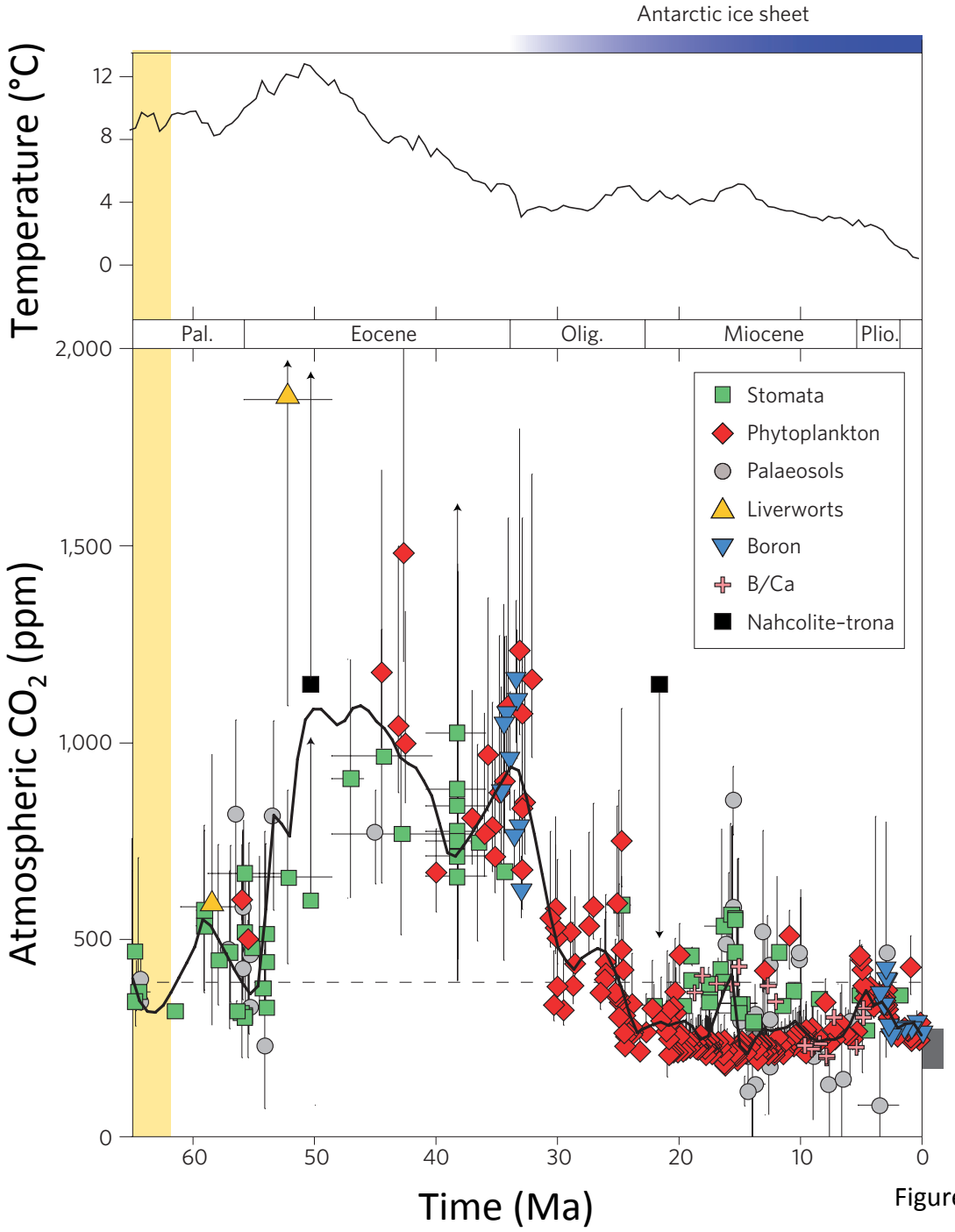
Multiple proxy estimates of atmospheric CO_2 from an early Paleocene rainforest



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Motivation

- ~2-fold scatter in CO_2 estimates
- Single fossil site: control for temporal and geographical CO_2 variations
- Compare multiple proxy results
- Early Paleocene: warm, moderately elevated CO_2

Figure 1 in Beerling & Royer (2011 *Nat. Geosci.* 4: 418-420)

Castle Rock fossil site



- Denver Basin, CO
- 63.8 +/- 0.3 Ma
- Forest floor preserved by riverbank flooding
- Unusually diverse
- MAT ~22°C
- MAP > 200 cm/yr
- No previous CO_2 estimates

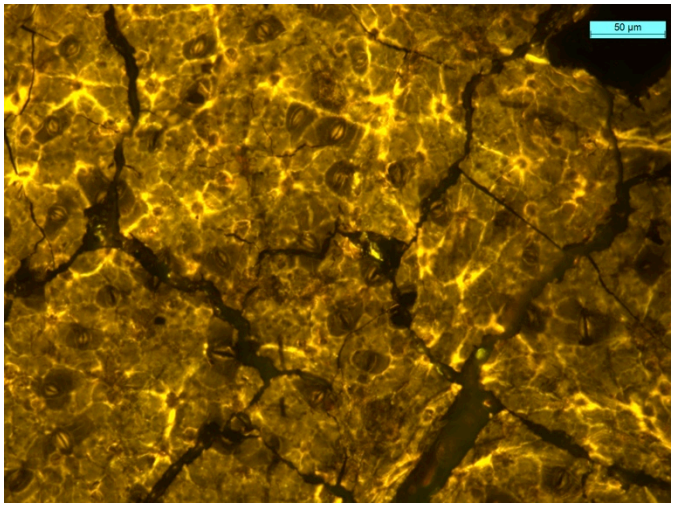
Ellis et al. (2003 *Rocky Mt. Geol.* 38: 73-100)

Painting by Jan Vriesen, DMNS Ancient Denvers Project

Methods & measurements

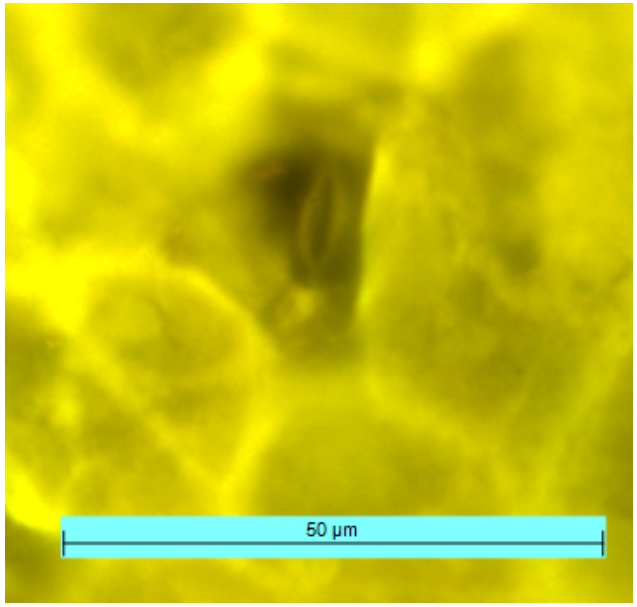






Fossil cuticle preparation following Kouwenberg et al. (2007 *Rev. Paleobot. Palyno.* 145: 243-248)

Methods & measurements





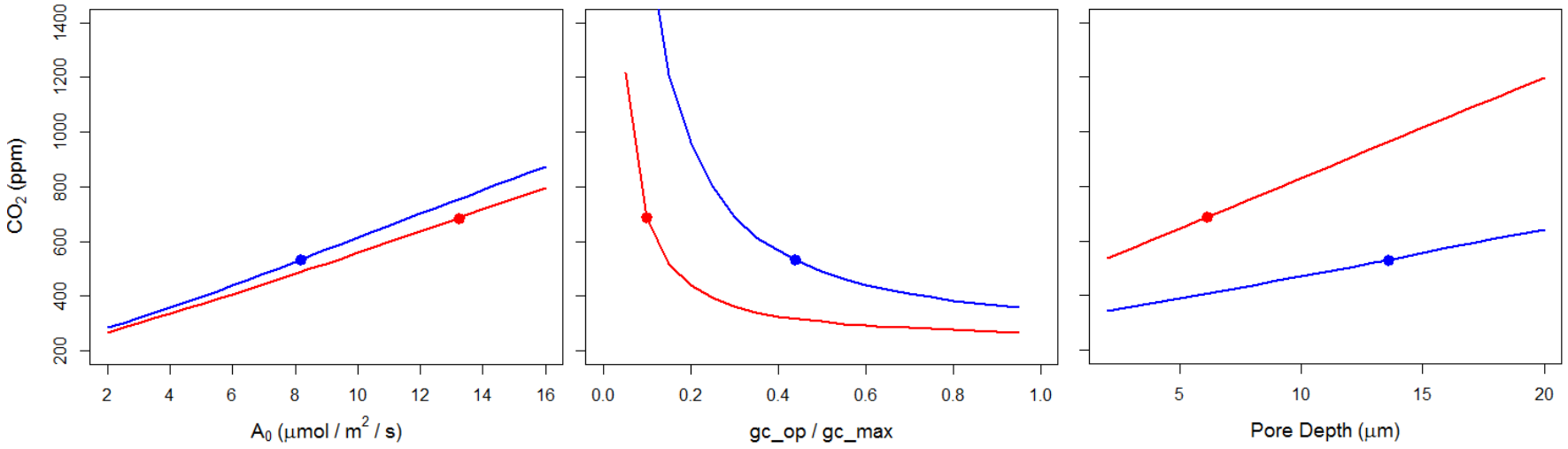
Can’t measure guard cell width on fossils (sunken stomata) so use measurements on modern relatives to scale

Franks model results

Ginkgo: median CO_2 = 532 ppm (95% CI = 433 – 666 ppm)

Sassafras: median CO_2 = 688 ppm (95% CI = 543 – 891 ppm)

Biggest sources of uncertainty: A_0, $g_{c(op)}/g_{c(max)}$, pore depth



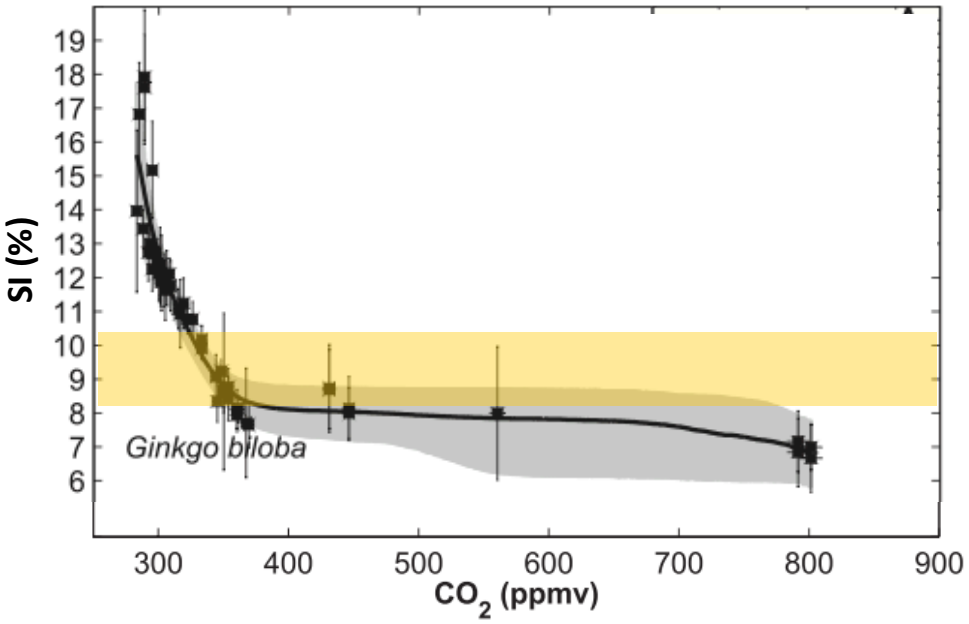
Stomatal Index

Castle Rock *Ginkgo*

- from 15 samples
- SI = 9.48 +/- 1.12%
- median CO_2 = 470 ppm
- 95% CI = 320 - 766 ppm

Previous *Ginkgo* results

- 64 Ma (Beerling et al., 2009)
- SI = 9.42 +/- 0.57%
- median CO_2 = 367 ppm
- 95% CI = 324 - 707 ppm



Modified from Figure 1 in Beerling et al. (2009 *Am. J. Sci.* 309: 775-787)

BRYOCARB proxy

- Liverworts: non-vascular, lack stomata
- Passive CO_2 intake, $\Delta^{13}C$ function of atmospheric CO_2
- Model inputs: $\Delta^{13}C$, temperature, O_2, irradiance



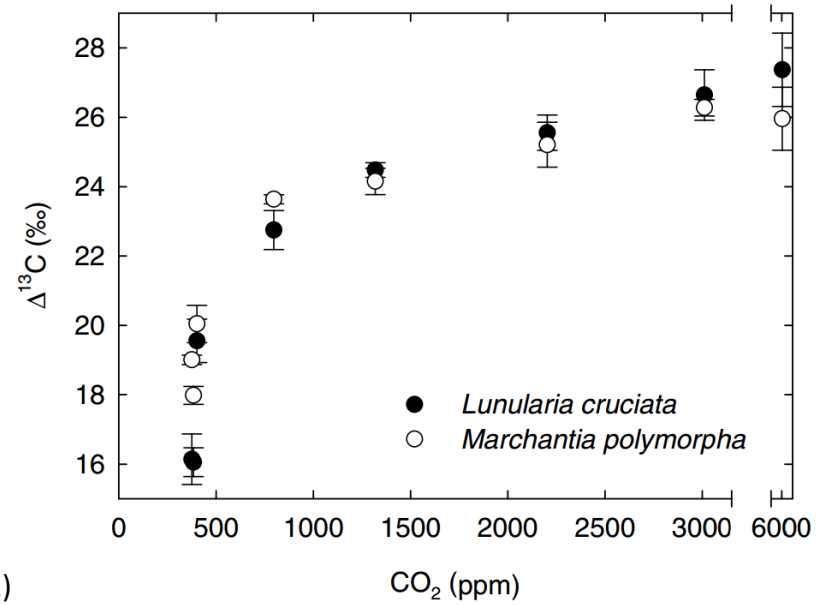


Figure 1 in Fletcher et al. (2006 *Geochim. Cosmochim. Ac.* 70: 5676-5691)

BRYOCARB results

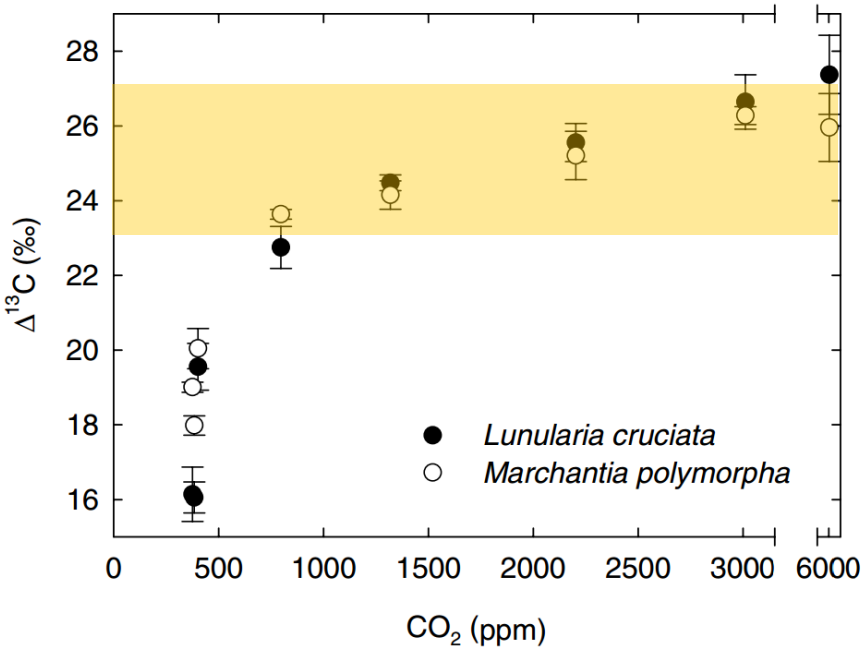


Figure 1 in Fletcher et al. (2006 *Geochim. Cosmochim. Ac.* 70: 5676-5691)

Depleted plant $\delta^{13}C$ → high atmospheric CO_2 estimate (> 1000 ppm)

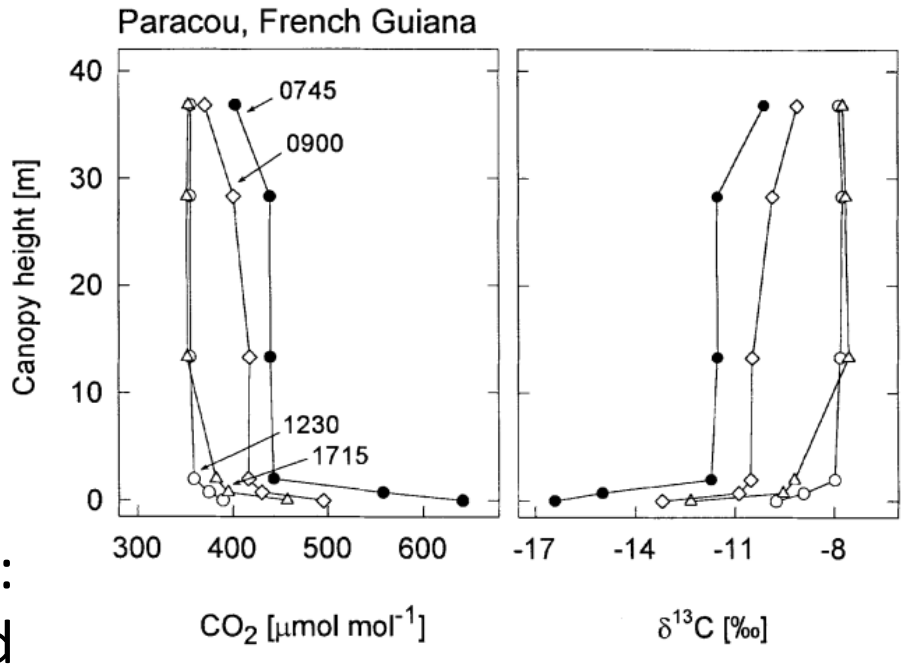
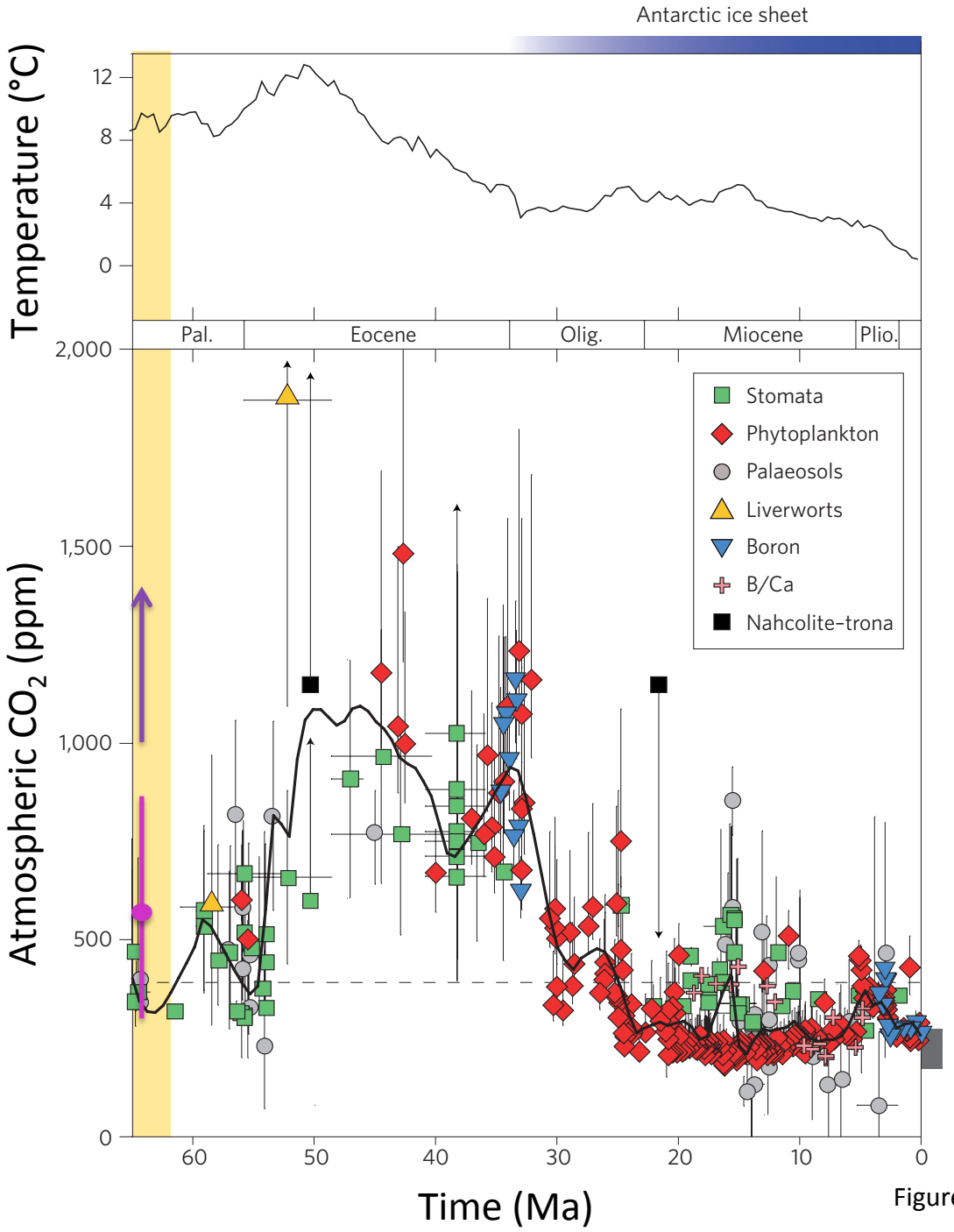


Figure 5 in Buchmann et al. (1997 *Oecologia* 110: 120-131)

Modern rainforest studies: atmospheric CO_2 higher and $\delta^{13}C$ depleted near forest floor



Summary

- Stomatal estimates (SI, Franks model): early Paleocene atmospheric CO_2 ≈ 560 ppm
- Higher than but not inconsistent with previous estimates
- Liverwort: CO_2 > 1000 ppm (forest floor effects?)
- Twofold difference in estimates

Figure 1 in Beerling & Royer (2011 *Nat. Geosci.* 4: 418-420)

Future work

- Measurements on second Castle Rock Lauraceae morphotype and three unidentified angiosperm taxa → Franks model
- Try gas exchange model in Konrad et al. (2008 *J. Theor. Biol.* 253: 638-658)