Reconstruction of atmospheric CO_2 concentration during the Devonian using fossil plant traits

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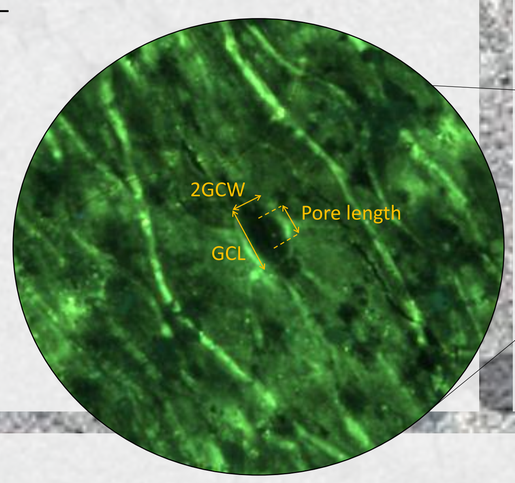
Introduction

The Devonian period was a key phase in plant evolution, distinguished by the appearance of a number of novel traits such as leaves, as well as the emergence of more complex ecosystems. During this time, largescale carbon cycle perturbations occurred, however there is a paucity of estimates for atmospheric CO_2 concentrations. This project aims to use the mechanistic model of Franks *et al.* (2014) to improve current understanding of palaeoatmospheric CO_2 concentrations over the Devonian.

Materials and Methods

Stomatal traits were directly measured from the fossilised cuticle of 21 hand specimens of *Sawdonia* from the Campbellton Fm., New Brunswick and the Battery Point Fm., Gaspé, Canada. $\delta^{13}C$ values for the fossil plants were obtained from Wan *et al.* (2019) and $\delta^{13}C$ air values were provided by Tom Algeo. The carbon assimilation rate (A_0) was estimated from extant terrestrial tropical-Subtropical, full-sun lycophytes (Brodribb and Holbrook, 2006; Carriqui *et al.*, 2019; Kennedy, Gensel and Gibling, 2012).



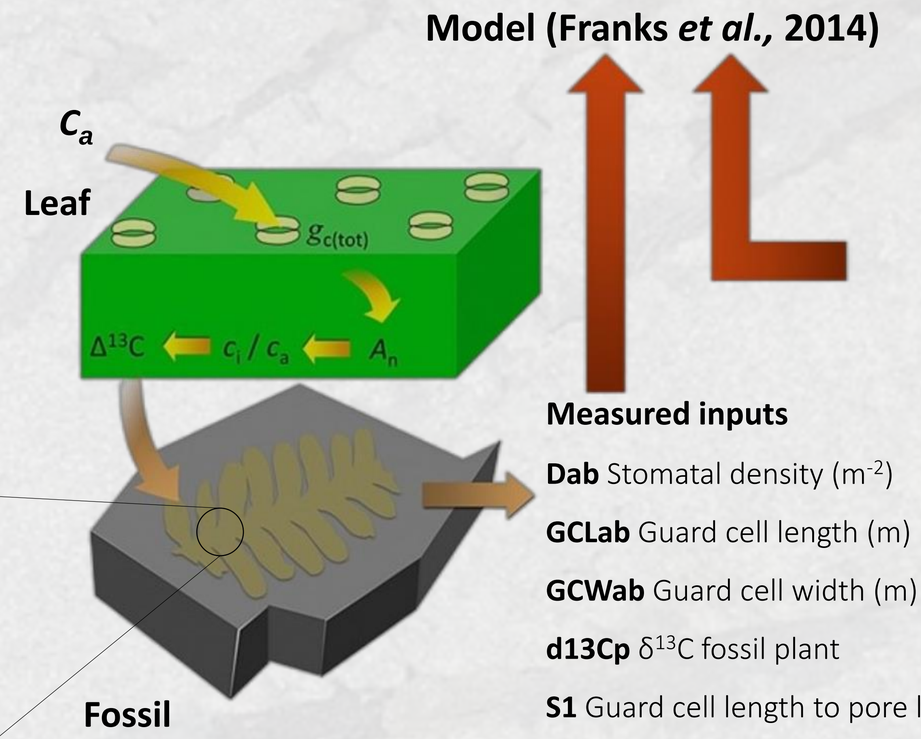


Figure 1. Summary of model inputs used. Adapted from Franks *et al.* (2014).

Results

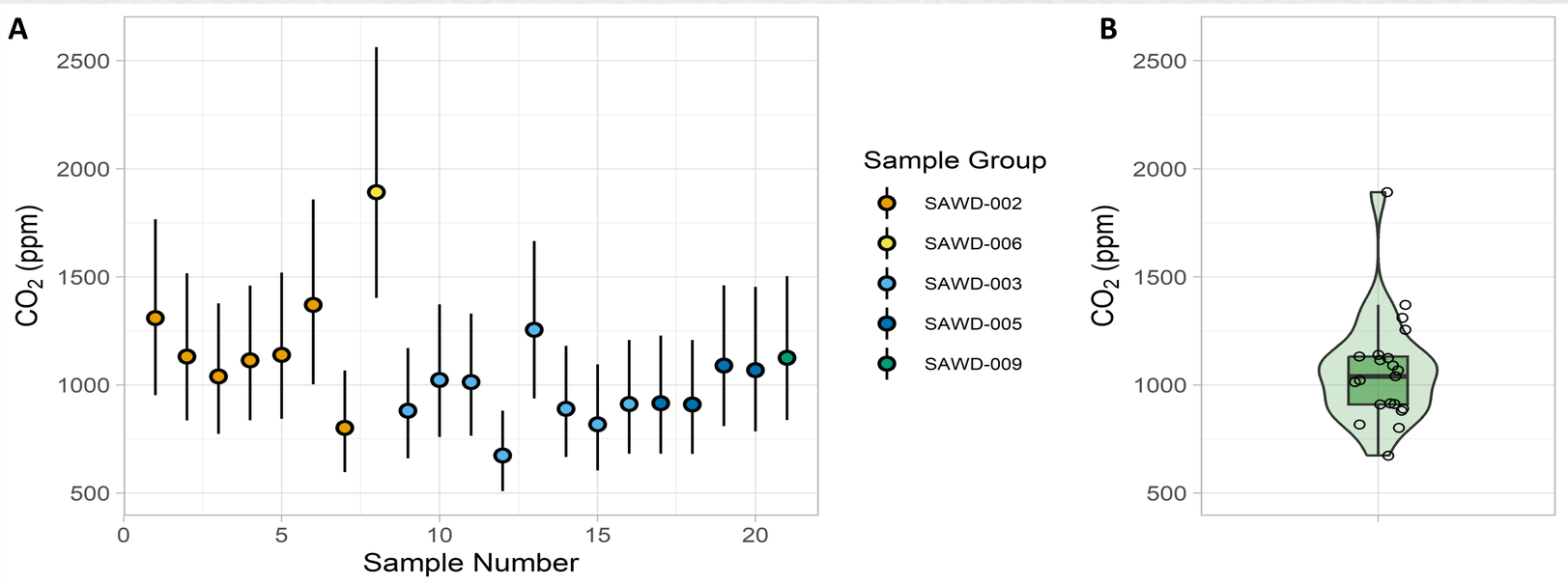


Figure 2. Average CO_2 estimates obtained for the Emsian (402.3 mya) from *Sawdonia* fossils. (A) The points show the average CO_2 estimates and the lines show the 16th and 84th percentile confidence intervals for the estimates from each sample. 10 observations were made per rock specimen. **(B)** The boxplot shows the **median CO_2 estimate (1040 ppm).** The sample groups SAWD-002 and 006 are from the Campbellton Fm.; groups SAWD-003, 005 and 009 are from the Battery Point Fm. The phylogenetically corrected $\delta^{13}C_{fossil}$ values and A_0 = 4.9 µmol m^{-2} s^{-1} inputs were used.

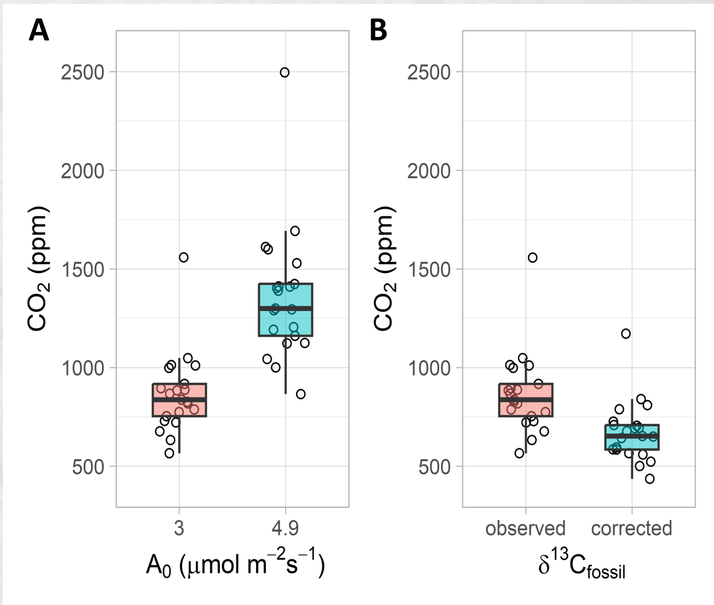


Figure 3. Model Sensitivity to A_0 and $\delta^{13}C_{fossil}$ inputs. (A) Using the mean A_n value ecologically equivalent lycophytes **increases the median CO_2 estimate by 461 ppm. (B)** Using the phylogenetic correction factor of Porter *et al.* (2017) **decreases the median CO_2 estimate by 185 ppm**.

Discussion

- The median CO_2 estimate (1040 ppm) lies within the 68% confidence interval of Foster, Royer and Hunt (2017) [1014, 2536].
- Future work will use additional fossil plant taxa to address gaps in the CO_2 record *(Fig. 4)*
- Fossil organisms associated with the *Sawdonia* specimens *(Fig. 5)* will be used to better constrain the $\delta^{13}C$ air parameter

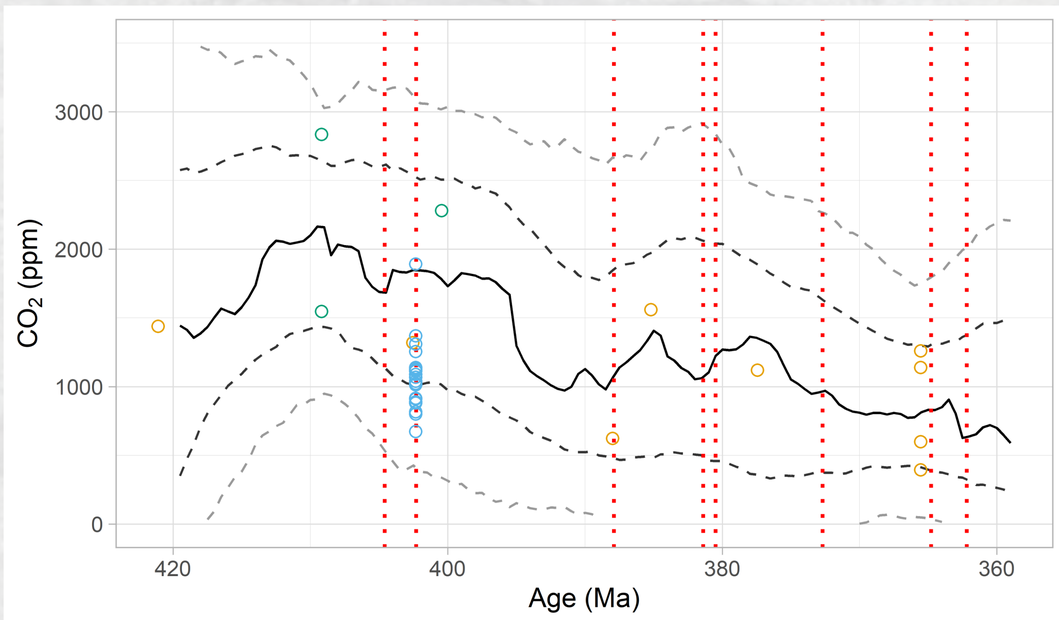


Figure 4. CO_2 estimates for the Devonian. Estimates obtained in this study are shown in blue. Values from published paleosol and plant-proxy studies (Foster, Royer and Hunt, 2017) are shown in orange and green, respectively. The most likely LOESS fit through the published data, is shown as the black line, with 68 and 95% confidence intervals shown as dark and light grey bands (Foster, Royer and Hunt, 2017). Dotted red lines indicate future data collection from fossil plant material.

Unknowns

Figure 5. Unknown fossil organisms. (A) Image of fossils found on *Sawdonia* (sample group SAWD-003) from the Battery Point Fm. Scale bar = 500 µm. **(B)** Photograph taken using epi-fluorescent microscope.

References
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