Cell size in *Ginkgo* and the paleo-\(\text{CO}_2\) proxy

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**Introduction**

Knowing how much \(\text{CO}_2\) there is in the atmosphere is central to understanding climate, but it can be difficult to assess for climates prior to ice core records. One common method for estimating atmospheric paleo-\(\text{CO}_2\) concentration is the stomatal index (SI), the proportion of stomata (pores in the leaf used for gas exchange) out of all epidermal and stomatal cells\(^1\). The SI is sensitive to changes in \(\text{CO}_2\) level because it is most advantageous for the plant to have as few stomata as possible, to reduce water loss, while still taking in enough carbon for growth and reproduction\(^2\).

The organism of choice for this proxy has been *Ginkgo*, the only extant genus of ginkgophyte gymnosperm. *Ginkgo* has been used in large part because Cenozoic fossil leaves, seeds, and fertile shoots assigned to *G. biloba*, the only extant genus of ginkgophyte gymnosperm, are very similar to modern *G. biloba*. This study’s purpose was to compare leaf epidermal cell size in *G. wyomingensis* and *G. biloba*.

**Results**

The *G. biloba* epidermal cells are about twice as large as those of *G. wyomingensis*, with the former having a mean cell area of 1119 \(\mu\text{m}^2\) and the latter a mean cell area of 573 \(\mu\text{m}^2\). The difference is significant with \(p < .000001\) (Student’s t-test, \(t = 7.59048, df = 176\)).

![Cell area in modern and fossil Ginkgo](image)

*G. biloba* cell area may have increased over historical time as well, although the relationship is highly influenced by the small size of the oldest specimen. The length of *G. biloba* stomatal pores is correlated with cell area, but this requires more data to confirm.

**Discussion**

Cell size in *Ginkgo* has not been constant since the early Cenozoic. Although these are preliminary results, we do not think taphonomic effects could have caused this magnitude of difference. The size and density of stomata are negatively correlated\(^3\), which affects stomatal density as a proxy for atmospheric \(\text{CO}_2\), and may affect SI models as well. Theory suggests that stomatal pore length should be correlated with cell area, but the linear fit does not explain the majority of the variation, suggesting that more samples should be added. If *G. wyomingensis* had smaller epidermal cells and stomatal pores, as well as fewer pores\(^4\), its evapotranspirative and photosynthetic rates would be lower. This in turns means that the relationship between \(\text{CO}_2\) and SI observed in *G. biloba* may not be directly applicable to fossil *G. wyomingensis*.

**Conclusions**

The results show that modern *G. biloba* and fossil *G. wyomingensis* are distinct in their epidermal cell size. This not only belies the notion that *Ginkgo* can be treated as a perfect “living fossil”, but, more importantly, impinges on the models used to reconstruct paleo-\(\text{CO}_2\) from stomatal indices. More work on epidermal cell size and morphology is required to establish if ancient \(\text{CO}_2\) levels can be inferred by using SI data from *G. biloba* and applying it to *G. wyomingensis*.

**Materials & Methods**

We examined three fossil cuticle specimens of *G. wyomingensis* from the early Eocene (55.8 Ma) Willwood Fm. of the Bighorn Basin, WY, USA. We compared these with 12 leaves of *G. biloba* from herbarium collections made 1877–1987 and living trees in experimental farms. All leaves were macerated with \(\text{Cr(VI)}\)O\(_3\) to separate the upper and lower cuticles, and the internal side of the lower cuticles were imaged with a Zeiss environmental SEM. The NIH software ImageJ was used to measure the area of cells. We made 1877–1987 and living trees in experimental farms. All leaves were compared these with 12 leaves of *G. biloba*.

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**References**