FOSSIL PLANTS FROM THE ASPEN SHALE OF SOUTHWESTERN WYOMING [1]

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Until recently no fossils other than fish scales, lingulas, and bones [2] have been reported from the Aspen shale of southwestern Wyoming. In 1931, Reeside and Weymouth [3] described a number of ammonites and pelecypods from this shale, but the first hint of the presence of fossil plants in the Aspen was given in a personal communication, May 17, 1930, by A. Allen Weymouth, of the California Company, Denver. In the latter part of June, 1930, W. H. Bradley, of the United States Geological Survey, and I visited the locality cited by Mr. Weymouth and made a good collection, which forms the basis for this paper.

The locality mentioned is northwest of Kemmerer, Wyo., in the NW. ¼ sec. 6, T. 24 N., R. 115 W., in the low bluff on the south side of the junction of Everly Creek and Fontanelle Creek and about 125 feet east of a north-south fence. The section of the Aspen shale exposed in this region is about 1,000 feet thick. It shows strata of black and gray shales, clay, thin coals, bentonite, gray sandstone, and light-colored tuff, all dipping 35° westward. The gray to bluish-gray shales weather into long rounded hills with a distinctive greenish-gray appearance. This was the only locality in the Aspen at which we found fossil plants.

The fossil plants occur in the uppermost 125 feet of the formation in a thin stratum of bluish-gray hard mudstone, which is very brittle and fractures conchoidally. The plants occur at all angles through the matrix, making it somewhat difficult to get entire specimens. They are very well preserved and stand out black against the bluish-gray background.

The Aspen flora occurs in deposits which directly underlie the Frontier formation of accepted Colorado age and are, therefore, somewhat earlier, but still Colorado in age. These two floras, there-

[1] Published by permission of the Director, U. S. Geological Survey.

[2] Schultz, Alfred R., Geology and geography of a portion of Lincoln County, Wyo. U. S. Geol. Surv. Bull. 543, p. 59, 1914.

[3] Reeside, John B., jr., and Weymouth, A. Allen, Mollusks from the Aspen shale (Cretaceous) of southwestern Wyoming. Proc. U. S. Nat. Mus., vol. 78, art. 17, pp. 1–24, pls. 1–4, 1931.

fore, become important as marking definite stratigraphic horizons. When a sufficient number of such cases come to light, the history of plant species and their migrations can be studied, thereby making identification of new or isolated collections easy and reliable.

The flora with which the Aspen would immediately be compared is that described by Knowlton [4] from the overlying Frontier formation. The lists of the two floras are arranged side by side below:

Aspen flora	Frontier flora
Anemia fremonti Knowlton.	*Anemia fremonti* Knowlton.
Asplenium occidentale Knowlton.	*Asplenium occidentale* Knowlton.
Cladophlebis readi, new species.	*Dennstaedtia? fremonti* (Hall) Knowlton.
Micrataenia paucifolia (Hall) Knowlton.	*Dryopteris coloradensis* Knowlton.
Sparganium aspensis, new species.	*Microtaenia paucifolia* (Hall) Knowlton.
Populus? aspensis, new species.	*Microtaenia variabilis* Knowlton.
Dryandroides lanceolata Knowlton.	*Tapeinidium? undulatum* (Hall) Knowlton.
Laurus aspensis, new species.	*Equisetum* sp.
Sassafras bradleyi, new species.	*Smilax? coloradensis* Knowlton.
Nelumbo weymauthi, new species.	*Myrica nervosa* Knowlton.
Liquidambar fontanella, new species.	*Salix cumberlandensis* Knowlton.
Prunus aspensis, new species.	*Salix frontierensis* Knowlton.
Staphylea? fremonti Knowlton.	*Quercus stantoni* Knowlton.
Sapindopsis schultzi, new species.	*Ficus fremonti* Knowlton.
	Ficus? sp.
	Ficus? sp.
	Cinnamomum hesperium Knowlton.
	Cinnamomum? sp.
	Dryandroides lancealata Knowlton.
	Aralia veatchii Knowlton.
	Staphylea? fremonti Knowlton.
	Dewalquea pulchella Knowlton.
	Phyllites ficifolia Knowlton.
	Phyllites dentata Knowlton.
	Phyllites.

It will be seen that five species are common to both floras, which is a large percentage when the small size of the floras is considered. So far as the general composition of the floras is concerned, they are very similar and, in my opinion, indicate the same climatic and environmental conditions, namely, a warm temperate and well-watered habitat. Knowlton argues for a tropical or subtropical habitat for the Frontier flora on the basis of several ferns supposed to be related to those now living in such an environment, and on a few species of supposed figs. Studying Knowlton's discussion of the davallioid

[4] Knowlton, F. H., A fossil flora from the Frontier formation of southwestern Wyoming. U. S. Geol. Surv. Prof. Paper 108, 1917.

ferns, one gets the impression that none of these is definitely determined in terms of living species, and two are assigned to a new genus. Their value, therefore, as habitat indicators is not very great. As for the supposed figs, the fact that two of these species are questioned and the third is identified on the basis of resemblance to another problematical *Ficus*, one can be pardoned for not placing great stress on their value as habitat indicators.

Opposed to all the uncertainties due to doubtful identification are a few determinations which come reasonably within the limits of certainty. The Aspen species which seem to me to be correctly assigned and beyond serious question are: *Nelumbo weymouthi*, *Liquidambar fontanella*, and *Sassafras bradleyi*. If *Liquidambar fontanella* alone is correct and if it had the habits of the living species, it would stamp the association as a temperate, perhaps a warm-temperate, one.

The absence from the Aspen of gymnosperms like the cycads and conifers leaves little for comparison with such older floras as that of the Potomac group, the Kootenai formation, and others. Besides *Sassafras bradleyi* and *Laurus aspensis* there are few resemblances to anything in the large and somewhat earlier flora of the Dakota formation. Likewise there are few if any points in common with such floras of later date as that of the Mesaverde formation, Judith River formation, Vermejo formation, and others. The Aspen and Frontier floras, therefore, hold a conspicuous place in the gap of our knowledge of western interior Cretaceous vegetation.

PTERIDOPHYTA

ANEMIA FREMONTI Knowlton

PLATE 1, FIGURE 3

Anemia fremonti KNOWLTON, U. S. Geol. Surv. Prof. Paper 108, p. 84, pl. 31, fig. 6; pl. 32, figs. 1–3, 1917.

The specimen figured here is similar to those described by Knowlton. Exception could be made in respect to the smaller size and the deeper lobing of the pinnules of the Aspen material; but these characters may well come within the variations of the species.

Plesiotype.—U.S.N.M. No. 39136.

ASPLENIUM OCCIDENTALE Knowlton

PLATE 1, FIGURE 5

Asplenium occidentale KNOWLTON, U. S. Geol. Surv. Prof. Paper 108, p. 84, pl. 31, figs. 2–5, 1917.

The specimen figured here is apparently a ternately divided portion of a young or deformed frond of the species described by Knowl-

ton. The pinnules are not elongated as in Knowlton's specimens, but the venation and marginal dentition are similar.

Plesiotype.—U.S.N.M. No. 39137.

CLADOPHLEBIS READI, new species

PLATE 1, FIGURE 2

This was probably a tree fern, if stoutness of the rachis is any indication of the size and habit of these ancient ferns. The rachis is 3.5 mm in diameter and bears narrow, elongated pinnae at intervals of 1.3 cm. The pinnae average 10 cm in length and bear numerous closely spaced, falcate, minutely stalked or sessile pinnules. The margin of the pinnules appears for the most part to be entire, but in some cases is noticeably crenulate. From the midrib of the pinnules emerge 8 to 10 pairs of secondary veins, which fork once close to the midrib. No sori are present on any of the specimens in this collection.

Many species of *Cladophlebis* have been described from Cretaceous rocks. The species which this most resembles is *Cladophlebis distans* Fontaine [5] from the Potomac group of Virginia and Maryland. The chief difference between the two seems to be that most of the pinnules of *C. readi* are conspicuously rounded at the base and are attached by a minute stalk. *C. readi* will no doubt be compared with *Dryopteris coloradensis* Knowlton.[6] That species, however, has more widely spaced pinnae; the venation of the pinnules is more open and oblique; and the rachis is much slenderer, suggesting a different habit. I name this species for my colleague, C. B. Read.

Holotype.—U.S.N.M. No. 39138.

MICROTAENIA PAUCIFOLIA (Hall) Knowlton

PLATE 1, FIGURE 4

Microtaenia paucifolia (HALL) KNOWLTON, U. S. Geol. Surv. Prof. Paper 108, p. 82, pl. 30, figs. 1, 2, 1917.

The specimen figured is fragmentary, but sufficient is present to identify it with those described by Knowlton.

Plesiotype.—U.S.N.M. No. 39139.

SPARGANIACEAE

SPARGANIUM ASPENSIS, new species

PLATE 2, FIGURE 2

This specimen has the general appearance of a *Sparganium* spike of staminate flowers. The portion preserved is 9 cm long and shows

[5] Fontaine, W. M., The Potomac or younger Mesozoic flora. U. S. Geol. Surv. Mon. 15, p. 77, pl. 13, figs. 4, 5, 1890.

[6] Knowlton, F. H., A fossil flora from the Frontier formation of southwestern Wyoming. U. S. Geol. Surv. Prof. Paper 108, p. 83, pl. 30, figs. 3, 4, 1917.

small staminate heads at intervals of 1 cm. The individual stamens can not be distinguished readily. Associated with these flowers on other blocks are portions of narrow striated leaves, which closely resemble the leaves of modern sparganiums.

The object with which this fossil may at once be compared is that described by Lesquereux [7] from the Dakota sandstone of Kansas, and called by him flowers of *Platanus primaeva.* Associated with these flowers are undoubted *Platanus* leaves, so that the identification of the flowers as *Platanus* flowers may be correct. On the other hand, there are objects in the Dakota group described as *Podozamites* which may be *Sparganium* leaves instead. I have found no *Platanus* leaves in the Aspen collection, where they certainly should have left fossil leaf remains if *Platanus* had been a tree along the Aspen river courses.

Holotype.—U.S.N.M. No. 39140.

SALICACEAE

POPULUS? ASPENSIS, new species

FIGURE 1

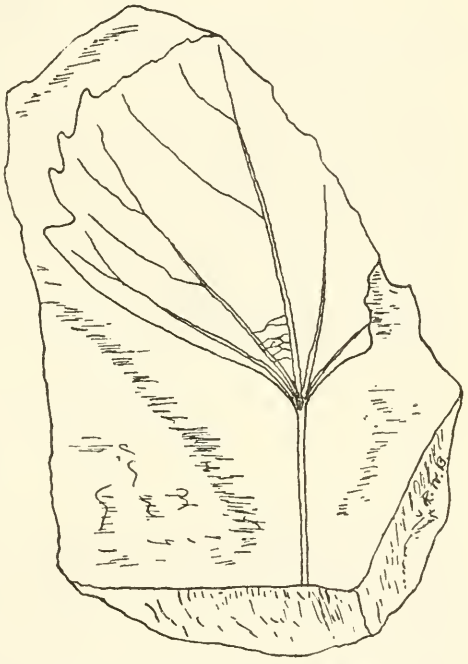

FIGURE 1.—Sketch of *Populus? aspensis.* ×1

The single specimen of this species (fig. 1) is the only one in this collection. It is fragmentary but enough is preserved to show the general characters. The leaf was orbicular, probably 6 cm in diameter, with few large blunt teeth on the margin and a cuneate base. From the top of the petiole arises a palmate system of primary veins, which curve upward toward the margin and send off secondaries toward the teeth. The finer venation is obscure. The petiole is 2.5 cm long.

In general this leaf resembles those forms from the Fort Union described as *Populus*, particularly *P. cuneata* Newberry, and illustrated by Ward.[8] The teeth in the present specimen are coarser,

[7] Lesquereux, Leo, The flora of the Dakota group. U. S. Geol. Surv. Mon. 17, p. 72, pl. 8, figs. 8, 8b, 1892.

[8] Ward, L. F., Types of the Laramie flora. U. S. Geol. Surv. Bull. 37, p. 19, pl. 4, figs. 5–8; pl. 5, figs. 1–3, 1887.

and because of the difference in age I venture the opinion that this is a different and perhaps an ancestral species.

The resemblance of these leaves to those of the modern genus *Grewia* of the Tiliaceae has led some paleobotanists to think their affinities may lie in that direction. I have, therefore, questioned the generic reference to *Populus*.

Holotype.—U.S.N.M. No. 39141.

PROTEACEAE

DRYANDROIDES LANCEOLATA Knowlton

PLATE 1, FIGURE 6

Dryandroides lanceolata KNOWLTON, U. S. Geol. Surv. Prof. Paper 108, p. 89, pl. 34, fig. 7, 1917.

This lanceolate coriaceous coarsely toothed leaf, although somewhat smaller, has the characters of that described by Knowlton from the Frontier formation. It is comparable to the leaves of some modern species of such proteaceous genera as *Dryandra* and *Banksia*. However, in the absence of more certain evidence than foliar characters, no definite commitment other than that already suggested by Knowlton can be made as to generic affinity.

Plesiotype.—U.S.N.M. No. 39142.

LAURACEAE

LAURUS ASPENSIS, new species

PLATE 2, FIGURE 1

This specimen is a short stem bearing one nearly entire leaf, a portion of another leaf, and the petiole of a third. There are no buds or leaf scars on the stem. The large leaf is 8 cm long and 2.5 cm wide, and is oblanceolate in form, the nature of the apex being unknown, but the base is cuneate to a petiole 1.5 cm long. Margin entire. The venation is pinnate from a strong midrib, and is composed of 12 or more subopposite pairs of secondaries, which emerge from the midrib at 50°, run out fairly straight to within a short distance of the margin, and then curve upward sharply and become lost near the margin beneath the curve of the secondary above. The tertiary venation is a system of irregular parallel diagonals connecting the secondaries.

It would seem that the affinities of this specimen are with the Lauraceae or Magnoliaceae. I have compared the specimen with all the available similar material in the United States National Museum, but find no exact reliable correspondence for definite iden-

tification in terms of past work. I venture, therefore, to name a new species, with the reservations necessitated by all such paleobotanic uncertainties.

Holotype.—U.S.N.M. No. 39143.

SASSAFRAS BRADLEYI, new species

PLATE 2, FIGURE 5

Only one specimen of this species was found. It is an obtusely trilobate leaf 5 cm long and 5 cm wide from tip to tip of the lateral lobes. The upper margin of the lateral lobes makes an approximately right-angle sinus with the margin of the middle lobe. Margin entire and noticeably thickened. Petiole of unknown length. The two lateral primaries arise from a point 3 cm above the top of the petiole and spread to the apices of the lobes. A few widely spaced secondaries arise at angles of 55° and curve upward to the margin, where they are lost in the thin vein, which arises at the base of the leaf and runs along the margin, giving it a thickened appearance. A secondary arises from the midrib and runs to the sinus where it forks, these forks in turn joining the marginal vein.

This leaf differs somewhat from modern sassafras leaves in having such unusually wide sinuses, but compares well in regard to internal structure. The chief difficulty here, it seems to me, is not whether this leaf ought to be called sassafras but just how it should be distinguished from many variable Cretaceous forms from the Dakota sandstone, Cheyenne sandstone, and elsewhere, called *Sassafras*, *Sterculia*, and *Aralia*.

No fruits of any kind were found in this collection and, therefore, an important source of evidence as to the affinity of these leaves is not at hand.

I take pleasure in naming this species for W. H. Bradley, of the United States Geological Survey.

Holotype.—U.S.N.M. No. 39144.

NYMPHAEACEAE

NELUMBO WEYMOUTHI, new species

PLATE 1, FIGURE 1

Only the central portion of this leaf is preserved, so that it is impossible to state exactly the size and shape of the entire leaf. There are 12 strong radiating primaries, some of which fork within a centimeter of the center and produce toward the margin the characteristic venation network of *Nelumbo*. Evidently the leaf was not large, possibly 6 to 8 cm in diameter, and was probably orbicular in shape.

This species appears to be different in size and venation from any other Cretaceous *Nelumbo*. The distribution and general relationships of the fossil nelumbos have been discussed by Berry.[9] I name this species for A. Allen Weymouth.

Holotype.—U.S.N.M. No. 39145.

HAMAMELIDACEAE

LIQUIDAMBAR FONTANELLA, new species

FIGURE 2; PLATE 2, FIGURE 3

The fragments of leaves in this collection would lead one to infer that all the leaves of this species were deeply and narrowly 3-lobed. The range of variation in modern liquidambars includes 3- to 7-lobed

FIGURE 2.—Reconstruction of *Liquidambar fontanella*. ×⅔

leaves with the 5-lobed leaf the usual and most common form. The over-all breadth of this leaf from tip to tip of the lower lobes is 13 cm and the length from the top of the petiole to the tip of the middle lobe is 8 cm. The lobes are 1 cm wide near the base and become narrowly attenuate to their tips. The margins are finely crenate-serrate. The base is slightly cordate. Length of petiole unknown.

The primary venation includes three strong veins arising from the top of the petiole, the laterals diverging at an angle of 60° from the middle vein. Eight to ten pairs of secondaries appropriately spaced branch off from the primaries at approximately 60°, loop upward near the margin, and connect with the secondaries above. In general the characters of this leaf compare well with those of the modern

[9] Berry, Edward W., Geologic history of the Wilcox group at Meridian, Miss. U. S. Geol. Surv. Prof. Paper 108, p. 64, 1918.

liquidambars, with the exception of the unusually long lobes and the restricted area of the basal region. From an esthetic point of view the tree which bore these delicately graceful leaves was undoubtedly a striking object in the Cretaceous landscape along the river courses and moist low country of southwestern Wyoming.

A review of liquidambar history discloses no earlier undoubted liquidambar than this. Several Cretaceous leaves have been called liquidambars, but because they have entire margins they are not now regarded as such. Not until Eocene and Miocene times did the liquidambars leave plentiful remains both of leaves and fruits.

Holotype.—U.S.N.M. No. 39146.

ROSACEAE

PRUNUS ASPENSIS, new species

PLATE 2, FIGURE 4

This is an oblong to lanceolate leaf with finely serrate margin, rounded base, and short petiole. Nature of the apex unknown. Approximate length 5 cm, width 2 cm. The venation is not clearly shown, but is pinnate with secondaries emerging from the midrib at 50° and becoming camptodrome near the margin. Finer venation undeterminable. The affinities of this leaf seem to me to be with the Rosaceae and I assign it to the genus *Prunus*. There are no Cretaceous species of *Prunus* so far as I know with which this could be identified.

Holotype.—U.S.N.M. No. 39147.

STAPHYLEACEAE

STAPHYLEA? FREMONTI Knowlton

PLATE 1, FIGURE 8

Staphylea? fremonti KNOWLTON, U. S. Geol. Surv. Prof. Paper 108, p. 93, pl. 32, figs. 4, 5; pl. 33, fig. 5, 1917.

The specimen figured here and the only one of the sort in this collection is at least a trifoliate leaf, but may be the terminal portion of a leaf which had more leaflets. Points of difference between this specimen and those figured by Knowlton are: Petiole of middle leaflet longer than those of the laterals; base of leaflets rounder; secondary veins less numerous. All these differences may be within the limits of variation in the species, and, therefore, I hesitate to designate a new species for this specimen from the Aspen formation. The question mark following the generic name, it seems to me, is much to the point.

Plesiotype.—U.S.N.M. No. 39148.

SAPINDACEAE

SAPINDOPSIS SCHULTZI, new species

PLATE 1, FIGURE 7

The specimen reproduced here was apparently a leaflet of a compound leaf as inferred from its markedly unequal base and from the fact that on another block in this collection are fragments of four such leaflets all oriented in the same direction and about equally spaced as if they had been attached to a rachis. Unfortunately the rock is broken off at that line, leaving this inference unproved. The leaflet is elliptic in form, with low crenate-serrate teeth on the margin and an inequilateral base. Length 3 cm, width 1.2 cm. The venation is pinnate with five or six pairs of secondaries emerging from the midrib at 60°, looping upward well within the margin to the secondary above. Finer venation obscure.

Following a precedent in regard to indefinite Cretaceous Sapindaceae, I venture to assign this species to *Sapindopsis*, because of its resemblance to *S. belviderensis* Berry.[10] That species, however, is larger, with coarsely toothed margins. I name this species for A. R. Schultz.

Holotype.—U.S.N.M. No. 39149.

[10] Berry, Edward W., Flora of the Cheyenne sandstone of Kansas. U. S. Geol. Surv. Prof. Paper 129, p. 216, pls. 49–54, 1922.

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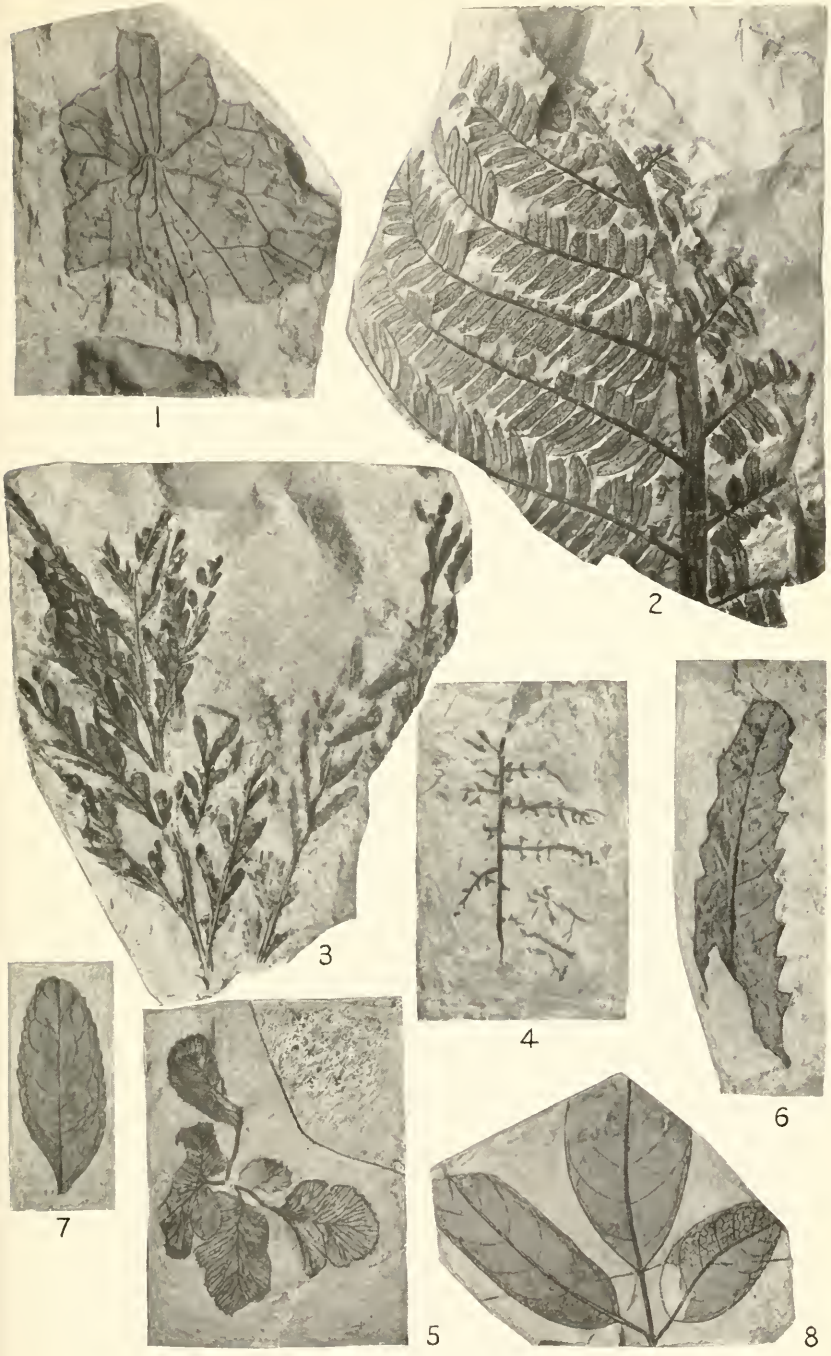

FOSSIL PLANTS FROM SOUTHWESTERN WYOMING

1, *Nelumbo weymouthi*, new species; 2, *Cladophlebis readi*, new species; 3, *Anemia fremonti* Knowlton; 4, *Microtaenia paucifolia* (Hall) Knowlton; 5, *Asplenium occidentale* Knowlton; 6, *Dryandroides lanceolata* Knowlton; 7, *Sapindopsis schultzi*, new species; 8, *Staphylea? fremonti* Knowlton. All natural size

FOSSIL PLANTS FROM SOUTHWESTERN WYOMING

1, *Laurus aspensis*, new species; 2, *Sparganium aspensis*, new species; 3, *Liquidambar fontanella*, new species; 4, *Prunus aspensis*, new species; 5, *Sassafras bradleyi*, new species. All natural size.