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THE UNIVERSITY OF KANSAS
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[No. 20

Grasses and Other Plants from the Tertiary Rocks of
Kansas and Colorado.

MAXIM K. ELIAS.

CONTENTS.

	PAGE
Summary	333
Introduction	334
Acknowledgments	335
Previous works on fossil herbs.....	337
Occurrence	341
Description of species.....	361
Literature cited	362
Explanation of plates.....	

SUMMARY.

THE fossil remains described in this paper represent protective covers of grains of true grasses and nutlets of herbaceous plants of the borage family, accompanied by hackberry (*Celtis*) stones. The flora consists of the following forms:

GRASSES.

Panicum (sensu lato) *elegans* Elias n. sp.

Stipa kansasensis Elias n. sp.

BERRIOCHLOA Elias n. gen.

Berriochloa glabra (Berry) Elias n. comb.

Berriochloa (?) *aristata* (Berry) Elias n. comb.

HERBS OF THE BORRAGE FAMILY.

BIORBIA Elias n. gen.

Biorbia rugosa (Berry) Elias n. comb.

Krynitzkia (*Cryptantha*) *coroniformis* Elias n. sp.

Krynitzkia (*Oreocarya*) *chaneyi* Elias n. sp.

Krynitzkia auriculata Elias n. sp.

(333)

TO VIRU
BERRIOCHLOA

ULMACEÆ.

Celtis cf. *willistoni* (Cockerell) Berry.

The plant remains were collected in Wallace county and adjacent territory and come from arenaceous and mostly unsorted continental deposits of early Pliocene age, which is indicated by the abundance of remains of *Pliohippus leidianus* and other typical vertebrates of this age buried in the same beds. These beds are considered by modern authorities to represent a flood plain environment of the Rocky Mountains piedmont. The remains of plants appear to be buried approximately at the place of their growth. They represent a rich and mostly herbaceous vegetation of semiarid prairies of early Pliocene time. The flora seems to indicate a somewhat warmer climate than that of to-day in the Great Plains region.

INTRODUCTION.

The described plant remains were collected by the writer in Wallace county, western Kansas, and in Yuma county, eastern Colorado, 1927-1928. Additional material was gathered in the autumn of 1929 and 1930 during exploration of Wallace county and other areas for the State Geological Survey of Kansas. The described material comes mostly from typical "mortar beds" of the Ogallala formation.¹

The High Plains Tertiary is famous for its rich fauna of mammals, many of which were typical grazing, cursorial animals with teeth apparently adapted for the grinding of hard herbs. Fossil remains of these herbs have never been recorded until recently, however. As early as 1884 John B. Hatcher made a large collection of Tertiary fruits in Phillips county, Kansas, and deposited them in the United States National Museum. It was not until 1928 that this and additional material from Kit Carson county, Colorado, were described by E. W. Berry, who recognized part of the remains as stones of *Celtis*, revising the opinion of Williston and Cockerell that identical fruits from other localities belong to *Tithymalus* of the Euphorbiaceæ. The other fruits were described by Berry as nutlets of an extinct species of *Lithospermum*,² the living species of which herbaceous plant are now widely scattered in temperate and tropical zones.

Two out of the three varieties of *Lithospermum fossilium* Berry were collected by the writer and are referred in the paper to a true

1. For the description of this formation see Wallace County Report, Elias, 1931.

2. Miss Betty Watt Brooks also contributed a description of one of these fruits in 1928 and 1929 and referred it to *Celtis*.

grass *Berriochloa* (n. gen.) related to *Hordeum* and others and to a new extinct genus *Biorbia* of the Borragnioideæ-Anchuseæ subfamily of the borragae family. Among the new fruits collected by the writer two represent protective covers of the common grasses, *Panicum* and *Stipa*, while others are nutlets of three new species of *Krynitzkia* of the borragae family and *Celtis* stones identical with those described by Cockerell and Berry.

ACKNOWLEDGMENTS.

The work of preparation and identification of the collected material was done at the State Geological Survey and the Department of Botany at the University of Kansas. The writer was encouraged in his research on the stratigraphy and paleontology of the Ogallala by the state geologist, Dr. Raymond C. Moore, and the assistant state geologist, Dr. K. K. Landes. Due to absence of literature on similar fossil forms³ a detailed comparison with living plants was the only way in which to undertake a better classification of the scant but beautifully preserved remains. Help in securing fruits of living herbs was rendered by Messrs. R. W. Chaney, F. H. Hillman, A. S. Hitchcock, W. H. Horr, C. E. Leighty, John Percival, J. B. Reeside, Jr., Eleanore M. Reid, P. A. Rydberg, H. C. Skeels, W. C. Stevens, and Emma E. Syrrine, to whom the writer wishes to extend sincere appreciation. Without their help, so cordially rendered, this work could not have been accomplished. The botanical part of the manuscript has been read by W. C. Stevens and the whole manuscript by R. C. Moore, to whom sincere thanks are due.

All sketches were made by the writer and represent actual and not generalized views of the fruits. The microphotographs were also prepared by the writer in the photo laboratory of the State Geological Survey.

PREVIOUS WORKS ON FOSSIL HERBS.

The literature on fossil grasses and other herbaceous angiosperms is not large and is much scattered. As far as known to the writer, the remains of these plants have never been a subject of special study, though incidental descriptions of fossils resembling modern grasses, rushes and other herbaceous angiosperms can be found in some papers dedicated to the remains of trees and shrubs of late Cretaceous Tertiary, and Quaternary times. The grasslike remains which have been found occasionally among the foliage of arboreal

3. Except the above referred pioneer work by Berry and Brooks.

types, which comprise the bulk of paleobotanical collections, usually consist of fragmentary linear leaves and herbaceous stems, the reference of which to this or that genus of living grasses is in most cases quite arbitrary. The determination of meadow grass (*Poa-cites*) from the Tertiary of Greenland by so able a paleobotanist as Heer⁴ was criticized by Gardner⁵ and other botanists, while the occurrence in the Tertiary of *Oryza*, *Panicum*, and other genera of typical prairie and pampas grasses, was also regarded as questionable. Engler⁶ concludes that only the presence of *Arundo*, *Phragmites* and perhaps of *Bambusa* was established on sufficient fossil evidence. Among the very best remains of fossil Gramineæ ever recorded are leaves and stems accompanied by well-preserved fruits from the "Lower Green River" formation of Colorado described by Lesquereux⁷ and referred by him to *Arundo*, the common reed grass of to-day.

In the last two decades several papers by Eleanore M. Reid, Jules Welch and other European authors have appeared, describing large collections of fossil seeds and fruits from the Pliocene and late Miocene of England and western Europe. Various types of Cyperaceæ were recognized, always associated with remains of mosses and with a considerable number of fruits of trees, shrubs and marsh and water herbaceous angiosperms.⁸ Not a single species resembling xerophytes of the grass and borragé families has been recognized among these remains, which is not surprising, as the whole assemblage indicates moist and not semiarid soil conditions.

The records of fossil herbs of the borragé family are also very scarce and the identifications are established mostly on questionable grounds. Fruits resembling some simple-sculptured nutlets of the borragé family were described by Heer and Ettingshausen from Middle European Miocene and named *Borraginities* and *Heliotropites* respectively. However, as Gürke⁹ justly remarks, no ring at the base of these fruits can be detected, and therefore they may belong to some other families as well. The remains of a little flower, from the same formation, which was named by Heer *Borraginities myosotiflorus*, resemble flowers of Borraginaceæ, indeed, but the exact relation of these scant remains to the family is far from being clear. The presence of Borraginaceæ in the Pleistocene is estab-

4. Heer, 1888, p. 67.

5. Gardner, 1886, p. 441.

6. In Hackel, 1887, p. 16.

7. Lesquereux, 1887, pp. 86-91.

8. Reid, 1920.

9. Gürke, 1897, p. 80.

lished on better grounds, fruits of *Myosotis cæspitosa* being known in the Pleistocene of Norfolk and nutlets of *Lithospermum* being recorded from the Pleistocene of Illinois.

Fruits and leaves of *Cordia* of the Borraginaceæ from the Tertiary of Colombia and other areas have been described by Berry and other authors, but the living species of *Cordia* are trees and shrubs, which are classified with the herbaceous plants of the borragé family on the ground of similarity of flowers and fruits.

It is probable that a diligent search through the Tertiary sediments of semiarid valley-flat environments in North America and elsewhere will disclose more remains of the types described in this paper, as they are far from rare in the Ogallala formation of Kansas and northeastern Colorado. Barbour, who described good specimens of Celtis stones from the Tertiary of western Nebraska, points out the great abundance and variety of "seeds and nuts" in the Tertiary, and especially in the Miocene, of Nebraska.¹⁰ It is true that they are inconspicuous and not as easy to find or to collect as the more ordinary assemblages of fossil plant remains.

OCCURRENCE.

The fossil fruits of the Ogallala were collected from poorly sorted grayish-pink semicemented grit and loam, which constitute the larger portion of the formation. The remains of fruits are scattered through the rocks and are small, being from two to three millimeters, or rarely up to one centimeter in length. They are snow-white and some are made of silica (probably opal) while others are composed of calcium carbonate. This is very unlike the ordinary occurrence of fossil plants (leaves and other parts) which are commonly collected in fine-grained sedimentary formations, such as fine sands, marls, volcanic ash and especially clayey rocks, and the color of which (chiefly leaves) in these rocks is usually darker than the matrix and often the remains are black, dark brown or otherwise darkly colored.

It is noteworthy that no fruits of any kind were found by the writer in fine sands, marls or clayey beds of the Ogallala though a special search through all available exposures of these beds was made. To the contrary the Ogallala fossil fruits in Wallace county and adjacent area are abundant in beds of grit and loam even where a considerable quantity of small pebbles is noticed in the material of these rocks. In spite of the presence in the rock of coarse grains

10. Barbour, 1925, pp. 87-88.

and even pebbles, the fossil fruits scattered among this coarse material usually show little abrasion of their delicate outer sculpture. This indicates that the fruits were not transported with debris from the Rocky Mountain area, but probably were buried in the sediments when their (sediments) transportation was nearly finished. It appears as if the fruits were dispersed by the aid of wind or animals, were scattered upon the ground, but for some reason, perhaps due to too large a loss of water, did not germinate and were mixed up and buried with the next portion of debris which mantled the prairie.

Dr. G. L. Knight, of the University of Kansas, has made an interesting discovery of fossil fruits in the Tertiary volcanic ash in Norton county, Kansas, and has kindly submitted the material to the writer for study. The flora consists of the following forms:

Celtis sp., probably *willistoni* (Cockerell) Berry.
Krynitzkia (*Cryptantha*) *coroniformis* Elias.

Dr. C. F. Taylor, superintendent of the State Sanatorium for Tuberculosis, generously donated through the writer to the University of Kansas remains of two large carapaces of a turtle which have been found in the same bed of volcanic ash. The remains seem to belong to *Testudo* (*Xerobites*) *farri* Hay, a late Tertiary turtle of Montana. The plant remains indicate Upper Pliocene age for the volcanic ash of Norton county. Knight considers that the ash of this locality was deposited in a small lake.¹¹

Fragments of small-diameter hollow stems (Pl. III, Fig. 8) were collected by the writer in a bed of greenish sand in the Ogallala formation directly below a thin bed of white limestone which contains diatoms and molds of gastropods. These stems are smooth and bear a faint and very regular longitudinal striation, and in some of the fragments very distinct joints are observed. Altogether they look like straw and can hardly belong to any other plants except true grasses.

Some peculiar stem and rootlike bodies made of calcium carbonate were observed in many "mortar beds" of the fossil herbs zone. These calcareous formations are white, cylindrical, slender, straight or somewhat irregularly curved, from a few millimeters to two or three centimeters wide. Usually they are nearly or quite erect or they are horizontal. They are scattered through some of the typical semicemented "mortar beds," but in some exposures they appear in great number at the top of escarpments and form a tangled labyrinth somewhat similar to the roots in ordinary sod, but much larger in

11. Knight, 1931, p. 166.

scale.¹² The stem and rootlike bodies do not have enough structural features to permit identification of any particular kind of plants. Nothing like joints has been observed in either the smaller or larger cylindrical bodies. These are invariably smooth or only gently and irregularly striated on the outside and are solid inside, usually with an irregular porosity in the middle. They can hardly belong to true grasses, but they may represent stems and roots of some other plants, the original anatomy of which has been nearly destroyed during fossilization. No foliagelike organs or fruits of any kind have ever been observed on or near these bodies, but often fruits occur in the nearest beds above or below in the section.

The fossil fruits usually appear in the form of hollow nutlets with thin and often fragile walls.¹³ Sometimes they are cracked and fall apart as soon as separated from the matrix, and often only fragments of the fruits can be seen in the rock.

Often the fruits are scattered in a bed, but occasionally they are crowded in a spot, sometimes forming a sort of a cluster. This is particularly the case with the *Celtis* stones, this mode of occurrence being suggestive of ejection by some animals that fed on them. Identical fruits have been found in the skull of a land turtle.¹⁴ Nutlets of *Biorbia rugosa* (= *Celtis microendocarpica* Brooks) have been found in the brain case of a skull of *Teleoceras fossiger* (Cope) from the Long Island quarry, Phillips county, Kansas.¹⁵

The foliage of a rich arboreous flora has been collected and reported by Cragin¹⁶ and later by Case¹⁷ from the Tertiary diatomaceous marl of Beaver county, Oklahoma, which borders the Kansas state line. These plant remains belong to the same age as the herbaceous flora described in this paper, or are of a slightly older age. In the small collection donated by E. C. Case to the United States National Museum Berry¹⁸ identified and described the following forms:

<i>Cyperacites</i> sp.	<i>Sapindus oklahomensis</i> Berry.
<i>Caulinites</i> sp.	<i>Rhamnus lesquereuxi</i> Berry.
<i>Salix</i> sp.	<i>Bumelia oklahomensis</i> Berry.
<i>Platanus aceroides</i> Goepfert.	<i>Diospyros brachysepala</i> Al. Braun.
<i>Gymnocladus casei</i> Berry.	

12. See Elias, 1931, Pl. XXVIII.

13. Only in one case internal molds of *Celtis* stones have been collected, and these were found in a thin streak of pinkish sandy limestone near the top of Ogallala.

14. See occurrence of *Tithymalus willistoni*-*Celtis willistoni* (Cockerell) Berry in Osborn, 1910, p. 342.

15. Brooks, 1928, p. 299.

16. Cragin, 1891, p. 29.

17. Case, 1894, p. 143.

18. Berry, 1918, pp. 627-636.

A richer collection of the same flora and from the same locality was deposited by Case at the University of Kansas and includes, besides some of the forms described by Berry, *Populus balsamoides* Goepfert (Pl. XXX, Fig. 6, this paper) and a variety of species of *Betula*, *Populus*, *Salix* and other arboreous vegetation now being studied by the writer. This mesophytic vegetation is regarded by Berry as of upper Miocene age, but he adds that "there is no conclusive evidence in existence that such a valley flora may not have continued in this region during the early Pliocene, there being no considerable American Pliocene floras, except that of the Gulf coast, with which to make comparisons."

The writer found one fragment of *Populus* cf. *balsamoides* Geopfert (Pl. XXX, Figs. 7a, 7b) in the diatomaceous marl of undoubted upper Pliocene age at the Marshall ranch in Wallace county,¹⁹ and an effort to collect more flora from these beds will be made by him.²⁰ The above referred fragment of a leaf of poplar was found in diatomaceous marl a few feet above the sand in which a rich fauna of vertebrates, chiefly mammals (*Pliohippus leidianus* and others), has been collected by H. T. Martin and referred to the lower Pliocene. This is an interesting bit of evidence that a mesophytic valley-flora existed in a few places of the Great Plains in Lower Pliocene time. By far the greatest part of the area of the Great Plains was, however, covered by a different, xerophytic and chiefly herbaceous, vegetation, numerous remains of which, mostly in the form of fruits as mentioned above, are very common in the regular unsorted arenaceous deposits of the Lower Pliocene. These beds are considered by modern authorities to represent a flood plain environment of the Rocky Mountains piedmont. The typical prairie and savannah flora which covered the greatest area of the piedmont in early Pliocene time included the following forms:

Panicum elegans
Stipa kansasensis
Berriochloa glabra
B. (?) aristata
Biorbia rugosa

Krynitzkia coroniformis
K. auriculata
K. chaneyi
Celtis willistoni

This assemblage seems to indicate a somewhat warmer climate than that of to-day in the Great Plains region.

19. Elias, 1931.

20. C. W. Hibbard, who assisted the late H. T. Martin in excavation of vertebrates at the Marshall ranch locality, related to the writer that he uncovered some impressions of dicotyledon leaves in diatomaceous marl, but they disintegrated by the time he came to collect them.

DESCRIPTION OF SPECIES.

PHYLUM SPERMATOPHYTA

CLASS ANGIOSPERMÆ.—SUBCLASS MONOCOTYLEDONÆ.—
ORDER GLUMIFLORÆ.

FAMILY GRAMINEÆ (GRASSES).

Annual or perennial herbaceous (rarely woody)²¹ plants, with usually hollow cylindrical and jointed stems; usually linear, parallel-veined leaves; flowers without any distinct perianth, mostly hermaphrodite (bisexual), arranged in panicles, racemes or spikes; each flower provided with green bracts (glumes); fruit is the characteristic caryopsis or grain.

To this family are referred three types of fruits from the Ogallala formation described below. No stems or leaves have been found in direct connection with these fruits, and, therefore, the herbaceous nature of the plants which bore the fruits cannot be directly demonstrated. However, all the living species of Gramineæ which bear similar types of fruits are typical herbs.²²

The fossil fruits consist of fertile glumes or lemmas and pales or paleas only, the starchy caryopsis being not preserved. Rarely inside of the glumes can be seen a thin semitransparent film which most probably corresponds to the pericarp of a caryopsis.

The protective cover of a grain of a grass is but a small integral part of the whole plant, but it is an important part from a taxonomic point of view. The characters presented by the spikelets or inflorescence are usually employed in defining the genera of grasses, and, according to A. S. Hitchcock, it is the protective fertile glume or lemma, "which is of great importance in classification, its shape, texture and nerving being uniform within definite limits in any given genus."²³

The fruits of grasses from the Ogallala formation are so well preserved that not only the characteristic shape, but also the keels or nerves and all minute details of texture can be readily observed and examined under proper magnification. Due to perfect preservation of these vital portions of the fossil grasses, their comparative study with the living forms and their classification can be made with a considerable degree of accuracy.

21. Tropical Bambuseæ are tree size and have woody stems.

22. Fragments of stems indistinguishable from those of living grasses have been collected in some beds, as referred above (Pl. XXX, Fig. 8). This is another, though indirect evidence that the fruits of Gramineæ type which were found in other beds of Ogallala were of herb size.

23. Hitchcock, 1914, p. 124.

Subfamily PANICOIDEÆ.—Tribe PANICEÆ.

Genus *Panicum* Linnæus.

Panicum (sensu lata) *elegans* Elias n. sp.

(Pl. XXVIII, Figs. 2a, 2b, 2c and 4.)

Only the protective cover of caryopsis is known. Lemma and palea smooth, shiny, connected together to form protective cover of grain. Length of fruit, $2\frac{1}{2}$ mm., width across lemma, $1\frac{3}{4}$ mm.; thickness of fruit, $1\frac{1}{4}$ mm. Apex cuspidate with two more smaller cusps, one on each side of the middle point, which is most prominent. These three points are somewhat continued down the lemma and form gradually flattened ridges, which correspond to three principal veins of the lemma (Fig. 2a-A).

Lemma much more inflated than palea. Palea with two distinct keels (nerves) which are not concealed by the margins of the overlapping lemma. At the base of the lemma is a lunar elevation (Fig. 2a-B). Similar elevations on the protective covers of living *Panicum* and allied genera are impressions of the embryo, the radicle protruding through these at germination.²⁴ Scar of attachment nearly flat, inclined to the side of the palea, trilobate on the opposite side (Fig. 2c-D). According to examination of the writer's sketch by A. S. Hitchcock "the shape of the scar is likely to be characteristic of the species."²⁵ In the middle of the scar is a little hole which, according to Hitchcock, is a scar of the fibrovascular bundle (Fig. 1c-E). The remains are composed of silica, the walls of lemma and palea being 0.035 mm. thick.

Faint subparallel striation can be seen on both lemma and palea under magnification. Microphotographs of corresponding portions of the palea of the fossil form and of the living *Panicum angustifolium* were made for a comparison of microstructure (Pl. XXVIII, Figs. 4 and 3). Both show subparallel rows of cells of the epidermis. The distance between two striæ on the palea of *P. elegans* is 0.034 mm., and on the palea of *P. angustifolia* 0.029 mm. These figures belong to the middle portions of the paleas. The striæ show a confluence in both apical and basal directions. Regularly spaced cross connections between the striæ can be seen on both fossil and living forms.

The fossil fruit is indeed strikingly similar to the protective cover of the caryopsis of living species of *Panicum* and allied genera:

24. Hitchcock and Chase, 1910, p. 18.

25. Personal communication to the writer.

Chaetochloa (*Setaria*), *Echinochloa*, *Paspalum*, *Milium* and others. The palea of the fossil fruit is, however, considerably more inflated than in most of the similar fruits of living species. Due to this the two keels of the palea are seen along their whole length in the fossil fruit, while in the majority of living species the keels of the palea are hidden by the edges of the overlapping lemma.

The appearance of the exposed keels on the palea of some specimens of *Chaetochloa italica* was pointed out by Hitchcock,²⁶ and a similar appearance of two keels of the palea can be noticed on some species of *Panicum* also. According to statement by Hillman, of the United States Department of Agriculture Seed Laboratory, the presence of ridges at the tip of the lemma indicate *Setaria*, but on the other hand "he does not know of any species of that genus that has a scar of the shape of the fossil fruits."²⁷ This scar of attachment resembles more the scars of the living species of *Panicum*. The general form of the fossil fruit also resembles very much the fruits of *Panicum fasciculatum* (Pl. XXVIII, Fig. 1) and of some other species of the Geminata group,²⁸ but all the fruits of this group have a rugose surface, while the fossil fruit is perfectly smooth. This smoothness is undoubtedly original, and not the result of abrasion, because all sharp cusps and edges of the thin protective cover are perfectly preserved.

All in all, the fossil form combines features of both *Panicum* and *Setaria* and is certainly closely related to these genera. In the time of Linnæus and earlier botanists the name *Panicum* was applied to *Chaetochloa italica* and many other species now referred to different genera and subgenera, allied to *Panicum* s.s. Though the advisability of recognition of *Chaetochloa* (*Setaria*) as a separate genus of Paniceæ is now shared by most of botanists, the Setarias still "might, under a broad conception of the genus *Panicum*, be referred to it."²⁹ It appears to be convenient, therefore, to describe the fossil form under the name *Panicum* with an understanding that this generic name is used in a broad sense. It is possible, however, that the fossil form belongs to a new genus or subgenus of Paniceæ, either extinct or not yet found or recognized among the living species of the tribe.

The living Paniceæ are largely tropical and subtropical grasses, few genera belonging to temperate zones. *Panicum* occurs in all

26. Hitchcock, 1914, p. 195.

27. Personal communication by A. S. Hitchcock to the writer.

28. Hitchcock and Chase, 1910.

29. Scribner and Merrill, 1900, p. 6.

warm countries, but together with *Paspalum* is a characteristic South American savanna grass.

OCCURRENCE OF FOSSIL FRUITS. Found in sec. 21, T. 14 S., R. 39 W., Wallace county, Kansas, in "mortar beds" of the Ogallala formation, Tertiary, about 40 feet below capping pink algal limestone. (See writer's report on the Geology of Wallace county, Bulletin 18, Kansas Geological Survey.)

Subfamily POACOIDEÆ.—Tribe AGROSTIDEÆ.

Genus *Stipa* Linnæus.

CHARACTER OF FERTILE FLORET. Rachilla articulate above the empty glumes and produced below the flowering glume into a strong, bearded, obconical and sharp-pointed callus. Lemma narrow, subcoriaceous, closely rolled around the flower and usually shorter palea, terminating in a twisted and geniculate, simple awn which is articulate with its apex. Grain closely enveloped by the hardened lemma.³⁰

Stipa kansasensis Elias n. sp.

(Pl. XXVIII, Figs. 5a, 5b, 6, 7, 8, 9 and 12.)

Only the fertile glume (lemma) preserved, cylindrical, 10 to 11 mm. long and 1.8 to 2.5 mm. wide. The surface of the lemma is covered with tubercles from the apex to the middle or beyond. It seems that along some portions of the rolled lemma tuberculation descends down nearly or quite to the base (Pl. XXVIII, Fig. 9). The inner volution of the lemma seems to be tuberculate to the base, while the outer volution is smooth at the base and narrows gradually into the conical hairy callus (Pl. XXVIII, Figs. 6 and 9). The hairs which surround the callus are exceedingly thin and fragile, being as fine as in the living *Stipa*. At the top of the fossil form there is a distinct bottle-necklike contraction (Pl. XXVIII, Figs. 7 and 8) forming a joint to which apparently an awn was connected. This joint is surrounded by short bristles very similar to those on some living species of *Stipa*. (Compare upper portions of microphotographs of *S. kansasensis* and *S. reesiana*, Pl. XXVIII, Figs. 12 and 11.)

The presence of a joint at the apex of the cylindrical or cigar-shaped fertile glume distinguishes the fruits of living *Stipa* (Pl. XXVIII, Fig. 10) from those of *Andropogon*, *Aristida* and *Mühlen-*

³⁰. Modified after Scribner—1900, p. 62.

bergia, which also have a subcylindrical lemma, but one that narrows gradually to the apex, in some cases is covered with tubercles and shows a hairy callus at the base. The lemmas of these fruits gradually pass into an awn without forming a joint.

Examination of the surface of the fossil form (Pl. XXVIII, Fig. 12) reveals a microstructure strictly similar to that of living species of *Stipa* (Pl. XXVIII, Fig. 11). The surface is covered with comparatively prominent tubercles which are not arranged in regular rows but are rather irregularly though densely spaced. The smooth surface between the tubercles as well as outside the tuberculate portions of the lemma shows faint striation corresponding to the rows of cells of the epidermis. On meeting a tubercle the striæ expand slightly, the marginal ones bending around the tubercle. The absence or presence of tubercles over the whole or only a part of the surface of the lemma, the size of the tubercles and the density of striation seem to be of specific value for species of *Stipa*. In the fossil form about 59 striæ can be counted in 1 mm. on the tuberculate portions of the lemma, while on the surface bare of tubercles there are up to 77 striæ in 1 mm. The diameter of the tubercles is 0.06 to 0.07 mm., one tubercle covering four rows of cells. The height of the tubercles is about 0.04 mm. above the striated surface. The thickness of the lemma, which is composed of silica, is about 0.035 mm., not counting the tubercles.

For comparison the corresponding structures of two living species of *Stipa* were measured. *Stipa neesiana* Trin. (Figs. 10 and 11) shows about 55 striæ in 1 mm. The tubercles are only a fraction wider than a row of cells, being about 0.02 mm. in diameter. They are confined to the apical portion of the lemma, about five-sixths of the surface being smooth and marked only with striations. *Stipa avenacea* L. has about 110 striæ in 1 mm. The tubercles average 0.035 mm. in diameter, each covering about 4 rows of cells. All the surface is tuberculate except the base, where tubercles gradually decrease in prominence.

The living *Stipa* belongs to tropical and temperate zones, being chiefly prairie, steppe and savanna grasses.

OCCURRENCE OF FOSSIL FRUITS. Found in the middle of the western border of sec. 4, T. 12 S., R. 42 W., Wallace county, Kansas, in "mortar beds" about 60 feet above the base of the Ogallala formation.

Tribe HORDEAE?

Genus *Berriochloa* Elias n. gen.

The species for which this new generic name is proposed was originally described by E. W. Berry under the name *Lithospermum fossilium* var. *glabrum*. The construction of the fossil fruits, as the writer's study reveals, is, however, of the type observed on the living grasses only. The characteristic features of the fruits of the genus are as follows:

Fruit consists of two glumes, the larger, the fertile glume or lemma, overlapping the smaller glume or pale or palea. The two glumes combine to form what is known as protective cover of caryopsis (grain). The latter is not preserved in a state of fossilization except its thin pericarp. The protective cover is provided with an awn at the apex and with a somewhat elongated scar of attachment at the base. The fruit is round in cross section, but the presence of five longitudinal ridges on lemma tends to make the cross section slightly subangular. Very rarely two faint longitudinal ridges can be observed in palea. It is appropriate to note that the palea of living grasses is always two-nerved.

In better preserved specimens fine and regular longitudinal striation can be seen on both lemma and palea. This is again a very typical feature for the protective cover of the grasses. In addition to longitudinal striation a more prominent but irregular transverse wrinkling is observable on all or nearly all fossil fruits in question. A similar transverse wrinkling exists on the protective covers of many living species of *Panicum* and of some other grasses.

The fossil fruits resemble in many respects the protective cover of cultivated barley (*Hordeum sativum*). They are of nearly the same size, are provided with an awn and their lemmas are five-nerved, a feature generally typical for genus *Hordeum*.³¹ On the other hand the fossil fruits are much less angular in shape than the fruits of all living *Hordeae* and are provided with a comparatively narrow and elongated, bottle-necklike scar of attachment, a feature uncommon in *Hordeae* or in other grasses of to-day. This distinction warrants separation of the fossil fruits under a new generic name.

The classification of *glabrum* fruits with living grasses was one time criticized by Mrs. Eleanore M. Reid, with whom the writer conferred on the matter. However, after having seen the best-preserved specimens of the writer's collection sent to her, on which

31. Scribner, 1900, p. 165.

the details of microstructure are observable, Mrs. Reid agreed with the writer in his referring of *glabrum* to true grasses.

The writer acknowledges, also, the suggestion made by Dr. John Percival, to whom he has sent a sketch of *glabrum*, that this fruit can hardly be classified with *Hordeum*, but is possibly a *Panicum*. The communication with Mrs. Reid and Mr. Percival clarified the matter of proper classification of *glabrum* considerably and induced the final decision of the writer to give the fruits a new generic name. The genus is named after Prof. E. W. Berry.

Berriochloa glabra (Berry) Elias n. comb.

(Pl. XXVIII, Figs. 13a, 13b, 13c, 14, 15 and 16; Pl. XXIX, Figs. 1a, 1b and 1c.)

1928. *Lithospermum fossilium* var. *glabrum* Berry. Proc. U. S. Nat. Mus., Vol. 78, Art. 18, p. 2; Pl. 1, Figs. 11, 12 and 13.

Only protective cover and pericarp of caryopsis known.

Lemma and palea smooth, shiny, in state of fossilization usually firmly connected together and making an asymmetrically fusiform fruit. The larger specimens (Pl. XXIX, Fig. 1a, b, c), which are most abundant, are up to 7 mm. long (without awn) and up to 3.2 mm. wide, but much smaller individuals (Pl. XXVIII, Fig. 13a, b, c) are frequently found together with larger types. The lemma of larger specimens is distinctly five-keeled. The middle keel or nerve is most prominent and runs from the base to the very apex of the lemma, where it passes into an awn, only a small basal portion of which is preserved (Pl. XXIX, Fig. 1b-D). The back of the lemma with the prominent middle keel (Pl. XXIX, Fig. 1a-B) attached to it is shaped much like a boat. The lateral nerves (Fig. 1a-B) are about two times less prominent than the middle keel and are almost indistinct near the apex of the lemma. Two lateral nerves can be seen on one photograph³² of *Lithospermum fossilium* var. *glabrum* Berry, which helps to identify our fossil with this type. On the smaller specimens of *B. glabra* (Pl. XXVIII, Fig. 13a, b, c of this paper and Fig. 11, Berry, 1928) only the middle keel is quite distinct, the lateral nerves being observed only as small ridges at the narrow base of the lemma (Pl. XXVIII, Figs. 13b and 13c).

The two nerves of the palea can be observed, also, on the larger types only (Pl. XXIX, Fig. 1b-D), being even there quite faint. A very gentle marginal bend on both sides of the palea, outside of the nerves, can be seen.

The smaller specimens are commonly found together with larger

32. Berry, 1928, Pl. 1, fig. 12.

types and, being not as fragile as the larger ones, the complete specimens of smaller types are predominant in the collection of the writer. The smaller types do not seem to represent younger stages of large fruits, but are more likely dwarfed mature fruits of the same species, unless they represent a distinct species of the same genus. They are as thick-walled as the larger specimens and have the same type of structure except that the keels are not as prominent. Also they appear to be more plump, being nearly as wide as the larger forms, but much shorter. The intermediate forms between larger and smaller specimens seem to exist. Possibly the smaller fruits occupied the apical portion of a spike and have been undernourished, being otherwise normal fertile florets. A similar arrangement of gradually diminishing fruits toward the apex of the spike is observed in some living grasses (compare, for instance, *Bouteloua*). The comparatively large per cent of smaller fruits seems to indicate rather short spikes with small number of florets rapidly decreasing in size toward the apex. If the future study should prove that the smaller fruits belong to a different species, the name *glabrum* is preferable to retain for the larger form, figures 12 and 13 (Berry, 1928) and figures 1a, 1b and 1c, Plate XXIX of this paper.

The microscopical examination of the remains reveals the following features (Pl. XXVIII, Figs. 15 and 16). The surface of the lemma and palea are smooth with occasionally observable fine and regular longitudinal striation (Pl. XXVIII, Fig. 15), about 35 to 40 striæ to 1 mm. on larger specimens and 40 to 45 striæ per mm. on smaller specimens; besides this, short transverse wrinkles can be nearly always observed over the whole surface of the fruits (Pl. XXVIII, Fig. 16). When the outer epidermis exfoliates the internal structure of lemma becomes visible. It consists of longitudinal ridges with cross connections in between. These ridges seem to correspond to the gentle striæ of the external surface (Pl. XXVIII, Fig. 15).

The fruits are hollow and are made of silica. The thickness of the lemma varies from 0.12 to 0.16 mm. within the same specimen. Inside of one broken specimen a very thin semitransparent film was observed—an empty wrinkled baglike envelope which is probably the pericarp of the caryopsis. The structure of the film is shown on pl. XXVIII, fig. 14. The black portions correspond to transparent tissue with less transparent white ridges between.

DISTRIBUTION OF FOSSIL FRUITS. Specimens are found at several localities in Wallace county, Kansas. (1) South side of Goose creek,

one-half mile west of the state line, in a bed about 60 feet above the base of the Ogallala. (2) In the southeast quarter of sec. 4, T. 12 S., R. 41 W., in beds 40 to 60 feet above the base of the Ogallala. (3) In the southeast quarter of sec. 7, T. 14 S., R. 38 W., in a bed 30 feet below algal limestone and 55 feet above the base of the Ogallala. The species is also observed in other parts of Wallace county in the middle portion of the Ogallala. The specimens described by E. W. Berry³³ were collected in 1884 by J. B. Hatcher from the "Loup Fork formation" of Phillips county, Kansas, which is Ogallala.

Berriochloa? aristata (Berry) Elias n. comb.

1928. *Lithospermum fossilium* var. *aristatum* Berry: Proc. U. S. Nat'l Mus., Vol. 73, Art. 18, p. 2; Pl. 1, Fig. 14.

This fruit described and figured by Berry has many features in common with his *L. fossilium* var. *glabrum*, now considered by the writer to represent a new genus *Berriochloa*. According to Berry *B. aristata* differs from *B. glabra* in being more slender and elongated, more symmetrical in side view and nearly circular in transverse section. The base is much like that of *B. glabra*, while "the apex is produced as an attenuating spine which may be two-thirds as long as the inflated portion." The spine or awn of *B. aristata* is certainly much more prominent than that of the other form and is about 1 mm. in width at the base, or two times wider than the awn of large specimens of *B. glabra*.³⁴ The keel of the *B. aristata* fruit is less elevated than that of *B. glabra*; the length of its fruit, exclusive of the awn, ranging from 5 to 10 mm. and the diameter from 1.5 to 3 mm.³⁵

The species *aristata* described by Berry was not found by the writer in the Ogallala beds of Wallace county and adjacent area. The photograph by Berry shows only the dorsal view of the fruit, and therefore the presence or absence of lateral ridges on what appears to be a lemma, and the presence or absence of an inclosed palea cannot be detected. The general similarity of the form with the fruits of *Berriochloa glabra*, the base, middle keel and awn of the two species being much alike, suggests a reference of the species *aristata*, also to genus *Berriochloa*. However, this conclusion cannot be proved without additional examination of the type material.

OCCURRENCE. "Loup Fork" (Ogallala) formation of Phillips county, Kansas, together with *Berriochloa glabra*.

33. Berry, 1928.

34. Measured by the writer on the photograph by Berry.

35. After Berry, 1928, p. 2.

SUBCLASS DICOTYLEDONÆ.—SERIES GAMOPETALÆ.—
ORDER TUBIFLORÆ.

FAMILY BORRAGINACEÆ.

Specialized dicotyledons with an elongated corolla tube bearing the stamens, the ovary being superior. Fruit mostly of four one-seeded nutlets.

Subfamily BORRAGINOIDEÆ-ANCHUSEÆ Gürke.

Genus *Biorbia* Elias n. gen.

Only nutlets known. Nutlets keeled, asymmetrically inflated, being more convex on the dorsal side. Surface rugose covered with ridges arranged in honeycomblike net. Dorsal keel turns to right or to left, spoiling the apparent bilateral symmetry of the nutlets. Probably four nutlets, two right and two left ones, constituted a complete fruit. Scar of attachment round, comparatively small and elevated, consists of double ring and an elaiosome in the center. Distinct canal in the ventral part of the scar.

Geno-type: *Lithospermum fossilium* var. *rugosum* Berry. U. S. National Museum.

Biorbia rugosa (Berry) Elias n. comb.

(Pl. XXIX, Figs. 2a, 2b, 2c, 2d and 2e.)

1928. *Lithospermum fossilium* var. *rugosum*, Berry, U. S. Nat. Mus., Vol. 73, Art. 13; Pl. 1, Figs. 1-10.

1928. *Celtis microendocarpica*, Brooks, Annals Carnegie Mus., Vol. XVIII, p. 297; Pl. XVIII, Fig. 1.

1929. *Celtis microendocarpica* Brooks, Annals Carnegie Mus., Vol. XIX, p. 135; Pl. IV, Figs. 1-9.

On account of the existing difference in opinions as to classification of these fossil fruits, the writer made a detailed study of their anatomy and an extensive survey among those living plants which could be their possible relatives. The fossil fruits have been described by E. W. Berry and by Betty Watt Brooks, who referred them to *Lithospermum* and to *Celtis*, respectively. The writer agrees with Berry that the nutlets in question belong to the borragace family, of which *Lithospermum* is one of the most common among the native American representatives. The writer concludes, however, that the fossil nutlets do not belong to *Lithospermum*, but must be classified with the Borragninoideæ-Anchuseæ group of Gürke, none of the genera of which group are native to the New World.

None of the living species of *Lithospermum* are known to have a

sculpture comparable to the honeycomblike net of ridges which covers the surface of the fossil nutlets. The surface of the nutlets of living *Lithospermum* is usually smooth and in some species (*L. linearifolium*) it is in addition somewhat pitted. Other species have somewhat rugose surface, but no ridges forming a net have ever been observed on the nutlets of this genus. This difference between the living *Lithospermum* and the fossil species *rugosa* was also emphasized by Miss Brooks (1929, p. 136). The nutlets of *Lithospermum* are, furthermore, fairly symmetrical about a plane which divides them into two equal halves, while the fossil nutlets are asymmetrical, and right and left individuals can be recognized among them. Finally, nutlets of *Lithospermum* have somewhat different construction of scars of attachment, which are flat (in rugose *L. arvense*) or, when elevated and concave (in *L. linearifolium* and others), do not develop wide ring and retain a flat bottom. No elaiosome of any prominence can be detected on these living nutlets. Contrary to this, nutlets of *rugosa* have a prominent elaiosome in the center of the double ring of the scar.

The writer can agree with Miss Brooks that the outer sculpture of the fossil nutlets in question makes them unlike the nutlets of *Lithospermum*; nevertheless he does not consider it possible to classify them with the living *Celtis* stones, in spite of the general resemblance of the netlike rugose character of the exterior.

The stones of *Celtis* have a very simple scar of attachment which is a mere small pit on the end opposite the somewhat cuspidate apex. The scar of *B. rugosa*, to the contrary, is very complicate, as described below. This important difference in the construction of the scar alone does not permit classification of the fossil fruits in question with *Celtis*. Besides the stones of all living and extinct species of *Celtis* known to the writer are fairly symmetrical about a plane that connects the apex and the scar, and, therefore, no right or left individual can be recognized among these stones. There is another important morphologic difference between the fruits in question, and this is the position of an opening which leads inside of them. The nutlets of *B. rugosa* have a canal at the ventral side of the scar of attachment, while the stones of both living and fossil *Celtis* have a canal at the cuspidate apex, but none at the scar.

In order to elaborate the comparison of the fossil fruits with their living relatives the writer secured a collection of fruits of the living European species of Borragninoidea-Anchusea group through the courteous help of Eleanor M. Reid, Emma E. Syrrine and H. C.

Skeels, and he also consulted the main literature on these living forms. All American species of the Borrage family which in some way resemble the fossil fruits in question were also comparatively studied. The following is a detailed description of the fossil nutlets and their comparison with some existing plants, among which their nearest living relatives must be sought.

Fossilized nutlets 2 to 3 mm. in length and 1.75 to 2.5 mm. in width, asymmetrically inflated, the dorsal side being much more convex than the ventral. On the ventral side (Pl. XXIX, Fig. 2a) a keel extends from a cuspidate apex nearly or quite to the scar of attachment. The keel is continued over the apex on the dorsal side (Pl. XXIX, Figs. 2b and 2c), but here it turns either to right or to left and makes a lateral connection with the scar of attachment, unless lost on the way. This, together with a moderate transverse twist (Pl. XXIX, Fig. 2d) of the whole nutlet, spoils its apparent bilateral symmetry. According to the right or left turn of the keel, which is accompanied by a corresponding twist, right and left nutlets can be recognized. The figured nutlet (Pl. XXIX, Figs. 2a, b, c, d) is a right one, and so are the nutlets of figure 8 and probably of figure 7, plate I, of Berry's paper. The nutlet in the right upper corner of figure 1, plate XVII, of Brooks' paper is a right one, while the lower central nutlet of the same figure is a left individual.

The writer observed about an equal number of right and left nutlets in his extensive collections.

The surface of the nutlets is rugose. They are covered with narrow and, when perfectly preserved, much elevated ridges forming an irregular honeycomblike structure. The surface of the ridges and of the space between is shiny. The shiny areas between the ridges are somewhat knobby, and besides the writer observed on one of the best-preserved specimens a very fine cellular structure, which is shown on the photograph (Pl. XXIX, Fig. 7). A similar structure can be observed under magnification on the nutlets of the living *Anchusa*, *Lycopsis*, *Nonnea* and *Symphytum*, with which genera the fossil nutlets are compared by the writer (Pl. XXIX, Fig. 6). This cellular structure observable on the surface of the nutlets is a termination of prismatic structure of the shell of nutlets. In a fresh break of both living and fossil nutlets this prismatic or fibrous structure can be readily observed. There are about 40 fibers in a row per 1 mm. in *B. rugosa* and about 45 fibers in a row per 1 mm. in *Anchusa officinalis* and *A. capensis* nutlets.

The scar of attachment of *B. rugosa* is round and elevated, being

about as high above the surface of a nutlet as the ridges of the exterior. The diameter of the scar is nearly one-half of the shorter diameter of a nutlet. The scar consists of a double ring, inside of which is a prominent central elevation apparently corresponding to elaiosome of the living Borrageoideæ-Anchuseæ. The outer of the double ring is comparatively thin and has a smooth or slightly wavy edge. The inner ring is inserted, as if it were in a cone-in-cone position, into the outer ring of the scar. The edge of the inner ring is irregularly dentate, which may be explained as a disrupted tissue. A short and ventrally curved delicate pipe is ordinarily observed ventrally between the outer and inner rings of the scar. When this pipe is not preserved a corresponding thin canal leading inside of a nutlet can be seen. If the fossil nutlets have been arranged to form a fruit, in about the same fashion as the nutlets of their living relatives of the Borrageoideæ-Anchuseæ group do, the crooked pipes must have occupied a central position in the fruit and were turned from the bottom up (see sketch, Pl. XXIX, Fig. 3). If this reconstruction is correct, the pipes must represent basal portions of styles, one style for each ovule. These styles might or might not have been united in the middle of the flower.

The nutlets are hollow, the thickness of the walls exclusive of the ridges being about .08 mm. The ridges when well preserved are about .1 mm. high above the interspaces, but usually they are less prominent. The nutlets seem to be made of silica and are comparatively strong. Due to this fact complete nuts are rather common and usually they do not break on being separated from the inclosing rock. Mrs. Reid writes: "I think you are quite right in putting this species [*rugosa*] into the subsection Borrageoideæ-Anchuseæ, because of its evident mode of germination, as well as the character of its sculpture. In this section the flat adjacent faces of the nutlets form the germination valves, which are rimmed round by a raised edge. If you will sow a seedman's packet of *Anchusa* you will see them germinate . . . the flat face opening like a little door."³⁶ This flat face of a nutlet is that seen on figure 2b (*Biorbia rugosa*) and on figure 5b, plate XXIX. Among several hundreds of specimens of the fossil *Biorbia* in the writer's collection he observed one nutlet with a cracked-off flat face in a fashion as described by Mrs. Reid for germinating nutlets of *Anchusa*. All the other numerous nutlets of *Biorbia* do not show any traces of splitting in this or any other fashion, which apparently indicates that for some reason

36. From a personal letter to the writer of February 16, 1931.

(probably on account of lack of moisture) they never started to germinate at all.

The outer sculpture of the fossil nutlets is occasionally more or less obliterated as is likewise the scar of attachment. The cuspidate apex in such cases is also more or less rounded. Berry writes that this variation in sculpture of the nutlets which he studied "is not due to abrasion before or after fossilization . . . since it would have been equally effective on the apical point or the delicate rim of the hilum,³⁷ which is not the case."³⁸

It seems possible that some nutlets could have been originally smoother than the others. Some living species of the borrago family, for instance *Cryptantha crassisepala*, have heterogeneous nutlets, one smooth and three rugose nutlets constituting a four-nutlet fruit. Other species of the family have mature nutlets commonly covered with papillæ, but sometimes they retain their smoothness at maturity.³⁹

The peculiar honeycomblike outer sculpture of the fossil nutlets is one of their most characteristic features. Among the living representatives of the Borrago family *Anchusa*, *Lycopsis*, *Nonnea* and some species of *Symphytum* of Borraginoideæ-Anchuseæ and *Echinosperrum greenii* Gray (probably of Borraginoideæ-Eritrichieæ) seem to be the only forms which have a similar sculpture of nutlets. However, the nutlets of American *Echinosperrum greenii* are provided with prominent prickles, one at each knot of the honeycomb net of ridges, while no traces of such prickles can be detected on the best-preserved fossil nutlets. *E. greenii* has furthermore an entirely different scar of attachment, which is in form of a split along the ventral edge of a nutlet. Finally these living nutlets are fairly symmetrical about a plane and no right and left nutlets can be recognized. The nutlets of the living native European and Mediterranean species of *Anchusa*, *Lycopsis*, *Nonnea* and *Symphytum* possess not only a honeycomblike sculpture of nutlets, comparable to that of *Biorbia rugosa*, but they have also the same type of scar of attachment, which is somewhat asymmetrically (ventrally) located, and is provided with a prominent ring and an elaiosome. The asymmetry of these living nutlets is also of the same type as is observed on the fossil nutlets, and right and left nutlets can be easily recognized. On plate XXIX, figures 5a 5b and 5c, different views of a

37. Scar of attachment, as interpreted by the writer.

38. Berry, 1928, p. 1.

39. Gray, 1885, p. 275.

right nutlet of *Anchusa officinalis* Linneus are shown. Plate XXIX, figure 4, shows the arrangement of these nutlets to form a complete four-nutlet fruit, which consists of two right and two left nutlets alternately spaced around the center.

In spite of the above outlined similarity of the nutlets of *Anchusa*, *Lycopsis*, *Nonnea* and *Symphytum* to the fossil nutlets in question, the latter cannot be referred to any of these four living genera on account of the following differences:

1. The scar of attachment of the fossil nutlets is provided with a double ring while all the above-named living forms have a single ring.
2. The fossil nutlets have a ventral canal at the scar, a feature not observable on the nutlets of *Anchusa*, *Lycopsis*, *Nonnea* or *Symphytum*.

It is interesting that a ventral canal between the elaiosome and the ring of the scar is indicated on a sketch of a nutlet of *Pulmonaria officinalis*,⁴⁰ but *Pulmonaria* differs from *B. rugosa* in having nutlets perfectly smooth and shiny, or smooth and covered with short hairs. Furthermore, the nutlets of this living genus of Borraginoideæ-Anchuseæ are perfectly symmetrical about a central plane and among them no right and left nutlets can be recognized; their scar consists of only one ring.

All in all, it appears as if the fossil nutlets combine various features observable on the nutlets of *Anchusa*, *Lycopsis*, *Nonnea*, *Symphytum* and *Pulmonaria*, and besides have a special feature of their own—a double ring of the scar. On account of this they are given a new generic name, *Biorbia*.

The Borrago family is widely distributed throughout the temperate and tropical parts of the world, the species of *Anchusa*, *Lycopsis*, *Nonnea*, *Symphytum*, *Pulmonaria* and allied genera being exclusive European and Mediterranean forms.

OCURRENCE OF FOSSIL FRUITS. Next to *Celtis* stones this is the most common species among fruits from the Ogallala beds in Kansas and Colorado. The writer collected nutlets of the species wherever the other herbaceous species have been found. It was not found by him, however, in the basal and topmost portions of Ogallala, where *Celtis* stones alone were collected.

40. Hegy, Illustrated flora von mittel Europe, 5 Band, 3 Teil, Fig. 8155, on page 2218.

Subfamily BORRAGINOIDEÆ-ERITRICHIEÆ Gürke.

Genus *Krynitzkia* Fisher and Meyer.

Krynitzkia (Cryptantha) coroniformis Elias n. sp.

(Pl. XXX, Figs. 1a, 1b, 1c and 1d.)

Only nutlets known. They are erect, ovate with acute apex, 1.5 longer than wide, rounded on the back and on the margins; coroniform in appearance from below, hence the specific name; apparently attached laterally to receptacle; the scar of attachment broad and trilobate at the base, passing into a gradually narrowing groove toward the apex. Some specimens have the back and sides covered with prominent prickles, while others are perfectly smooth and shiny. In the locality at Beecher Island, Colo., the smooth specimens outnumber considerably the tuberculate ones, while in the volcanic ash of Norton county, Kansas, only tuberculate nutlets occur. The presence or absence of tubercles seems to be the only difference between the two kinds of nutlets. There seems to be no objection to referring both smooth and tuberculate nutlets to one species; as Gray observes, some species of the borraginaceæ, though commonly tuberculate, sometimes retain their smoothness in maturity.⁴¹ The size of the nutlets is quite uniform, the length being about 2 mm. and the width slightly less than 1.5 mm.

The nutlets are hollow and are composed of calcium carbonate, the thickness of the walls in prickled nutlets being 0.035 to 0.075 mm. without prickles and to 0.13 mm. with prickles. The thickness of the walls in smooth nutlets is up to 0.12 mm.

The fossil nutlets resemble slightly the fruits of *Cynoglossum*, but they are several times smaller and their mode of attachment is different. The fruits of living *Oreocarya* are of the same magnitude as the fossil nutlets and have a similar scar of attachment. They differ, however, from the fossil form in having acute or winged margins. The living species of *Cryptantha* resemble the fossil form the most, and the nutlets of *Cryptantha crassisepala* (T. & G.) Greene are nearly identical with the fossil nutlets, except for their smaller size (Pl. XXX, Figs. 3a, 3b). They have obtuse margins and are coroniform from below; their scar of attachment is the same, except for the prominent median lobe at the base of the fossil form, which is absent in the living species. The latter has hetero-

41. Gray, 1885, p. 275.

geneous nutlets, three nutlets of a fruit being always tuberculate while the fourth one is always smooth and slightly longer than the others. The tuberculate and smooth nutlets of the fossil form are equal in size.

The living species of *Cryptantha* are natives of North and South America, and are most common in the western United States.

OCCURRENCE OF FOSSIL NUTLETS. Found at Black Wolf creek, near Beecher Island, Yuma county, Colorado, near the base of a bluff, 12 to 15 feet above the base of the Ogallala. Fruits, mostly halves of nutlets, in scores of specimens in grit. A great number of prickled fruits are scattered in the volcanic ash one mile east of Norton, Kan., where they occur together with *Celtis* stones.

Krynitzkia (Oreocarya) chaneyi Elias n. sp.

(Pl. XXX, Figs. 4a, 4b, 4c and 4d.)

Only nutlets known. They are triangular-ovate in outline both from the back and above; the width is only slightly less than length, which is 2.5 mm.; round and tuberculate on the back; the sides smooth; margins winged, the wings being short and dentate; the scar of attachment broad and slightly trilobate at the base, rapidly narrowing into a groove which does not quite reach the apex. The nutlets are hollow but comparatively strong, the thickness of the walls being 0.075 mm. They consist of calcium carbonate.

The fossil species apparently belongs to the living subgenus *Oreocarya*, which has nutlets that are triangular and nearly as wide as high. No such nutlets are known to the writer among other genera of the Borraginaceæ. The fossil nutlets approach in size and shape the nutlets of *Oreocarya suffruticosa*, *O. virgata* and *O. glomerata* (Pl. XXX, Figs. 2a, 2b), but these are smooth or only wrinkled on the back and are not winged. Some other species of *Oreocarya* (*O. virginiensis*, *O. oblata* and others) have a tuberculate back, but their flanks are also tuberculate and they are not winged. The winged species among the living *Oreocarya* (*O. setosissima* and others) have very thin wings which form a membranaceous margin all over the nutlets and are not restricted to the flanks only, as is the case in the fossil nutlets. *O. chaneyi* differs from all living nutlets of *Oreocarya* also in being more inflated. The scar of attachment of the fossil species is typical for both *Oreocarya* and *Cryptantha*, but the other features, as discussed above, relate the

fossil form with *Oreocarya*.⁴² The species is named after Dr. Ralph W. Chaney.

The living species of *Oreocarya* are natives of western North America, including Mexico.

OCCURRENCE OF FOSSIL NUTLETS. Found in about a dozen specimens in sandstone about 45 feet below the top of the Ogallala, on the south side of Goose creek, in Wallace county, Kansas, near the state line.

Krynitzkia auriculata Elias n. sp.

(Pl. XXX, Figs. 5a, 5b, 5c and 5d.)

The nutlets of this species resemble in some respects *Krynitzkia (Oreocarya) chaneyi*, while in some other respects they approach *Krynitzkia (Cryptantha) coroniformis*. In the whole they represent a sort of an intermediate stage between the other two fossil forms of *Krynitzkia*, as if being their hybrid.

The nutlets are subtriangular in shape, being viewed both from the sides and from the base, but the triangularity of the shape is not as sharp as in *O. chaneyi*, and the basal view approaches the coroniform shape of *K. (Cryptantha) coroniformis*. The back of *K. auriculata* is as densely covered with prickles as the back of *K. coroniformis*, but the flanks of the former nutlets are only irregularly rugose, approaching the smoothness of the flanks of *O. chaneyi*. In the majority of the nutlets of *K. auriculata* there can be detected that the prickles at the edges between the back and the flanks tend to fuse together, creating an embryo of a wing or an ear (hence specific name *auriculata*). In this the *K. auriculata* nutlets exhibit again a feature that is intermediate between the wingless *K. coroniformis* and the winged *K. chaneyi*. The scar of attachment of *K. auriculata* is of the same general type as in the last two species.

OCCURRENCE OF FOSSIL NUTLETS. Found in scores of specimens in somewhat cemented grit about 90 feet below the top of the Ogallala in W. of sec. 4, T. 12 S., R. 42 W., Wallace county, Kansas. Near by in the same bed a few nutlets of *Biorbia rugosa* and numerous fruits of *Berriochloa glabra* have been found.

42. The species united by Greene in genus *Oreocarya* were included by A. Gray in the genus *Krynitzkia* Fischer and Meyer, with which also the species of *Cryptantha* were classified. Many botanists use the generic name *Krynitzkia* in the sense of Fischer and Meyer and Gray, although the name *Cryptantha* has priority over *Krynitzkia*. *Oreocarya* and *Cryptantha* are considered as subgenera of *Krynitzkia*.

Celtis willistoni (Cockerell) Berry.

(Pl. XXIX, Figs. 8a, 8b and 8c.)

1909. *Tithymalus willistoni*, Cockerell, Torrey, vol. 9, p. 119.
 1914. *Tithymalus willistoni*, Cockerell, Torrey, vol. 14, p. 187, Fig. 2c.
 ?1914. *Tithymalus phenacodorum*, Cockerell, Torrey, vol. 14, p. 187, Figs. 2A, 2B.
 1925. *Celtis besseyi*, Barbour, E. H., Nebraska State Museum, vol. 1, Bull. 8, p. 89, Fig. 48.
 ?1925. *Celtis hatcheri*, Chaney, Carnegie Institution Publ. 349, p. 54, Pl. 1, Fig. 8.
 ?1927. *Celtis barbouri*, Chaney, American Museum Novitates, No. 288, pp. 1-2, Figs. 1, 2.
 1928. *Celtis willistoni*, Berry, American Museum Novitates, No. 298, pp. 1-5, Figs. 1-6.

Hackberry (*Celtis*) stones are not rare in the Tertiary and Pleistocene of North America and in some arenaceous rocks of late Tertiary of the Great Plains they are very common. Several species have been established by various authors on the ground of these fossil stones alone, but the features of specific distinction, as given in the descriptions, are not very definite and the noted differences may be explained as variation within a single species. The variability in size and in rugosity of *Celtis willistoni* stones was a subject of some research by Berry,⁴³ and the writer believes that only an extension of a similar quantitative research in the variation of the stones of the living species of *Celtis* may help us to establish some valid criterion for specific separation of fossil *Celtis* stones. The features which have been thus far offered for discrimination between the fossil stones are a slight difference in size, difference in rugosity or slight difference in design of the rugosity. They were found by the writer of but little, if any, help in his attempt of an impartial (not influenced by stratigraphical occurrence) comparison of the *Celtis* stones collected by him in the Ogallala of northwestern Kansas with the numerous species previously described. He, furthermore, found that his fossil stones are indistinguishable from the stones of *C. occidentalis*, which now grows in the same area where the fossil stones have been collected.

In view of all this the writer is content at present that *Celtis* stones of his collections are referable to the earliest described fossil hackberry stones or *C. willistoni*, and provisionally he also concludes that *C. willistoni* stones belong to a hackberry closely related, if not identical, to living *C. occidentalis*.

The writer wishes to point out that among hundreds of specimens of *Celtis* stones which he collected in the Ogallala one can select specimens with very pronounced rugosity of the surface, and specimens which are nearly smooth. In two cases, furthermore, the writer

43. Berry, 1928, Am. Mus. Novitates, No. 298.

collected perfectly smooth and lustrous specimens which undoubtedly represent casts of the internal part of the same species of *Celtis*.

It is worth while to note here an interesting anatomical feature of *Celtis* stones to which little, if any, attention has previously been given, but which helps considerably in generic identification of these stones. This is the presence of a thin canal at the apex of hackberry stones. The canal is located slightly below the apex and is oblique to the surface of the stone (Pl. XXIX, Fig. 8c).

OCCURRENCE. In numerous localities of Ogallala in northwestern Kansas and northeastern Colorado. Mostly in the middle portion of the formation, but occasionally also near the base and about at the top of it. Usually stones are scattered in a bed of grit or loam, but occasionally segregated to form irregular clusters.

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PLATE XXVIII.

FIG. 1. Living *Panicum fasciculatum chartaginense* (Swartz) Doell. Fruit, dorsal view. From type specimen, after A. S. Hitchcock and Agnes Chase. Magnified about 12 times.

FIGS. 2a, 2b, 2c. Fossil *Panicum elegans* Elias n. sp. Protective cover of a fruit made of pale or palea, overlapped by fertile glume or lemma. Type specimen. Magnified about 12 times. 2a, Dorsal view of lemma. A. Three ridges at the apex corresponding to three principal veins of lemma. B. Lunular impression of embryo. Black spot in the lower part of lemma is an incidental break. 2b, Side view showing distally inflated palea on the right and overlapping lemma on the left. 2c, Ventral view showing palea inserted in lemma. C. Two keels or veins of palea. D. Scar of attachment of the fruit. E. Scar of fibrovascular bundle.

FIG. 3. Living *Panicum angustifolium* Ell. Microphotograph of middle portion of palea. Magnified 38 times.

FIG. 4. Fossil *Panicum elegans* Elias n. sp. Microphotograph of middle portion of palea. Magnified 44 times.

NOTE.—Black portions on the photograph of the living specimen figure 4 correspond to white portions of the fossil specimen figure 5, and vice versa. This difference is due to fossilization of protective cover, the transparent exterior of the glumes changing to semi-transparent or nearly opaque.

FIGS. 5a, 5b. Fossil *Stipa kansasensis* Elias n. sp. Probably an upper portion of rolled palea with an apical extension into an awn (broken), accompanied by a twist (Fig. 5b). Note that the awn of living *Stipa* (Fig. 10) is pronouncedly twisted. 5a and 5b are different views of the same specimen, magnified 5 times.

FIGS. 6, 7, 8, 9. Fossil *Stipa kansasensis* Elias n. sp. Protective cover of fruit made of rolled lemma with a joint for awn at the apex. Awn broken away. Cotypes. Magnified 5 times. 6, Nearly complete lemma with hairy callus at the base. Lemma mostly exfoliated in the upper half, exposing internal cast made of sand cemented with calcium carbonate. Lower portion of lemma nearly bare of tubercles. 7, Large fruit with base broken off. Remains of lemma, tuberculate in upper half, smooth in lower half, surround internal cast made of sand. 8, Upper part of lemma covered with upright bristles at the joint and with tubercles below. Microphotograph 12 is made from this specimen. 9, Lower part of lemma.

FIG. 10. Living *Stipa neesiana* Trin. Sketch is made from a herbarium specimen. Magnified 2 times.

FIG. 11. Living *Stipa neesiana* Trin. Apical portion of lemma, showing bristles of the top and tubercles below with striations on the interspaces of the surface. Tubercles appear as black round spots, which is due to their transparency. The corresponding tubercles of the fossil fruits (Fig. 12) are opaque, which is due to fossilization. Thus they appear white and prominent on the photograph. Magnified 31 times.

FIG. 12. Fossil *Stipa kansasensis* Elias n. sp. Apical portion showing bristles at the top and tubercles below with striations on the interspaces of the surface. Cotype. Magnified 33 times.

FIGS. 13a, 13b, 13c. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Small-size fruit. Magnified 5 times. 13a, Ventral view of lemma with inclosed palea. 13b, Side view of lemma. A, Middle keel or vein. B, Basal portion of awn which is broken away. 13c, Basal view of lemma with inclosed palea. C, Scar of attachment. D, Lateral keels or veins.

FIG. 14. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Apparently pericarp of caryopsis, which was found inside of a protective cover. Portion to show anatomy. Black spots represent transparent tissue with less transparent ridges forming a net. Magnified 35 times.

FIG. 15. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Portion of lemma to show longitudinal striation. Magnified 32 times.

FIG. 16. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Portion of lemma to show irregular transverse sculpture. Magnified 32 times.

PLATE XXVIII.

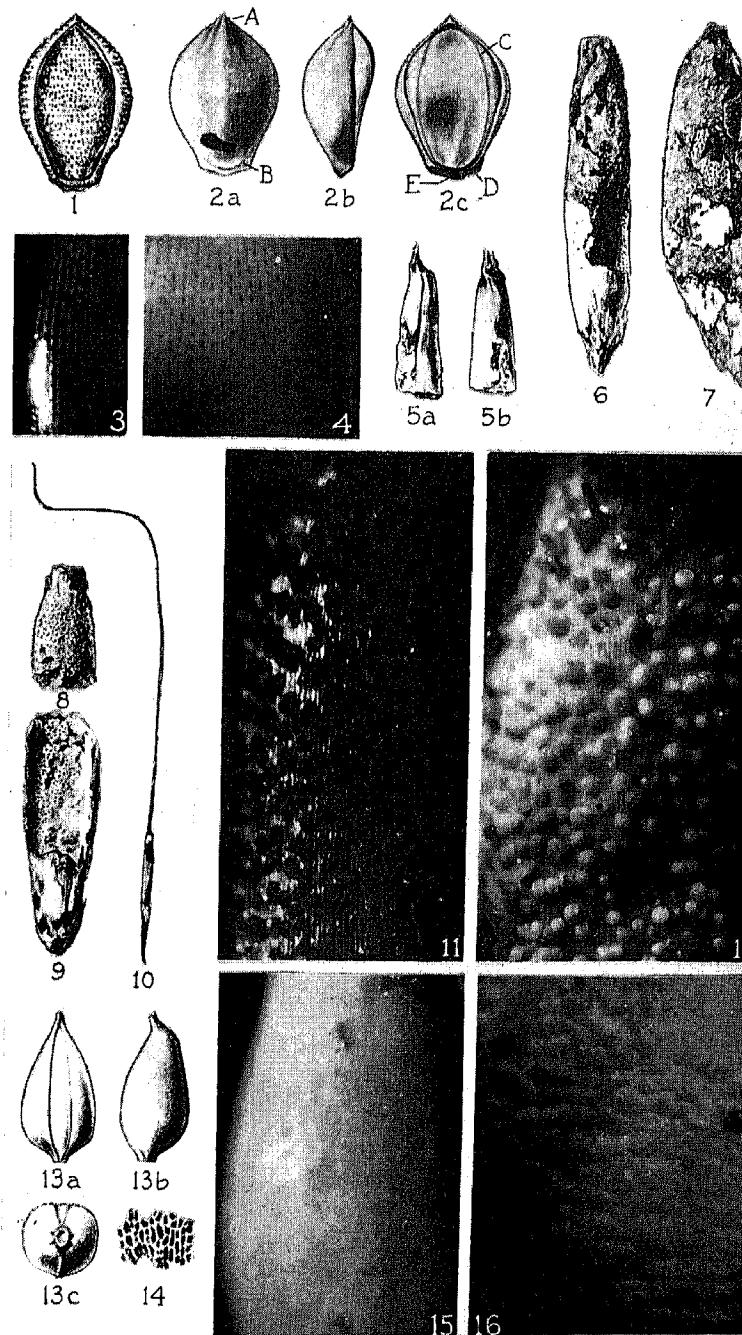


PLATE XXIX.

Figs. 1a, 1b, 1c. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Large-size fruit. Magnified 5 times. 1a, Side view of lemma. A, Middle keel or vein. B, Lateral veins. C, Basal portion of awn which is broken away. 1b, Ventral view of lemma with inclosed palea. D, Two ribs or veins of palea. 1c, Basal view. Note five ribs of lemma and two of palea.

Figs. 2a, 2b, 2c, 2d. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Right (in differentiation from left) nutlet. Magnified 10 times. 2a, Ventral view, 2b, Side view. 2c, Dorsal view. 2d, Basal view.

FIG. 3. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Restoration of a fruit made of four nutlets. Side view. Magnified about 5 times.

FIG. 4. Living *Anchusa officinalis* Linneus. Four nutlets fruit. Top view. Specimen from Denmark, Botanical Gardens. Magnified 10 times.

Figs. 5a, 5b, 5c. Living *Anchusa officinalis* Linneus. Left nutlet, from same locality. Magnified 10 times, 5a, Dorsal view. 5b, Side view. 5c, Ventral view.

FIG. 6. Living *Anchusa officinalis* Linneus. Microphotograph of the distal part of a nutlet. Magnified 35 times.

FIG. 7. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Microphotograph to show fine tubular holes which are seen on somewhat exfoliated surface of a nutlet. Magnified 35 times.

Figs. 8a, 8b, 8c. Fossil *Celtis willistoni* (Cockerell) Berry. 8a, Side view. 8b, Rear view (sculpture not shown). 8c, Internal view of apical portion of a stone. 8a, 8b magnified 5 times. 8c magnified 10 times.

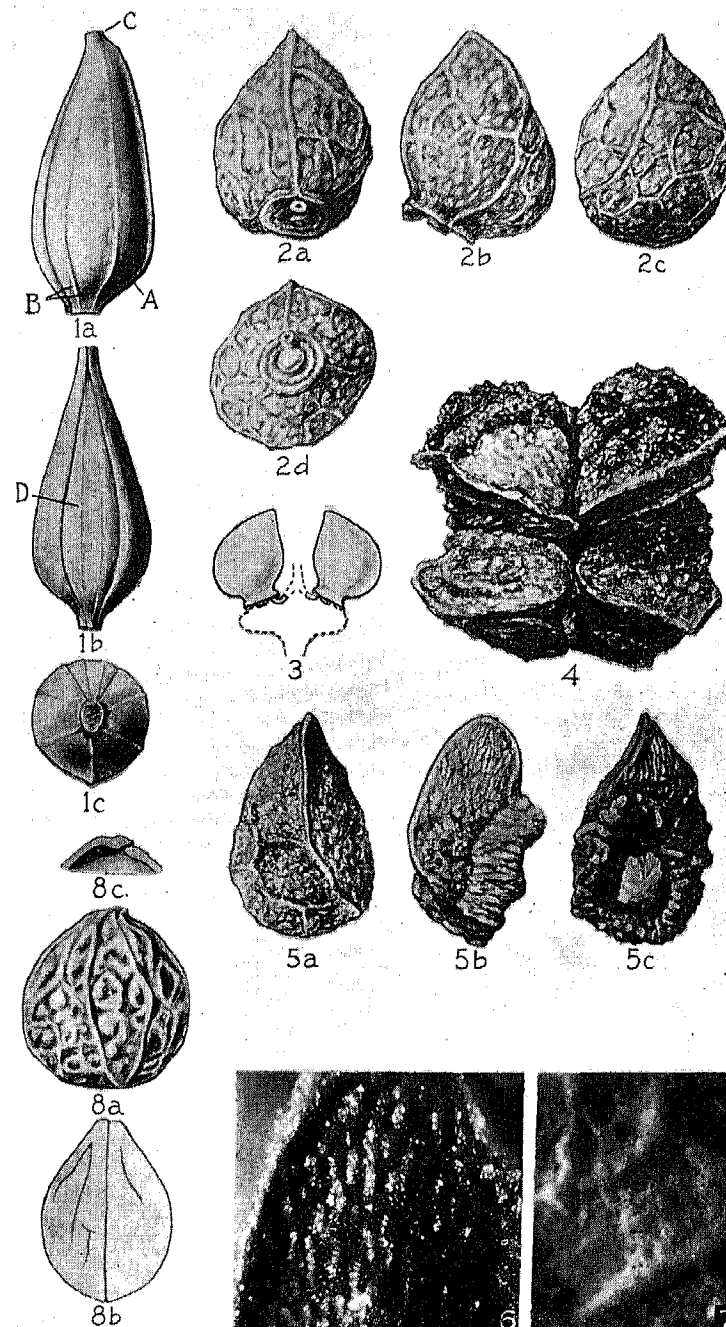


PLATE XXX.

FIGS. 1a, 1b, 1c, 1d. Fossil *Krynitzkia (Cryptantha) coroniformis* Elias n. sp. Nutlet. Type specimen. Magnified 10 times. 1a, Basal view. 1b, Dorsal view. 1c, Side view. 1d, Ventral view.

FIGS. 2a, 2b. Living *Krynitzkia (Oreocarya) glomerata* (Pursh) Green. Nutlet from Canon City, Colo. Magnified 10 times. 2a, Ventral view. 2b, Top view.

FIGS. 3a, 3b. Living *Krynitzkia (Cryptantha) crassisepala* (T. & G.) Green. Tuberculate nutlet from Wichita county, Kansas. Magnified 10 times. 3a, Basal view. 3b, Ventral view.

NOTE.—Vertical line to the right indicates comparative length of the smooth nutlet of the same fruit, to which the tuberculate nutlet belongs.

FIGS. 4a, 4b, 4c, 4d. Fossil *Krynitzkia (Oreocarya) chancyi*. Elias n. sp. Nutlet. Magnified 10 times. 4a, Top view. 4b, Dorsal view. 4c, Side view. 4d, Ventral view.

FIGS. 5a, 5b, 5c, 5d. Fossil *Krynitzkia auriculata* Elias n. sp. Nutlet. Magnified 10 times. 5a, Bottom view. 5b, Dorsal view. 5c, Side view. 5d, Ventral view.

FIG. 6. Fossil *Populus balsamoides* Goepfert. From the diatomaceous marl of Beaver county, Oklahoma. Natural size.

FIGS. 7a, 7b. Fossil *Populus cf. balsamoides* Goepfert. From the diatomaceous marl of Wallace county, Kansas. Natural size. 7a and 7b are positive and negative of the same fragmentary leaf. 7a shows nerves. 7b shows dentate edge of the leaf.

FIG. 8. Petrified stems (straw) of grasses. Natural size. From Ogallala formation, Kansas.

