Building a fossil identification database for the leaves of Florissant Fossil Beds National Monument

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Background

Florissant Fossil Beds National Monument, Colorado, preserves one of the most diverse fossil assemblages in the world. More than 130 late Eocene fossil plant species, in the form of wood, leaves, seeds, fruits, flowers, and pollen, have been described from the Florissant Formation. The collections at the Monument are made up primarily of dicotyledonous angiosperm leaves preserved in paper shale (fig. 1). Definitive identification of these leaves is an ongoing process.

Florissant plant fossils have been described continually since excavations began in the 1870s. In 1953, Harry MacGinitie revised previous paleobotanical work and published a monograph[1] on the flora of the Florissant Formation. Various researchers have subsequently revised species from this work and described new species. Despite these efforts, there is no current searchable set of descriptions of the fossil leaves from Florissant, making identification of the fossils difficult.

We constructed a database in Microsoft Access™ 2010 containing descriptive information about all of the dicotyledonous leaves found at Florissant described as species or morphotypes. The database allows researchers to assign unknown Florissant fossil leaves to described morphotypes without having to search through previous literature and descriptions.

Figure 1. A sample of dicotyledonous leaves from Florissant's collection showing the variety of features present in the flora. Top, left to right: *Koelreuteria allenii*, *Populus crassa*, *Ribes errans*, *Paracarpinus fraterna*, and *Crataegus copeana*. Bottom, left to right: *Rhus lesquereuxi*, *Cedrelospermum lineatum*, *Rhus stellariaefolia or Sapindus coloradensis*, *Hydrangea fraxinifolia*, and *Caesalpinites coloradicus*. Scale bars 0.5 cm.

Methods

We compiled descriptions of the leaf morphotypes from several sources to maximize the potential variation in features within each morphotype included in the database. We included:

- The most recent published description of every morphotype. Published descriptions came primarily from MacGinitie (1953), but we also included earlier descriptions that were missing from the monograph and more recent descriptions of newly defined/classified types.
- Descriptions and diagrams made for a previous intern project at the monument.
- New descriptions we compiled based upon specimens from the Monument's collection and images from the Monument's online Museum Database[2] of published specimens.

The *Manual of Leaf Architecture*[3] provided standardized terms and definitions for characters and characters states. Older descriptions were updated to standardize characters according to those defined in the *Manual*. For example, "… secondaries approaching close to margin, ascending and looping, simulating a marginal vein…" (MacGinitie p. 144) was recorded in the database as "brochidodromous secondary venation."

Characters were removed and additional characters were added in order to clearly distinguish among the leaf types. We also produced a guide for use of the database, including how to search the database and how to score leaf characters.

List of characters used in the fossil leaf database

Leaf Attachment
Leaf Organization
Leaflet Arrangement
Leaflet Number *
Leaflet Attachment
Petiole Features
Laminar Attachment
Laminar Shape
Medial Symmetry
Base Symmetry
Lobation
Margin Type
Tooth Type
Special Margin Features
Apex Angle
Apex Shape
Base Angle
Base Shape
Primary Vein Framework
Number of Basal Veins
Major Secondary Framework
Interior Secondaries
Secondary Vein Branching*
Agrophic Veins
Minor Secondary Course
Perimarginal Veins
Major Secondary Spacing
Variation of Secondary Angle
Major Secondary Attachment
Basal Secondaries *
Intersecondary Veins
Intersecondary Proximal Course
Intersecondary Length
Intersecondary Distal Course
Intersecondary Vein Frequency
Intercostal Tertiary Veins
Tooth Spacing
Tooth Frequency *
Number of Tooth Orders
Sinus Shape
Tooth Shape
Principal Vein Termination
Tooth Apex Features

* characters not taken from the *Manual of Leaf Architecture*

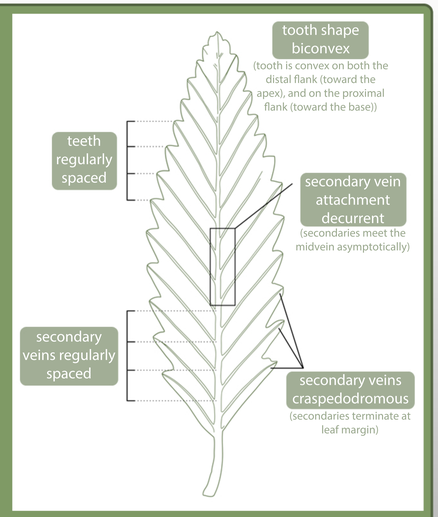
Results

The database includes all 98 published dicotyledonous leaf morphotypes and 44 characters, 40 of which were taken directly from the *Manual of Leaf Architecture*. The others were added after we found that more characters were needed to distinguish between certain morphotypes.

How to use the database

1. Determine whether a fossil leaf is sufficiently well preserved to identify and note well preserved features (left).

2. Describe these features (right).
   - leaf shape: elliptic
   - apex angle: acute
   - apex shape: convex
   - base angle: acute
   - base shape: straight
   - secondary vein course: craspedodromous
   - secondary vein spacing: regular
   - secondary vein attachment to midvein: decurrent
   - tooth spacing: regular
   - tooth shape: biconvex



3. Check the matching character states in the dropdown menu for each relevant character column in the database (below).

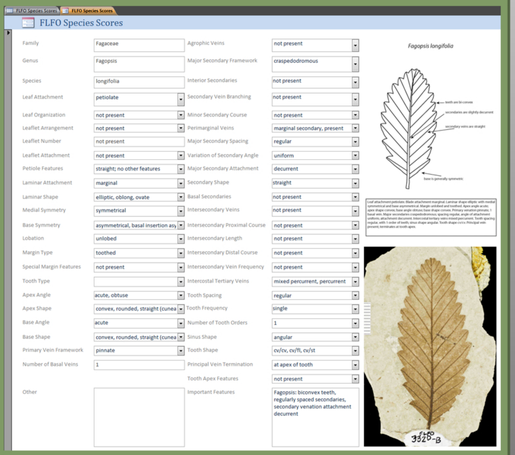
FLFO Species Scores

Family	Genus	Species	Laminar Shape	Apex Angle	Apex Shape	Base Angle	Base Shape	Major Secondary Framework	Major Secondary Spacing	Major Secondary Attachment	Tooth Spacing
Styracaceae	Halesia	reticulata	elliptic, ovate	acute	convex, rounded, straight (cuneate)	acute		dromous	irregular	decurrent, excurrent	not present
Rutaceae	Ptelea	cassiodes	elliptic, obovate, ovate	acute, obtuse	acuminate, convex, rounded, straight	acute		dromous,	irregular, regular	decurrent, excurrent	not present
Rosaceae	Rosa	hilliae	elliptic, ovate	acute, obtuse	convex, rounded, truncate	acute, obtu		dromous, pedodromous	irregular	excurrent	regular
Rosaceae	Amelanchier	scudderi	elliptic, obovate, ovate	acute, obtuse	convex, rounded, straight (cuneate)	acute, obtu		dromous,	irregular, regular	decurrent, excurrent	irregular, regular
Rosaceae	Cercocarpus	myricaefolius	elliptic, obovate, ovate	acute, obtuse	convex, rounded, straight (cuneate)	acute		dromous	gradually increasing proximally, regular	decurrent	regular
Rhamnaceae	Rhamnites	pseudo-stenophyllus	elliptic, obovate	acute, obtuse	acuminate, convex, rounded	acute		dromous, dromous	irregular	excurrent	not present
Lauraceae	Lindera	coloradica	elliptic, obovate	acute, obtuse	convex, rounded	acute, obtu		dromous, dromous	decreasing proximally and distally, irregular	excurrent	not present
Juglandaceae	Carya	libbeyi	elliptic, obovate, ovate	acute, obtuse	acuminate, convex, rounded, straight	acute, obtuse	convex, rounded, straight (cuneate)	craspedodromous, semicraspedodromous	decreasing proximally, irregular	excurrent	irregular
Fagaceae	Fagopsis	longifolia	elliptic, oblong, ovate	acute, obtuse	convex, rounded, straight (cuneate)	acute	convex, rounded, straight (cuneate)	craspedodromous	regular	decurrent	regular
Anacardiaceae	Cotinus	fraterna	elliptic, obovate	acute	convex, rounded, straight (cuneate)	acute	concave, convex, decurrent, rounded,	cladodromous, semicraspedodromous	irregular	decurrent	not present

4. The database will filter out all morphotypes that do not share those character states, leaving one or a few candidate types (below). The types can be verified by comparing the unknown leaf to images in the database species forms (right), or images from the online Museum Database.

FLFO Species Scores

Family	Genus	Species	Laminar Shape	Apex Angle	Apex Shape	Base Angle	Base Shape	Major Secondary Framework	Major Secondary Spacing	Major Secondary Attachment	Tooth Spacing	Tooth Shape
Fagaceae	Fagopsis	longifolia	elliptic, oblong, ovate	acute, obtuse	convex, rounded, straight (cuneate)	acute	convex, rounded, straight (cuneate)	craspedodromous	regular	decurrent	regular	cv/cv, cv/fl, cv/st



Discussion

The Florissant fossil leaf identification database is a work-in-progress and will continue to change as more research is done on Florissant fossils and as more efficient ways to store and share this information are found. At present, the database has a number of limitations:

- Only well preserved leaves or leaves with especially distinctive features will be precisely matched to a morphotype.
- Only leaves that belong to published morphotypes will be accurately identified; leaves belonging to new morphotypes may be incorrectly assigned to published morphotypes. However, the database also has the capacity to recognize potentially new morphotypes when unknown leaves cannot be matched to a published morphotype.
- The database is only available to researchers at Florissant Fossil Beds National Monument.
- Microsoft Access™ has limits on how many characters can be used, restricting the amount of detail and variation that can be included in the database.

Despite these limitations, this database is currently the most efficient way to identify dicotyledonous leaves from Florissant. It is the only source that combines all previous work on the leaves and therefore the only way to identify Florissant leaves without searching through numerous descriptions of published morphotypes in the previous literature.

References

1. MacGinitie, H.D. 1953. *Fossil Plants of the Florissant beds, Colorado*. Carnegie Institution of Washington Publication 599.
2. "Search Museum." Explore the World of Florissant Paleontology. http://planning.nps.gov/flfo/tax3_Search.cfm
3. Ellis, B., Daly, D.C., Hickey, L.J., Johnson, K.R., Mitchell, J.D., Wilf, P., and S.L. Wing. 2009. *Manual of Leaf Architecture*. Cornell University Press.

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