Supplementary Text

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

The original scoresheet filed for Baris and used for the CLANN analysis is attached as separate document.

<u>Diversity of the Northeastern Africa floras compared with other fossil and living samples</u>

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

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

<u>CLANN code used in R</u>

```
clann <- function(physio, meteo, fossil,

spread=c(0.52,0.55,0.49,0.56,0.57,0.58,0.56,0.52,0.49,0.56,0.55)){
  # physio is the calibration matrix of physiological traits (column: traits, rows: localities)
  # meteo is the calibration matrix of meteorological data ( (column: parameters, rows:
localities)
  # fossil is the matrix of fossil physiological traits that need to be assessed (each row is a
different locality)
  # spread: set to FALSE to make the function recalculate the hyperparameters of the neural
network.
        require(fields)
        if(all(!spread)) spread <- findSpread(physio, meteo, k=10)
        predict <- matrix(ncol=ncol(meteo), nrow=nrow(fossil))
        minp <- apply(physio,2,min)
        maxp <- apply(physio,2,max)
        norm_phys <- t(2*(t(physio)-minp)/(maxp-minp)-1)
        for (m in 1:nrow(fossil)){
                pred_it <- numeric(ncol(meteo))
                norm_f <- t(2*(t(fossil[m,])-minp)/(maxp-minp)-1)
                weights <- rdist(norm_phys,norm_f)
                for (k in 1:ncol(meteo)){
                b.input <- weights*0.8326/spread[k]
                a1 <- exp(-b.input^2)
```

```
            weight_all <- sum(a1)
            if(weight_all==0)  weight_all <- 1
            pred_it[k] <- crossprod(a1,as.matrix(meteo[,k]))/weight_all
            }
            predict[m,] <- pred_it
      }
      colnames(predict) <- colnames(meteo)
      rownames(predict) <- rownames(fossil)
      predict
}

findSpread <- function(x,y,k=10,r=200){
 # x is the calibration matrix of physiological traits (column: traits, rows: localities)
 # y is the calibration matrix of meteorological data ( (column: parameters, rows: localities)
 # k is the nb of partitins for the k-fold cross validation
 # r is the number of replicates
 require(fields)
 require(cvTools)
 nr <- nrow(x)
 cvr <- cvFolds(nr, K = k)
 subcvr <- cvr$subsets
 nm <- ncol(y)
 rsquare_all <- matrix(nrow=r,ncol=nm)
 for(s in 1:r){
  predict <- matrix(nrow=nr,ncol=nm)
  spread <- s/100
  for(i in 1:k){
   train.physg <- x[subcvr[cvr$which != i], ]
   validation.physg <- x[subcvr[cvr$which == i], ]
   train.met <- y[subcvr[cvr$which != i], ]
   validation.met <- y[subcvr[cvr$which == i], ]
   minp <- apply(train.physg,2,min)
   maxp <- apply(train.physg,2,max)
   train.physg <- t(2*(t(train.physg)-minp)/(maxp-minp)-1)
   corr_validation.physg <- t(2*(t(validation.physg)-minp)/(maxp-minp)-1)
   w.input <- rdist(train.physg,corr_validation.physg)
   b.input <- w.input*0.8326/spread
   a1 <- exp(-b.input^2)
   weight_all <- colSums(a1)
   for(h in 1:ncol(a1)){if(weight_all[h]==0){weight_all[h]<-1}}
   pred_it <- (t(a1) %*% as.matrix(train.met))/weight_all
   row.names(pred_it) <- row.names(validation.met)
   predict[subcvr[cvr$which == i],] <- pred_it
  }
  res <- predict - y
  stdev <- numeric(nm)
  rsquare <- numeric(nm)
  for(n in 1:ncol(res)){
```

```
      if(all(predict[,n]  == 0)){predict[1,n]=0.01}
      stdev[n] <- sd(res[,n])
      rsquare[n] <- cor(y[,n],predict[,n])^2
    }
    rsquare_all[s,] <- rsquare
  }
  best.spread <- numeric(nm)
  test <- cbind((1:r)/100,rsquare_all)
  for(nn in 1:nm)  best.spread[nn] <- test[which.max(test[,nn+1]),1]
  best.spread
}
```

Table S1.

Morphotype	Synonyms	Reference	Cerrejon	affinities	BA	KI	WA	NU	AB	QE	figured	leaf size
M-01	Annonophyllum sewardii 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	Smilacites cf. mohgaoensis 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 Lakhanpal, 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	Dipterocarpophyllum maximum Kahlert et al.	Kahlert et al., 2009		angiosperm	2						B1593	macrophyll
M-18				angiosperm	1						B1591	macrophyll
M-19	Dipterocarpophyllum 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	Protaephyllum sagenopteroides Lejal-Nicol	Lejal-Nicol, 1987	CJ47	Araceae	2				13		MB Pb 2016/802	herbaceous
M-31	Araceen-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	Dipterocarpophyllum kisheibense Lejal-Nicol	Lejal-Nicol, 1987		angiosperm		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	Magnoliaeophyllum amplifolia	Lejal-Nicol, 1987		angiosperm				3		3	B57xa	
M-57	Laurophyllum africanum Lejal-Nicol et Dominik, Saliciphyllum 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	Dipterocarpophyllum abyadense Lejal-Nicol	Lejal-Nicol, 1987		angiosperm					1		10	
M-69				angiosperm					3		6	
M-70				angiosperm					2		14	

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

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	Microphyllopteris 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	Menispermites ettingshausenii	dicots	
10	Sphenopteris ungeri	ferns	10	36	Menispermites summesbergeri	dicots	
11	Sphenopteris sp.	ferns	1	37	Myricophyllum serratum	dicots	
12	Marsileaceaephyllum 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 neueweltensis	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	

Grünbach fossil collection

Table S3.

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

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

Data S1. (separate file)

original scoresheet filed for Baris and used for the CLANN

Score	Locality	Latitude	Longitude	Altitude	Date Collected	Completeness	Yes = 1 No = leave blank	Notes:
Status								

CLAMP

Species Number	Species / Morphotypes	Lamina		Margin Character States										Size Character States									Apex Character States				Base Character States			Length to Width Character States					Shape Character States		
		Unlobed	Lobed	No Teeth	Teeth	Teeth Regular	Teeth Irregular	Teeth Close	Teeth Distant	Teeth Round	Teeth Acute	Teeth Compound	Compound<50%	Nanophyll	Leptophyll I	Leptophyll II	Microphyll I	Microphyll II	Microphyll III	Mesophyll I	Mesophyll II	Mesophyll III	Emarginate	Round	Acute	Attenuate	Cordate	Round	Acute	L:W <1:1	L:W 1-2:1	L:W 2-3:1	L:W 3-4:1	L:W >4:1	Obovate	Elliptic	Ovate
1	M-01	1		1																	1				1			1				1					1
2	M-02	1		1																	1								1								
3	M-03	1		1																		1	1						1			1					1
4	M-04	1			1	1		1		1			1						1						1				1		1					1	
5	M-05	1																				1					1				1						
6	M-06	1		1																1				1				1			1						1
7	M-07	1		1																1					1			1			1						
8	M-08	1		1																		1						1									
9	M-09	1		1															1										1			1				1	
#	M-10	1		1																1			1					1				1				1	
#	M-11	1		1																1														1			
#	M-12	1		1																	1								1								
#	M-13	1			1	1		1		1			1							1				1						1						1	
#	M-14	1		1																1						1							1				1
#	M-15	1		1																		1					1				1						
#	M-16	1		1																		1			1												
#	M-17	1		1																		1															
#	M-18																					1					1										
#	M-19	1		1																		1		1													
#	M-22			1																		1					1										
#	M-23	1		1																		1						1									
#	M-24	1		1																		1						1									

Status	No.	Name	Lamina Dissection	Margin Character States	Size Character States	Apex Character States	Base Character States	Length to Width Character States	Shape Character States
Finished	1	OK	OK	OK	OK	OK	OK	OK	OK
Unfinished	2	OK	OK	OK	OK		OK		
Finished	3	OK	OK	OK	OK	OK	OK	OK	OK
Finished	4	OK	OK	OK	OK	OK	OK	OK	OK
Unfinished	5	OK	OK		OK		OK	OK	
Finished	6	OK	OK	OK	OK	OK	OK	OK	OK
Unfinished	7	OK	OK	OK	OK	OK	OK	OK	
Unfinished	8	OK	OK	OK	OK		OK		
Unfinished	9	OK	OK	OK	OK		OK	OK	OK
Finished	10	OK	OK	OK	OK	OK	OK	OK	OK
Unfinished	11	OK	OK	OK	OK			OK	
Unfinished	12	OK	OK	OK	OK		OK		
Unfinished	13	OK	OK	OK	OK	OK		OK	OK
Unfinished	14	OK	OK	OK	OK	OK		OK	OK
Unfinished	15	OK	OK	OK	OK		OK	OK	
Unfinished	16	OK	OK	OK	OK	OK			
Unfinished	17	OK	OK	OK	OK				
Unfinished	18	OK			OK		OK		
Unfinished	19	OK	OK	OK	OK	OK			
Unfinished	20	OK		OK	OK		OK		
Unfinished	21	OK	OK	OK	OK		OK		
Unfinished	22	OK	OK	OK	OK		OK		