Canon Paleo Curriculum
Background 2
Unit: 2

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 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.

[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)

- 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

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