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Miao, Y, et al., 2019, Miocene fire intensification linked to continuous aridification on the Tibetan Plateau: Geology, https://doi.org/10.1130/G45720.1

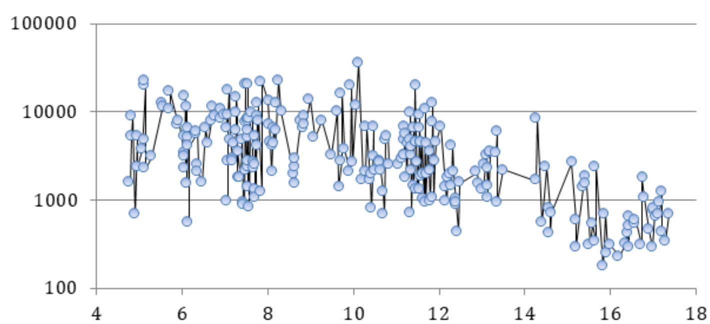
Supplementary material

Details of the statistical analyses performed

Statistical analyses were performed to confirm or reject correlations between the palynological data (e.g., abundance in xerophytic species) and the macrocharcoal records with trends in CO_2 and $\delta^{18}O$. To do so, we analyzed the MC_{total} data correlations amongst the two new sites in this study (KC-1 core in Qaidam Basin and KM/KNX sections in Kumkol Basin) and the data from the NG site (from Miao et al., 2016). As these data exhibit similar trends, all MC_{total} data from these three sites were grouped together to then correlate to the evaluation indexes, such as $\delta^{18}O$, ρCO_2, and xerophytic pollen percentages ($\%_{xero}$) using the Pearson Correlation Coefficient. Details of the statistical procedure are given below.

First, we analyzed the correlation of MC_{total} time series amongst the three sites.

Let's consider one of the three MC_{total} time series – say, the 250 MC_{total}-values observed for the KM section between 17.37 and 4.79 Ma. We have this graph:



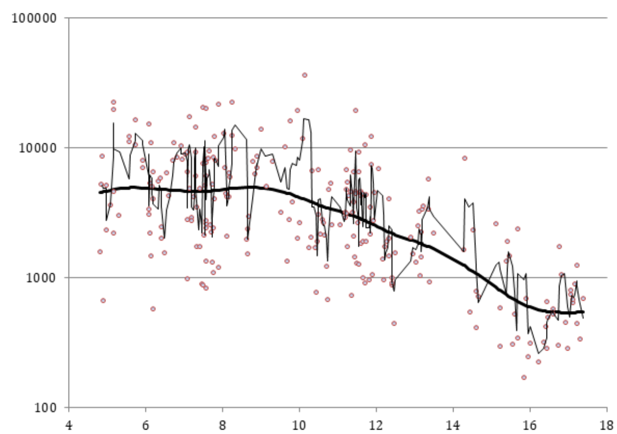
Graph S1

The existence of an overall trend (either increase or decrease) in MC_{total} in this time series can be tested using the nonparametric Mann-Kendall trend test. Results of this test for the three separate time series are given in Table S1, evidencing a similar, highly significant trend towards an increase in MC_{total} through time in all three cases.

Table S1. Mann-Kendall trend test for the three separate MC_{total} time series (based on observed values), showing a similar, highly significant trend towards an increase in MC_{total} over time (H0: no trend towards increase or decrease through time).

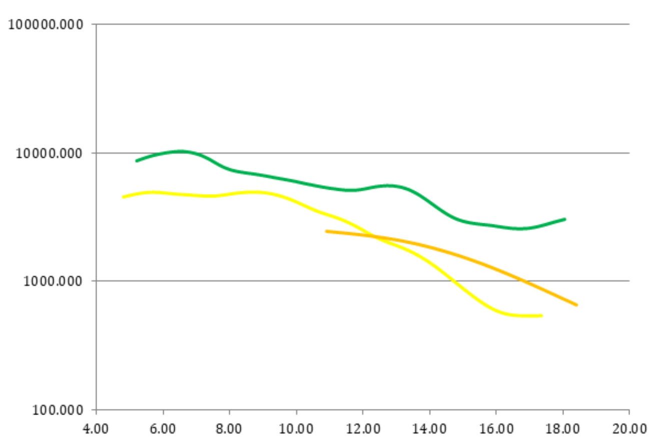
Time series	S	Z	p-value
KM/KNX	12286	9.30	1.5×10^{-20}
KC-1	6385	7.34	2.1×10^{-13}
NG	2658	4.03	5.5×10^{-5}

Based on this common trend, we then evaluated the correlation between the three MC_{total} time series. Because the ages for which MC_{total}-values are available differ between the three time series, fitted curves were first calculated for each site (based on the Log-transformed observed MC_{total}-values) using the Spline and Loess functions implemented in PAST. For all three time-series, these two fitting techniques returned essentially the same results. For each site, we used the Spline curve to interpolate MC_{total}-values within a common timeframe involving 50 kyr-spaced ages along each time series. It is worth noting that for each time series analyzed, the inferred trend consists of MC_{total}-values interpolated every 50 kyr, and *not* averaged over a given time interval. As a consequence, the subsequent correlation analyses do not depend on an arbitrarily chosen time interval, as modifying the time interval between two interpolated values will eventually affect the significance of the correlation (which partly relies on the number of points analyzed) but in no case the value of the correlation between two time series. For KM, this gives the following graph (red points: observed MC_{total} -values; black thin curve: 3-point-averaged time series as shown in Fig. 3; bold curve: Spline curve):



Graph S2

The next graph shows the three Spline curves resulting from the three analyzed time series (yellow curve: KM/KNX; green curve: KC-1; orange curve: NG).



Graph S3

We then computed Pearson correlation coefficients between these three fitted time series and tested these correlations against nullity using Mantel tests (Manhattan distance matrix; 99,999 permutations) based either on the raw interpolated MC_{total}-values or on the 1st order differences between raw interpolated MC_{total}-values (i.e., the time series of the differences between a raw interpolated MC_{total}-value and the previous one, which take into account the time-autocorrelation between the raw interpolated MC_{total}-values) (Table S2).

Table S2. Pearson Correlation Coefficient of MC_{total} data amongst the three different time series. Statistical significance of correlation values estimated using a Mantel test (Manhattan distance matrix; 99,999 permutations; H0: no correlation) based on raw interpolated MC_{total}-values (1) and 1st order differences (2).

	Min age	Max age	Pearson r	p-value[1]	p-value[2]
KM/KNX *vs*. KC-1	5.20	17.35	0.945	<0.00001	<0.00001
KM/KNX *vs*. NG	10.90	17.35	0.968	<0.00001	<0.00001
KC-1 *vs*. NG	10.90	18.05	0.873	<0.00001	4×10^{-4}

All three couples of time series show very high (close to 1, meaning a perfect positive relation between the two compared Spline curves) and highly significant (very small p-values) correlation values. Thus the three time series show highly significantly positively correlated trends in increase of MC_{total} through time.

Secondly, we analyzed the correlation of MC_{total} to the three potential controlling factors, i.e., $\delta^{18}O$, ρCO_2 and aridification ($\%_{Xero}$)**.**

Based on the high correlation between the three analyzed MC_{total} time series (see above), we grouped the MC_{total} of three sites (KM&KNX, KC-1 and NG) into a single composite curve; then we correlated this composite curve to the $\delta^{18}O$, ρCO_2 and $\%_{Xero}$ (Xerophytic pollen percentages) time series, using the very same Spline interpolation-based procedure as explained above. The three couples of time series involving MC_{total} show highly significant correlations (based either on raw interpolated or 1st order difference values), especially those involving □^{18}O and $\%_{xero}$, corresponding to very high, positive correlations (Table S3).

Table S3. Pearson Correlation Coefficient amongst evaluation indexes (MC_{total} is the sum of the three sites mentioned in Table S2; $\delta^{18}O$, Zachos et al., 2001; ρCO_2, Foster et al., 2012; Greenop et al., 2014; Kürschner et al., 2008; Zhang et al., 2013; Tripati et al., 2009; Ji et al., 2018). $\%_{Xero}$ (xerophytic taxa percentages), Miao et al., 2011). Statistical significance of correlation values estimated using a Mantel test (Manhattan distance matrix; 99,999 permutations; H0: no correlation) based on raw values (1) and 1st order differences (2).

MC_{total} *vs*.	Min age	Max age	Pearson r	p-value[1]	p-value[2]
$\delta^{18}O$	5.20	18.00	0.939	<0.00001	<0.00001

ρCO_2	5.20	18.00	-0.859	<0.00001	<0.00001
$\%_{Xero}$	5.20	18.00	0.947	<0.00001	<0.00001

Table S4. Microcharcoal data of KC-1 core, KM/KNX and NG sections.

KC-1 core

Age (Ma)	MC (grains/g)
5.19	3040
5.25	12747
5.31	10875
5.37	6346
5.43	15077
5.50	13042
5.55	3526
5.61	46294
5.61	3968
5.67	29220
5.73	3518
5.85	12421
5.87	14321
5.92	8075
6.10	4694
6.22	9527
6.29	3680
6.35	14851
6.41	9305
6.47	9012
6.53	12293
6.65	3549
6.71	5239
6.78	22549
6.84	2548
6.89	7610
6.95	10444
7.03	9106
7.09	21543
7.15	18200
7.19	7925
7.25	18852
7.32	19847
7.39	4655

7.45	30674
7.51	21078
7.57	2862
7.63	5257
7.69	7188
7.75	2100
7.81	4404
7.87	9827
7.93	3629
7.99	5114
8.06	4792
8.12	4918
8.18	11647
8.24	9751
8.37	11774
8.43	11604
8.47	1786
8.54	12764
8.59	11405
8.67	2180
8.74	24100
8.79	10552
8.85	2440
8.91	24031
8.98	4084
9.04	5726
9.10	9224
9.16	6709
9.27	4973
9.34	7861
9.40	3253
9.46	8969
9.52	6838
9.58	2836
9.63	6296
9.69	6801
9.82	6694
9.88	13943
10.01	13974
10.07	5305
10.13	2333
10.19	6337

10.25	7898
10.31	1498
10.44	8606
10.56	14411
10.62	6042
10.74	4614
10.80	3951
10.86	3562
10.92	5074
10.99	5793
11.04	1209
11.10	27682
11.16	6900
11.28	12961
11.32	5678
11.39	4843
11.53	4814
11.59	1337
11.65	3981
11.71	5469
11.77	2768
11.83	8580
11.89	4638
11.95	1671
12.01	9523
12.07	6275
12.13	1921
12.19	7417
12.26	8623
12.32	2442
12.38	18006
12.44	22731
12.51	2381
12.57	4992
12.63	4585
12.69	2352
12.75	11573
12.81	21389
12.87	1150
12.93	4841
12.99	10199
13.12	7119

13.18	3937
13.24	2893
13.30	16306
13.56	7873
13.60	6592
13.66	8237
13.73	5285
13.79	1584
13.85	3692
13.91	3316
13.97	4739
14.03	11401
14.09	5486
14.15	912
14.21	6788
14.27	11688
14.33	1551
14.40	3125
14.46	1568
14.58	5085
14.64	2578
14.70	2149
14.76	2701
14.82	2485
14.88	1063
14.94	2902
15.07	5958
15.13	2702
15.37	3312
15.42	3864
15.45	1871
15.51	3632
15.54	1482
15.58	1555
15.65	3260
15.77	4319
15.80	8191
15.86	4176
15.92	2995
15.98	3371
16.04	1698
16.10	2194

16.22	2031
16.29	5793
16.35	1866
16.39	1853
16.45	3731
16.59	3067
16.65	859
16.71	3068
16.74	2274
16.85	3310
16.90	1848
16.96	7501
17.02	891
17.08	1553
17.14	2894
17.20	3085
17.26	1249
17.32	5613
17.38	2967
17.50	1928
17.57	2960
17.69	4443
17.75	4648
17.81	2451
17.87	6101
17.93	3292
17.99	1308
18.05	3164

KM/KNX sections

Age (Ma)	MC (grains/g)
4.79	1577
4.82	5278
4.84	8637
4.89	670
4.97	5182
4.97	2337
5.07	3638
5.14	19776
5.14	4667
5.14	22462
5.15	2207
5.30	3032
5.55	12171
5.57	11350
5.72	10562
5.72	16672
5.91	6987
5.92	8024
6.06	3398
6.07	15376
6.07	3040
6.08	2226
6.08	5409
6.10	11015
6.12	1477
6.15	5038
6.16	6568
6.17	569
6.17	4036
6.32	5520
6.35	5894
6.39	2477
6.39	2041
6.47	1551
6.54	6390
6.60	4337
6.68	7984
6.72	11063
6.80	8516
6.91	10409
6.92	8091

7.01	8945
7.06	6596
7.06	982
7.07	2812
7.07	9289
7.11	17406
7.12	4852
7.17	2907
7.18	2739
7.23	4246
7.27	6092
7.27	14448
7.28	9437
7.30	1732
7.30	3521
7.38	1745
7.39	4854
7.44	897
7.46	879
7.48	20584
7.49	7608
7.50	2145
7.53	5131
7.54	2602
7.54	1345
7.54	2417
7.54	7775
7.54	20165
7.54	6082
7.54	2756
7.55	8262
7.56	835
7.59	8380
7.64	9504
7.65	2591
7.69	2246
7.71	1330
7.71	5268
7.73	1090
7.73	2444
7.75	8519
7.77	4099
7.78	12300

7.79	8027
7.87	1217
7.87	21940
8.01	13132
8.04	7101
8.06	4485
8.10	2078
8.11	4204
8.14	6443
8.16	4223
8.19	6013
8.22	12508
8.24	22664
8.32	9938
8.61	1977
8.63	2365
8.64	1536
8.66	2966
8.78	7944
8.82	6326
8.87	8676
8.88	6989
8.98	13924
9.11	5078
9.28	7919
9.50	3209
9.62	10186
9.66	1351
9.72	2813
9.74	16081
9.80	3815
9.92	2035
9.95	19352
9.98	2639
10.06	11882
10.11	36079
10.23	1703
10.28	2047
10.31	6645
10.38	1702
10.43	778
10.44	1933
10.48	6827

10.48	3085
10.53	2170
10.59	2798
10.62	2626
10.65	2104
10.69	1231
10.72	682
10.75	4782
10.80	5376
10.83	2529
11.04	2546
11.16	2955
11.19	3217
11.20	6804
11.20	3139
11.21	4803
11.22	5484
11.24	1745
11.27	4327
11.32	4669
11.32	9636
11.34	730
11.37	3212
11.39	3849
11.39	2094
11.40	6534
11.41	1454
11.44	19396
11.45	4600
11.46	4439
11.48	1290
11.52	2631
11.53	1286
11.54	9232
11.54	6559
11.57	1850
11.59	4642
11.60	4337
11.61	4496
11.62	1925
11.65	989
11.68	10577
11.69	910

11.71	1904
11.73	4381
11.80	957
11.82	3533
11.83	2164
11.86	7458
11.86	12325
11.88	1069
11.91	2767
11.93	4514
12.03	6927
12.15	1377
12.17	970
12.21	1732
12.24	1916
12.30	1469
12.32	4039
12.33	2013
12.39	876
12.39	992
12.39	911
12.45	443
12.48	1555
12.89	2047
12.93	1528
13.02	1330
13.08	2496
13.11	3246
13.13	1041
13.15	2257
13.16	1443
13.18	3348
13.19	3575
13.33	3388
13.36	5736
13.37	933
13.49	2194
14.26	1645
14.28	8325
14.41	549
14.50	2319
14.58	797
14.59	413

14.63	719
15.09	2619
15.19	584
15.20	297
15.37	1341
15.41	1892
15.44	1486
15.53	307
15.59	523
15.65	342
15.66	2382
15.84	172
15.89	690
15.93	250
15.99	310
16.20	224
16.34	321
16.39	419
16.43	285
16.44	648
16.46	501
16.58	528
16.59	573
16.72	301
16.74	1722
16.80	1059
16.90	453
16.98	288
17.03	739
17.04	808
17.09	639
17.12	678
17.16	895
17.20	1244
17.21	442
17.28	335
17.37	685

NG section (Miao et al., 2016)

Age (Ma)	MC (grains/g)
10.90	1489
10.95	1005
10.97	2931
10.97	2880
11.11	1253
11.20	2627
11.23	202
11.33	2646
11.38	2857
11.51	2994
11.54	6806
11.61	10521
11.64	3904
11.66	3661
11.68	13644
11.69	2776
11.69	994
11.73	2037
11.73	1378
11.74	1448
11.77	1446
11.79	3620
11.81	1201
11.81	751
11.82	3275
11.85	2781
11.85	3594
11.88	4838
11.89	1104
11.89	2418
11.92	931
11.92	2865
11.96	2496
11.98	1242
11.99	879
12.00	3069
12.02	6409
12.03	3410
12.03	1219
12.06	1260

12.07	2057
12.08	5268
12.09	5391
12.09	4607
12.10	3502
12.10	1361
12.11	1002
12.12	1110
12.12	2059
12.13	7164
12.14	717
12.16	2532
12.16	1610
12.17	5564
12.18	1358
12.19	1100
12.23	21111
12.24	1274
12.25	2034
12.27	1996
12.28	3445
12.29	1351
12.30	2387
12.37	2033
12.38	848
12.76	1628
12.77	1761
12.77	734
12.78	5110
12.83	2755
12.92	2441
12.93	2007
12.94	2781
12.96	8392
12.97	3068
13.02	1348
13.03	1385
13.10	3171
13.16	1174
13.17	1158
13.20	4930
13.23	3767
13.24	3289

13.24	1661
13.25	5089
13.25	2720
13.37	1555
13.40	1288
13.42	661
13.43	1537
13.44	4457
13.45	1334
13.48	402
13.53	5852
13.54	1341
13.54	10268
13.56	1811
13.57	3229
13.58	1867
13.62	2293
13.67	521
13.68	1668
13.70	2604
13.73	3517
13.73	5128
13.74	2032
13.80	1131
13.82	1530
13.84	908
13.89	1821
13.91	9670
14.22	7079
14.27	44
14.28	973
14.28	2278
14.29	1511
14.29	1285
14.30	2603
14.30	1862
14.31	3302
14.31	2656
14.32	12560
14.33	877
14.33	3256
14.34	2390
14.38	1918

14.45	219
14.47	1200
15.12	1817
15.13	5862
15.17	1251
15.77	1117
16.03	1231
16.04	2279
16.05	532
16.06	2288
16.13	627
16.23	935
16.28	1958
16.31	1343
16.32	1231
16.38	1608
16.80	874
16.89	6628
16.90	708
16.97	872
17.00	1243
17.05	932
17.15	717
17.24	358
17.30	272
17.45	1100
17.47	913
17.92	574
17.95	346
18.10	795
18.40	564