Appendix DR1

Modeling Stomatal Transpiration

We use the stomatal model of Beerling and Woodward (Beerling and Woodward, 1997, 2001). The Astartekløft Tr-J climate is reconstructed as tropical to subtropical with a minimum mean annual temperature of 25°C, based on paleoclimate model estimates (Huyhn and Poulsen, 2005) and abundant occurrence of Dipteridacae ferns (eg. *Thaumatopteris*, *Dictyophyllum*), which today are exclusively tropical in distribution. The coastal position of Astartekløft and proximity to rivers and an extensive inland lake, and absence of any sedimentological evidence for even moderate levels of evaporation, suggest that at least regionally, relative humidity was high. We have therefore set average relative humidity of 70% within the model. Based on a palaeolatitude of approximately 45 to 50 ºN we have assumed a mean daily photosynthetically active radiation of 600 µmol m^{-2} s^{-1}. The stomatal model uses observations of SD and SL to calculate leaf and canopy transpiration. The degree of stomatal opening, defined as stomatal conductance, is determined by both the leaf vapour pressure deficit with the surrounding air and by the [CO_2] within the leaf, with stomatal conductance decreasing with increasing [CO_2] (Ainsworth and Rogers, 2007). In order to simulate stomatal conductance it is therefore necessary to estimate the impact of photosynthesis and stomatal conductance on intercellular [CO_2] of the leaf. The Farquhar *et al.* (Farquhar et al., 1980) model of photosynthesis is used. In this model it is assumed that the maximum rate of carboxylation is equally low for all of the species under investigation (c. 10 µmol m^{-2} s^{-1}) and is correlated with the rate of electron transport (Beerling and Woodward, 1997, 2001). The stomatal conductance is then defined as the value that satisfies both the constraints of the vapour pressure deficit of the leaf with the air and the direct effect of the intercellular CO_2 concentration, determined by the rate of photosynthesis.

Leaf Area Index (LAI) is the ratio of total upper leaf surface of vegetation, divided by the surface of the land on which the vegetation grows (Chen et al., 1997). LAI is a dimensionless value and typically ranges from 0 (bare ground) to 6 (dense forest). Together, stomatal conductance and LAI have a profound effect on the terrestrial water and energy balance (Kürschner et al., 1997). LAI is traditionally used to predict photosynthetic primary production and forest health, and is also one of the key biological variables in modelling future climatic consequences of the anthropogenic [CO_2] increase. Results from coupled biosphere-atmosphere models suggest that in general a 25-50% decrease in canopy conductance takes place when [CO_2] doubles (Chen et al., 1997; Dai et al., 2004; Kürschner et al., 1997). We calculate canopy transpiration by solving the equations at the end of the stomatal model (Beerling and Woodward, 2001), assuming an extinction coefficient for light through the canopy of 0.5 and estimating transpiration for both sunlit and shaded parts of the canopy. Reconstructions of the Astartekløft floral communities show that the Triassic forest canopy was dominated by broadleaf gymnosperms, such as *Podozamites, Ginkgo* and *Baiera*, with ferns, cycads and the bennettitaleans *Anomozamites* and *Pterophyllum* mid canopy and in the understory (McElwain et al., 2007). The Triassic flora was rich and diverse, but began degenerating in beds 3 and 4, where *Podozamites* and *Pterophyllum* became dominant in the plant community, and collapsed at the Tr-J transition zone (bed 5), where *Stachytaxus* (deciduous conifer) became completely dominant (McElwain et al., 2007; McElwain et al., 2009). In the Jurassic, floral eveness and richness recovered slowly. Dominant Jurassic canopy trees include the ginkgoaleans

Ginkgo, Sphenobaiera and *Czekanowskia*, as well as the fern *Cladophlebis* in the understory (dominant in the poorly developed swamp environment of bed 6) (McElwain et al., 2007). The Tr-J floral community at Astartekløft has been interpreted as most closely resembling modern day southern hemisphere broadleaf conifer forests, such as forests dominated by the broadleaf evergreens *Podocarpus* and *Agathis* (McElwain et al., 2007). These are tropical to temperate evergreen broadleaf forests – TrEBL and TeEBL respectively (Scurlock et al., 2001). According to the “Global Leaf Area Index Data from Field Measurements, 1932-2000”, such forests have a mean LAI of approximately 4.8-5.7 (Scurlock et al., 2001). Due to the nature of the depositional environment at Astartekløft, on more open flood plains rather than in a dense inland forest, we calculate canopy transpiration here using the conservatively appropriated LAI of 4 and 5.

REFERENCES

Ainsworth, E. A., and Rogers, A., 2007, The response of photosynthesis and stomatal conductance to rising [CO2]: mechanisms and environmental interactions: Plant, Cell and Environment v. 30, p. 258-270.

Beerling, D. J., and Woodward, F. I., 1997, Changes in plant function over the Phanerozoic: reconstructions based on the fossil record: Botanical Journal of the Linnean Society v. 124, p. 137-153.

-, 2001, Vegetation and the terrestrial carbon cycle. Modelling the first 400 million years, Cambridge, Cambridge University Press, 405 p.:

Chen, J. M., Rich, P. M. S., Gower, T., Norman, J. M., and Plummer, S., 1997, Leaf area index of boreal forests: theory, techniques, and measurements: Journal of Geophysical Research-Atmospheres, v. 102, p. 29429-29443.

Dai, Y., Dickinson, R. E., and Wang, Y.-P., 2004, A two-big-leaf model for canopy temperature, photosyntheis, and stomatal conductance: Journal of Climate v. 17, p. 2281-2299.

Farquhar, G. D., von Caemmerer, S., and Berry, J. A., 1980, A biochemical model of photosynthetic CO2 assimilation in leaves of C3 species: Planta, v. 149, p. 78-90.

Huyhn, T. T., and Poulsen, C. J., 2005, Rising atmospheric CO2 as a possible trigger for the end-Triassic mass extinction: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 217, p. 223-242.

Kürschner, W. M., Wagner, F., Visscher, E. H., and Visscher, H., 1997, Predicting the response of leaf stomatal frequency to a future CO2-enriched atmosphere: constraints from historical observations: Geologische Rundschau v. 86, p. 512-517.

McElwain, J. C., Popa, M. E., Hesselbo, S. P., Haworth, M., and Surlyk, F., 2007, Macroecological responses of terrestrial vegetation to climatic and atmospheric change across the Triassic/Jurassic boundary in East Greenland: Paleobiology, v. 33, p. 547-573.

McElwain, J. C., Wagner, P. J., and Hesselbo, S. P., 2009, Fossil plant relative abundances indicate sudden loss of Late Triassic biodiversity in East Greenland: Science, v. 324, p. 1554-1556.

Scurlock, J. M. O., Asner, G. P., and Gower, S. T., 2001, Global Leaf Area Index Data from Field Measurements, 1932-2000, Volume 2001: Oak Ridge, Tennessee, U.S.A., Oak Ridge National Laboratory Distributed Active Archive Center, p. Data set.

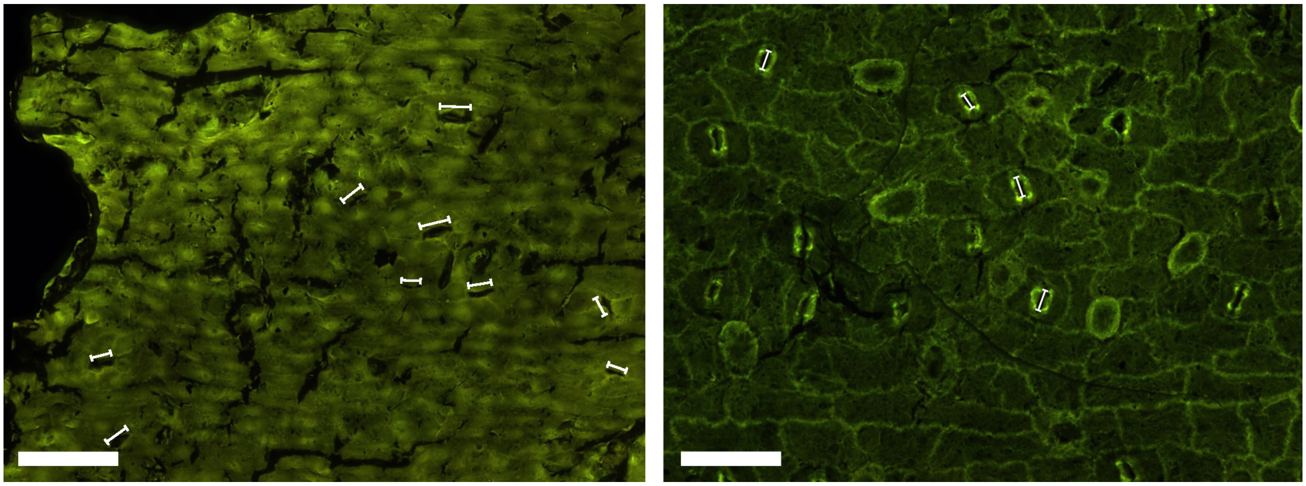

Figure DR1. The figure shows the epidermal surface of Gingkoales (left) and Bennettittales (right) leaf specimens. White I symbols illustrate the measured stomatal lengths (SL). SL was measured using Automontage software, and the I symbols have been added using Adobe Illustrator to show graphically how length was measured. While Bennettitalean SL measurements are fairly straight forward, Ginkgoaleans often have sunken guard cells and stomatal complex openings which may obscure these. Therefore, the SL measurement symbols have been moved to the side of the stomatal complex, allowing the reader to zoom in and observe the relationship between the stomatal complex openings, the sunken guard cells (often visible) and the SL measurements. Scalebar on both photographs is 100 µm.

Table DR1. The table lists stomatal length measurements (with standard error, SE), stomatal density and transpiration for each fossil leaf specimen, listed by their specimen ID number, genus name where available, plant bed and height in the sedimentary section. Also listed is the CO_2 concentration used for each plant bed in the numerical leaf gas exchange model, and transpiration using leaf area index LAI 1-5, as well as the average transpiration for each plant group in each bed.

Bennettites								Transpiration mm/day						Transpiration Average mm/day					
(cm)	Bed	Genus	Specimen ID	Stomatal length	SE	Stomatal density	CO_2	Transp	LAI=1	LAI=2	LAI=3	LAI=4	LAI=5	Transp	LAI=1	LAI=2	LAI=3	LAI=4	LAI=5
1358	1	*Pterophyllum*	46876	25.8	0.77	61.05	1000	2.14	1.73	2.86	3.63	4.19	4.60	2.39	1.93	3.19	4.05	4.67	5.14
1358		*Anomozamites*	46893	20.8	0.38	131.40		3.00	2.42	4.01	5.09	5.87	6.46						
1358		*Anomozamites*	46905	25.1	0.34	58.83		2.05	1.65	2.74	3.48	4.00	4.41						
1358		*Pterophyllum*	46921	19.0	0.31	85.47		2.18	1.77	2.92	3.71	4.27	4.70						
1358		*Pterophyllum*	46953	20.3	0.38	80.50		2.19	1.77	2.93	3.72	4.29	4.72						
1358		*Anomozamites*	46963	17.5	0.27	123.70		2.62	2.12	3.51	4.45	5.13	5.64						
1358		*Anomozamites*	46975	20.1	0.32	101.00		2.52	2.04	3.37	4.28	4.93	5.43						
2356	1.5	*Anomozamites*	46843	24.0	0.40	65.49	1000	2.14	1.73	2.86	3.63	4.18	4.60	2.29	1.86	3.07	3.89	4.48	4.93
2356		*Pterophyllum*	46851	21.5	0.24	79.29		2.26	1.82	3.02	3.83	4.41	4.85						
2356		*Pterophyllum*	47122	17.8	0.35	65.01		1.72	1.39	2.30	2.92	3.37	3.70						
2356		*Pterophyllum*	47128	19.8	0.26	98.51		2.46	2.00	3.29	4.18	4.81	5.29						
2356		*Anomozamites*	47667	22.4	0.26	114.10		2.89	2.34	3.87	4.91	5.65	6.22						
3388	2	*Anomozamites*	46988	23.1	0.27	109.40	1000	2.87	2.32	3.84	4.88	5.62	6.18	2.14	1.73	2.86	3.63	4.18	4.60
3388		*Anomozamites*	46991	20.8	0.29	116.60		2.80	2.27	3.75	4.76	5.49	6.04						
3388		*Pterophyllum*	46992	19.8	0.27	71.36		1.99	1.61	2.66	3.37	3.88	4.27						
3388		*Pterophyllum*	47023	17.4	0.22	72.20		1.83	1.48	2.44	3.10	3.57	3.93						
3388		*Anomozamites*	47042	20.3	0.38	75.50		2.10	1.70	2.81	3.57	4.11	4.52						
3388		*Pterophyllum*	47075	17.5	0.27	56.60		1.53	1.24	2.05	2.60	3.00	3.30						
3388		*Anomozamites*	48864	20.0	0.29	63.27		1.84	1.48	2.46	3.12	3.59	3.95						
3751	3	*Pterophyllum*	47224	19.6	0.41	71.04	1000	1.97	1.59	2.63	3.34	3.85	4.23	2.07	1.67	2.77	3.52	4.05	4.45
3751		*Pterophyllum*	47230	19.9	0.34	79.92		2.15	1.74	2.88	3.66	4.21	4.63						
3751		*Pterophyllum*	47125	19.9	0.40	76.59		2.09	1.69	2.80	3.55	4.09	4.50						
4097	4	*Anomozamites*	47140	20.5	0.32	78.80	1200	2.07	1.67	2.77	3.52	4.05	4.46	2.13	1.72	2.85	3.62	4.17	4.59
4097		*Anomozamites*	47147	19.2	0.28	89.91		2.17	1.75	2.90	3.68	4.24	4.66						
4097		*Pterophyllum*	47278	20.3	0.35	77.70		2.04	1.65	2.73	3.46	3.99	4.38						
4097		*Anomozamites*	47376	19.7	0.29	98.70		2.34	1.89	3.13	3.98	4.58	5.04						
4097		*Pterophyllum*	47476	21.7	0.34	56.60		1.70	1.38	2.28	2.89	3.33	3.67						
4097		*Pterophyllum*	48241	20.8	0.30	111.00		2.61	2.11	3.49	4.43	5.10	5.62						
4097		*Pterophyllum*	48251	17.2	0.25	88.80		1.99	1.61	2.67	3.38	3.90	4.29						
4600	5	*Anomozamites*	48080	20.8	0.41	49.33	1800	1.27	1.02	1.69	2.15	2.48	2.72	1.10	0.89	1.47	1.87	2.15	2.36
4600		-	Ast-5-SH-3	20.3	0.43	44.40		1.14	0.92	1.53	1.94	2.23	2.46						
4600		-	Ben 1	20.4	0.36	44.40		1.15	0.93	1.53	1.95	2.24	2.47						
4600		-	Ben 5	22.1	0.35	49.30		1.33	1.07	1.78	2.25	2.60	2.86						
4600		-	Ben 6	22.4	0.39	29.60		0.89	0.72	1.19	1.51	1.73	1.91						
4600		-	Ast-5.06-SH-3	18.1	0.58	33.30		0.82	0.66	1.09	1.39	1.60	1.76						
6086	6	-	Ben 1	16.9	0.60	26.96	2000	0.61	0.49	0.82	1.04	1.19	1.32	0.85	0.69	1.14	1.45	1.67	1.84
6086		-	Ben 2	19.9	0.88	59.20		1.34	1.08	1.79	2.27	2.62	2.88						
6086		-	Ben 3	18.9	0.89	19.43		0.51	0.41	0.68	0.86	0.99	1.09						
6086		-	Ben 4	20.1	0.32	57.09		1.31	1.06	1.75	2.23	2.56	2.82						
6086		-	Ben 5	17.3	1.14	14.80		0.37	0.30	0.50	0.63	0.73	0.80						
6086		-	Ben 6	17.3	0.56	46.30		0.98	0.79	1.31	1.66	1.92	2.11						
7249	7	*Anomozamites*	47672	19.8	0.38	85.63	1000	2.25	1.82	3.01	3.82	4.40	4.84	2.30	1.86	3.08	3.90	4.50	4.95
7249		*Anomozamites*	47739	23.3	0.42	77.70		2.35	1.90	3.14	3.98	4.59	5.05						

Ginkgos								Transpiration mm/day						Transpiration Average mm/day					
(cm)	Bed	Genus	Specimen ID	Stomatal length	SE	Stomatal density	CO_2	Transp	LAI=1	LAI=2	LAI=3	LAI=4	LAI=5	Transp	LAI=1	LAI=2	LAI=3	LAI=4	LAI=5
1358	1	*Ginkgo*	46884	14.86	0.34	74.37	1000	1.66	1.34	2.23	2.83	3.25	3.58	1.64	1.33	2.19	2.79	3.20	3.53
1358		*Baiera*	46972	24.32	0.57	82.14		2.50	2.02	3.34	4.24	4.88	5.37						
1358		*Baiera*	46978	19.54	0.60	52.20		1.57	1.27	2.10	2.66	3.06	3.37						
1358		*Baiera*	46980	16.09	0.48	51.80		1.34	1.08	1.79	2.28	2.62	2.88						
1358		*Baiera*	46983	19.95	0.31	26.64		0.93	0.75	1.24	1.58	1.82	2.00						
1358		*Ginkgo*	46882	18.45	0.53	65.49		1.78	1.44	2.38	3.02	3.47	3.82						
1358		*Ginkgo*	46883	18.03	0.39	63.30		1.70	1.38	2.28	2.89	3.33	3.67						
3388	2	*Ginkgo*	46992	18.80	0.36	56.61	1000	1.62	1.31	2.16	2.75	3.16	3.48	1.57	1.27	2.10	2.66	3.07	3.37
3388		*Ginkgo*	47069	19.14	0.49	57.72		1.66	1.34	2.22	2.82	3.25	3.58						
3388		*Ginkgo*	47080	21.50	0.54	58.70		1.83	1.48	2.45	3.11	3.59	3.94						
3388		*Ginkgo*	47099	19.12	0.54	68.80		1.89	1.53	2.53	3.21	3.69	4.06						
3388		*Ginkgo*	47103	19.10	0.46	41.07		1.28	1.03	1.71	2.17	2.5	2.75						
3388		*Ginkgo*	46988	26.66	1.45	33.30		1.41	1.14	1.88	2.39	2.75	3.03						
3388		*Ginkgo*	47113	17.45	0.41	45.51		1.29	1.04	1.73	2.19	2.52	2.78						
3751	3	*Baiera*	47200	15.29	0.29	59.94	1000	1.44	1.17	1.93	2.45	2.82	3.11	1.63	1.32	2.18	2.76	3.18	3.51
3751		*Sphenobaiera*	47212	17.48	0.33	103.00		2.34	1.89	3.13	3.97	4.57	5.03						
3751		*Sphenobaiera*	47215	17.77	0.37	82.10		2.03	1.64	2.72	3.45	3.97	4.37						
3751		*Sphenobaiera*	47216	16.59	0.39	74.00		1.80	1.45	2.40	3.05	3.52	3.87						
3751		*Baiera*	47250	17.78	0.45	55.50		1.53	1.23	2.04	2.59	2.99	3.29						
3751		*Sphenobaiera*	47213	16.45	0.61	31.10		0.90	0.73	1.21	1.53	1.76	1.94						
3751		*Sphenobaiera*	48140	17.00	0.53	50.00		1.36	1.10	1.82	2.31	2.66	2.93						
4097	4	-	Bulk- Ginkgo 1	16.41	0.76	34.89	1200	0.93	0.75	1.25	1.58	1.82	2.00	1.04	0.84	1.40	1.77	2.04	2.24
4097		-	Bulk- Ginkgo 2	20.02	0.75	30.13		0.97	0.79	1.30	1.65	1.9	2.09						
4097		-	Bulk- Ginkgo 3	18.74	0.54	42.81		1.23	0.99	1.64	2.08	2.4	2.64						
4600	5	-	Ast.5.2_SH_8	19.23	0.60	27.13	1800	0.72	0.59	0.97	1.23	1.42	1.56	0.64	0.52	0.85	1.08	1.25	1.37
4600		-	CB_5.2_Ginkgo 1	17.50	0.71	33.30		0.80	0.64	1.06	1.35	1.56	1.71						
4600		-	5.6/5.7_Ginkgo 1	15.41	0.54	22.20		0.51	0.41	0.68	0.86	0.99	1.09						
4600		-	5.6/5.7_Ginkgo 2	15.09	0.40	24.42		0.54	0.44	0.72	0.91	1.05	1.16						
4600		-	5.6/5.7_Ginkgo 3	17.47	0.52	24.98		0.62	0.50	0.83	1.06	1.22	1.34						
6086	6	-	Ginkgo 1	12.07	0.24	98.05	2000	1.34	1.09	1.80	2.28	2.63	2.89	0.79	0.64	1.06	1.34	1.55	1.70
6086		-	Ginkgo 2	14.10	0.24	57.09		0.98	0.80	1.32	1.67	1.93	2.12						
6086		-	Ginkgo 3	12.80	0.70	15.54		0.30	0.24	0.40	0.51	0.59	0.65						
6086		-	Ginkgo 4	15.08	0.44	35.15		0.69	0.56	0.93	1.18	1.36	1.49						
6086		-	Ginkgo 5	14.29	0.48	33.30		0.63	0.51	0.85	1.07	1.24	1.36						
7249	7	*Ginkgo*	47671	16.95	0.38	40.00	1000	1.14	0.92	1.52	1.93	2.22	2.45	1.31	1.06	1.75	2.22	2.56	2.81
7249		*Ginkgo*	47689	27.63	0.92	32.19		1.41	1.14	1.89	2.40	2.76	3.04						
7249		*Sphenobaiera*	47692	16.03	0.35	42.20		1.13	0.92	1.52	1.93	2.22	2.44						
7249		*Ginkgo*	47720	24.56	1.67	35.50		1.39	1.12	1.86	2.36	2.72	2.99						
7249		*Sphenobaiera*	47735	19.84	0.32	38.85		1.26	1.02	1.69	2.14	2.47	2.71						
7249		*Ginkgo*	47700	23.99	0.87	35.52		1.36	1.10	1.82	2.32	2.67	2.94						
7249		*Ginkgo*	47760	19.72	0.61	46.60		1.45	1.17	1.94	2.46	2.83	3.11						
9145	8	*Sphenobaiera*	47805	26.48	0.53	48.10	1000	1.85	1.49	2.47	3.13	3.61	3.97	1.56	1.26	2.09	2.65	3.06	3.36
9145		*Sphenobaiera*	47820	24.58	0.83	35.77		1.40	1.13	1.87	2.37	2.73	3.01						
9145		*Sphenobaiera*	47856	24.92	0.48	50.00		1.82	1.47	2.43	3.08	3.55	3.91						
9145		*Sphenobaiera*	47869	23.49	0.77	27.8.0		1.10	0.89	1.48	1.87	2.16	2.37						
9145		*Sphenobaiera*	47853	35.14	0.95	44.40		2.13	1.72	2.84	3.61	4.16	4.57						
9145		*Sphenobaiera*	47863	35.10	0.84	30.00		1.60	1.30	2.15	2.72	3.14	3.45						
9145		*Sphenobaiera*	47889	25.03	0.87	24.40		1.04	0.84	1.40	1.77	2.04	2.25						