



Supplement of

The emergence of the tropical rainforest biome in the Cretaceous

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1 **Supplementary Text**

2 This file contains supporting information on the Campanian-Maastrichtian fossil plant
3 assemblages of Egypt and Sudan as well as data concerning the Campanian Grünbach
4 assemblage in information on assemblages which were compared. Furthermore, it contains
5 additional details on the methods and results of our analyses. The sections are: 1) Morphotype
6 catalog of the Northeastern African assemblages from the Campanian-Maastrichtian; 2)
7 Diversity of the Northeastern Africa floras compared with other fossil and living samples.
8 This part includes the source for the modern and fossil comparative collections mentioned in
9 the article as well as the detailed data of the Grünbach assemblage based on Herman &
10 Kvaček 2010; 3) CLANN code used in R to estimate the climatic parameters; 4) Results of
11 the Climate Leaf Analysis with Neural Networks (CLANN) obtained using the above-
12 mentioned code.
13 The original scoresheet filed for Baris and used for the CLANN analysis is attached as
14 separate document.

15

16 Diversity of the Northeastern Africa floras compared with other fossil and living samples

17 Diversity of the Northeastern Africa floras compared with other fossil and living samples
18 We compared the diversity of fossil samples from Northeastern Africa with similar samples
19 from the Cretaceous, Paleocene and Eocene. The data from Cerrejon, Castle Rock, Bison
20 basin, Rio Negro, Barro Colorado were taken from Wing et al. (2009) completed with data
21 from Hunco (Wilf et al., 2005) and Grünbach (Herman and Kvaček, 2010). The data from
22 Grünbach are based on the number of specimens of each taxon mentioned as material given.

23

24 CLANN code used in R

```
25 clann <- function(physio, meteo, fossil,  
26  
27 spread=c(0.52,0.55,0.49,0.56,0.57,0.58,0.56,0.52,0.49,0.56,0.55)){  
28   # physio is the calibration matrix of physiological traits (column: traits, rows: localities)  
29   # meteo is the calibration matrix of meteorological data ( (column: parameters, rows:  
30   localities)  
31   # fossil is the matrix of fossil physiological traits that need to be assessed (each row is a  
32   different locality)  
33   # spread: set to FALSE to make the function recalculate the hyperparameters of the neural  
34   network.  
35   require(fields)  
36   if(all(!spread)) spread <- findSpread(physio, meteo, k=10)  
37   predict <- matrix(ncol=ncol(meteo), nrow=nrow(fossil))  
38   minp <- apply(physio,2,min)  
39   maxp <- apply(physio,2,max)  
40   norm_phys <- t(2*(t(physio)-minp)/(maxp-minp)-1)  
41   for (m in 1:nrow(fossil)){  
42     pred_it <- numeric(ncol(meteo))  
43     norm_f <- t(2*(t(fossil[m,])-minp)/(maxp-minp)-1)  
44     weights <- rdist(norm_phys,norm_f)  
45     for (k in 1:ncol(meteo)){  
46       b.input <- weights*0.8326/spread[k]  
47       a1 <- exp(-b.input^2)
```

```

1         weight_all <- sum(a1)
2         if(weight_all==0) weight_all <- 1
3         pred_it[k] <- crossprod(a1,as.matrix(meteo[,k]))/weight_all
4         }
5         predict[m,] <- pred_it
6     }
7     colnames(predict) <- colnames(meteo)
8     rownames(predict) <- rownames(fossil)
9     predict
10 }
11
12 findSpread <- function(x,y,k=10,r=200){
13 # x is the calibration matrix of physiological traits (column: traits, rows: localities)
14 # y is the calibration matrix of meteorological data ( (column: parameters, rows: localities)
15 # k is the nb of partitins for the k-fold cross validation
16 # r is the number of replicates
17 require(fields)
18 require(cvTools)
19 nr <- nrow(x)
20 cvr <- cvFolds(nr, K = k)
21 subcvr <- cvr$subsets
22 nm <- ncol(y)
23 rsquare_all <- matrix(nrow=r,ncol=nm)
24 for(s in 1:r){
25     predict <- matrix(nrow=nr,ncol=nm)
26     spread <- s/100
27     for(i in 1:k){
28         train.physg <- x[subcvr[cvr$which != i], ]
29         validation.physg <- x[subcvr[cvr$which == i], ]
30         train.met <- y[subcvr[cvr$which != i], ]
31         validation.met <- y[subcvr[cvr$which == i], ]
32         minp <- apply(train.physg,2,min)
33         maxp <- apply(train.physg,2,max)
34         train.physg <- t(2*(t(train.physg)-minp)/(maxp-minp)-1)
35         corr_validation.physg <- t(2*(t(validation.physg)-minp)/(maxp-minp)-1)
36         w.input <- rdist(train.physg,corr_validation.physg)
37         b.input <- w.input*0.8326/spread
38         a1 <- exp(-b.input^2)
39         weight_all <- colSums(a1)
40         for(h in 1:ncol(a1)){if(weight_all[h]==0){weight_all[h]<-1}}
41         pred_it <- (t(a1) %*% as.matrix(train.met))/weight_all
42         row.names(pred_it) <- row.names(validation.met)
43         predict[subcvr[cvr$which == i],] <- pred_it
44     }
45     res <- predict - y
46     stdev <- numeric(nm)
47     rsquare <- numeric(nm)
48     for(n in 1:ncol(res)){

```

```
1   if(all(predict[,n] == 0)){predict[1,n]=0.01}
2   stdev[n] <- sd(res[,n])
3   rsquare[n] <- cor(y[,n],predict[,n])^2
4   }
5   rsquare_all[s,] <- rsquare
6   }
7   best.spread <- numeric(nm)
8   test <- cbind((1:r)/100,rsquare_all)
9   for(nm in 1:nm) best.spread[nm] <- test[which.max(test[,nm+1]),1]
10  best.spread
11  }
12
13
```

1 **Table S1.**

Morphotype	Synonyms	Reference	Cerrejon	affinities	BA	KI	WA	NU	AB	QE	figured	leaf size
M-01	Annonophyllum seawardii Kahlert et al., Magnolia cf. hilgardiana Lesquereux	Kahlert et al., 2009		angiosperm	8						B1597	noto- mesophyll
M-02			CJ55	Lauraceae	2						B1602a	mesophyll
M-03	Smlacites cf. mohgaensis Nambudiri	Kahlert et al., 2009		angiosperm	1						B1602b	mesophyll
M-04	Celtis pileoides Kahlert et al.	Kahlert et al., 2009	CJ48	Salicaceae	2						B1627	microphyll
M-05	cf. Lauraceae, Ficus ramahensis Knowlton	Kahlert et al., 2009		angiosperm	4						B1691	mesophyll
M-06	Ficus ramahensis Knowlton	Kahlert et al., 2009		angiosperm	4						B1596	notophyll
M-07	Ficus cf. celtidifolia Berry	Kahlert et al., 2009, Klitzsch and Lejal-Nicol, 1984		angiosperm	6	1					B1704	notophyll
M-08	Magnolia cf. hilgardiana Lesquereux	Kahlert et al., 2009		angiosperm	1						B1589	noto- mesophyll
M-09				angiosperm	3						340a	notophyll
M-10	Magnolia sp.	Kahlert et al., 2009		angiosperm	2						B1600	notophyll
M-11				angiosperm	2						107c	notophyll
M-12	Magnolia cf. hilgardiana Lesquereux	Kahlert et al., 2009		angiosperm	2						B1692b	notophyll
M-13				angiosperm	3						B1616	notophyll
M-14	Ficus cf. precunia Lakhnupal, Oreodaphne sp.	Kahlert et al., 2009		angiosperm	3						B1597a	notophyll
M-15	cf. Credneria daturaefolia Ward	Kahlert et al., 2009		angiosperm	1						B1701	mesophyll
M-16	Ficus pandurifolia Berry	Kahlert et al., 2009		angiosperm	1						B1607	macrophyll
M-17	Dipterocarphyllum maximum Kahlert et al.	Kahlert et al., 2009		angiosperm	2						B1593	macrophyll
M-18				angiosperm	1						B1591	macrophyll
M-19	Dipterocarphyllum maximum Kahlert et al.	Kahlert et al., 2009		angiosperm	2						B1717	macrophyll
M-20	Nelumbites virginensis Berry	Kahlert et al., 2009		angiosperm	3						B1629	aquatic
M-21	Nymphaeites desertorum Kräusel	Kahlert et al., 2009		Nymphaeales	3						B1626	aquatic
M-22				angiosperm	1						89	mesophyll
M-23				angiosperm	2						129	mesophyll
M-24				angiosperm	1						164a	notophyll
M-25	Nelumbo tenuifolium (Lesquereux) Knowlton, Nelumbites sp., Nelumbites giganteum Lejal-Nicol	Kahlert et al., 2009, Klitzsch and Lejal-Nicol, 1984, Lejal-Nicol, 1987		Nelumbonaceae	33	1	?	1			B1616	aquatic
M-26	Echinodorus cf. cordifolius (L.) Griesebach	Kahlert et al., 2009		monocot	2						MB Pb 2016/799	herbaceous
M-27				monocot	3						MB Pb 2016/806	aquatic
M-28				monocot	2						MB Pb 2016/804	aquatic
M-29	Pontederia bogneri Kahlert et al.	Kahlert et al., 2009	CJ59	Araceae	45						MB Pb 2016/803	herbaceous
M-30	Protaphyllum sagenopteroides Lejal-Nicol	Lejal-Nicol, 1987	CJ47	Araceae	2				13		MB Pb 2016/802	herbaceous
M-31	Araceae-Blatt-Fragment	Kahlert et al., 2009	CJ3	Araceae	6						MB Pb 1997/1555	herbaceous
M-32	Pontederia bogneri Kahlert et al., Zingiberites magnifolia (Knowlton) Hickey	Kahlert et al., 2009	CJ49	Zingiberales	7						B1705	herbaceous
M-33	Pontederia bogneri Kahlert et al.	Kahlert et al., 2009		monocot	4						B1617	herbaceous
M-34	Typhaephyllum sp.	Lejal-Nicol, 1987		monocot	18			1	4		255	herbaceous
M-35	Eichhornia primordialis Kahlert et al.	Kahlert et al., 2009		fern	14						B1619	aquatic
M-36				fern	1						B1694	herbaceous
M-37				fern	3						B1695	herbaceous
M-38	Salvinia sp.	Kahlert et al., 2009		fern	31						B0002	aquatic
M-39	Dipterocarphyllum kischeibense Lejal-Nicol	Lejal-Nicol, 1987		angiosperm	1	1					B666	
M-40				angiosperm	1						B665	
M-41				angiosperm	1						B670b	
M-42	Magnoliaephyllum sp., Laurophyllum sp.	Klitzsch and Lejal-Nicol, 1984		angiosperm	4						B670a	
M-43	cf. Dammaritens albens	Lejal-Nicol, 1987		conifer	1						B663	
M-44				angiosperm			4				B659a	
M-45				angiosperm			1			1	B651a	
M-46				angiosperm			2				B659b	
M-47				angiosperm			3	2			B646a	
M-48	Credneria sp.	Klitzsch and Lejal-Nicol, 1984		angiosperm			1				B650	
M-49				angiosperm			1				B642a	
M-50	Ficophyllum sp.	Klitzsch and Lejal-Nicol, 1984		angiosperm			4				B648	
M-51				angiosperm			1				B646c	
M-52	Cassiaephyllum aegyptiacum Lejal-Nicol	Lejal-Nicol, 1987		angiosperm			1				B645	
M-53				angiosperm			1				B655	
M-54	cf. Rogersia angustifolia Fontaine	Klitzsch and Lejal-Nicol, 1984		angiosperm			1				B651a	
M-55	Magnoliaephyllum speciosa	Lejal-Nicol, 1987		angiosperm			3				B573a	
M-56	Magnoliaephyllum amplifolia	Lejal-Nicol, 1987		angiosperm			3		3		B57xa	
M-57	Laurophyllum africanum Lejal-Nicol et Dominik, Saicophyllum aswani Lejal-Nicol	Lejal-Nicol, 1987		angiosperm			2				B576b	
M-58				angiosperm			1				B577a	
M-59				angiosperm			2				B577b	
M-60				angiosperm			6				B791	
M-61				angiosperm			2				B819	
M-62				angiosperm			1				B817	
M-63				monocot			1				7	
M-64	Salvinia sp.	Lejal-Nicol, 1987		fern			3		7		B810	
M-65				angiosperm					1		B160	
M-66				angiosperm					1		B152	
M-67				angiosperm					3		B171	
M-68	Dipterocarphyllum abyadense Lejal-Nicol	Lejal-Nicol, 1987		angiosperm					1		10	
M-69				angiosperm					3		6	
M-70				angiosperm					2		14	

2
3 Morphotype catalog of the Northeastern African assemblages from the Campanian-
4 Maastrichtian.

1 **Table S2.**

Taxon	affinities	Number of specimens	Taxon	affinities	Number of specime
1 Equisetites sp.	ferns	1	27 Compositiphyllum serratum	dicots	
2 Gosaupteris danaeoides	ferns	98	28 Debeya insignis	dicots	
3 Monheimia ungeri	ferns	10	29 Ettingshausenia gruenbachiana	dicots	
4 Microphylopteris austriaca	ferns	42	30 Ettingshausenia cf. Laevis	dicots	
5 Coniopteris sp.	ferns	1	31 Ettingshausenia sp.	dicots	
6 Cladophlebis gosauensis	ferns	25	32 Grebenkia europaea	dicots	
7 Raphaelia lobifolia	ferns	22	33 Juglandiphyllites pelagicus	dicots	
8 Sphenopteris heterophylla	ferns	1	34 Leguminosites mucronatus	dicots	
9 Sphenopteris gruenbachia	ferns	73	35 Menispermities ettingshauseni	dicots	
10 Sphenopteris ungeri	ferns	10	36 Menispermities summesbergeri	dicots	
11 Sphenopteris sp.	ferns	1	37 Myricophyllum serratum	dicots	
12 Marsileaceaphyllum campanicum	ferns	15	38 Myricophyllum sp.	dicots	
13 Nilsonia cf. Holyi	cycads	1	39 Quereuxia angulata	dicots	
14 Geinitzia reichenbachii	conifers	43	40 Rogersia sp.	dicots	
15 Geinitzia formosa	conifers	19	41 Ternstroemites neuweltensis	dicots	
16 Pagiophyllum sp.	conifers	1	42 Viburniphyllum austriacum	dicots	
17 Podozamites cf. Lanceolatus	conifers	1	43 Viburniphyllum ermanniorum	dicots	
18 Lysichiton austriacus	monocots	1	44 Dicotylophyllum proteoides	dicots	
19 Pandanites trinervis	monocots	106	45 Dicotylophyllum sp. 1	dicots	
20 Gruenbachia pandanoides	monocots	8	46 Dicotylophyllum sp. 2	dicots	
21 Sabalites longirachis	monocots	54	47 Dicotylophyllum sp. 3	dicots	
22 Theiaiphyllum	monocots	23	48 Dicotylophyllum sp. 4	dicots	
23 Monocotyledon	monocots	1	49 Dicotylophyllum sp. 5	dicots	
24 Brassenites krasseri	dicots	31	50 Dicotylophyllum sp. 6	dicots	
25 Celastrophyllum johannae	dicots	10	51 Dicotylophyllum sp. 7	dicots	
26 Celastrophyllum sp.	dicots	2	52 Ceratoxylon sp.	dicots	

2
3 **Grünbach fossil collection**

4

5

1 **Table S3.**

	MAT	WMMT	CMMT	GROWSEAS	GSP	MMGSP	Three_WET	Three_DRY	RH	SH	ENTHAL
2 Baris	24.32	26.79	21.22	12.00	179.55	14.97	91.10	13.09	72.63	13.70	35.06

3 Results of the Climate Leaf Analysis with Neural Networks (CLANN)

4

5

1 **Data S1. (separate file)**

2

3 original scoresheet filed for Baris and used for the CLANN

