# The Paleontologist's Path: Discovering Florissant Fossils

**Grades 4-6**

**Activities:**
- **Cataloging**
- **Identifying fossil plants from the Florissant Formation: Paleobotany**
- **Students learn plant characteristics**
- **Students learn observation and inference skills**

**Materials Needed:**
- **Fossil ID Packets**
- **Paper Fossils**
- **Catalog Sheet**
- **Pieces/ Parts Sheet**
- **Observation and Inference Sheets**
- **Background Materials: Vocabulary and Short Story about Florissant's Fossil Formation**

**State Science Standards:**
**Standard 1 -** Processes: Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.
Students are able
- to identify and evaluate alternative explanations and procedures.
- to demonstrate that scientific ideas are used to explain previous observations and to predict future events.
- to ask questions and state hypotheses that lead to different types of scientific investigation.
- use appropriate tools.
- communicate results of their investigations in appropriate ways.
- use metric units in measuring and reporting result.
- to give examples of how collaboration can be useful in solving scientific problems and sharing findings.

**Standard 3**- Life Science: Students know and understand the characteristics and structure of living things, the processes of life, and how living things interact with each other and their environment.
**3.1**- Student know and understand the characteristics of living things, the diversity of life, and how living things interact with each other and with their environment.
- Students will be able to construct and use classification systems based on the structure of organisms

**3.4**- Students know and understand how organisms change over time in terms of biological evolution and genetics.
- Students will be able to describe evidence that reveals changes or constancy in groups of organisms over geologic time.

**Standard 4:** Earth and Space Science: Students know and understand the processes and interactions of Earth's systems and the structure and dynamics of Earth and other objects in space.

**4.1**- Students know and understand the composition of Earth, its history, and the natural processes that shape it.
Students will be able:

- to explain how minerals, rocks, and soils form.
- to explain how fossils are formed and used as evidence to indicate that life has changed through time.
- to explain the distribution and causes of some natural events.

# Activity One:  Fossil Identification

**Materials Needed:**

- **Fossil ID Packets (share packet between a group of 4-5 students)**
- **Paper Fossils Sheets (two fossils for each student)**

**Skills:**

- This activity is designed to sharpen the visual skills needed to classify fossil plants.
- Students learn to research materials and use available information.

**Directions:**

- Copy **Paper Fossils** and cut up, give each student two fossils.
- Have students assign their **Paper Fossil** a number and write number on both the **Paper Fossil** and on the sheet provided
- Copy **Fossil ID Packets** and have students work in groups of 4-5 sharing the **Fossil ID Packets**, helping each other identify their fossils.
- Each student identifies their plant fossils from the **Fossil ID Packets**.

**Activity 1 – Fossil ID – Worksheet**

**Name________________________**
**Name of Partners________________________**
**________________________**

**Fossil #_________________**

***Common Name*** _______________________

**Fossil #______________________**

***Common Name*** _______________________

# Activity Two: Observation and Inference

**Materials and Skills**

Provide each student with an **Observation and Inference sheet** or have students pair up and follow directions.
Read the definitions for "observation and inference" from the **Vocab List** they begin.

**Key to Activity Two:**

**Climatic Environments Section**
Most of the student's plants will fall in Subtropical and Warm Temperate

Question 1:
Generally should fall in Subtropical and Warm Temperate and that very few fall in Cool Temperate.

Hint: List by percentage of what is in each climate.

Question 2:
List the characteristics from the climate description page.

Question 3:
List the strongest inference from the list the class made above.

That the climate was warmer 35 million years ago.
That there was more moisture 35 million years ago.

# Activity Three:  Environments

**Materials**

- **Climate Work Sheet**
- **Climate Descriptions**
- **Investigating Paleoclimates**

**Skills:**

- **Using observation to make an inference**
- **Categorizing**

**Directions:** Activity One uses fossils found at Florissant Fossil Beds National Monument. Have students again form groups of 5 students. Take the fossils identified by each group of students in Activity One and place each fossil (genus) into a climate zone in **Investigation Paleoclimates**.

Name____________________________

# Investigating Paleoclimate

## Climatic environments of extant plant genera.

| Subtropical | Warm Temperate | Cool Temperate |
|---|---|---|
| *Dryopteris* fern | *Pinus* pine | *Pinus* pine |
| *Sequoia* redwood | *Sequoia* redwood | *Cercocarpus* mountain mahogany |
| *Zizyphus* lotus | *Crataegus* hawthorn | *Populus* poplar |
| *Cardiospermum* soapberry | *Carya* hickory | *Chamaecyparis* white cedar |
| *Rhus* anacard | *Fagopsis* beech | *Acer* maple |
| *Salix* Willow | *Acer* maple | Salix willow |
| | *Cercocarpus* mountain mahogany | |
| | *Chamaecyparis* white cedar | |
| | *Cedrelospermum* elm | |
| | *Paracarpinus* beech | |
| | *Ulmus* elm | |

**The plants you circled are the closest living relatives of genera typically found in the Florissant Fossil Beds.**

Answer the next three questions using the list above and the climate discriptions.

# Climate Descriptions

**Tropical:** Within five degrees of the equator there is little seasonal variation, it being hot and wet year round. Between five and fifteen degrees from the equator wet and dry seasons are common.

- The coolest month is above 18 degrees C.
- The annual mean temperature approaches 27 degrees C.
- Average rainfall between 100 and 200 cm per year.

*Examples:* Brazilian Lowlands, Philippine Islands

**Subtropical:** More noticeable seasonal variation in temperature, as well as distinct wet and dry seasons.

- Coldest month above 6 degrees C but below 18 degrees C.
- Annual mean temperature approximately 20 degrees C.
- Average annual rainfall between 50 and 100 cm.

*Examples*: Hawaiian Islands

**Warm Temperate:** Thoroughly differentiated seasons. Warm Temperate is further divided based on the wet season. Many interior continental regions have warm wet summers and mild winters. Those regions that have mild wet winters and hot dry summers are termed *Mediterranean*.

- Coldest month above 0 degrees C.
- Annual mean of 12 degrees C.
- Average annual rainfall is between 25 and 75 cm.

Examples: Milan, Italy; San Francisco, CA

**Cool Temperate**: Thoroughly differentiated seasons. Cool Temperate is also divided into two categories: *Oceanic* and *Continental*. *Oceanic Cool Temperate* is mild and rainy year round, while *Continental* regions experience cold winters and warm summers.

- Coldest month below 0 degrees C.
- Annual mean of 6 degrees C.
- Average annual rainfall is 25 to 75 cm.

*Examples*: Woodland Park, CO; Nova Scotia, Canada

**Cold**: Cold climates are defined as regions that spend 6 to 9 months below 6 degrees C.

- Coldest month well below 0 degrees C.
- Average rainfall is often below 25 cm per year.

*Examples*: Fairbanks, AK

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Climate Information:

http://www.fs.fed.us/colorimagemap/images/230.html

Espenshade, E. B. and Morrison, J. L., 1974, *Goode's World Atlas*. Chicago, Rand McNally and Co. pp. 10-15.

Pearce, E.A. and Smith, C.G., 1998, *Fodor's World Weather Guide*. New York, Random House. p. 11.

NA, 1987, *Encyclopedia of Climatology, Volume XI*, New York.

[1] MacGinite, H.D., 1953, *Fossil Plants of the Florissant Beds, Colorado*: Baltimore, Lord Baltimore Press. 198pgs.

# Climate Work Sheet

1. What are some observations about the plant list?

2. What are the characteristics of a Subtropical Climate? Of a Warm Temperate Climate? Of a Cool Temperate Climate?

3. What would you infer about the past climate at Florissant based on the plants you circled above?

# Activity Four:  Pieces Parts

**Materials:**

- **Pieces/Parts sheet**
- **Blank paper for drawing**

**Skills:**

- **Observation**
- **Learning to key plants for identification**
- **Names of plant parts.**

Have students use fossils from Activity One and using the **Pieces/Parts** handout as a guide, draw three identifiable parts of the fossil leaf.

Have the students label the parts according to the sheet.

# Activity Five:  Cataloging Fossil

**Materials:**

- **Cataloging sheets**
- **One paper fossil per student**

**Skills**

- **Scientific Data Collection**
- **Observation**
- **Research**

Have students select one paper fossil.
They should use the information they have gathered from the previous exercises to fill out the catalog sheets.
Have them draw a complete picture of their fossil.
Measure their fossil in centimeters, the grid is laid out in centimeters.

# Activity Six:

**Directions:**  Using **Fossil ID Packets**, have students use the supplied catalog sheet to catalog the fossils they found at the Florissant Fossil Quarry.

## Classroom Activity 1
## Keys to the Past

**Objectives:** Students will learn what an inference is and differentiate between inference and observation. They will examine a scene and a series of statements about the scene and then determine which statements are observations and which are inferences.

**Background:** Modern science is based on observation and inference. Observation is seeing and noting facts. Inference is a proposed reason or assumption based on observation. Paleontologists use these two principles to form theories, or put together a picture of what the past was like. By making observations of fossils they can make inferences about the animals or plants they represent. Also, by making observations of modern day plants and animals that are similar to the fossils, they can make inferences about the past.

**Materials:**
Handouts (3) for each student or team:
Dinosaur scene
List of statements
Petrified Bones and Tracks page

**Procedure:** Discuss the difference between observation and inference then pass out the handouts.
Have the students work individually or in teams. They will determine whether each statement is an observation or an inference. Later, go over their answers as a group, discussing the logic used in making their choices.

**Answers:**

**Dinosaur Page**

1. O
2. I
3. I
4. O
5. I
6. O
7. I
8. O
9. O
10. I
11. O
12. I
13. O
14. I
15. O
16. I
17. O
18. O

**Tracks and Bones**

1. O
2. I
3. O
4. I
5. O
6. O
7. I

## Putting Together the Pieces

**Dinosaur Scene:** A time machine has been invented that travels into the past and takes pictures, sending them to the present. You are asked to look at one of the pictures and interpret what you see. Put an "O" before the statements that are observations and an "I" before the statements that are inferences.

____ 1. The volcano is erupting.

____ 2. The camptosaurus is going to eat the stegasaurus.

____ 3. The stegosaurus will run into the water to escape.

____ 4. The camptosaurus is leaving tracks in the ground.

____ 5. The ground where the camptosaurus is walking is wet.

____ 6. There are plants growing in the water.

____ 7. The camptosaurus is going into the water to eat the plants.

____ 8. There is a tree growing next to the river.

____ 9. The tree looks like a palm tree.

____ 10. The climate is warm.

____ 11. The stegosaurus is eating the plant.

____ 12. The stegosaurus is an herbivore.

____ 13. There are bones from a dead animal by the shore.

____ 14. The camptosaurus killed the animal.

____ 15. Some more bones are in the water.

____ 16. The camptosaurus can't swim and will drown.

____ 17. Lava is coming down the sides of the volcano.

____ 18. The camptosaurus has sharp teeth for eating meat.

## Putting Together the Pieces

# Putting Together the Pieces

### Tracks and Bones

You are a paleontologist and you have just discovered a layer of rock with many fossils in it, both petrified bones and tracks. Decide whether the following statements are observations or inferences.

____ 1. There are tracks from three different animals in the rock.

____ 2. One animal was chasing another animal.

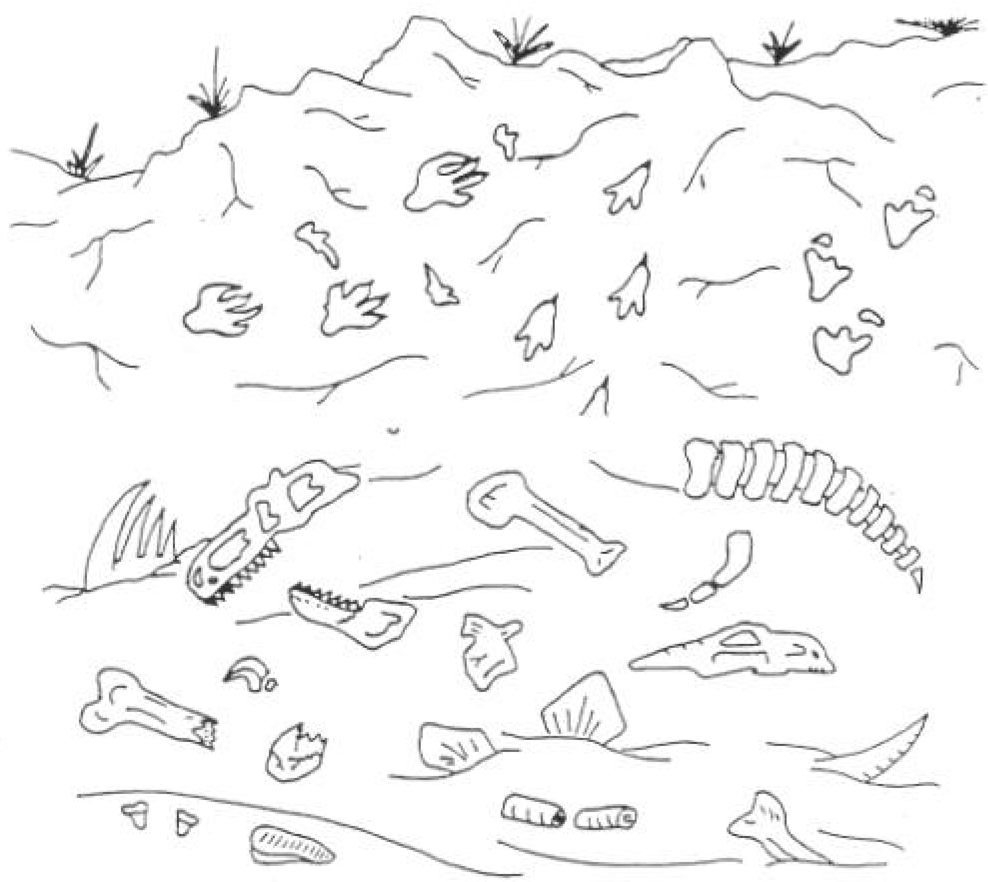
____ 3. Two different animals died in this spot.

____ 4. When the animals walked here the ground was wet.

____ 5. One of the animals that died here had bony plates.

____ 6. One of the animals that died here had sharp teeth.

____ 7. The animal that had sharp teeth ate meat.



# 4-6 Catalog Sheet

Name of fossil________________________________ Date_______________

Number of Fossil____________________________________________

Place Fossil was found_______________________________________

Cataloger (Name of Student)___________________________________

Measure the fossil and draw a picture of your fossil in the grid.
Boxes are1 cm square.

## Background Information on Dendroclimatology Studies Conducted at Florissant by Kathryn M. Gregory

The thirty-five million-year-old petrified stumps found on the National Monument are exceptionally preserved extinct redwoods (*Seguoia affinis*) closely related to the modern coast redwoods (*Sequoia sempervirens*) found in California today. During the late Eocene these giant trees lined a small stream in a paleovalley of low relief. About 35 million years ago a volcaniclastic mudflow originating in the Guffey Volcanic Center 18 miles to the west-southwest flooded the paleovalley and surrounded the trees with up to 4 meters of silica-rich mud. While modern redwoods can survive burial by sprouting new roots higher up the stump, the lack of these features on any of the fossil stumps at Florissant suggests that the speed and depth of burial killed these trees. (Gregory 1992) Later, another volcanic debris flow dammed the stream running over the earlier mudflow, causing a large lake to develop in the valley. Most of the upper portions of *Seguoia affinis* would have rotted away but the lower 4 meters were protected by the mudflow, and the slow process of petrification preserved the remnants of these ancient organisms.

The petrified stumps found at Florissant today are valuable scientific artifacts for several reasons. First, the process of petrification that these stumps underwent, called *permineralization*, preserves much more detail than the process of *replacement*, seen in logs from the Petrified Forest in Arizona. (Kiver and Harris 1999) Permineralization preserves individual cellular structures and internal features of the tree, will in replacement most cellular information is lost and only the outer features of the tree can be distinguished. (Kiver and Harris 1999) Secondly, it is believed that as many as 28 of the unearthed stumps are *in situ* -- they have not moved relative to each other in 35 million years. (Gregory 1992) In the Petrified Forest of Arizona only the northern Black Forest portion contains *in situ* stumps. (Kiver and Harris 1999) Unfortunately, it is uncertain how many of Florissant's petrified trees were *in situ,* since nearly a century of collection and vandalizing took place before the National Monument was established in 1969. Lastly, there is evidence that suggests that these trees co-existed. Two of the trees have ring width series that overlap, or *crossdate*, for 180 years. These two trees contain the best crossdating relationship yet found in the fossil record. (Gregory 1994) Crossdating emphasizes the climatic events observable in tree rings, while selecting against anomalies found in a single tree's growth pattern.

Among the numerous scientific papers published about Florissant, paleoelevation and paleoclimate have captured the most attention. While most research in the past relied on the plant fossils from the shales for information, Kate Gregory furthered her study of paleoelevation and paleoclimate by examining the finest details of the petrified stumps. The *Sequoia affinis* specimens from Florissant contain remarkably well preserved tree rings, which record the annual growth, and by extension the growing conditions, of individual trees. Wide, light-colored bands of earlywood are added underneath the bark during the early part of the growing season. The thin, dark band is called latewood, and marks the end of the growing season. Wetter, warmer, more favorable growing conditions are marked by a thicker earlywood band, while dry years show up as thin bands of earlywood. Furthermore, climate anomalies may show up as missing rings, rings that pinch out, or false rings (two rings during the same year). Trees that grow in tropical regions often lack true annual growth rings, since conditions may be suitable for growth year round. In these instances, rings record growth interruptions that may have no temporal significance. Some trees from Petrified Forest National Park contain interruption rings, as they record a much earlier (220mya) and warmer period in Earth history than those trees found at Florissant. (Kiver and Harris 1999)

When trees can be crossdated the limiting climatic factors influencing plant growth in a region can be distinguished from a poor growth year for one individual tree. As Gregory states

> "Crossdating is the hallmark of dendrochronology; it is the fundamental principle that establishes that a common year-to-year variable signal exists in tree ring series." - Gregory, 1994

For her dissertation Gregory collected ring width data from 28 stumps where she could find series of more than 50 rings exposed. Ring width was measured to a tenth of a millimeter using a hand lands, and in the field she also noted the potential for missing or false rings. (Gregory 1992) Once her data was collected, standard dendrochronology statistics were conducted using the information she gathered.

These calculations include “mean ring width, percentage of missing and false rings, mean sensitivity, standard deviation, and first order autocorrelation.” (Gregory 1994) Mean sensitivity is a statistic used to describe the “year to year variability of a series.” (Gregory 1992) First order autocorrelation describes the width difference between one ring and immediately adjacent rings. Gregory also noted the importance of comparing her results with ring width series from modern sequoias to better understand the limiting factors of climate as opposed to “site and genotype” variability. (Gregory 1994)

Gregory noted several interesting results from her study. Like the modern *Sequoia sempervirens*, *Sequoia affinis* stumps from Florissant have a distinct earlywood/latewood boundary, which Gregory inferred to be evidence of annual rings. (Gregory 1994) The two species of redwood also shared an affinity for missing rings and rings that pinch out, though no false rings were found in the Florissant stumps. (Gregory 1994) Many of the trees she sampled internally crossdate, and as previously mentioned, two stumps more than 50 meters apart crossdated for 180 years. (Gregory 1994) One of the most striking differences that Gregory noted between the two species was mean ring width. Giant sequoias were found to have a mean ring width between .84 and .96mm, coast redwoods had a mean ring width between .98 and 1.04mm, and *Sequoia affinis* had a mean ring width of 1.4mm. (Gregory 1992) Gregory found these numbers to be “significantly different at the 95% confidence level.”

The significant difference in mean ring width between modern sequoias and *Sequoia affinis* led Gregory to infer that the fossil trees were growing under more favorable conditions then their modern counterparts. Gregory proposed two potential explanations for this difference. First, while mean annual temperature (MAT) along the modern California coast is similar to the MAT at Florissant in the late Eocene[1], the growing season precipitation (GSP) may have been quite different. Modern sequoias see only 3.8cm of rain during their growing season, while it is believed that Florissant received up to 57cm of rain in the summer months. (Gregory, 1994) The hypothesized

[1] Gregory calculated the MAT at Florissant in the late Eocene to be 12.8 +/-1.5 degrees celsius using plant physiognomy. The coast of California today has a MAT of 11.8 degrees C. (Gregory, 1992)

summer precipitation is further supported by the sharp differentiation between earlywood and latewood in the fossil stumps, marking a "rapid end to the growing season" that may have been coincident with the end of the rainy season. (Gregory 1994)

Another, less established theory explains the difference in mean ring width between the species of sequoia with change in atmospheric carbon dioxide levels. Several scientific studies have shown that there is a direct relationship between increases in carbon dioxide levels and plant growth. Furthermore, it is believed that carbon dioxide levels were significantly higher during the Eocene. However, the long-term impact of increased carbon dioxide levels is not known. (Gregory 1994) For this reason, Gregory favored the hypothesis that growing season precipitation was the primary factor influencing the increase of mean ring width of *Sequoia affinis* found at Florissant.

To sum up:

- Unlike petrified trees that have undergone replacement, the permineralized sequoias at Florissant contain a remarkable amount of detail, including annual growth rings and cellular structure.
- Many of the petrified stumps are vertical, in situ, and at least two have been proven co-eval, providing even more information about their growing conditions and environment.
- Fossilized *sequoia affinis* stumps at Florissant have many features in common with their closest living relatives in California, including a high number of missing rings or rings that pinch out.
- The larger average mean ring width (1.4mm) in *sequoia affinis* fossils, when compared to rings of *sequoia sempervirens* or Giant sequoias (.95mm), is most likely a result of a wetter growing season, or less likely an increase in carbon dioxide levels.

# References Cited

Gregory, K.M., 1992, Late Eocene paleoelevation, paleoclimate, and paleogeography of
the Front Range region, Colorado [Ph.D. thesis]: Tucson, University of Arizona.

Gregory, K.M., 1994, *Florissant Petrified Forest: Discussion of* Sequoia affinis *Ring-Width Series*: Guidebook for the Field Trip: Late Paleogene Geology and Paleoenvironments of Central Colorado with emphasis on the Geology and Paleontology of Florissant Fossil Beds National Monument, p. 45-53.

Kiver, E.P., and Harris, D.V., 1999, Geology of U. S. Parklands: New York, John Wiley & Sons, Inc.