

## ***Interactive comment on “The $p\text{CO}_2$ estimates of the late Eocene in South China based on stomatal density of *Nageia Gaertner* leaves” by X.-Y. Liu et al.***

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#### General comments

There is unabated interest in  $p\text{CO}_2$  estimates for the Eocene, also driven by partially conflicting results between the different proxy methods. The study of Liu et al. adds a data set for the Late Eocene, based on stomatal frequency of fossil *Nageia* leaves. While it is generally desirable to increase proxy data information about Eocene  $p\text{CO}_2$ , there are several problems with the manuscript of Liu et al. The authors should at least discuss the following points, and conduct some statistical analyses on their data to obtain information on statistical soundness.

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1. The number of fossil and extant leaves that were available for the study is quite low, causing problems with respect to statistical soundness of the data, as was already remarked by the editor and referee D. Royer. The extant data set on which calibration of fossil stomatal density against  $p\text{CO}_2$  is based, consists of samples from five historical collections dating back to 1868, 1932, 1934, 1936, and 1955, and so to periods of different atmospheric  $\text{CO}_2$ . While the leaves from 1932–1936, six in total, appear to represent a statistically sufficient data set for the corresponding historical  $p\text{CO}_2$  value, there is only one leaf for the 1868  $p\text{CO}_2$  level and two leaves for the 1955  $p\text{CO}_2$  level. This raises serious questions about statistical significance of the correlation stomatal density –  $p\text{CO}_2$  presented in this study. At least data from modern leaves are required to improve statistical reliability.

2. The generally assumed reason for the sensitivity of stomata to  $p\text{CO}_2$  is adaptation of the total gas conductance of leaves to atmospheric  $\text{CO}_2$  level. Besides stomatal density, stomatal size can also change, and this may interfere with the stomatal  $\text{CO}_2$  signal. Is there any evidence of changing pore length in fossil *Nageia*, compared to modern plants? While the methodology used by Liu et al. is empirical, there were quite a few efforts, during the last years, to put the response of stomatal density to  $p\text{CO}_2$  into an ecophysiological perspective.

3. Usually, the response of stomatal density to increasing  $p\text{CO}_2$  decreases with the  $p\text{CO}_2$  level meaning that the response shows a saturating and therefore non-linear behavior: with low (subambient)  $p\text{CO}_2$ , the response curve shows a much steeper gradient than with higher  $p\text{CO}_2$  while in the high- $p\text{CO}_2$  region (often starting with ambient  $p\text{CO}_2$ ), stomatal density response flattens out. This means that for higher  $p\text{CO}_2$  levels, it can become more difficult to evaluate the stomatal density response, and to reliably calculate  $p\text{CO}_2$  from stomatal data. Particularly for higher  $\text{CO}_2$ , a higher amount of data is necessary.

Figure 3a, b (putting aside statistical problems) shows a stomatal density response to a quite limited  $p\text{CO}_2$  interval, extending only to 313 ppm. Considering the usually

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nonlinear response, data of modern *Nageia* are urgently needed to evaluate the behavior of stomatal density under higher pCO<sub>2</sub>. Otherwise it will be difficult to obtain a sound pCO<sub>2</sub> signal with fossil leaves. The stomatal ratio method is based on a linear approach, and to me it appears difficult to obtain a reliable result with it, particularly for periods for which at least ambient or higher pCO<sub>2</sub> is to be expected.

#### Specific comments

p. 2623, l. 6: " However, the SDs and SIs data of the abaxial sides, summarized in Table 3, give significantly higher values (53.22–82.71 in SDs and 3.13–4.66 in SIs) than those from the adaxial sides." Did the authors check the differences in stomatal density between both leaf sides for statistical significance?

#### Minor comments

p. 2623, l. 19: ". . .and Royer (2001) considered both the SD and SI vary with economical and 20 biological factors such as irradiance, temperature, and water supply. . ." Probably, the authors mean "ecological factors".

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