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Late Eocene Legume Pod Fossils from Western North America and Their Paleoclimate Analysis

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Abstract

In this paper, we analyzed the characteristics of fossil legume pods from the "Committee Creek" formation of the Teater Road, John Day Formation in Crook County, Oregon, in western North America. 23 fossil specimens were collected and compared with the existing genera of the family through detailed observation of the legume pods. A total of three genera and four species of nearest relatives were identified as extant, and four undetermined species were studied. These include the similar species of Acacia vine and Acacia (undetermined species) of the genus Acacia; the species of Caesalpinia of the genus Caesalpinia; and the species of Bauhinia of the genus Bauhinia. Combining the distribution range of this genus and its fossil record in the Late Eocene, we inferred a mild and humid climate in the Late Eocene of western North America by comparing the distribution range with that of the fossil extant genus and making a distribution map.

Subject Areas

Paleontology, Geology

Keywords

Legume Pods Fossil, John Day formation, Paleoclimate, Late Eocene, Western North America

1. Introduction

Over the past 65 Ma, the Earth has changed from a "greenhouse Earth" with no ice at the north and south poles to a "chamber Earth" with year-round ice at the north and south poles, a major process that has been characterized by several ice-cap expansion cooling events. As early as the 1970s, Robert *et al.* [1] found that during the Eocene-Oligocene transition, the groundwater temperature dropped by 3˚C - 4˚C and a large-scale ice cap began to appear on the Antarctic continent, with the first appearance of the East Antarctic ice cap occurring near the Eocene-Oligocene (E/O) boundary at about 34 Ma BP, an event that is considered to be an extremely important phase of global climate transition in geological history [2]. Geologists have found that during this Eocene-Oligocene transition, global temperatures decreased dramatically and organisms on land and sea became extinct to varying degrees, and many records of biological evolution have been found in the oceans and continents, all indicating to us trends in global climate change. In fact, the location of this study area is further west than the Florissant Fossil Bed, a famous fossil site in the United States, but this location is also rich in legume pod fossils and well preserved. As an extremely sensitive plant to climatic changes, legume pod fossils can provide valuable information on climatic changes [3], and their pods belong to the reproductive organs of the plant, which can improve the accuracy of plant identification. At the same time, the Late Eocene is a period of climatic transition, and the study of the plants of this era can reveal the changes in the climate of the era, but in the process of this change, whether the climate of the region is a continuous or fluctuating change can be directly reflected by the plants [4].

The Late Eocene, as a transitional period in climate, has been used by domestic and international scholars to quantitatively recover the Eocene flora paleoclimate of some regions using the characteristics of leaf phase assemblages of fossil flora. For example, Jacobs and Herendeen [5] showed that the annual rainfall in the region was close to modern values in their study of the Middle Eocene flora of Tanzania. In addition, Davies [6] studied leaf morphological assemblages of the Wyoming flora in the United States during the extreme heat period and found that during the extreme heat period, leaf assemblages of this flora reflected hot climatic characteristics. In Europe, the work on Eocene paleoclimate is mainly based on fossilized spore powder, and coexistence analysis is an effective method to study paleoclimate [7]. Jue Qiu [8] studied fossils of the genus Podocarpus from the Changchang Basin, Hainan Island, and through systematic identification and comparative discussion, a new species of *P. hainanensis* sp. nov was identified, indicating that it was the earliest fossil of the genus Podocarpus with the earliest age found at that time. Jia Gaowen [9] reported and discussed the migration routes of the genus Phellodendron from the Bangmai Formation in the Lincang area of Yunnan, and Wang Yunfeng [10] identified the fossil maple leaves and wing fruits from the Bangmai Formation in the Lincang area of Yunnan and performed a quantitative paleoclimate reconstruction using leaf phase analysis. The genus Podocarpus is an extinct genus with relatively few reports of Eocene fossil studies, and in addition, the study area is in a special geographical location in western North America, making it of great research value.

Because the fossil pods have characteristics that their leaves do not have, combining the fossil record of pods found in the area and the distribution pattern of extant legumes, it is possible to analyze and study the relationship between the climatic environment and the distribution of extant legumes in the geological-historical period, as well as to analyze the problems between the fluctuating changes of legumes and the changes of the paleoclimatic environment in the geological-historical period, so the study of legumes and their fossil record is of great The study of legumes and their fossil records is therefore of great importance.

Roughly bounded by 95˚W, the western part of the country is landlocked to the west of 95˚W, and most of its western part has a semi-arid or arid climate. The specimen is located in the "Committee Creek" formation of the John Day Formation at Teater Road, Crook County, Oregon, western North America, with geographic coordinates of N 44˚9'59.96" and W 120˚14'55.88" (**Figure 1**). Oregon is located on the Pacific coast of the United States, with California to the south and Washington to the north, and has a mild climate with distinct seasons. Clay stones and olivine basalts; its lower horizon is the Clarno Formation, consisting of andesitic lava, volcanic breccia and sedimentary rocks [11]; at the base of the graben is the Herren Formation, whose lithology consists of mudstone and a little coal [12], the thinner Committee Creek Formation represents a small lake deposit with sediments including planktonic ferns (Salvinia) and different angiosperm fronds with a diverse assemblage of plants and fruits. Although there is no directly determined age, the minimum age of this fossil in the district was determined to be about 36 Ma based on radiometric dating of a nearby white powdery tuff [13].

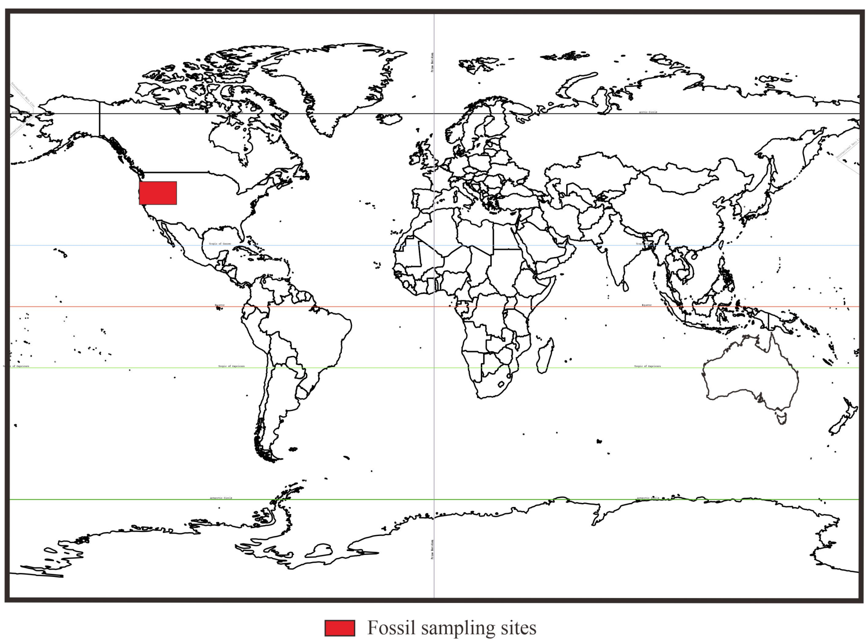

Figure 1. Fossil sampling sites in western North America.

2. Comparison of Fossil Bean Pods with Extant Genus Species

The fossil material of the legume pods in this study was subjected to branching analysis and numerical classification by mathematical statistics to find the taxa of modern plants that are closest to the macroscopic morphology (leaf structure, leaf morphology, and fruit morphology) and microscopic structure (leaf cuticle and internal fruit structure) of the fossil, thereby identifying the nearest extant relatives or corresponding groups (taxa) of the fossil specimens. The fossil specimens were described in normative terms and characterized in relation to extant species in combination with the Flora of China (Science Press, 2004), Flora of North America (Chapter 14, 2019), and the Chinese Digital Herbarium (CVH) for plant macrofossils.

2.1. Specimen I: Description and Identification

This fossil specimen is preserved as an impression, the fossil as a whole is relatively well preserved, and the color of the specimen is brown. The pod is oblong, with an aspect ratio of 5:1 (5 cm in length and 1cm in width), the pod is relatively full, the base is incompletely preserved, the tip is rounded with a rostral tip, the suture is straight, the pod has an inconspicuous double wing and dehiscences after maturation; the seeds are spherical, six are preserved, flattened in shape and about 10 mm in diameter.

2.1.1. Identification Characteristics at the Genus Level

Among the legumes, Mimosa spp., Zingiber spp., Caesalpinia spp., and Xanthosiphon spp. are more similar in size and morphology, with Mimosa spp. and Caesalpinia spp. being more similar to the specimen pods. Although the pods are all oval in shape and the wings of the pods are all long, the genus Caesalpinia is most similar to the pods of the current fossil specimen in the shape of the sutures, which are all straighter, and therefore the current specimen is classified as a genus Caesalpinia. The pods of this genus are ovoid-oblong or lanceolate, sometimes falcate and curved, flattened or swollen, with an aspect ratio of about 4:1. The pods are indehiscent or dehiscent, wingless or winged, and the wing lines are parallel to each other. Seeds are ovoid to spherical, with a variable number of seeds, about 10 cm in diameter, and dehiscent at maturity. (Table 1)

2.1.2. Identification Characteristics at the Species Level

In terms of species-level identification characteristics, the current fossil specimen was found to be the most similar to the cloudy fruit in the genus Caesalpinia, with their pods being oblong in shape, most notably swollen along the ventral suture line, and both having obvious double wings, seeds being spherical, and both having dehiscence when the pods mature. Therefore, the current specimen is designated as Caesalpinia. (Table 2)

2.1.3. Comparison and Discussion

The morphological characteristics of the specimens are similar to those of

Table 1. Comparison of the characteristics of Specimen I with similar genera.

Genus	Aspect Ratio	Bean Pod Shape	Fruit Wing	Wing Pattern	Seed Shape	Number of Seeds	Sutures	Whether Cracking
Mimosa Genus	5:1	Long oval or linear	Wingless or winged	Yes	Oval or round	Multiple	Wavy	Cracking
Bauhinia Genus	6:1	Narrowly elliptical, lanceolate linear	Narrow wings on one side of the ventral suture	Longitudinal parallelism	Small, oval, flat	2 to many pills	Straight	No cracking or splitting
Caesalpinia Genus	4:1	Ovate, oblong or lanceolate, sometimes falcate and curved, flattened or swollen	Wingless or winged	Parallel	Seeds ovoid to globose	Multiple	Straight	No cracking or splitting
Dalbergia Genus	3:1	Flattened, strap-shaped or oblong, seed pods often reticulate in epidermal part, base often contracted into a longer stalk	Two Wings	No	Elliptical, oblong kidney-shaped	1 - 3 pills	Flatter or curved	No Cracking
Current Specimens	4:1	Long oval	Swelling along the ventral suture, double wing	not obvious	Spherical	6 pills	nearly flat and straight	Cracking

Table 2. Comparison of the characteristics of Specimen I with similar genera.

Genus	Aspect Ratio	Bean Pod Shape	Fruit Wing	Wing Pattern	Seed Shape	Number of Seeds	Sutures	Whether Cracking
Mimosa	3:1	Long oval	Single wing	Parallel	Oval	Multiple	Wavy	Cracking
Bauhinia	7:1	Flat and narrow shape	Single wing, wing width about 1.5 mm	Parallel	Long Oval	2 - 6 pills	Nearly flat and straight	No Cracking
Caesalpinia	4:1	Oblong, ribbon-like	Swelling along the ventral suture, double wing	Not obvious	Seeds ellipsoid to spherical	6 - 9 pills	Nearly flat and straight	Cracking
Current Specimens	4:1	Long oval	Swelling along the ventral suture, double wing	Not obvious	Spherical	6 pills	Nearly flat and straight	Cracking

Zingiber officinale in southeastern China and Yichang Caesalpinia in Hubei, China. The current pod specimens and Caesalpinia are oblong in shape and generally have double wings, but *Zingiber officinale* pods are flat and narrowly elongated with a single wing and a wing width of about 1.5 mm, which is a significant difference from the current specimens. Second, the seeds of the pods and clouds of the current specimen are ellipsoidal to spherical, and the seeds of the pods of *Zingiber officinale* are broad and oblong to distinguish them from the fossil species. Therefore, it is named Caesalpinia.

2.1.4. Identification Results

Specimen I is from the phylum Angiosperma, class Dicotyledonea, subclass Primitive Perianth, order Rosaceae, suborder Rosaceae, family Leguminosae, subfamily Caesalpinia, tribe Caesalpinia, genus Caesalpinia, and Caesalpinia.

2.2. Specimen II: Description and Identification

The fossil is orthogonal and antisymmetric on both sides, this fossil specimen is preserved as an impression, the fossil as a whole is relatively well preserved, and the color of the specimen is brown. The pod is cuneate, broad at the base, flattened, with a length-to-width ratio of 2:1, and single-winged, but the wing pattern is not obvious. The apical part of the pod is short beak-shaped on the side of the ventral suture line and semicircular on the side of the dorsal suture line, the ventral suture line is wider than the dorsal suture line, and both edges are nearly flat; no seed traces are seen, and several grooves can be seen on the side of the ventral suture line, which may be traces of the striae or equivalent to the "seed overflow" structure.

2.2.1. Identification Characteristics at the Genus Level

The genera Acacia, Saponaria, and Sophora in the family Leguminosae are relatively similar in size and seed morphology, with Acacia being the most similar to the specimen pods. Firstly, the shape of the current specimen is a cuneiform with antisymmetric sides, and only Acacia spp. is similar to the current specimen in this feature; secondly, the tip of the pod of the current specimen is short beak-shaped on the side deviating from the ventral suture line and semicircular on the side deviating from the dorsal suture line, the ventral suture line is wider than the dorsal suture line, and the edges of both sides are nearly flat, and the suture line of the specimen as a whole is flatter, which is also consistent with the features of Acacia spp. and therefore the current specimen is classified as This is also consistent with the characteristics of Acacia spp.

The pods of this genus are characterized as follows: some seeds show overflowing shrinkage, the number of seeds is variable, and the sutures are nearly straight or undulate. (**Table 3**)

2.2.2. Identification Characteristics at the Species Level

In terms of species-level identification features, the current specimen was found to be more similar to the vine acacia and acacia of the genus Acacia, both of which have obvious single-winged pods, seeds that are difficult to preserve in fossils, and pods that do not dehiscence at maturity. In addition, the current specimen has an antisymmetric wedge shape, and at some point, the vine acacia also has similar morphological features to the current specimen; secondly, the suture characteristics of the vine acacia are also similar to the current fossil specimen, but the difference is that the edge of the vine acacia is strong and straight, with signs of contraction at the edge, and its shallow suture is stronger and straighter. Therefore, the current specimen is named Vine Acacia (similar species). (**Table 4**)

Table 3. Comparison of the characteristics of specimen II with similar genera.

Genus	Aspect Ratio	Bean Pod Shape	Fruit Wing	Wing Pattern	Seed Shape	Number of Seeds	Sutures	Whether Cracking
Acacia Genus	2:1	Tongue-shaped, rectangular, wedge-shaped	Wingless or winged	Not obvious	Seeded egg type, partially showing overflow shrinkage	Multiple	Straight or wavy	Cracking or non-cracking
Sapotaceae Genus	5:2	Flat, strong straight, bent or twisted	Wingless or winged	No	Ovate or elliptic, flat or subcolumnar	1 to many pills	Wavy	Cracking or non-cracking
Sophora Genus	5:2	Cylindrical or slightly flat, bead-shaped	Sometimes winged	Not obvious	Ovoid, ellipsoidal or subglobose	1 to many pills	Wavy	No cracking or different ways of cracking
Current Specimens	2:1	Wedge, strip, slightly curved	Single wing	Yes	No traces of seeds seen	No	Nearly flat and straight	No cracking

Table 4. Comparison of characteristics of specimen II with similar species.

Genus	Aspect Ratio	Bean Pod Shape	Fruit Wing	Wing Pattern	Seed Shape	Number of Seeds	Sutures	Whether Cracking
Acacia Vine	2:1	Wedge, strip, slightly curved	Single wing	Yes	No traces of seeds seen	No	Nearly flat and straight	Cracking or non-cracking
Acacia	2:1	Swelling, flattening	No	No	Oval	Seeds multiple	Wavy	No Cracking
Current Specimens	2:1	Wedge	Single wing	Yes	No traces of seeds seen	No	Nearly flat and straight	No Cracking

2.2.3. Comparison and Discussion

The features are quite consistent with those of the Tertiary Acacia from Alaska, with the base only slightly wider than that of the Alaskan specimen. Compared in construction, both are characterized by grooves, differing in that the grooves in the pods of Acacia from Alaska are smaller, with multiple grooves arranged in successive rows at regular intervals. The size of the specimen has some similarity to Acacia, which is native to tropical America, although the fruit wings of their pods both have a distinctive single wing and the pods both are dehiscent at maturity. However, the shape of the current specimen is a cuneiform with anti-symmetric sides, while the pod form of Acacia is flat and swollen, in this feature only Vine Acacia is similar to the current specimen; secondly, the suture of Vine Acacia is similar to that of the current specimen. However, the edges of Acacia vine are straight and have traces of constriction at the edges, while the sutures of Acacia vine are mostly wavy, which is also different from the current specimen. Therefore, the current specimen is designated as Acacia vine (similar species).

2.2.4. Comparison and Discussion

Specimen II was identified as Angiospermae, Dicotyledonea, Primitive Perianth, Rosaceae, Rosaceae, Fabaceae, Mimosa, Acacia, similar species of Acacia vine.

Based on the above identification methods, specimen III was identified as Angiospermae, Dicotyledoneae, Primitive Perianth Subclass, Rosaceae, Rosaceae, Leguminosae, Caesalpinia Subfamily, Bauhinia Clan, genus Bauhinia, Bauhinia.

Specimen IV was identified as Angiospermae, Dicotyledoneae, Primitive Perianth Subclass, Rosaceae, Rosaceae, Leguminosae, Mimosa subfamily, Acacia tribe, Acacia genus, Acacia (undetermined species).

Due to the large number of samples collected, only five fossil specimens are shown in this paper (See the Appendix). All the preserved fossils are impressions, taken from the "Committee Creek" formation of the Teater Road John Day Formation, Crook County, Oregon, in the Late Eocene of western North America, and are now preserved in the Florida Museum of Natural History (Paleontology). The fossil record is based on published literature and monographs. Of the five fossil specimens, three genera and four species were identified as the nearest extant relatives of 14 genera and 21 extant species. The nearest relatives of the four species were investigated from the Chinese Digital Herbarium (CVH), Flora of China, and Flora of North America.

3. Paleoclimate Analysis

3.1. Habitat and Late Eocene Fossil Record of Pods of the Nearest Extant Relatives

Legumes are capable of adapting to the tropics, and it is widely distributed globally, with its centers of distribution in Africa-Madagascar, tropical America, and southeastern North America, which coincides with the fossil record [14]. Leguminose-related taxa are thought to have originated in the humid tropics during the Late Cretaceous [15], with the earliest plausible legume fossils found on the African continent (Late Cretaceous or Paleocene) [14]. The paleoclimate of the above-mentioned Late Eocene legume pod fossils from western North America was analyzed using the "extant proximate species method". A total of five fossil specimens were identified with a total of three genera and four species. Among them, the genus Acacia was numerically dominant, while most of the modern legumes' modern relatives were distributed in tropical-subtropical regions (**Figure 2**).

As the Eocene subtropical vegetation in the northern hemisphere moved northward from its modern limits, the distribution of the genus migrated from higher to lower latitudes and the fossil record decreased, and the fossil record of the genus after the Pliocene was mainly found in Oceania [16]. The following figure shows the distribution of Late Eocene legume fossils and extant legumes. It is clear that the Late Eocene legume fossils were widely distributed, and the modern legume distribution area was narrowed and concentrated in tropical-subtropical regions, while the dry climate of western North America today can indicate that the western North America was warm and humid in the Late Eocene at that time.

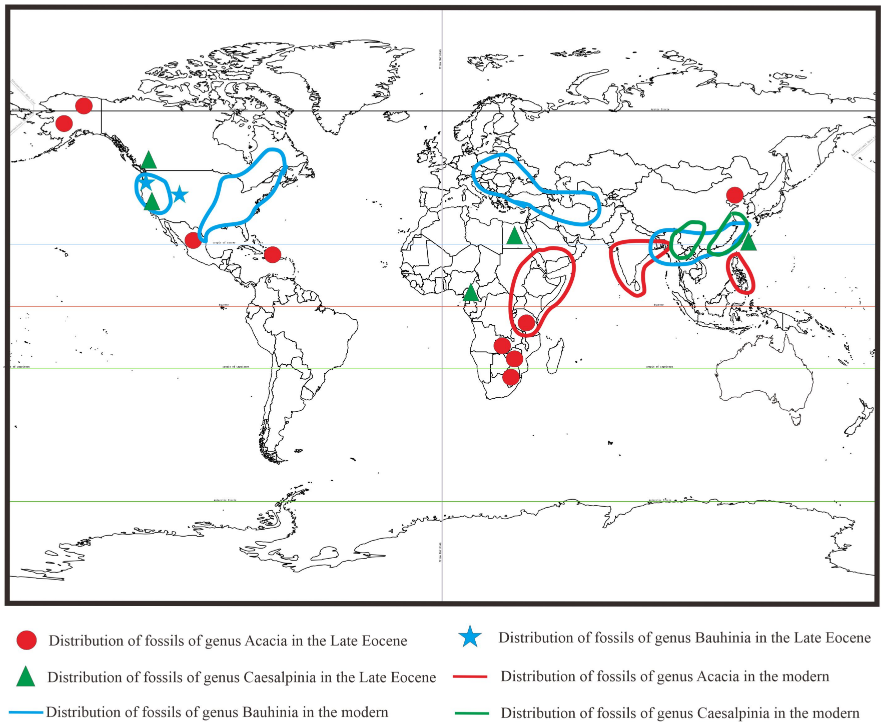

Figure 2. Distribution of Late Eocene legume fossils and extant legumes.

3.2. Habitats of the Genus Acacia and Their Fossil Distribution

The modern species of Acacia are basically distributed in tropical and subtropical regions, with latitudes of 0˚N-27˚N, 0˚S-14˚S, and longitudes of 28˚E-122˚E. The main production areas are Oceania, and southwestern to eastern China are the main production areas. The modern species of this genus are mainly distributed in East Africa, and in Asia in India, Myanmar, Sri Lanka and other countries. China's Guangdong, Guangxi and other places have the genus Acacia in the vine Acacia [17].

From the following figure (**Figure 3** and **Figure 4**), it can be seen that the distribution of fossils of the genus Acacia in the Late Eocene is wide and the latitude of distribution is higher than that of the extant genus.

The Late Eocene fossils of Acacia spp. were distributed in western North America, but there is no extant distribution of Acacia spp. in western North America today, and the present western North America has a temperate arid climate, so the fossil distribution of Acacia spp. and the distribution of extant species of the genus can indicate a humid climate in western North America in the Late Eocene.

3.3. Habitats of the Genus Acacia and Their Fossil Distribution

The distribution range of extant Bauhinia and the fossil record of Late Eocene Bauhinia spp. are shown in **Figure 5**. Late Eocene Bauhinia spp. have fossil records in North America, Colorado, USA, and Oregon, USA, and there are no fossil records elsewhere [13]. The Oligocene genus Bauhinia is distributed in

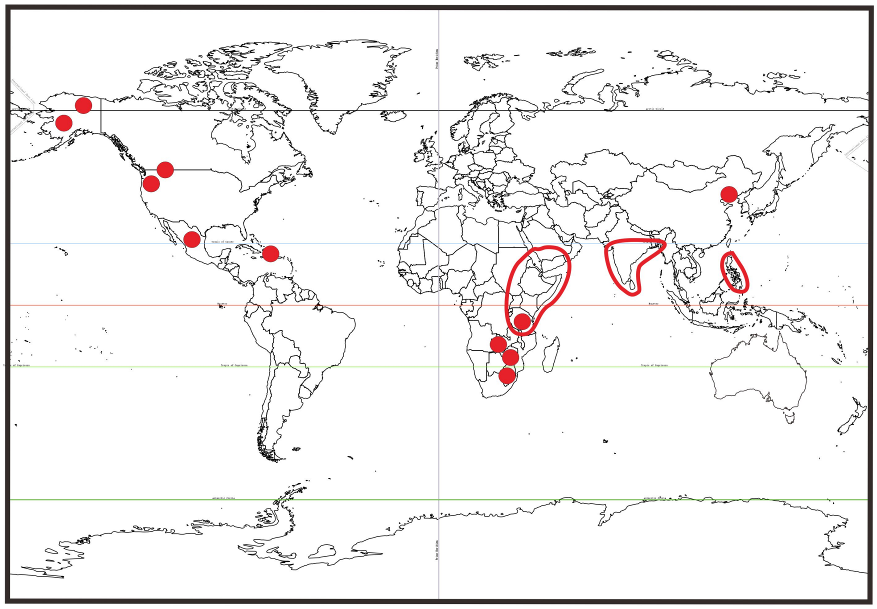

Figure 3. Distribution of fossil and extant Acacia spp. in the Late Eocene.

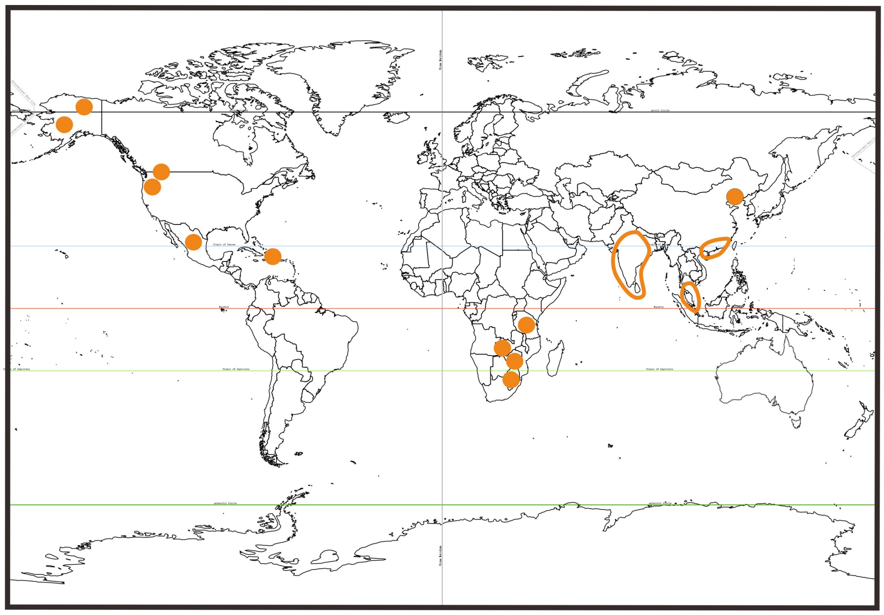

Figure 4. Distribution of Late Eocene fossils of Acacia spp. and extant vine Acacia.

North America, Europe, and Asia, and there are more fossil localities. The Miocene genus Bauhinia is most widely distributed in the Asian region.

The extant genus Bauhinia is mainly distributed in the mid-latitudes of the Northern Hemisphere, mostly in the northern temperate zone, with a latitude of 15˚N-54˚N, longitude of 14˚E-122˚E, and 65˚W-128˚W. Bauhinia is one of the most widely distributed species in the genus Bauhinia, and is common in provinces and regions from the southwest to Yunnan, as well as in the eastern provinces and regions along the south of the Yangtze River, with a relatively wide range of growth environments [17].

As can be seen from the figure (**Figure 5**), the latitude of distribution of fossil Bauhinia spp. in western North America in the Late Eocene is similar to that of the extant species, and the difference is not significant, but the distribution range of the fossil species is smaller than that of the extant species. Therefore, the distribution of fossils of the genus Bauhinia and the distribution of extant species cannot clearly indicate the Late Eocene climate of western North America.

3.4. Habitats of the Genus Caesalpinia and Their Fossil Distribution

Relatively few fossil records of legumes have been reported from the earliest Eocene strata in Africa, and some fossil pods and pollen of the genera Caesalpinia and Mimosa have been reported mainly from the late Eocene strata, most of which occur in Cameroon and Egypt in Africa [18], and fossil records of the genus Caesalpinia have also been found in Hainan and other places in China.

The extant genus Caesalpinia is mostly distributed in tropical and subtropical regions, with latitudes of 20˚N-35˚N and longitudes of 98˚E-122˚E. In China, the southern and southwestern parts of the genus have also become the main sources, with Caesalpinia being one of the most widely distributed species in the genu. The latitude of distribution of Late Eocene fossils of the genus Caesalpinia is higher than that of the extant species, and the distribution of Late Eocene fossils of the genus Caesalpinia is extensive (**Figure 6**). The Late Eocene fossil distribution of the genus Caesalpinia in western North America, however, there is no extant distribution of the genus Caesalpinia in western North America today,

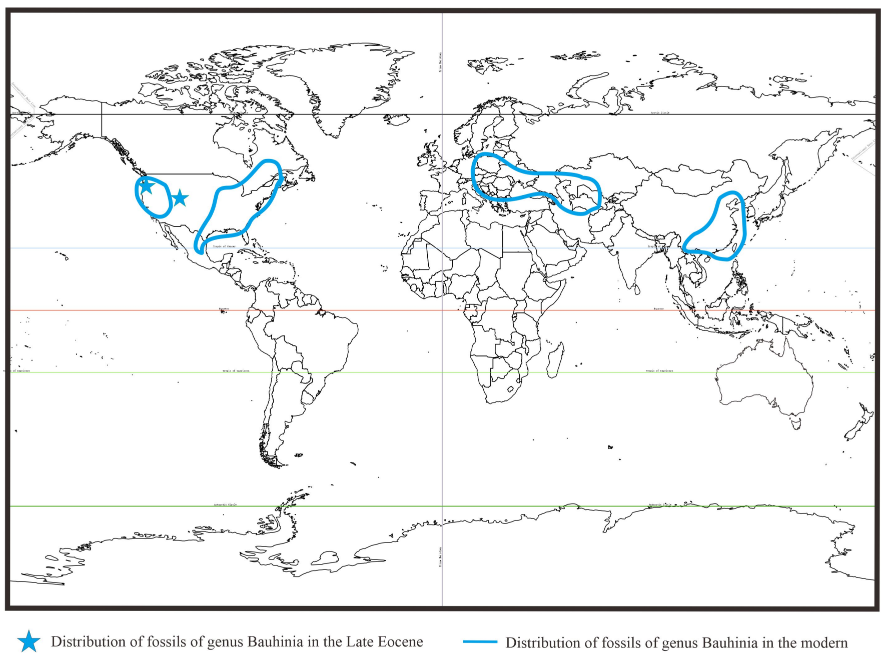

Figure 5. Distribution of fossil and extant Bauhinia spp. in the Late Eocene.

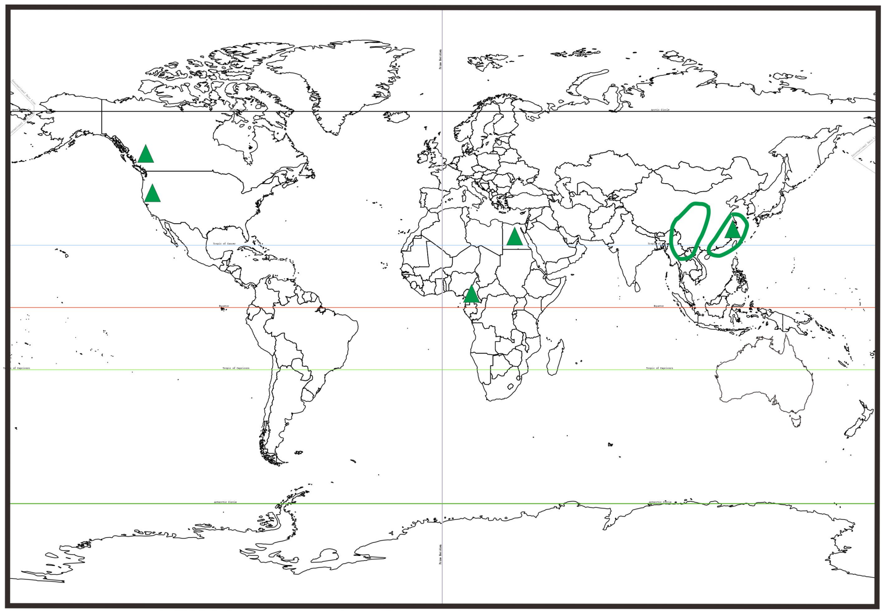

Figure 6. Distribution of Late Eocene fossil clouds and extant clouds.

which now belongs to a temperate arid climate, thus can indicate a mild and humid climate in western North America in the Late Eocene.

The results of fossil identification and habitat analysis of the nearest extant relatives can show that the composition and morphological characteristics of legume species from the Late Eocene period in western North America are significantly different from modern vegetation, plant ecological characteristics, and climate. Since the plants maintained close contact with the external environment [19], the fossils are a good indicator of the climatic environment of the time. Among the extant nearest relatives of the Late Eocene legume family in western North America, the temperate components are mainly Bauhinia spp. and the tropical-subtropical components are Acacia spp. and Caesalpinia spp.

The regional distribution characteristics of fossil legumes and extant legumes from the Late Eocene can be seen: the distribution of Acacia spp. migrated from high latitudes to lower latitudes, the distribution latitude of fossil Bauhinia spp. did not differ much from that of extant species, and the distribution latitude of fossil Caesalpinia spp. was higher than that of extant genera. However, in general, the regional distribution of extant legumes as a whole is in the tropical-subtropical low latitudes, and in comparison with the Late Eocene fossil record, the distribution range of extant legumes is reduced and concentrated in the southeastern part of China. Although the Late Eocene fossil distribution and distribution of extant species of Bauhinia cannot be clearly pointed out from the Late Eocene fossil distribution and distribution of extant species of Bauhinia, it can be basically concluded from the above Late Eocene fossil distribution and distribution of extant species of Acacia and Caesalpinia that there were fossil distributions of Acacia and Caesalpinia in western North America in the Late

Eocene, but there are no extant distributions of Acacia and Caesalpinia in western North America nowadays, and The current climate in western North America is temperate and arid, indicating that the present-day climate in western North America is not suitable for the growth of Acacia and Clerodendron, so it can be concluded that the Late Eocene climate in western North America was mild and humid.

4. Conclusions

1) This paper presents a detailed study of Late Eocene legume pod fossils collected from the Committee Creek Formation, John Day Formation, Teater Road, Crook County, western Oregon, North America. A total of 23 fossil specimens were collected, combining 17 fossil species from 14 genera as well as 21 extant species from 14 genera, and the collected fossil specimens were compared with them. Among the five fossil specimens, the nearest extant relatives were identified in a total of three genera and four species. Among the five fossil specimens, a total of three genera and four species were identified as the closest surviving relatives, including the similar species of Acacia vine and Acacia (undetermined species) of the genus Acacia; the species of Caesalpinia of the genus Caesalpinia; and the species of Bauhinia of the genus Bauhinia.

2) The Late Eocene paleoclimate of western North America was analyzed using the "extant proximate species method". By comparing the Late Eocene fossil legumes with the extant legumes, it can be seen that, on the whole, the extant legumes are distributed at low latitudes in the tropics and subtropics, and the distribution of the extant legumes is reduced when compared with the Late Eocene fossil record.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix. Plates

Specimen I, Specimen II, Specimen III and Specimen IV are all fossil specimens of legumes, uniform scale: 1 mm.