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Carbon accumulation rates of Holocene peatlands in central–eastern Europe document the driving role of human impact over the past 4000 years

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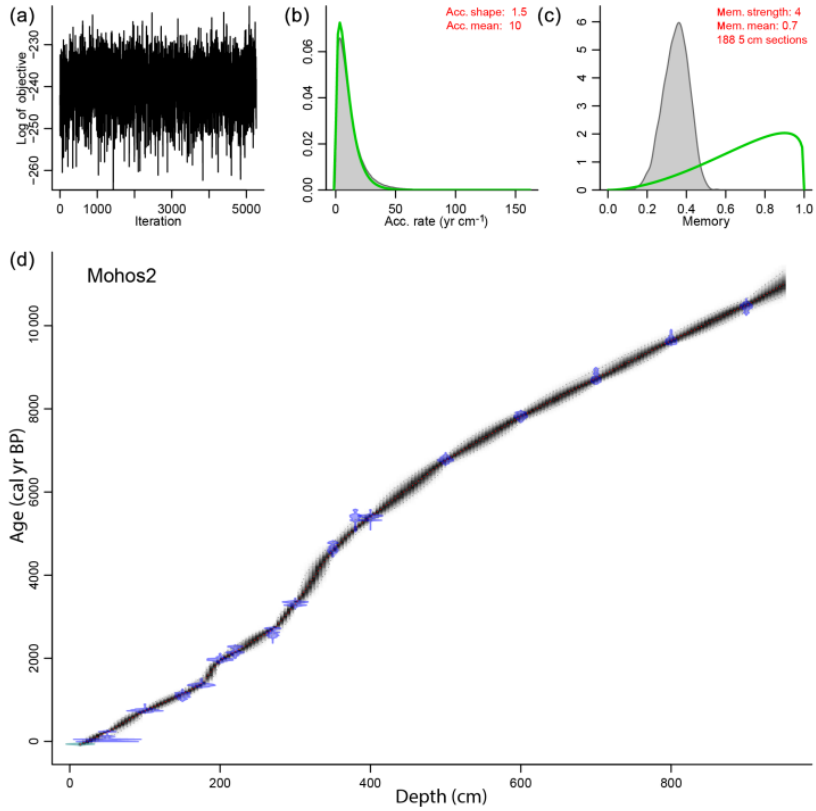
Radiocarbon dating

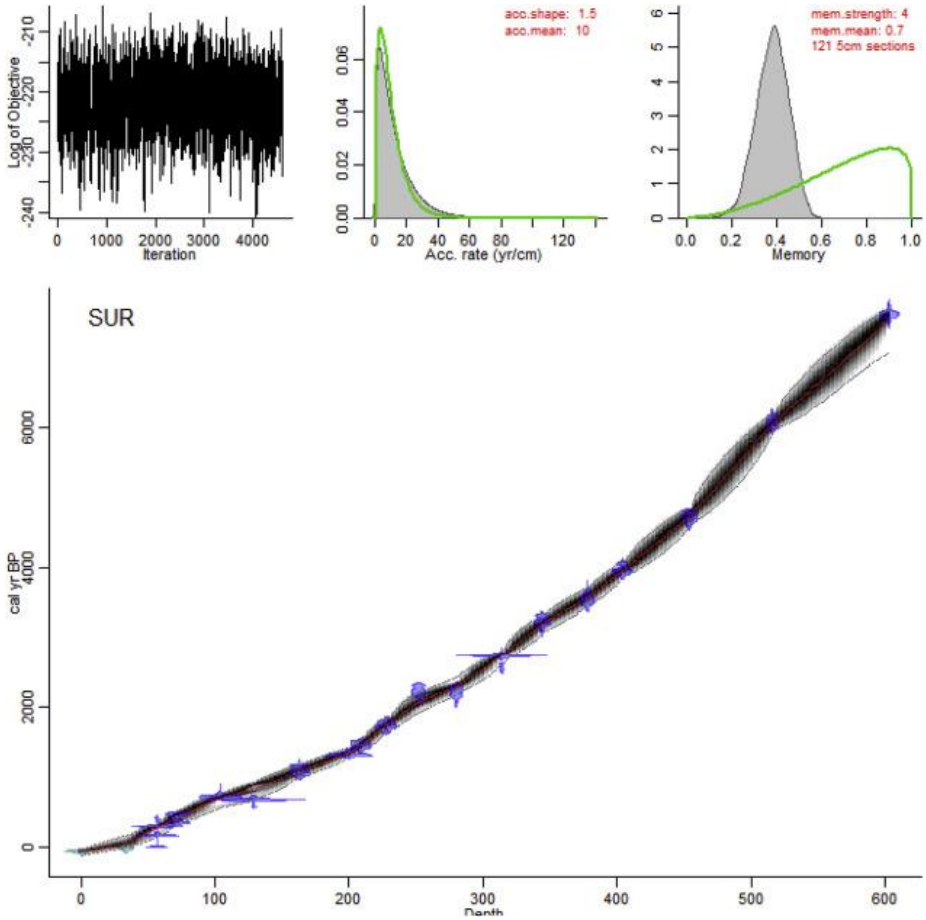
For samples dated at Horia Hulubei National Institute for Physics and Nuclear Engineering, Magurele, Romania (sample code RoAMS), the standard acid-base-acid (ABA) extraction was employed for removing inorganic carbon and humic substances. The protocol follows the steps of the organic materials pretreatment described in Sava et al. (2019). Briefly, the *Sphagnum* stems were inspected and selected from the bulk sample under the microscope, followed by an acid leaching (3.7% HCl, T = 80 °C, 20 min), ultrapure water rinsing (MilliQ®, Millipore, USA), alkali treatment (0.8% NaOH, T=80 °C, 20 min), ultrapure water rinsing, acid treatment (3.7% HCl, T = 80 °C, 1 hr), followed by ultrapure water washing to neutral pH. At the end of the protocol, the samples were dried. During this protocol the inorganic carbon is dissolved and discarded in acidic solution, the soluble organic carbon (humic acid) is eliminated in the alkali solution, while the alkali insoluble organic carbon (humin) is washed with ultrapure water.

The graphite from organic compounds was produced using an AGEIII system (Ionplus, Switzerland), coupled with and elemental analyzer (VarioMicroCube, Elementar, Germany) for sample combustion (Wacker et al., 2010). Following the graphitization step, the peat graphite was measured on 1 MV AMS system together with a batch of charcoal blanks and modern carbon reference material (NIST SRM 4990C, Oxalic Acid II). The radiocarbon ages were calculated according to Stuiver and Polach (1977) considering blank and fractionation corrections and subsequently calibrated on IntCal20 atmospheric curve (Reimer et al., 2020). All age-depth models were created using Bacon (Blaauw & Christen, 2011) in RStudio (RStudio Team, 2020).

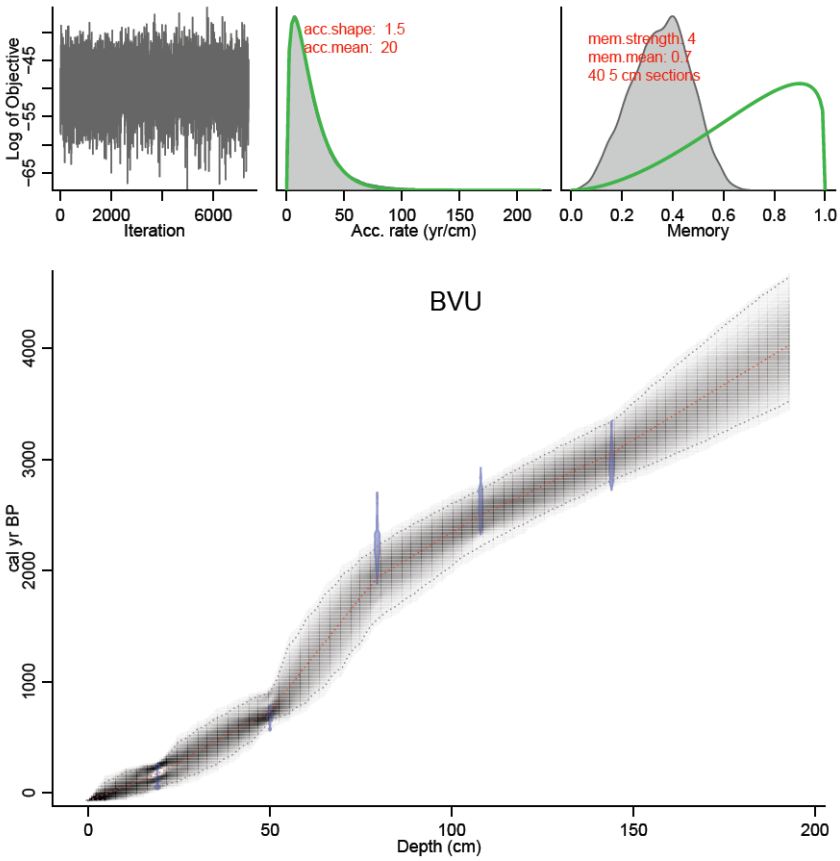
Supplementary Figures



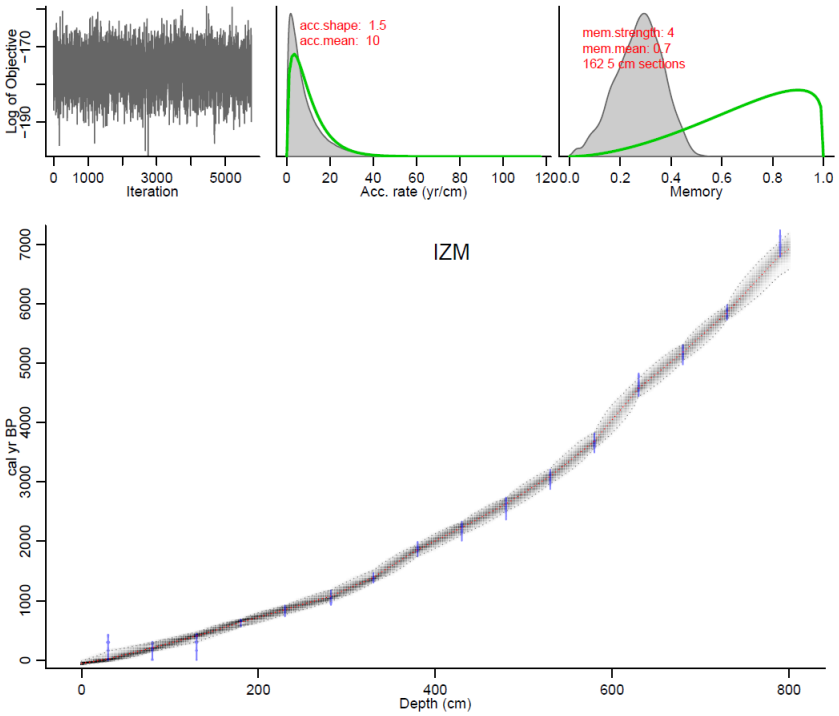
Supplementary Figure 1: Age–depth model of Mohos (MOH) peat record, as determined via Bacon (Blaauw & Christen, 2011), using IntCal20 (Reimer et al., 2020). (a) Graph indicates Markov chain Monte Carlo iterations. Also in (b) and (c) are prior (green line) and posterior (grey histogram) distributions for the accumulation rate (b) and memory (c). For panel (d), calibrated radiocarbon ages are in blue. The age–depth model is outlined in grey, with darker grey indicating more likely calendar ages. Grey stippled lines show 95 % confidence intervals, and the red curve indicates the single best model used in this work. The base of this model (between the last radiocarbon date and basal peat) is interpolated, and so carbon accumulation rates calculated from these depths should be treated with caution.



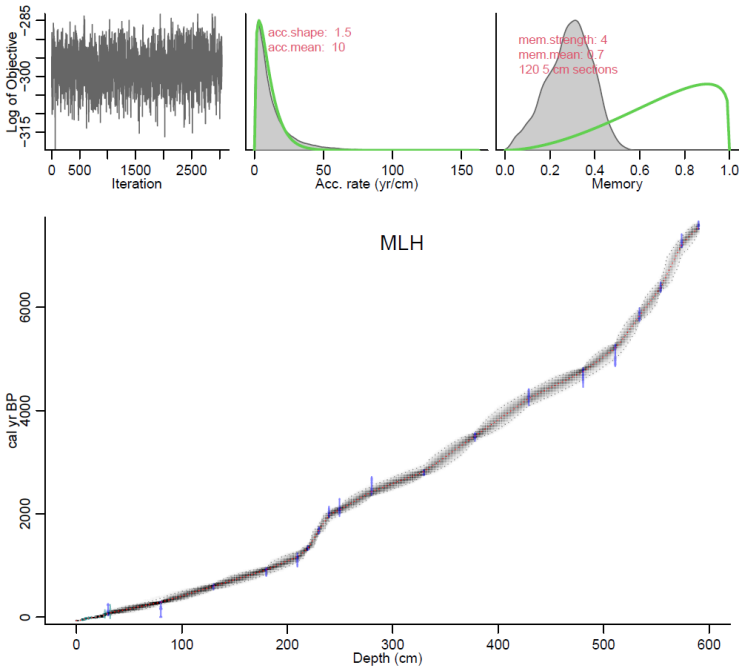
Supplementary Figure 2: Age-depth model of Sureanu (SUR) peat bog. Panels are the same as in Supplementary Figure 1.



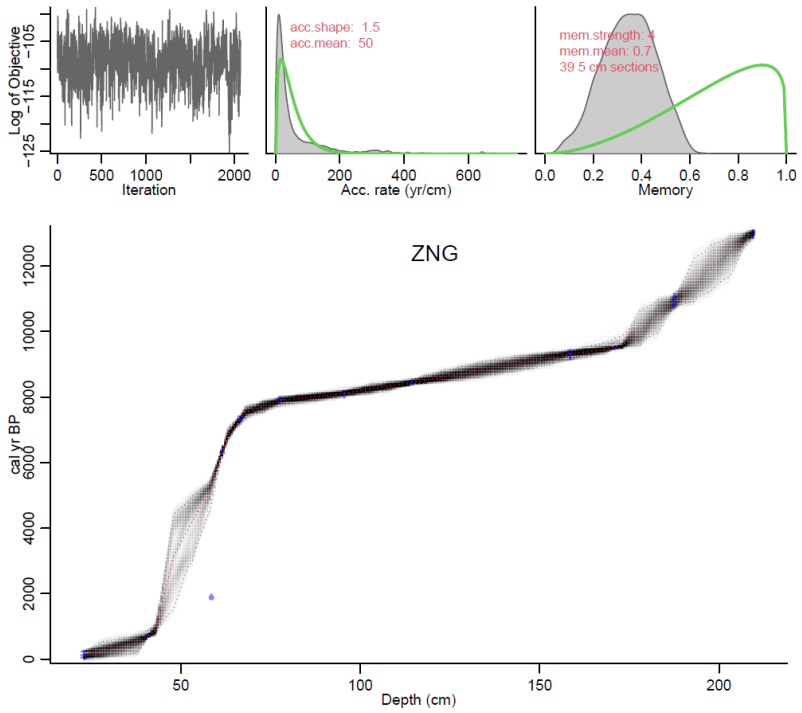
Supplementary Figure 3: Age-depth model of Baia Vulturilor (BVU) peat bog. Panels are the same as in Supplementary Figure 1. The base of this model (between the last radiocarbon date and basal peat) is interpolated, and so carbon accumulation rates calculated from these depths should be treated with caution.



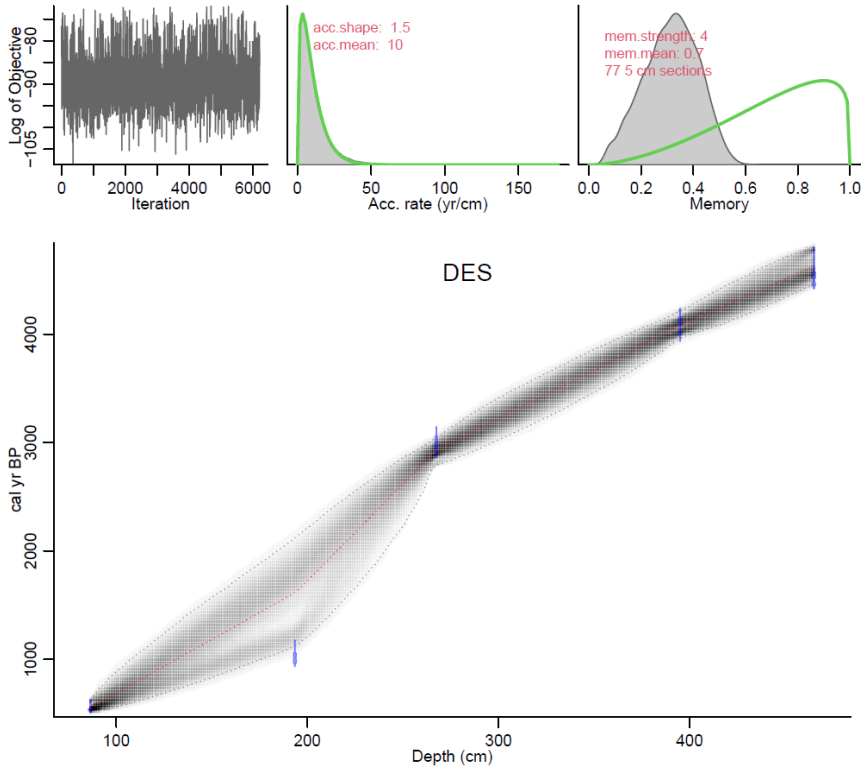
Supplementary Figure 4: Age-depth model of Iezerul Mare (IZM) peat bog. Panels are the same as in Supplementary Figure 1. The base of this model (between the last radiocarbon date and basal peat) is interpolated, and so carbon accumulation rates calculated from these depths should be treated with caution.



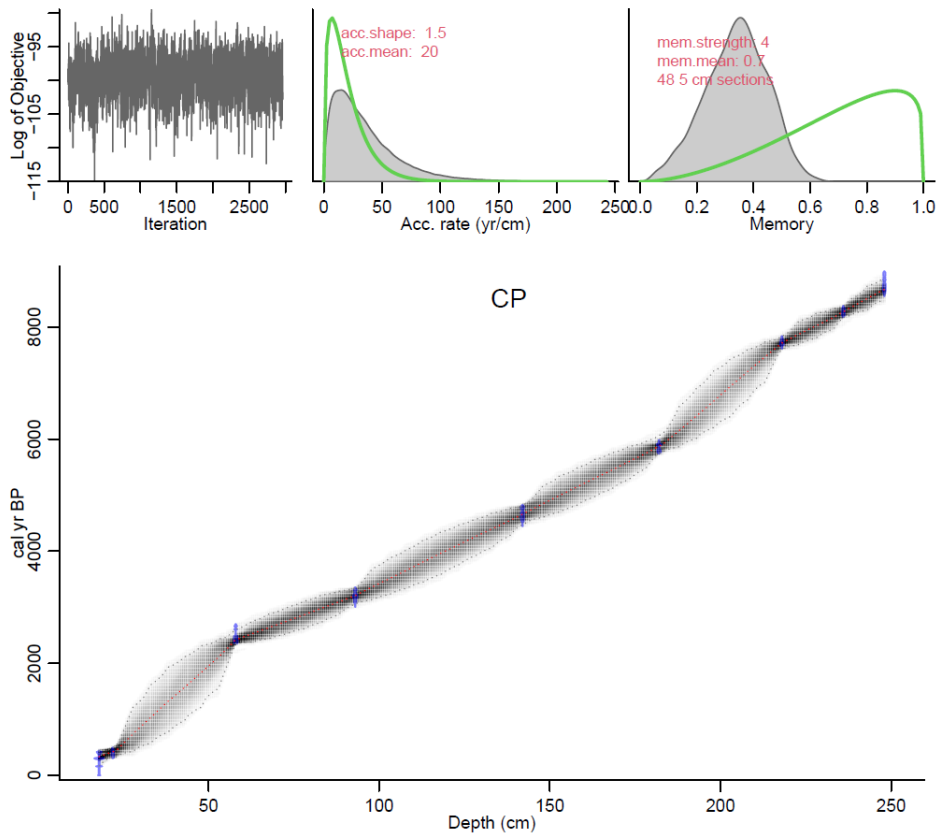
Supplementary Figure 5:Age-depth model of Mluha (MLH) peat bog. Panels are the same as in Supplementary Figure 1.



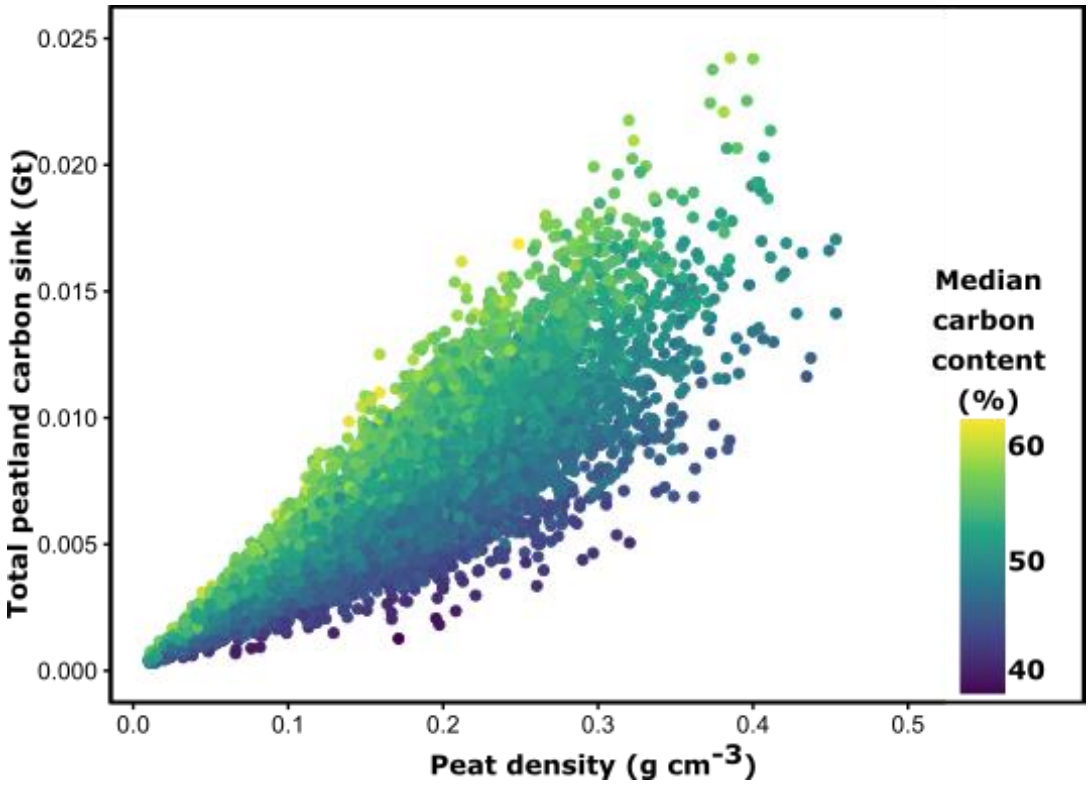
Supplementary Figure 6: Age-depth model of Zanoage Rosie (ZNG) peat bog. Panels are the same as in Supplementary Figure 1. For the uppermost section of peat, the model interpolates between coring date and the first radiocarbon date



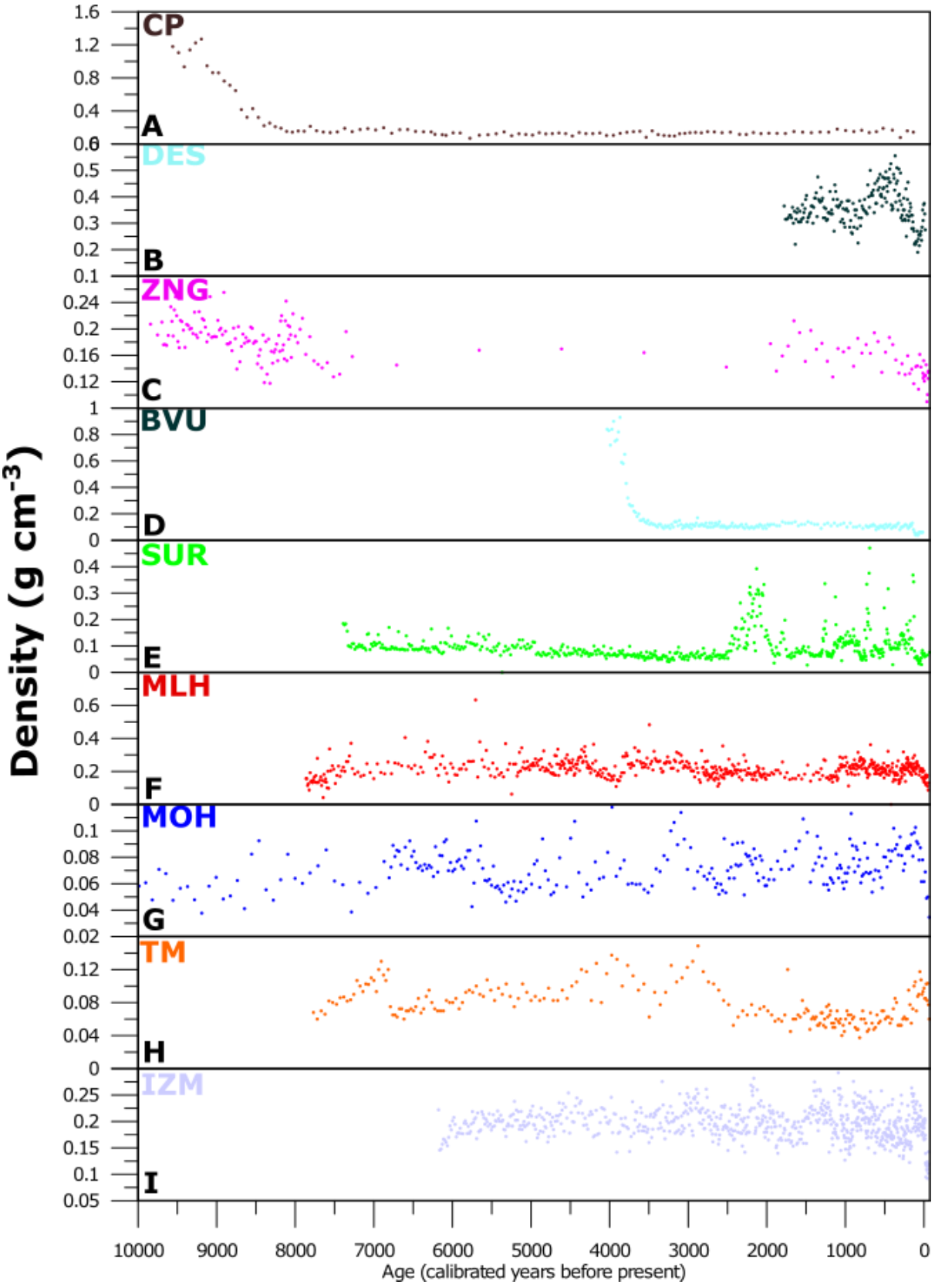
Supplementary Figure 7: Age-depth model of Despotovac (DES) peat bog. Panels are the same as in Supplementary Figure 1. For the uppermost section of peat, the model interpolates between coring date and the first radiocarbon date



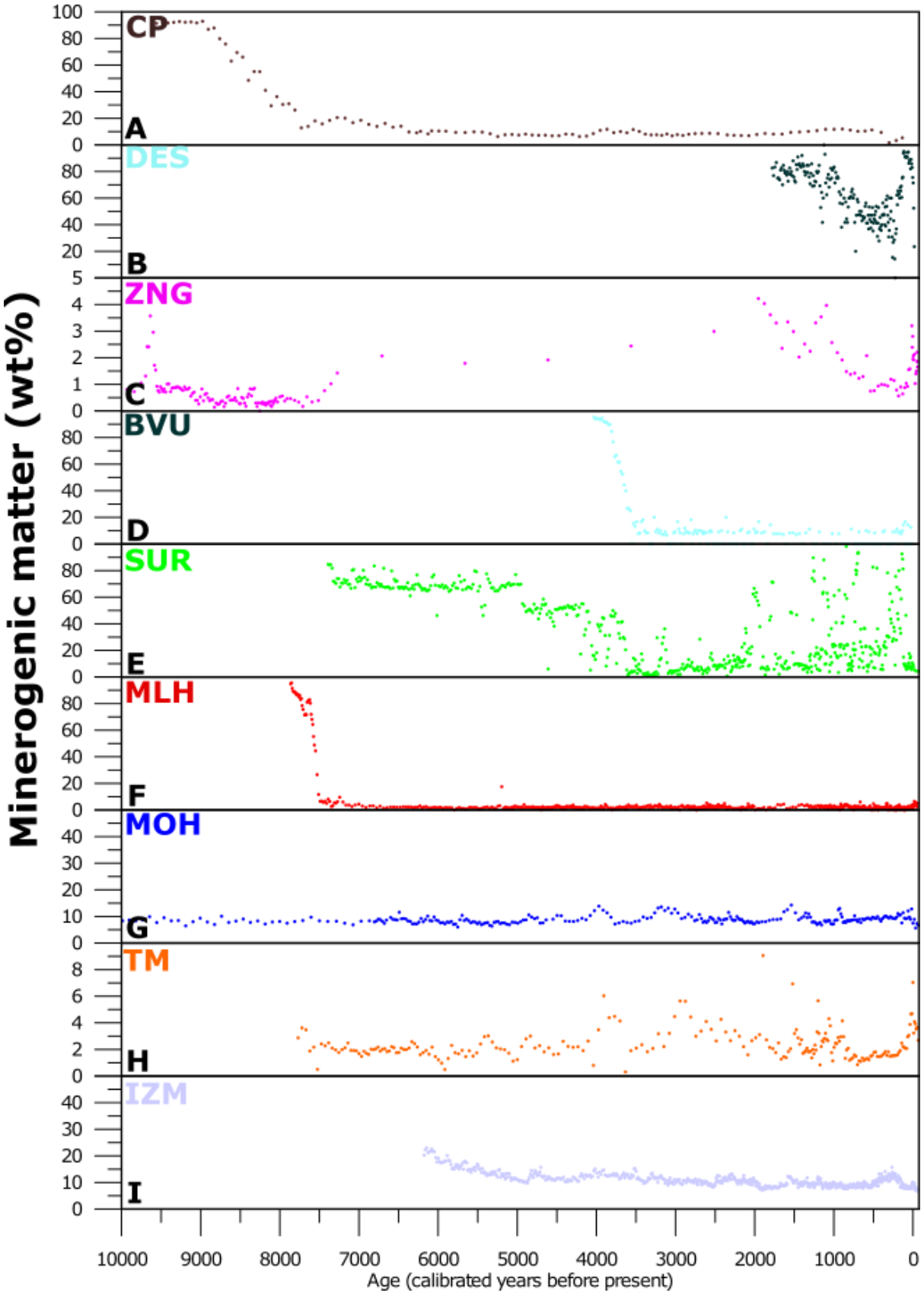
Supplementary Figure 8: Age-depth model of Crveni Potok (CP) peat bog. Panels are the same as in Supplementary Figure 1.



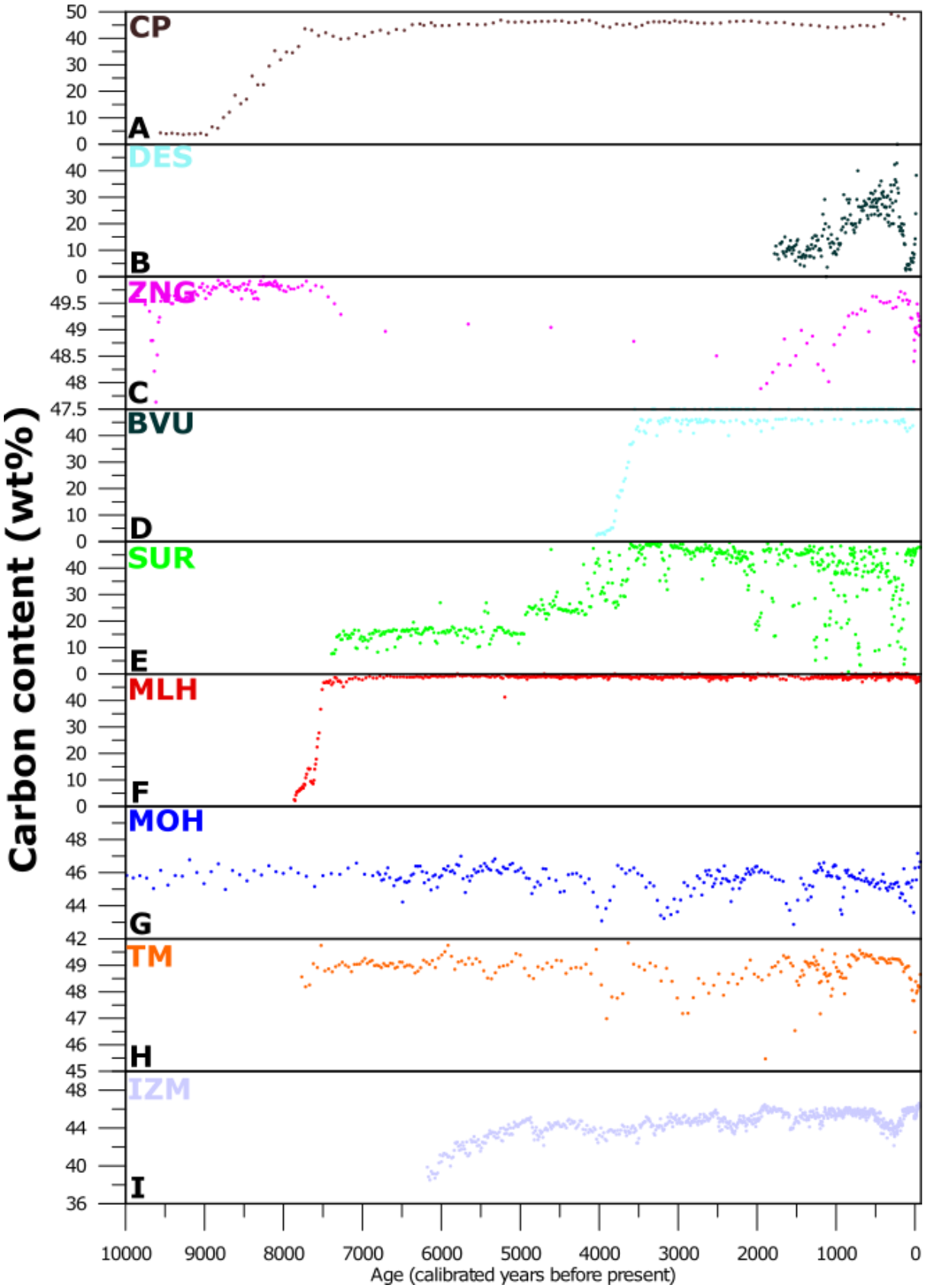
Supplementary Figure 9: Output of Monte Carlo modelling of total carbon sink represented by Romania peat bogs. The total carbon sink is calculated 10,000 times to cover the range of error for each of the variables (see Table 3).



Supplementary Figure 10: Bulk density values for all bogs used in this study.



Supplementary Figure 11: Minerogenic matter content (what remains after ashing of samples) for all bogs used in this study.



Supplementary Figure 12: Carbon content (assumed to be 50% of all organic matter) for all bogs used in this study.

Supplementary Tables

Supplementary Table 1: All radiocarbon dates used in this study.

Sureanu

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
DeA-7256	34	Bulk peat (Sphagnum stems)	−16 ± 22	
DeA-7257	57	Bulk peat (Sphagnum stems)	236 ± 23	
DeA-7258	72	Bulk peat (Sphagnum stems)	368 ± 22	
DeA-7259	104	Bulk peat (Sphagnum stems)	805 ± 22	
DeA-7260	129	Bulk peat (Sphagnum stems)	728 ± 21	
DeA-7261	163	Bulk peat (Sphagnum stems)	1164 ± 25	
DeA-5795	172.5	wood	3176 ± 26	Outlier
DeA-7262	200	Bulk peat (Sphagnum stems)	1417 ± 26	
DeA-5796	209	Bulk peat (Sphagnum stems)	1560 ± 27	
DeA-7263	228	Bulk peat (Sphagnum stems)	1809 ± 22	
UBA-31373	252	Bulk peat (Sphagnum stems)	2228 ± 44	
UBA-31374	280	Bulk peat (Sphagnum stems)	2202 ± 44	
DeA-7264	314	Bulk peat (Sphagnum stems)	2595 ± 24	
UBA-31375	344	Bulk peat (Sphagnum stems)	3023 ± 30	
UBA-31376	378	Bulk peat (Sphagnum stems)	3317 ± 50	
DeA-7265	404	Bulk peat (Sphagnum stems)	3638 ± 29	
UBA-31377	454	Bulk peat (Sphagnum stems)	4181 ± 32	
DeA-5797	516	Bulk peat (Sphagnum stems)	5301 ± 36	
UBA-31378	603	Bulk peat (Sphagnum stems)	6777 ± 54	

Mohos

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
DeA-8343	50	Bulk peat (Sphagnum stems)	37 ± 18	
DeA-8344	100	Bulk peat (Sphagnum stems)	838 ± 19	
DeA-10111	150	Bulk peat (Sphagnum stems)	1174 ± 28	
DeA-10112	175	Bulk peat (Sphagnum stems)	1471 ± 26	
DeA-8345	200	Bulk peat (Sphagnum stems)	2022 ± 21	
DeA-10137	225	Bulk peat (Sphagnum stems)	2155 ± 27	
DeA-10138	280	Bulk peat (Sphagnum stems)	2530 ± 28	
DeA-8346	300	Bulk peat (Sphagnum stems)	3112 ± 23	
DeA-10139	350	Bulk peat (Sphagnum stems)	4110 ± 31	
DeA-10140	380	Bulk peat (Sphagnum stems)	4641 ± 54	
DeA-8347	400	Bulk peat (Sphagnum stems)	4638 ± 26	
DeA-10141	500	Bulk peat (Sphagnum stems)	5949 ± 36	
DeA-10142	600	Bulk peat (Sphagnum stems)	6989 ± 43	
DeA-8348	700	Bulk peat (Sphagnum stems)	7909 ± 33	
DeA-10143	800	Bulk peat (Sphagnum stems)	8687 ± 45	
DeA-8349	900	Bulk peat (Sphagnum stems)	9273 ± 36	

Crveni Potok

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
Poz-72891	18	Sphagnum stems	260 ± 30	
Poz-72892	22	36 Picea sp. needle pits; 1 Abies sp. needle pits; Sphagnum stems	345 ± 30	
Poz-58430	58	Sphagnum stems; 1 Picea abies Seed; 6 Potentilla fruits; 1 Picea abies Needle	2415 ± 30	
Poz-55928	93	Bark, indet.	3005 ± 35	
Poz-55929	142	Wood (Picea/Larix type)∗	4120 ± 35	
Poz-58431	182	Wood fragments (Larix/Picea or Pinus sp.)	5120 ± 35	
Poz-55930	218	Wood (Picea/Larix type) ∗∗	6890 ± 40	
Poz-55931	236	Wood (Picea/Larix type)∗∗	7460 ± 40	
Poz-55932	248	Wood (Picea/Larix type)	7920 ± 50	

Despotovac

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
DeA-7476	86.5	Bulk sediment	541 ± 11	
DeA-7477	193.5	Bulk sediment	1019 ± 31	
DeA-7478	267.5	Bulk sediment	2989 ± 46	
DeA-7479	395	Bulk sediment	4091 ± 60	
DeA-7480	465	Bulk sediment	4528 ± 60	

Baia Vulturilor

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
RAD-4-2016-1	19	Bulk peat (Sphagnum stems)	104.55 ± 1.44	
RAD-4-2016-2	50	Bulk peat (Sphagnum stems)	757 ± 50	
RAD-4-2016-3	79.5	Bulk peat (Sphagnum stems)	2230 ± 100	
RAD-4-2016-4	108	Bulk peat (Sphagnum stems)	2534 ± 100	
RAD-4-2016-5	144	Bulk peat (Sphagnum stems)	2820 ± 100	

Iezerul Mare

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
IZM-1.1-30	30	Bulk peat (Sphagnum stems)	248 ± 31	
IZM-1.1-80	80	Bulk peat (Sphagnum stems)	207 ± 30	
IZM-1.3-130	130	Bulk peat (Sphagnum stems)	261 ± 32	
IZM-1.3-180	180	Bulk peat (Sphagnum stems)	697 ± 29	
IZM-1.5-230	230	Bulk peat (Sphagnum stems)	923 ± 30	
IZM-1.5-282	282	Bulk peat (Sphagnum stems)	1093 ± 30	
IZM-1.7-330	330	Bulk peat (Sphagnum stems)	1486 ± 30	

IZM-1.7-380	380	Bulk peat (Sphagnum stems)	1957 ± 30	
IZM-1.9-430	430	Bulk peat (Sphagnum stems)	2191 ± 33	
IZM-1.9-480	480	Bulk peat (Sphagnum stems)	2500 ± 33	
IZM-1.11-530	530	Bulk peat (Sphagnum stems)	2909 ± 36	
IZM-1.11-580	580	Bulk peat (Sphagnum stems)	3403 ± 31	
IZM-1.13-630	630	Bulk peat (Sphagnum stems)	4118 ± 38	
IZM-1.13-680	680	Bulk peat (Sphagnum stems)	4522 ± 35	
IZM-1.17-730	730	Bulk peat (Sphagnum stems)	5109 ± 36	
IZM-1.17-790	790	Bulk peat (Sphagnum stems)	6123 ± 54	

Mluha

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
DeA-3695	30	Bulk peat (Sphagnum stems)	76 ± 21	
DeA-3696	80	Bulk peat (Sphagnum stems)	209 ± 21	
DeA-3697	130	Bulk peat (Sphagnum stems)	583 ± 23	
DeA-3698	180	Bulk peat (Sphagnum stems)	990 ± 23	
DeA-5789	209.5	Bulk peat (Sphagnum stems)	1180 ± 27	
DeA-5790	219.5	Bulk peat (Sphagnum stems)	1436 ± 27	
DeA-3699	230	Bulk peat (Sphagnum stems)	1799 ± 23	
DeA-5791	239.5	Bulk peat (Sphagnum stems)	2078 ± 26	
DeA-5792	249.5	Bulk peat (Sphagnum stems)	2112 ± 26	
DeA-3700	280	Bulk peat (Sphagnum stems)	2459 ± 25	
DeA-5793	329.5	Bulk peat (Sphagnum stems)	2664 ± 27	
DeA-3702	378	Bulk peat (Sphagnum stems)	3290 ± 24	
RoAMS: 1399.87	429	Bulk peat (Sphagnum stems)	3873 ± 38	
DeA-5794	480.5	Bulk peat (Sphagnum stems)	4130 ± 30	
RoAMS: 1400.87	511	Bulk peat (Sphagnum stems)	4415 ± 39	
RoAMS: 1401.87	534	Bulk peat (Sphagnum stems)	5115 ± 40	
RoAMS: 1402.87	554	Bulk peat (Sphagnum stems)	5592 ± 43	
RoAMS: 1403.87	574	Bulk peat (Sphagnum stems)	6341 ± 45	
DeA-3703	590	Bulk peat (Sphagnum stems)	6730 ± 30	

Zanoaga Rosie

Lab Code	Depth (cm)	Material dated	14 C Age (±1σ)	Remarks
DeA-5798	23	Bulk peat (Sphagnum stems)	15 ± 24	
DeA-5799	41	Bulk peat (Sphagnum stems)	821 ± 24	
DeA-3680	58.5	Bulk peat (Sphagnum stems)	1959 ± 17	Outlier
DeA-8389	61.5	Bulk peat (Sphagnum stems)	5525 ± 26	
DeA-8390	66.5	Bulk peat (Sphagnum stems)	6411 ± 27	

DeA-5784	77.5	Bulk peat (Sphagnum stems)	7121 ± 32
DeA-5780	95.5	Bulk peat (Sphagnum stems)	7280 ± 38
DeA-3681	114.5	Bulk peat (Sphagnum stems)	7654 ± 25
DeA-3682	158.5	Bulk peat (Sphagnum stems)	8308 ± 26
DeA-5785	171	Bulk peat (Sphagnum stems)	8505 ± 34
DeA-5786	187.5	Bulk peat (Sphagnum stems)	9566 ± 38
DeA-3683	209.5	Bulk peat (Sphagnum stems)	11082 ± 33

Supplementary Table 2: Averages and standard deviations for the variables used in the Monte Carlo modelling.

Variable	Unit	Average	Standard Deviation	Reference
Carbon content	%	50.31	10.87	This study
Bulk density	g cm-3	0.16	0.08	This study
Oligotrophic bog area	km2	13.53	1.37	(Pop, 1960)
Eutrophic bog area	km2	57.31	5.66	(Pop, 1960)
Oligotrophic bog depth	cm	201.62	20.08	(Pop, 1960)
Eutrophic bog depth	cm	90.84	6.44	(Pop, 1960)

Supplementary Table 3: Correlation coefficients and p-values between dust deposition and modelled climate data, for a selection of times periods.

All	Pearson's r	p-value
Mean Precip	0.20	0.05
Precip Seasonality	-0.35	0.00
Area Mean	0.15	0.12
Min Temp	-0.06	0.54
Max Temp	0.19	0.05
Diurnal range	0.20	0.05
Annual range	-0.22	0.02
Isothermality	0.29	0.00
Temp seasonality	-0.26	0.01

5000-4000 yr BP	Pearson's r	p-value
Mean Precip	-0.09	0.70
Precip Seasonality	-0.15	0.49
Area Mean	-0.20	0.35
Min Temp	0.03	0.90
Max Temp	-0.53	0.01
Diurnal range	-0.44	0.03
Annual range	-0.21	0.34
Isothermality	-0.05	0.82

Temp seasonality	-0.33	0.12

3950-3000 yr BP	Pearson's r	p-value
Mean Precip	-0.27	0.22
Precip Seasonality	-0.04	0.86
Area Mean	-0.18	0.42
Min Temp	-0.10	0.64
Max Temp	-0.10	0.66
Diurnal range	0.02	0.92
Annual range	0.08	0.71
Isothermality	-0.08	0.72
Temp seasonality	0.10	0.67

2950-2000 yr BP	Pearson's r	p-value
Mean Precip	-0.22	0.30
Precip Seasonality	-0.48	0.02
Area Mean	-0.57	0.00
Min Temp	-0.41	0.05
Max Temp	-0.37	0.07
Diurnal range	0.21	0.34
Annual range	0.32	0.14
Isothermality	-0.19	0.40
Temp seasonality	0.19	0.40

1950-1000 yr BP	Pearson's r	p-value
Mean Precip	0.01	0.95
Precip Seasonality	0.08	0.73
Area Mean	0.36	0.09
Min Temp	0.29	0.17
Max Temp	0.07	0.75
Diurnal range	-0.31	0.15
Annual range	0.12	0.58
Isothermality	-0.29	0.18
Temp seasonality	-0.07	0.77

1000-Present yr BP	Pearson's r	p-value
Mean Precip	0.22	0.32
Precip Seasonality	-0.14	0.51
Area Mean	-0.38	0.07
Min Temp	-0.44	0.03
Max Temp	-0.30	0.16
Diurnal range	0.36	0.09
Annual range	0.08	0.71

Isothermality	0.12	0.58
Temp seasonality	0.19	0.38

Supplementary References

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