteris*, the nerve branches anastomosing only at rare intervals, the meshes being many times longer than broad.

In the original notice of *Chiropteris*, by Dr. H. G. Bronn (Jahrbuch für Mineralogie, 1858), the fronds are represented as radiating in a whorl from a common base, and the nerves are neither figured nor described as inosculating, but Schimper in his Palæontologie Vegetale, (Vol. I, p. 643, Pl. XLIII) describes and figures the frond of *C. Kurriana*, as flabellate, digitately-incised, the nerves frequently forked and anastomosing to form narrow meshes. This description corresponds closely with some specimens of our plant, and while it is specifically distinct I do not feel justified, without more material, in separating it from the genus *Chiropteris*. Possibly facts will hereafter come to light which will require this to be set apart as the type of a new genus.

The horizon of the type specimen of *Chiropteris* is the upper Trias or Rhaetic. In the Jurassic rocks the genus has not been recognized, but its place has been taken by the allied *Sagenopteris*. Prof. Fontaine, in Monograph XV, U. S. Geological Survey, describes several species of *Sagenopteris*, but in these the form was very different and the nervation much more closely reticulated.

Formation and locality, Kootanie group, Great Falls, Montana. Collected by Mr. R. S. Williams and dedicated to him.

Chiropteris spatulata, n. sp.

Pl. XIV, figs. 1, 2.

Pinnules 1½–2 inches long, spatulate in outline, midrib strong, lateral nerves well defined, coarsely reticulated.

The plants to which I have given the above name have precisely the nervation of the large rounded or lobate leaves, figured on the same plate and named *Chiropteris Williamsii;* and I have therefore provisionally placed them together. The form of both species is so different from that of the typical *Chiropteris*, that I have included them in that genus with much hesitation. The nervation is however so peculiar and so much alike in these two ferns, that while waiting for more material that shall permit a new genus to be defined upon them, I have concluded to group them together and under the old name.

Formation and locality, Kootanie group, Great Falls, Montana. Collected by Mr. R. S. Williams.

Zamites apertus, n. sp.

Pl. XIV, fig. 4, 5.

Fronds several inches in length by about one inch in width, pinnules leaving the rachis at nearly a right angle, linear, obtuse, somewhat widely separated; nerves invisible, sunk in the parenchyma.

This is a small species having the general aspect of *Zamites arctica*, Gœpp (Flora Arctica, vol. iii, p. 67, Pl. XV, figs. 1, 2), but is much more open in structure, the pinnules being separated by spaces sometimes as wide as themselves.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Baiera brevifolia, n. sp.

Pl. XIV, fig. 3.

Leaves flabellate, long petioled, one inch in width by one-half to three-quarters of an inch in length, deeply lobed; lobes truncate, sometimes undulate and slightly contracted at the summit.

This species has much the aspect of *B. pluripartita*, Schimper (Palæontologie vegetale, vol. i, p. 423, Pl. XXXI, fig. 12,) (Schenk, Flora Nordwestdeutschen Wealdenformation, p. 10, Pl. III, figs. 1–8), but is much smaller. Possibly, however, it is merely a depauperate form or smaller variety of that species. Further material will be required for deciding this question. However, the specimens which we have are not half the size of those figured by Schimper, Schenk, Dunker and Brongniart. The specimens of *B. pluripartita* (*Cyclopteris digitata*, Dunker) are all from the Wealden of different localities in Europe.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Cladophlebis angustifolia, n. sp.

Pl. XIV, fig. 8.

Pinnæ several inches in length by one inch in maximum width; pinnules ten to twelve mm. in length by three mm. in width at base, distinctly separated, attached to the entire base, curved or falcate in form, subacute or obtuse at summit; nervation open, strong.

This plant resembles *C. falcata* Fontaine (Monog. XV, p. 72, Pl. V, figs. 1–6), but the pinnules are smaller, narrower and less acute.

Formation and locality, Kootanie group, Great Falls of the Missouri, Montana.

Collected by R. S. Williams.

Sequoia acutifolia, n. sp.

Pl. XIV, fig. 7, 7a.

Leaves crowded, from one-quarter to one-half an inch in length, wedge-shaped, rounded or abruptly contracted at the base, summit long pointed, very acute.

Only one twig of this tree is contained in the collection, but its leaves are so peculiar that I feel quite justified in considering it a new species. Its most striking feature is the wedge-shaped outline of the leaves which are broadest near the base and are drawn out in a long and very acute point. In the Cretaceous rocks of Vancouver's Island occur twigs of a species of *Sequoia* to which I have given the name of *Sequoia cuneata* because they are so decidedly wedge-shaped, but in that species the leaves are spatulate, broadest near the rounded summit and terminate below in a wedge-shaped base. In the species now under consideration the leaves have quite an opposite form; being broadest at or near the base and terminating above in a long drawn acute point.

Among all the living and fossil species of *Sequoia* there is no other known to me that has leaves of this peculiar form.

Formation and locality, Kootanie group, Great Falls, Montana.

Collected by Mr. R. S. Williams.

Podozamites nervosa, n. sp.

Pl. XIV, fig. 6.

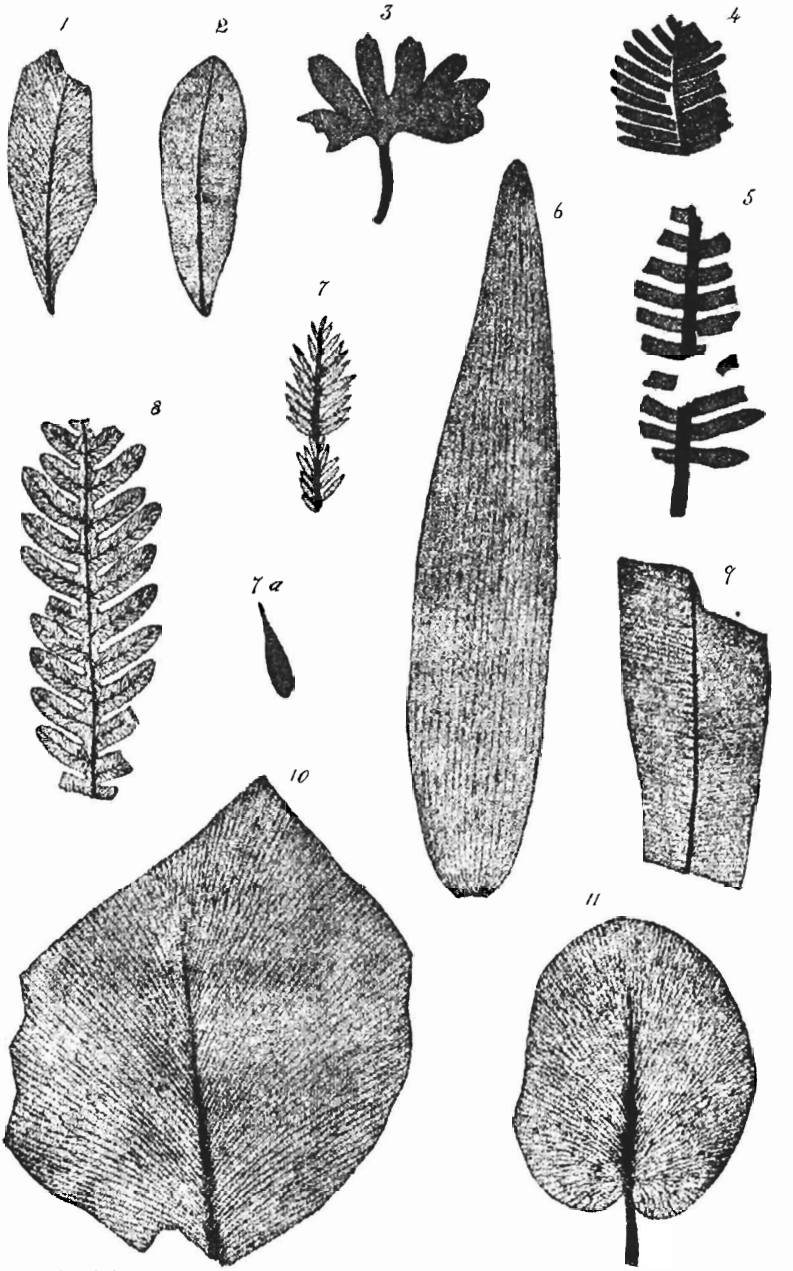
Leaflets, four inches in length, lanceolate, broadest toward the base, subacute at the summit; nerves parallel, distant, strong.

This is a leaflet of a frond of a strong-growing species of zamites similar to Heer's *B. marginatus*, but differing from that in its much more remote parallel and distinct nerves. Only one specimen has been as yet received from Mr. Williams, and more will be needed before we can define the range of variation in the pinnules.

Oleandra arctica Heer.

Pl. XIV, fig. 9.

The specimen figured agrees in all essential characters with Heer's plant from the Kome group, Greenland, described in vol. iii of his Flora Arctica. A much larger and finer specimen has been sent to me by Mr. Williams, but the figure now given will permit the identification of the plant wherever found. This is interesting as another connecting link between the flora of the Great Falls group, and that of the Lower Cretaceous of Greenland.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