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Desert Grass Savanna.....	2,300,000			
+1/10 Desert Shrub and Desert Grass.....		1,060,000	3,360,000	13
Mountain Grassland.....	790,000			
+Temperate Rain Forest....		550,000	1,340,000	5
Tundra (1/2 of total).....	2,200,000		2,200,000	8
Totals.....	14,770,000	11,330,000	26,100,000	100

These considerations may be summarized as follows:

Type	As Mapped	%	Actual Occupancy	%	Potential	%
Forest.....	21,970,000	42	20,710,000	40	30,250,000	58
Grassland.....	12,570,000	24	17,090,000	33	23,900,000	46
Desert.....	17,430,000	34	14,170,000	27		
	51,970,000	100	51,970,000	100		

About half (57%) of the land surface of the earth is covered with pedalfer soils. In these soils, the moisture is in excess of the demands of the vegetation and water passes down through the soils leaching them and moistening the subsoils down to the water table. About half (43%) of the land surface of the earth is covered with pedocal soils. In these soils, moisture is held in a surface layer and usually completely absorbed by the growing vegetation and none passes down into the sub-soils which remain dry.

As a rule, forests are found on pedalfer soils and can only succeed on the very best of the pedocals. Grasslands are confined to largely to pedocals and when growing on pedalfers are not strictly climax but except for the aid of clearing, cutting, or burning of the forest growth would be replaced by trees or brush.

If one excludes alluvial bottom lands, the most productive soils are built up under grasslands on the moister side of the pedocals.

## A NEW PINE FROM THE CRETACEOUS OF MINNESOTA AND ITS PALEOECOLOGICAL SIGNIFICANCE

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Fossil records of the Pinaceae are much less numerous in the northern hemisphere than those of the Taxodiaceae. Their relative scarcity seems not so much an indication of sparse occurrence in the forests of the past as a result of factors limiting their entrance into the sediments of Cretaceous and Tertiary basins. With some notable exceptions, such genera as *Pinus*, *Abies*, and *Pseudotsuga* have their greatest abundance on upland slopes at the present time. By contrast *Sequoia* and *Taxodium* are largely confined to lowlands, and *Metasequoia*, although a highland tree, is restricted to valleys. Not only are these lowland and valley trees in a more favorable situation to enter the sedimentary record, but their habit of shedding shoots with numerous attached leaves provides a more conspicuous foliage sample than the single needles of *Abies* and *Pseudotsuga* and the fascicles of *Pinus*. *Metasequoia* and *Taxodium* drop their foliage annually and the crop is a large one because of the great size of the trees; in the Tertiary record of North America, in which these two genera are more abundant than any other conifers, leafy shoots are the most numerous units of the plant represented. If *Pinus*, *Abies*, and *Pseudotsuga* lived on slopes remote from sites of deposition in the past, as most trees of these

genera live today, we should expect to find their readily disseminated seeds more common as fossils than their leaves and cones; this is actually the case in most of the Tertiary floras in which they are found.<sup>1</sup> So it seems probable that the abundance of certain of the Taxodiaceae as fossils is to a large extent due to factors which favored their entrance into the sedimentary record, and does not indicate that they were more numerous or widespread than the Pinaceae during Tertiary time. Authentic records of the genus *Pinus* in the preceding Cretaceous period are comparatively few, and have rarely received more than superficial attention. This study of well-preserved cones from the Dakota sandstone of Minnesota is the first to establish the presence there of a pine closely related to the living red pine, *P. resinosa* Aiton, the Minnesota state tree. During intervening scores of millions of years there must have existed trees representing on the one hand the descendants of this Cretaceous pine, and on the other the more immediate ancestors of the red pine; but there is

<sup>1</sup> Pine pollen is reported by Wodehouse from the Eocene Green River formation of Colorado and Utah (1933: 487-488), and by Jane Gray, graduate student at the University of California, from the Eocene Claiborne formation of Alabama; there is no other record of *Pinus* from these deposits.

no known Cenozoic record of a fossil pine of the *P. resinosa* type.<sup>2</sup> This gap in the history of the red pine is one of the many examples of the incompleteness of the fossil record, and serves to emphasize the limitations of our knowledge of past vegetation.

A total of 86 species of *Pinus* have been recognized in North America, in deposits ranging in age from Jurassic to Pleistocene. There is much question regarding the generic status of foliage specimens referred to *P. nordenskiöldi* Heer from Jurassic deposits in Oregon (Fontaine 1905: 131, Pl. 35, Figs. 10-17) and in California (Fontaine 1900: 362, Pl. 45, Fig. 3). Heer's original specimens of *P. nordenskiöldi*, as figured from Spitzbergen in *Flora Fossilis Arctica* (1877: 45, Pl. 9, Figs. 1-6), represent dissociated fragments which may represent pine needles, but his discussion and illustrations are not convincing. In view of the recently reported occurrence of *Sequoia* from the Jurassic of Manchuria (Endo 1951: 228-230, Figs. 1, 2), there would seem to be no reason why *Pinus* may not also have lived during this period. Seventeen species have previously been recorded from Cretaceous deposits, including several represented by fragmentary foliage of uncertain status; there are 50 species, not all of which are in good standing, from the Tertiary, and 19 species from the Pleistocene. Wood, foliage, cones, seeds, and pollen are preserved as fossils, with foliage and seeds most commonly encountered. Many of the Pleistocene species are represented by most or all of these organs or groups of organs, and it has been possible to refer them to species now living. Some of the older remains also show resemblances to corresponding structures of living species, but in no case are they sufficiently complete to establish specific identity.

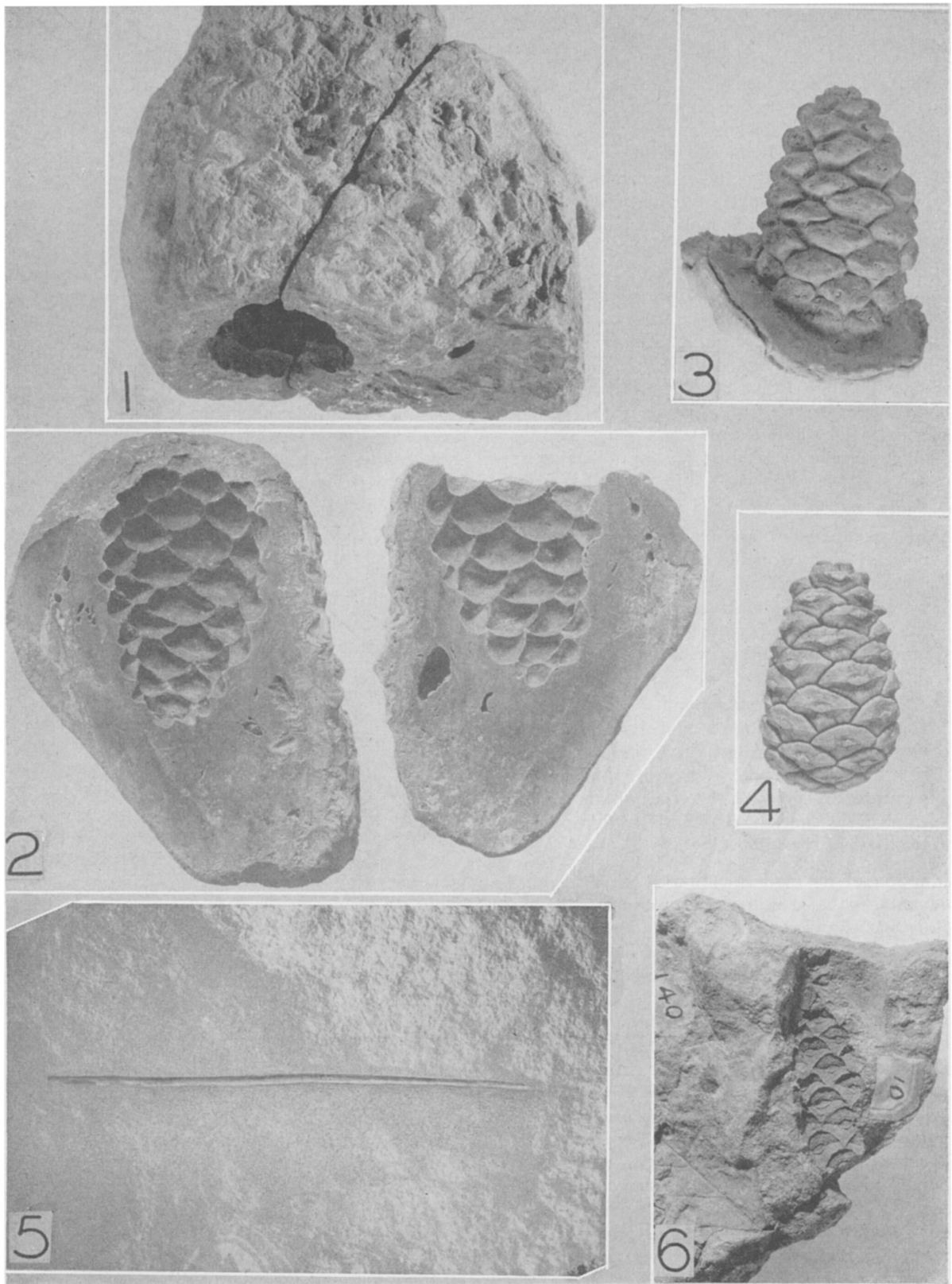
I am grateful to Emeritus Professor C. O. Rosendahl for bringing a nearly complete fossil cone to my attention during a recent visit to the University of Minnesota, and for turning it over to me for study. Dr. Rosendahl has always shown a keen interest in fossil plants, and has made large collections from the shales and sandstones of the Dakota group in south-central Minnesota. This specimen was given to him by C. W. Blue a number of years ago, and was found at the pits of the A. C. Ochs Brick and Tile Company near Springfield. It represents the external mold of an ovuliferous cone whose shape has not been altered by compression, and is complete except for the base which has been broken off from the piece of rock in which it is embedded. This rock mass is ir-

regularly lenticulate in shape, with dimensions 8 x 7 x 5 cm. (see Figure 1). It appears to represent a sideritic concretion in a sandy mudstone, a center where iron carbonate has been concentrated. One end has been broken exposing the mold of the cone within; if any of the material of the cone was ever preserved, it was no longer in the mold when the concretion, sawed in the longitudinal plane of the cone and slightly off-center, was turned over to me (see Figure 2). The suggestion may be made that this concretion represents an aggregate somewhat similar to the coal balls of the Carboniferous, in which the pine cone served as a nucleus. Like coal balls, it shows evidence of other plant fragments in its interior, but these also occur as molds from which the plant material has disappeared, rather than as petrified structures. So far as known this is the only cone discovered at Ochs Clay Pit, although on one side of the concretion there are numerous, apparently dissociated, scales which may represent the remains of a second cone. Impressions of angiosperm leaves are numerous in the layers of hard, calcareous sandstone interbedded with the clay, and have been studied in a preliminary way by Rosendahl and his students.

During the study of this cone, I have had occasion to survey previous records of *Pinus* from the Cretaceous of Minnesota and adjacent states, and have found that Lesquereux reported the presence of this genus near New Ulm, some 25 miles east of Springfield. He described, without illustration, a leaf assigned to *Pinus* species (1895: 10), and listed *P. quenstedti* Heer<sup>3</sup> from the same or an adjacent locality without either description or illustration (p. 22). An inquiry regarding these specimens to Dr. John W. Hall of the Department of Botany at the University of Minnesota has been most productive; he has sent me Lesquereux's original specimen of *P. quenstedti*, No. 5384, representing the impression of a leaf (see Figure 5), and a second specimen not mentioned by Lesquereux on which there are impressions and a compression of three cones apparently identical

<sup>3</sup> Lesquereux also described leaves and a cone of *P. quenstedti* from the Cretaceous of Kansas, but this material is wholly unlike the Minnesota pine for the leaves are in fives, and the cone is elongate and asymmetrical (1883: 33, Pl. 1, Figs. 3, 4). Resemblance of his specimens to "the living Mexican Pines" is noted by Lesquereux; formerly known as *P. montezumae* Lambert, this pine is now considered by Martinez (1948: 260-266) to represent the Montezuma Complex (Grupo Montezumae) including a number of species of which *P. michoacana cornuta* Martinez has cones most similar to the Kansas fossil (see Martinez's Figure 213, also Shaw, 1914, Pl. 25, Fig. 222). It will be a matter of great interest if the ancestry of the Montezuma pines can be traced back to the Cretaceous period.

<sup>2</sup> Foliage resembling that of *P. resinosa* is figured by MacGinitie (1953, pl. 18, fig. 1) as *Pinus* leaves, but there are no accompanying cones.



FIGS. 1-6. Illustrations of *Pinus clementsii* Chaney.

FIG. 1. Concretion showing the mold of a cone. Holotype. Univ. Minn. Dept. Botany, Paleob. Coll., No. C770. Ochs Clay Pit, Springfield, Minn.

FIG. 2. Concretion opened to show the cone in vertical section.

FIG. 3. Cast of the cone shown by figures 1 and 2.

FIG. 4. *Pinus resinosa* Aiton for comparison with the

fossil. Cone from a tree growing under cultivation at the Institute of Forest Genetics, Placerville, California.

FIG. 5. Impression of a portion of a leaf. Paratype. x 3. Univ. Minn. Dept. Botany, Paleob. Coll., No. 5384. New Ulm Minn.

FIG. 6. Compression of a cone. Paratype. Univ. Minn. Dept. Botany, Paleob. Coll., No. C771. New Ulm, Minn.

with the cone from Ochs Clay Pit (see Figure 6); these specimens carry the New Ulm locality designation, No. 140. The specimen on which Lesqueux based his brief description of a leaf referred to *Pinus* species is not now known to be in the collections at the University of Minnesota. The recently received specimens occur in association with angiosperm leaf impressions on slabs of fine-grained limonitic sandstone.

In spite of the fact that this fossil material seems scarcely distinguishable from corresponding parts of the living *P. resinosa*, and over the long-remembered objections of Frederic E. Clements who, with many other botanists, often seemed to favor calling fossil plants by the names of living species which they resembled, I am assigning a distinct specific name to it for the following reasons:

(1) We know nothing of the wood, microsporangiate cones, and pollen of this Cretaceous pine. It is reasonable to suppose that, during the scores of millions of years since our cones were borne on living trees, there may have been changes in some of these organs or groups of organs which would provide a basis for specific distinction.

(2) From the standpoint of the historian (and all paleontologists and stratigraphic geologists are historians), it is preferable to assign a different name to a plant which is so far separated in age from the pines of our day; this emphasizes the temporal and stratigraphic distinctness of the fossil pine.

Mention of its modern affinities gives all of the advantages that would accrue from using the name *P. resinosa*, and at the same time does not commit us to an opinion, and to a record of specific identity, which cannot now be established on the basis of the material available.

My selection of a name for these fossils might have brought about another mild argument with Dr. Clements. In assigning the name *Pinus clementsii*, I am disregarding his preference for bisyllabic specific names, but if this procedure were followed consistently, no one with two syllables in his name could ever have a species named in his honor without leaving off the case ending; and that, to a classical scholar like Clements, would have been a greater sin than tri-syllaby. At any rate, if I had named this pine in honor of Dr. Rosendahl, which would also have been highly appropriate, I should have used a still longer specific name. So I am assigning the name *Pinus clementsii* in appreciation of the man who guided my early paleobotanical studies in western North America, giving me suggestions and ideas from his

great store of knowledge of vegetation, both present and past.

When I brought the cone of *P. clementsii* to Berkeley, my first thought was to discuss it with Dr. Nicholas T. Mirov, Plant Physiologist of the California Forest and Range Experiment Station of the United States Forest Service, for in recent years he has made an extensive study of the living and fossil species of *Pinus*. His judgment regarding the modern relationship of our material has proved to be of great value, as indicated by the following statement which he has prepared for inclusion here: "The fossil cone you sent me apparently belongs to the subgenus *Diploxylon* (hard pines). Within the subgenus, the cone falls into the group *Laricion* 'which represents the first stage in the evolution of the hard pines' (Shaw 1914: 51). This group consists of 12 living species; seven are Asiatic, three European, and two American, *P. resinosa* and *P. tropicalis*. The cone in question differs a great deal from the cones of the European and Asiatic *Laricion* either in shape or in the appearance of the apophysis. A difference in shape and size is also apparent when it is compared with *P. tropicalis*. The fossil cone is indistinguishable from the cone of *P. resinosa* in its shape and especially in the appearance of the apophysis, characterized by an unarmed, delicately outlined umbo."

It is fortunate that the cones of this fossil pine and of its living relative are so characteristic, for with the exception of a fragmentary needle there is nothing else to indicate its modern relationship. The paleobotanist must often make use of fragmentary evidence in his study of Cretaceous and Tertiary specimens, for although there is occasional record of a fossil plant which is essentially complete, as in the occurrence of *Metasequoia disticha* Miki in the Pliocene of Japan (Miki 1941: 260-262), it is unusual to find more than one or two parts of any plant associated in the same deposit, and extremely rare to find them in direct attachment. Most of the conifers and angiosperms of these later floras show a close resemblance to living species; here the standard procedure is to bring together one or more parts of a plant if all of them show similarity to the corresponding parts of a living species, and to assign them all to a single fossil species even though they do not occur in direct attachment. Where only one part of a plant is found, sufficiently well-preserved or sufficiently distinctive to make possible a generic identification, it is described as a new fossil species if nothing resembling it has previously been found. Subsequently other parts may be discovered in rocks of approximately the same age, and these may be assigned to the same fossil species if they

show similarities to the corresponding parts of a related living species.

This procedure has been followed in the study of the cones and needle from the Cretaceous of Minnesota. Future discoveries may provide a more adequate concept and may alter some of our conclusions, but such a contingency is not limited to the study of fossil plants. Following is the description of the material now at hand:

*Pinus clementsii* new species

*Description.*—Foliage represented by a fragment of a leaf 2.5 cm. long, complete at neither end; slightly over .5 mm. in width, tapering slightly distad; deeply concave in cross-section, subtending an angle of approximately 180 degrees. Ovuliferous cones ovoid-conical, symmetrical, broadly rounded toward the base which is missing, only slightly more gradually rounded distally to a blunt tip; maximum length (actual) 4.5 cm., (estimated) 4.7 cm.; greatest diameter 2.8 cm.; scales of the cones closed in all cases, so that the apophyses are confined within the surrounding apophyses; apophyses approximately rhombic in cross section, but more rounded above and more angular below, up to 1.1 cm. across and 7 mm. high on the uncompressed specimen, with a strongly convex surface protruding as much as 2 mm., with a distinct transverse keel, with a strong ridge extending from the umbo down to the base, and with faint, and in some cases a few strong, linear grooves radiating out from the umbo; umbos dorsal, up to 2 mm. across, mutic, broad rhombic or irregularly lenticular, surrounded by a distinct moat.

DISCUSSION

Shape and size in the above description are based upon the uncompressed cone shown as Figure 3. The surface characters of the apophyses and umbos are best preserved on the fragmentary cone shown as Figure 6, in which compression has not only flattened the cone, but appears to have squeezed it longitudinally until the apophyses are approximately as high as they are wide.<sup>4</sup> Pressure applied to a cone of the living *P. resinosa* after soaking produces a similar increase in its length, and a vertical distortion of its apophyses.

These two cones, and two other fragments not figured, closely resemble those of *P. resinosa* in shape, size, apophyses, and umbos (see Figure 4). The only observed difference is that the apophyses of our best preserved specimen have stronger protuberances than those of any of the cones of *P. resinosa* examined. In one further feature, which

may be only coincidental, this specimen is suggestive of *P. resinosa*: it is incomplete at the base as a result of the fracturing of the nodular mass of rock in which it is preserved; fallen cones of the living species commonly have the base missing since they tend to leave a few basal scales at the point of attachment. The possibility exists that this fossil cone also was incomplete at the time of burial, and that the position of the break across the enclosing concretion was determined by the end of its mold. The closed scales on all our cones, with their apophyses closely surrounded by those adjacent, are interpreted as indicating that they were in water at their time of entry into the sedimentary record. Cones of *P. resinosa* close their scales when placed in water (see Figure 4) even though they have been open and spreading at maturity; when removed from water, they reopen their scales within a few hours. With the exception of the specimen shown as Figure 6, the apophyses and umbos on all the fossil cones appear to have been abraded prior to burial. Modern pine cones float in water, and it seems probable that the abrasion of the fossil cones occurred while they were being transported in suspension from the place where their parent trees grew to the sites of deposition farther down the valley, as will be mentioned below.

The foliage specimen, although only a fragment, also shows characters which indicate its resemblance to the leaves of *P. resinosa*, or at least to those of a two-needled pine. At first glance it might be doubted whether so incomplete a specimen (see Figure 5) could have any bearing on the modern relationships of *P. clementsii*, or whether it could even be considered to represent the same species of pine as the fossil cones. While two needles associated in a fascicle would immediately have served to confirm the reference of our foliage and cone specimens to a single fossil species similar to *P. resinosa*, the cross-section of this incomplete leaf in itself is sufficient to indicate its binate character. As above described, it is concave, forming a sector of approximately 180 degrees, which as Shaw has stated (1914: 4) is a definite indication of a fascicle of two leaves. Examination of the foliage of all the common living American pines shows that only the two-needled species have leaves similarly concave in cross-section; of these several have leaves much more heavy than the fossil specimen, leaving *P. contorta* Dougl., *P. muricata* D. Don, and *P. resinosa* as the only living species with wholly similar leaves. No fossil cones have here been found with spines like those on the apophyses of *P. contorta* and *P. muricata*, and so the possibility of relationship to these species can be eliminated, at least so far as

<sup>4</sup> A thin carbonaceous film representing the remains of this cone covers several of its scale imprints. This material is now being studied by Adriance S. Foster.

cones now known are concerned. Close similarity of *P. clementsii* to *P. resinosa* appears to be established on the basis of comparisons both of the cones and of the foliage.

#### PHYSICAL CONDITIONS

The absence of Mesozoic rocks of pre-Cretaceous age from southern Minnesota indicates a long expanse of time during which erosion equalled or exceeded deposition. That some of the highlands lasted through this stage of emergence in an adjacent area, or were uplifted during Cretaceous orogeny, is indicated by the coarse character of some of the sediments of the Dakota group in which the cone of *P. clementsii* was collected. (For sections, see Stauffer and Thiel 1941: 128-130). The Dakota sandstone, basal member of the Upper Cretaceous, is largely continental in origin, and represents a stage in earth history during which streams were depositing sediments on broad floodplains over a wide area between the Front Range and the Mississippi Valley. The local occurrence of poorly drained areas is indicated by thin lenses of lignite in the section at Ochs Clay Pit and elsewhere.

The vegetation of the Dakota stage in North America gives the first record of a predominantly angiosperm forest. Preceding floras of the Lower Cretaceous show still a large element of such older Mesozoic plants as the Cycadophyta and Ginkgoales, together with ferns and conifers of ancient types. But with Upper Cretaceous time, flowering plants, and to a lesser extent modern conifers, became the dominant members of the forests of the northern continents. With the exception of the pine here described, and a foliage shoot considered by Lesquereux to represent *Sequoia*, the flora from southern Minnesota is made up entirely of angiosperm leaves. These have been assigned to such genera and form genera as *Alnites*, *Salix*, *Populites*, *Platanus*, *Ficus*, *Laurus*, *Cinnamomum*, *Diospyros*, *Andromeda*, *Bumelia*, *Cissus*, *Magnolia*, *Liriodendron*, *Dezvalchia*, *Juglans*, *Crataegus*, *Sapindus*, *Protophyllum*, *Aralia*, *Leguminosites*, and *Laurophyllum* (Lesquereux 1895: 22), but it requires only a brief survey of the illustrations to indicate that many or most of the figured specimens are at best blurred copies of the leaves of modern angiosperms, and do not show characters which permit accurate generic determinations. This is true also of leaf impressions from localities of the Dakota sandstone in adjacent states.<sup>5</sup> Even

<sup>5</sup> Lesquereux expressed uncertainty regarding the generic status of some of his leaves by referring them to such form genera as *Protophyllum*, *Proteoides*, and *Phyllites*. And at one point (1891: 231) he asked the question. "Is *Sassafras* (*Araliopsis*) *platanoides* referable to *Sassafras*, to *Aralia*, or to *Platanus*?"

in the case of the much later flora from the Lance formation, the uppermost member of the Upper Cretaceous, Dorf has stated (1942: 97): "The task of allocating Upper Cretaceous species to their proper botanical genera continues to be a difficult one. Many of the Lance species are still of very uncertain systematic position. Others are believed to show only a family relationship to existing forms. Not many can be shown to have a marked resemblance to living genera." It is not until the Tertiary period that the leaves of angiosperms, often in association with seeds and fruits, can be assigned with confidence to modern genera. This being the case, the question may be raised whether the angiosperm flora of the Dakota sandstone provides any reliable basis for reconstructing the Upper Cretaceous environment in southern Minnesota. The answer can be given that whatever the systematic position of these Cretaceous leaves, whether *Alnites crassus* Lesquereux represents an alder or a *Viburnum* (which the venation and margin appear to indicate), whether *Laurus nebrascensis* Lesquereux is actually a lauraceous leaf or a member of any one of a dozen other genera and families with lanceolate leaves, there are still characters shown by the leaves themselves which suggest the physical conditions of their day. These characters of size, venation, margin and texture, while perhaps not reliably interpretable from Lesquereux's drawings, are none the less suggested by his figures, and can be readily checked by examination of leaf impressions from the Dakota sandstone. Reference may be made to numerous papers in which the principles of leaf analysis are discussed in connection with Tertiary floras (see Chaney and Sanborn 1933: 18-23), and it is clear that these principles apply equally well to the treatment of Cretaceous leaves.

An analysis of 200 species of the Dakota flora from Minnesota, Nebraska and Kansas, based upon an examination of the descriptions and illustrations of angiosperm leaves (Lesquereux 1874, 1883, 1891), has provided the data summarized in Table I. Analyses of other floras are included for comparison.

A large majority of the Dakota leaves have entire margins and thick texture; these are characters found in many leaves of the tropics where the evergreen habit is predominant. The relatively large size of nearly half of the Dakota leaves is another point of resemblance to living foliage of low latitudes. The percentage of Dakota leaves with palmate (or plinerved) venation does not offer conclusive evidence. Far more significant would be figures on the relative number of camptodrome and craspedodrome leaves, but since this feature has not been considered in previous leaf

TABLE I. *Leaf characters of dicotyledons, showing percentages in each category*

Flora	Margin		Length		Venation		Texture	
	Entire	Non-entire	Over 10 cm.	Under 10 cm.	Pal-mate	Pin-nate	Thick	Thin
Dakota, 200 species...	73	27	44	56	27	73	74	16*
Lance, 46 species....	54	46	41	59	46	54	67	33
Medicine Bow, 42 species.....	67	33	45	55	40	60	71	29
Laramie, 55 species...	71	29	45	55	36	64	73	27
Panama, 41 species (modern).....	88	12	56	44	17	83	98	2
Bridge Creek, 20 species.....	15	85	30	70	30	70	55	45
Muir Woods, 22 species (modern)...	23	77	27	73	23	77	64	36

\*This number includes those designated as thin in Lesquereux's descriptions and also those whose texture was not noted and which may be presumed not to have been thick.

analyses, adequate comparisons cannot be made here. However, it should be noted that 72 per cent of the Dakota leaves have camptodrome nervation, which relates the flora to tropical rather than to temperate forests of today. Comparison with data assembled by Dorf (1942: 101, Table I) for later Cretaceous floras of the Rocky Mountain area indicates a striking similarity to their leaves and to those of a modern forest in Panama. There is a marked difference between the Dakota leaves and those of the middle Tertiary Bridge Creek flora and of the modern forest of Muir Woods. Dorf considers the Lance and Medicine Bow floras to indicate climatic conditions intermediate between warm temperate and subtropical, and the Laramie flora as definitely subtropical; the Bridge Creek and Muir Woods floras are temperate. On the basis of the characters of its angiosperm leaves, the Dakota flora may be supposed to have lived under conditions more subtropical than temperate. In apparent agreement with this assumption are several ferns and Cycadophytes which are suggestive of a frost-free climate. The sediments in which all these plants are preserved indicate a floodplain deposit.

In conclusion, we may consider the habitat relationship of *Pinus clementsii* to this lowland forest. Unlike many of the angiosperms, its generic status appears to be above question, and the only doubtful element of our appraisal is whether this pine occupied the same habitat as the majority of those now living. In support of our opinion that *Pinus clementsii* was an upland tree rather than a member of the valley forest, the scarcity of its needles is in marked contrast to the abundance of angiosperm leaves. Furthermore, the smoothed surfaces of all except one of the cones suggests

transportation for some distance before their ultimate deposition on a floodplain; this would have involved floating rather than dragging along the bed of the stream, for the cones of living pines are buoyant for a week or more until they become water-soaked, and our specimens show no evidence of heavy abrasion. The Dakota sediments themselves are also indicative of adjacent high relief, for the sands are poorly assorted and cross-bedded, and layers of gravel or conglomerate with well-rounded pebbles may make up a conspicuous part of many sections exposed (Stauffer and Thiel 1941: 99-104, 128-130). The cones and leaf which are the subject of this paper appear to have been washed down from these not distant highlands into the valley occupied by the earliest known forest of Minnesota.

In Japanese art and literature the pine, matsu, is a symbol of strength and longevity. In their home on the mountains, we are told, pine trees reach a great age and hold their branches high against the wind. Such is the history of the red pine, whose ancestry extends back for a hundred million years, through intervals of climatic vicissitude, to the Clements pine of the Cretaceous.

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