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The effect of a reciprocal peat transplant between two contrasting Central European sites on C cycling

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Abstract

An 18-month reciprocal peat transplant experiment was conducted between two peatlands in the Czech Republic. Both sites were 100% *Sphagnum*-covered, with no vascular plants, and no hummocks and hollows. Atmospheric depositions of sulfur were up to 10 times higher at the northern site Velke jerabi jezero (VJJ), compared to the southern site Cervene blato (CB). Forty-cm deep peat cores, 10 cm in diameter, were used as transplants and controls in five replicates. Our objective was to evaluate whether CO_2 and CH_4 production potentials in *Sphagnum* peat bogs are governed mainly by organic matter quality, or by environmental conditions. Production rates and $\delta^{13}C$ values of CO_2 and CH_4 were measured in the laboratory at time t=18 months. All measured parameters converged to those of the host site, indicating that, at least in the short-term perspective, environmental conditions were a more important control of greenhouse gas emissions than organic carbon quality. Since sulfate reducers outcompete methanogens, we hypothesized that the S-polluted site VJJ should have lower methane emissions than CB. In fact, the opposite was true, with higher methane emissions from VJJ. As a first step in an effort to link C isotope composition of emitted gases and residual peat substrate, we determined whether multiple vertical $\delta^{13}C$ profiles in peat agree. A high degree of within-site homogeneity in $\delta^{13}C$ was found. The $\delta^{13}C$ value increased downcore at both CB and VJJ. However, 20 cm below surface, a reversal to lower $\delta^{13}C$ downcore was seen at VJJ. Based on ^{210}Pb dating, peat at 20 cm depth at VJJ was only 15 years old. Increasing $\delta^{13}C$ values in VJJ peat accumulated between 1880–1990 could not be caused by assimilation of atmospheric CO_2 gradually enriched in the light isotope ^{12}C due to fossil fuel burning.

1 Introduction

It is estimated that one third of global soil carbon is stored in wetlands, mainly at northern latitudes (Woodwell and Mackenzie, 1995). According to most atmospheric cir-

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culation models, it is these northern latitudes where global warming will be most pronounced during the 21st century (IPCC, 2007). Microbial activities and solubilities of dissolved gases are strongly temperature-dependent (Moore et al., 1998). Therefore, recent studies have focused on whether thinning of peat deposits and higher emissions of greenhouse gases may contribute to stronger climate forcing, and accelerate temperature increases (Yavitt et al., 2005). Some C sequestration studies have suggested that local hydrological factors are more important than climate (Yu et al., 2001). For Holocene peat profiles, concave plots of total mass vs. age have indicated continuous decomposition throughout the peat column (Wieder and Vitt, 2006). Over time, the efficiency of peatlands as atmospheric C sinks diminishes (Belyea and Clymo, 2001).

Isotopes can be used to constrain the global budgets of greenhouse gases, such as CO_2 and methane (Bouwman, 1999). When isotope abundances in an atmospheric gas change, a shift in sources or sinks of the gas is indicated. Thus, isotopes may be instrumental in identifying a previously unknown source or sink of greenhouse gases. Sofar, few attempts have been made to isotopically link two complementary reservoirs of carbon, solid peat substrate, and atmospheric gases (Jedrysek et al., 2005). The $\delta^{13}C$ values can potentially be a useful tracer of past methane emissions because biogenic methane contains isotopically extremely light C (Woodwell and Mackenzie, 1995). Can removal of this isotopically light C from peat be detected in isotopically heavier residual organic C remaining in situ? Before any isotope mass balance considerations are made, the degree of within-site and between-site homogeneity in $\delta^{13}C$ values of vertical peat profiles must be assessed. Upscaling the results of research plot studies is possible only if a variety of sites exhibit similar isotope features. Our first objective was to isotopically analyze bulk C in a number of replicate peat columns within two *Sphagnum* wetlands, and compare the vertical $\delta^{13}C$ profiles. We discuss possible explanations of the found vertical $\delta^{13}C$ profiles in solid peat.

Our second objective was related to the fact that the current rate of increase in methane concentrations in the atmosphere is lower than several decades ago (Dise and Verry, 2001). Suggestions have been made that elevated sulfur depositions in

industrial countries have led to suppression of methane emissions from wetlands and rice paddies (Wieder and Vitt, 2006). Thermodynamically, anaerobic bacterial sulfate reduction should outcompete methanogenesis (Blodau and Moore, 2003). We used a sharp north-south pollution gradient in Central Europe to investigate whether higher S inputs lead to lower rates of methanogenesis.

Our third objective was to evaluate whether CO_2 and CH_4 production potentials in *Sphagnum* peat bogs are governed mainly by organic matter quality, or environmental conditions. Again, we used the north-south pollution gradient in Central Europe, and conducted a reciprocal peat transplant experiment between a highly polluted and a relatively unpolluted *Sphagnum* bog. We hypothesized that if organic matter quality, i.e. the ratio between labile and recalcitrant C forms, is the primary control of terminal C mineralization, the productions of CO_2 and CH_4 at the host site will remain similar to those at the home site. If environmental parameters are the primary control, the productions of CO_2 and CH_4 will become similar to the host site.

2 Materials and methods

2.1 Study sites

The two peat bogs selected for the reciprocal transplant experiment (Fig. 1 and Table 1, Novak and Pacherova, 2008) represented extremes in atmospheric S deposition. The northern site, Velke jerabi jezero (VJJ), is located in the "Black Triangle" region, one of the most polluted parts of the world. The Black Triangle comprises the northern Czech Republic, southeast Germany and southern Poland. VJJ is situated in the Krusne hory Mts. near a cluster of coal-fired power plants, which were built in the 1950s, but had desulphurization units installed only in the late 1990s. Spruce (*Picea abies*) stands died back on 1000 km^2 in the Black Triangle between 1975 and 1995, partly as a result of high atmospheric SO_2 concentrations. In the vicinity of VJJ (25 km north-west of the power plants), symptoms of crown thinning and needle yellowing were observed. The

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industrial air pollution in the area peaked in 1987, with the highest spruce throughfall of 160 kg S ha^{-1} yr^{-1} recorded at the nearby Jezeri (Novak et al., 2005). After 1987, industrial emission rates decreased rapidly, and are now 90% lower.

The southern site, Cervene blato (CB, Fig. 1 and Table 1), is located in the relatively unpolluted Trebon Basin, a natural preserve near the Czech border with Austria. The bog is surrounded by healthy mature spruce stands. The distance between CB and VJJ is 220 km. CB is currently four times less polluted with atmospheric S and twice less polluted with reactive forms of atmospheric N, compared to VJJ (Novak, and Pacherova, 2008).

2.2 Design of peat transplant experiment

A total of 30 peat cores, 40 cm long, 10 cm in diameter, were collected in April 2002 using polyvinylchloride (PVC) cylinders with a sharpened bottom edge. Fifteen peat cores were collected at VJJ and 15 peat cores at CB. All cores were taken from peat lawns whose surface was 100% *Sphagnum*-covered, with no vascular plants. Five cores from each site were transported to the laboratory and analyzed. At each site, additional five cores were transplanted back to their original positions. Before replacing the five cores into the soil at their home sites, the cores were removed from the PVC cylinders, wrapped individually with plastic mesh (openings 2.5 mm×2.5 mm), leaving the surface free. The mesh was fastened around each peat core and secured with cable ties. At each site, the remaining five cores were capped and placed vertically into a cooler for immediate transport to the host site. Five replicate peat cores were transplanted from VJJ to CB, and five replicate cores from CB to VJJ. Upon arrival at the host site, the five peat cores were removed from PVC cylinders, wrapped with mesh and inserted into the positions of five local peat cores, which had been previously collected and transported to their host site.

The transplanted cores remained in the soil for 18 months. In September 2003, we retrieved 10 cores from VJJ (five control cores originating from VJJ and five transplanted cores originating from CB) and 10 cores from CB (five control cores originating

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from CB and five transplanted cores originating from VJJ). The cores were transported to the laboratory.

One 50 cm long, 10 cm in-diameter, peat core was collected from each VJ and CB in April 2002 for ^{210}Pb dating of peat accretion history.

2.3 Analysis

Five 40-cm long peat cores per site taken into the laboratory at time t=0 (April 2002) were frozen, cut into 2 cm thick segments, dried at 60°C, weighed, and homogenized. Ash content was determined on a 0.5 g aliquot at 550°C. Carbon concentrations were measured on a Carlo Erba Elemental Analyzer and corrected for ash content, C isotope compositions were determined on a Finnigan MAT 251 mass spectrometer following on-line combustion of the peat. Carbon isotope data are given in the usual notation as δ^{13}C values in ‰ relative to the V-PDB standard. Reproducibility of δ^{13}C determinations was better than ±0.3 ‰.

The two 50 cm long peat cores were processed as above. Three grams of pulverized peat from each 2 cm section were digested with HCl and HNO_3, spiked with ^{209}Po as a chemical yield tracer, and ^{210}Po, along with ^{209}Po were plated on Ag discs (Vile et al., 2000). Polonium activities were measured on an EGG and Ortec 576 A dual α spectrometer, and ^{210}Pb dates calculated.

A 27 h laboratory incubation study was performed to assess CO_2 and methane emission potentials from transplanted and control peat cores extruded in September 2003.Three peat cores were randomly selected from each of the following four treatments: CB cores extruded from CB, CB cores extruded from VJJ, VJJ cores extruded from VJJ, and VJJ cores extruded from CB. The headspace was purged with N_2 for 10 min. The 12 capped peat cores were anaerobically incubated at 20°C and gas samples taken 2, 4, 8, 12 and 27 h after the beginning of the incubation. At each time, 60 mL of headspace gas were removed using a syringe and injected into an evacuated Hungate tube. An additional 60 mL of N_2 were added to each headspace for vacuum prevention, and headspace dilution corrections were made. Concentrations of CO_2

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and CH_4 were determined on a Shimadzu 14A gas chromatograph. Rates of CO_2 and CH_4 production were estimated from changes in headspace concentrations over time. Hungate tube content was transferred by He carrier into a line for trace gas measurements. $CO_2$was collected in a condensation trap, $CH_4$was combusted over Pd catalyst. The $\delta^{13}C$ values were determined with reproducibility better than ±0.5‰.

Following the 27 h laboratory incubation, the 10 peat cores previously transplanted to their host site (five from CB to VJJ, and five from VJJ to CB) were frozen, cut into 2 cm thick segments, dried at 60°C, weighed, and homogenized. Bulk C concentrations and $\delta^{13}C$ values were determined for each 2 cm thick peat segment.

Statistical analysis was performed using linear mixed models (Laird, and Ware, 1982) and the R 2.6.2 software (R Development Core Team, 2008).

3 Results

3.1 Peat accretion history

Cumulative dry mass increased smoothly with an increasing depth and age at both sites, and was slightly higher at CB than at VJJ (Fig. 2a). Lead-210 dates revealed faster peat accumulation at the northern, colder site VJJ, compared to the southern, warmer site CB (Fig. 2b). At a depth of 34 cm, peat at CB was 140 years old, whereas peat at VJJ was just 55 years old.

3.2 Downcore C concentration trends

The vertical C concentration patterns differed between the two sites (Fig. 3). Whereas C concentrations at VJJ steadily increased with an increasing peat depth, those at CB showed no vertical gradient.

3.3 Downcore δ^{13} C trends

Also the vertical trends in δ^{13}C values of bulk peat differed between the two sites (Fig. 3). With an increasing depth, peat at CB became progressively enriched in the heavier isotope ^{13}C (higher δ^{13}C values). In contrast, peat from VJJ exhibited a clear-cut δ^{13}C maximum at a depth of 20 cm below surface. Between 0 and 20 cm, peat at VJJ became progressively enriched in the heavier isotope ^{13}C, similar to CB. However, at depths greater than 20 cm, peat at VJJ became progressively enriched in the lighter isotope ^{12}C, and the δ^{13}C values decreased with increasing depth. Importantly, at both sites, when a specific vertical δ^{13}C trend was seen in one peat core, the same trend was also seen in all the remaining peat cores. There was a high degree of within-site homogeneity in vertical δ^{13}C trends.

3.4 The effect of peat transplant on substrate C

Figures 4 and 5 show mean C concentrations and δ^{13}C values for five replicate peat cores per treatment, along with standard errors. The four treatments are marked as follows: "CB" are peat cores taken from CB to the laboratory at the beginning of the experiment. "VJJ" are peat cores taken from VJJ to the laboratory at the beginning of the experiment. "CB to VJJ" are peat cores originating from CB which were transplanted to VJJ for 18 months, and then analyzed. "VJJ to CB" are peat cores originating from VJJ which were transplanted to CB for 18 months, and then analyzed.

As seen in Fig. 4, transplanting peat cores from VJJ to CB had no effect on the vertical C concentration gradient: both sets of peat cores originating from VJJ had higher C concentrations at greater depth than at peat surface (cf. Fig. 4a, b). At the same time, transplanting peat cores from CB to VJJ resulted in higher C concentrations at greater depths, even though their home site CB had similar C concentrations along the entire profile. The CB to VJJ carbon concentration profiles were indistinguishable from VJJ profiles, i.e. from their host site (Fig. 4b).

As seen in Fig. 5, transplanting peat cores between both sites had little effect on their

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vertical δ^{13}C trends. CB to VJJ peat cores exhibited higher δ^{13}C values downcore, identical to CB peat cores (Fig. 5a). VJJ to CB peat cores exhibited a peak in δ^{13}C values at 20 cm depth, similar to VJJ peat cores (Fig. 5b).

3.5 Emissions of CO_2 and CH_4 from incubated peat

The 27 h incubation was performed on peat cores taken into the laboratory at time t=18 months. The four preceding treatments (transplant types) included: CB to CB, CB to VJJ, VJJ to VJJ and VJJ to CB. Detailed time series of concentrations of CO_2 and CH_4 and their δ^{13}C values during the 27 h incubation are depicted in Figs. A1–A4 in the Appendix. CO_2concentrations increased linearly in all four treatments. Methane concentrations increased in three treatments during the first 12 h.

3.6 Comparison of CO_2 and CH_4 production

Figure 6 compares CO_2 and CH_4 production rates and δ^{13}C values among the four transplant types, obtained from the 27 h laboratory incubation. All data in Fig. 6 were measured at room temperature (20°C). For both CO_2 and CH_4, the same relative magnitude of production rates was observed: CB to CB had the lowest gas production rates, VJJ to VJJ had the highest gas production rates. CO_2 production in the peat cores kept at their home site VJJ was almost four times higher than CO_2 production in the peat cores kept at their home site CB. Methane production in the peat cores kept at their home site VJJ was nine times higher than that in any other treatment. A striking feature of every graph in Fig. 6 is that all four measured parameters (concentrations and isotope compositions of CO_2 and CH_4) converged to their host site toward the end of the transplant experiment. Transplanting peat cores from CB to VJJ resulted in a 3.5-fold increase in CO_2 production, approaching that of the host site. Transplanting peat cores from VJJ to CB resulted in a 50% decrease in CO_2 production, approaching that of the host site. The same systematic pattern was seen for methane production, e.g. transplanting peat cores from VJJ to CB resulted in 15 times lower methane pro-

duction compared to the home site VJJ.

3.7 Comparison of $\delta^{13}C_{CO2}$ and δ^{13} C_{CH4}

Also the $\delta^{13}C$ values of both gases emitted from transplanted peat cores converged to those of the host site (Fig. 6). The $\delta^{13}C$ values of both CO_2 and methane were lower for VJJ to VJJ peat cores than for CB to CB peat cores. The peat cores producing more CO_2 and methane at their home location (i.e. VJJ) always had isotopically lighter carbon. In general, transplanting peat cores to a host site resulted in either a decrease or an increase in $\delta^{13}C$ so that the C isotope composition became more similar to the host site (Fig. 6).

4 Discussion

4.1 C sequestration in peat

Over millennia, peat deposits developing in colder climate tend to accumulate more carbon and are thicker compared to peat deposits developing in warmer climate (Yu et al., 2001). Such a relationship was found for VJJ and CB for the most recent 150 years. The mean annual temperature at the northern site VJJ is 3.8°C lower compared to the southern site CB. The vertical growth rate of VJJ was twice that of CB (Fig. 2b). Substrate accumulates whenever the rates of net primary production are greater than the rates of decomposition. While higher temperature leads to higher *Sphagnum* growth, also the decomposition rate is greater. Lower net primary production at lower temperature is usually associated with slower decomposition. A number of records of recent peat slow similar litter additions and decay rates despite climatic differences (Belyea and Clymo, 2001; Wieder and Vitt, 2006; Novak et al., 2008). The positive relationship between C accumulation and colder climate valid for entire Holocene deposits is not always valid for the topmost peat layers. Net primary production appears to be more

sensitive to environmental parameters than decay (Moore et al., 1998). The main difference between VJJ and CB is in fertilization levels by anthropogenic N and S. Thus higher availability of nutrients at VJJ may have contributed to the higher peat accumulation. Temperature may not be the main control of the greater peat accumulation at VJJ.

4.2 Controls on δ^{13}C of ageing peat

The δ^{13}C values of vertical peat profiles are a useful tool for studying maturation and diagenesis of peat if four conditions are met: (i) δ^{13}C gradients exist in peat substrate with age, (ii) δ^{13}C gradients are widespread, (iii) C maturation in peat is isotopically selective, and (iv) other isotope-selective processes can be distinguished from peat maturation. As seen from Figs. 3 and 5, clear-cut vertical δ^{13}C signals are found in *Sphagnum* peat. From peat surface to a depth of 20 cm, these signals (higher δ^{13}C downcore) seem to be common (cf. Novak et al., 2009). In contrast, we do not know of any other peatland where a systematic decrease in δ^{13}C downcore (such as the one starting at a depth of 20 cm at VJJ) was reported.

A small kinetic C isotope fractionation during peat degradation was reported by Wynn et al. (2006). In an open system, Rayleigh distillation may result in isotopically heavier residual C in situ while low-δ^{13}C is removed as a gas. Indeed, biogenic methane can have δ^{13}C values as low as –110‰. We also note a possible analogy between ageing of organic C in well-aerated upland soils, and wetland soils. For upland soils, Nadelhoffer, and Fry (1988) concluded that mineralization-related preferential release of the light isotope ^{12}C may contribute to higher δ^{13}C in deeper soil horizons. Isotopically heavier residuum in deeper soils has been reported also for N (Nadelhoffer, and Fry, 1988 and references therein, Novak et al., 2003), and for S (Novak et al., 1996, 2005). Degradation of organic S-containing molecules in peat also preferentially releases the light isotope ^{32}S (Novak et al., 1994, 1999).

Two processes linked to assimilation of atmospheric CO_2 by plants can mask a possible C isotope effect of peat degradation. Burning of fossil fuels over the past 200

years has injected into the atmosphere isotopically light CO_2-C (Friedli et al., 1986), and this lower $\delta^{13}C$ may be seen in the uppermost layers of organic soils. While this effect is well documented, we propose that it is not the dominant control of $\delta^{13}C$ values in young peat layers in our study. As seen in Figs. 3 and 5, gradual admixture of isotopically light fossil-fuel C from the atmosphere is not consistent with the VVJ $\delta^{13}C$ profile below the depth of 20 cm. When moving upward, higher, instead of lower, $\delta^{13}C$ were observed. The lower $\delta^{13}C$ at greater depth at VJJ could be explained by drier conditions before 1987 (the year corresponding to the 20 cm peat depth). Lower water contents leads to lower external CO_2 diffusion resistance, and greater C-isotope discrimination upon assimilation. If so, $\delta^{13}C$ records in peat can be used as a geochemical archive of site-specific moisture conditions.

4.3 Decoupling of C concentrations and $\delta^{13}C$ in peat profiles

In intact peat profiles, increasing C concentrations at greater depth are often viewed as a manifestation of substrate degradation, with faster removal of functional -OH groups than removal of carbon. Surprisingly, we found that, in some sample types, the two signs of substrate degradation were decoupled. For example, at CB, $\delta^{13}C$ values increased downcore, possibly reflecting substrate degradation, while C concentration did not increase. Further study is needed to ascertain how common the decoupling of C concentration and isotope trends in maturating peat is.

4.4 Linking sulfate reduction and methane production

Atmospheric S inputs at VJJ were four times higher than at CB at the time of the transplant experiment, and 10 times higher 15 years earlier (Novak et al., 2005). Because microbial sulfate reducers should outcompete methanogens (Dise and Verry, 2001), we expected higher methane emissions at CB than at VJJ. In fact, the opposite was true, and peat cores originating from the polluted site VJJ had nine times higher CH_4 production rate than other peat cores. Methane production at CB was close to zero.

This is an unexpected result, even more so that some explanations are ruled out. One potential explanation would be presence of vascular plants with conduits transporting methane to the peat surface. There were no vascular plants on the research plots. We note that the measured production rates of methane were affected by methane oxidation, which mainly takes place at the lower edge of the green *Sphagnum* plants. This is documented by $\delta^{13}C_{CH4}$ values in the range of –20 to –45‰, a result of preferential oxidation of low-$\delta^{13}C$ methane (Chanton, 2005). Fresh biogenic methane has $\delta^{13}C$ values between –50 and –110‰, depending on the methanogenic pathway (Wieder and Vitt, 2006).

4.5 The effect of peat transplant on CO_2 and CH_4 emissions

The main objective of the reciprocal peat transplant experiment was to evaluate whether organic carbon quality or environmental parameters are the main control of CO_2 and CH_4 production potentials. At the studied depths, peat from VJJ was younger and provided more labile organic C than peat from CB. This corresponded to significantly higher rates of microbial activity at VJJ, but, at the same time, substrate degradation was lower compared to CB. Over the 18 months of the experiment, metabolism and trace gas production of all transplanted peat cores converged to those of the host sites (Fig. 6). This allows us to conclude that environmental parameters were by far the dominant control of terminal C mineralization potentials at our study sites. Availability of labile C forms played a much less role, as illustrated, e.g. by a dramatic suppression of CH_4 emissions when VJJ peat was transplanted to CB (Fig. 6).

5 Conclusions

Sensitivity of carbon cycling in peatlands to various environmental parameters, such as mean annual temperature and sulfur deposition, was studied at two *Sphagnum*-dominated peat bogs in Central Europe. Both sites were waterlogged throughout the

year, with negligible differences in hydrology. It was found that the colder northern site VJJ accumulated more organic carbon over the past 150 years than the southern warmer site CB. The emission rates of both products of terminal C mineralization, CO_2 and CH_4, were also higher at the colder site VJJ. One possible explanation is that peat at the northern site VJJ had been continuously fertilized by elevated sulfur and nitrogen depositions since the beginning of the Industrial Revolution. While net primary productivity increased due to higher nutritional status of the northern site, decomposition rates, which are believed to be less sensitive to environmental parameters, were also higher at the northern than at the southern site. The difference between organic mass production and decomposition was still higher at the northern site compared to the southern site.

Since microbial sulfate reducers outcompete methanogens, we hypothesized that the sulfur-polluted site VJJ should have lower methane emissions than CB. However, the opposite was true, with higher methane emissions from VJJ. This finding cannot be explained by presence of vascular plants at VJJ, known to facilitate methane transport to the atmosphere, because such plants were not found at the sampling sites. It may be related to the overall greater rates of organic mass production at VJJ and thus higher availability of labile organic C.

A replicated peat transplant experiment revealed that imported peat adjusted its carbon cycling to that of the host site. It follows that the organic carbon quality inherited from the original site did not control C transformation rates. Rather, environmental parameters, such nutritional status, were the main controls of C storage in the wetland.

Extensive replication of peat monoliths, needed for a peat transplant experiment, was used for a complementary C isotope study of both the solid substrate and emitted gases, CO_2 and CH_4. Vertical $\delta^{13}C$ trends in solid peat exhibited a high degree of within-site homogeneity, but were site specific. In all 20 studied peat cores, the $\delta^{13}C$ value increased downcore in the topmost ca. 20 cm. This trend could have been caused by both preferential removal of the light isotope ^{12}C from older peat due to decomposition, or by growing fossil fuel burning which spikes ^{12}C-rich CO_2 into the

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atmosphere. In peat deeper than 20 cm at VJJ, however, $\delta^{13}C$ increased upcore. VJJ peat at the 20 cm depth was relatively young (year 1987). Between 1880 and 1987, fossil fuel burning was already adding isotopically light CO_2-C to the atmosphere, and could not have dominated the increasing $\delta^{13}C$ trend upcore at VJJ. Consequently, a different C isotope selective mechanism must have dominated the C isotope systematics between 1880 and 1987 at VJJ, overprinting both peat degradation and fossil-fuel derived C input. This mechanism might be related to historical moisture conditions, because droughts lead to greater C-isotope discrimination during photosynthesis.

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Table 1. Characteristics of the studied peat bogs.

Site	Location	Elevation (m)	Mean annual temperature (°C)	Annual precipitation (mm)	Annual sulfur deposition [a] ($kg\,ha^{-1}$)	Annual nitrogen deposition [a] ($kg\,ha^{-1}$)	Bog water pH
Velke jerabi jezero (VJJ)	50°24′N 12°36′ E	930	4.0	1000	28.7	23.4	3.0–5.5
Cervene blato (CB)	48° 52′N 13°47′E	450	7.8	600	7.6	11.8	2.5–5.0

[a] Atmospheric S and N inputs into semi-open peat bogs were calculated as arithmetic mean of open-area deposition and spruce canopy throughfall (Novak and Pacherova, 2008).

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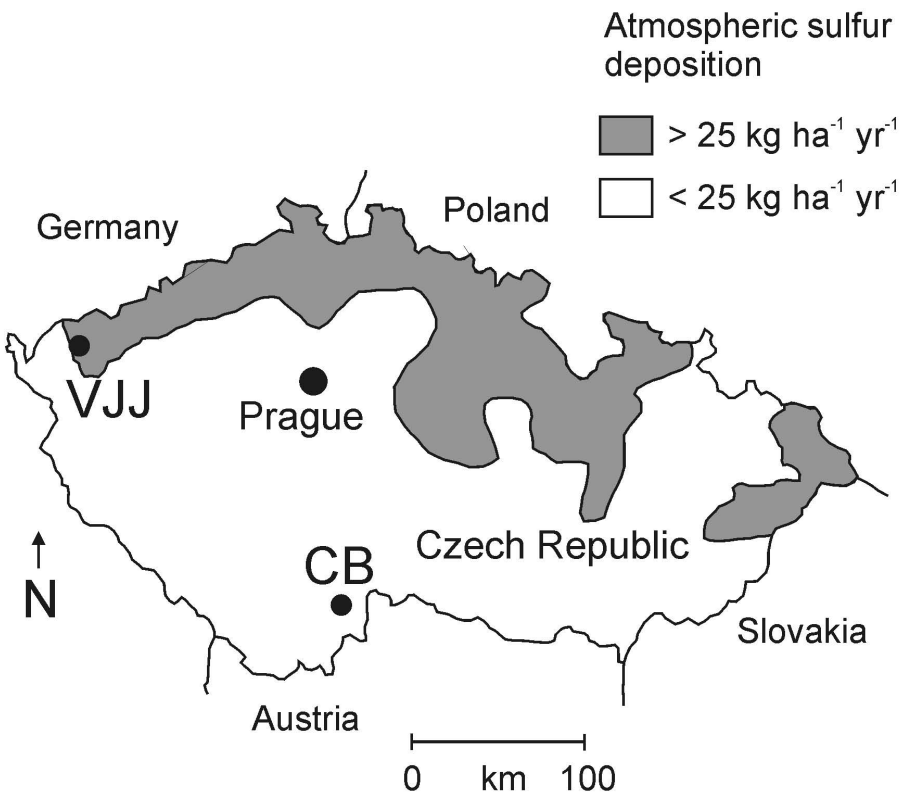

Fig. 1. Location of the studied peatlands. Sulfur pollution contours from Novak et al. (2005).

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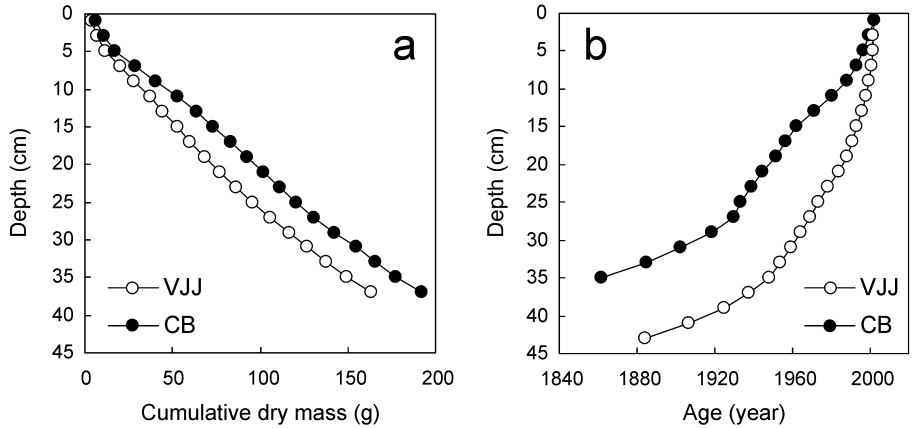

Fig. 2. Peat accretion history. **(a)** cumulative dry mass, **(b)** ^{210}Pb dates.

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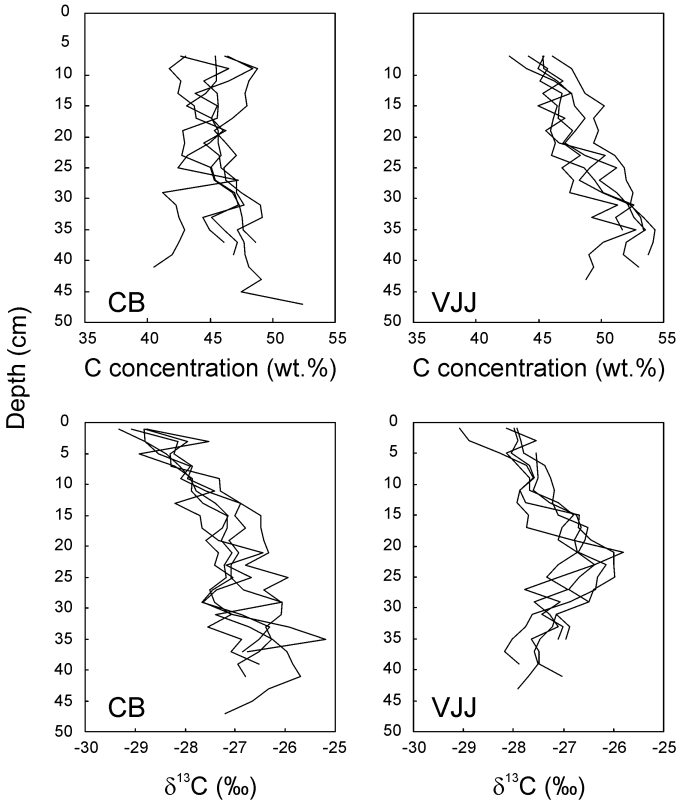

Fig. 3. Carbon content and $\delta^{13}C$ values in replicated peat cores (means±SE, n=5).

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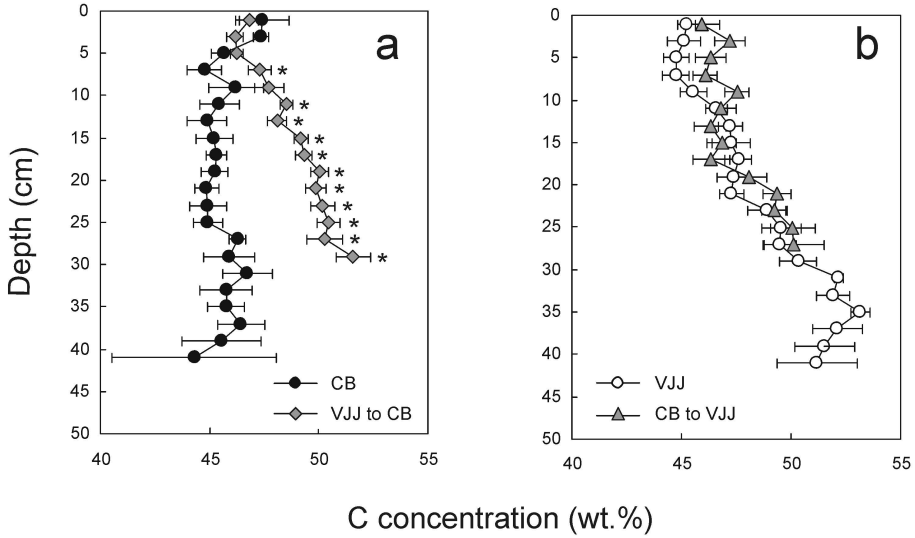

Fig. 4. Effect of the peat transplant on C concentration (means±SE, n=5). Asterisks denote statistically significant differences ($p<0.05$).

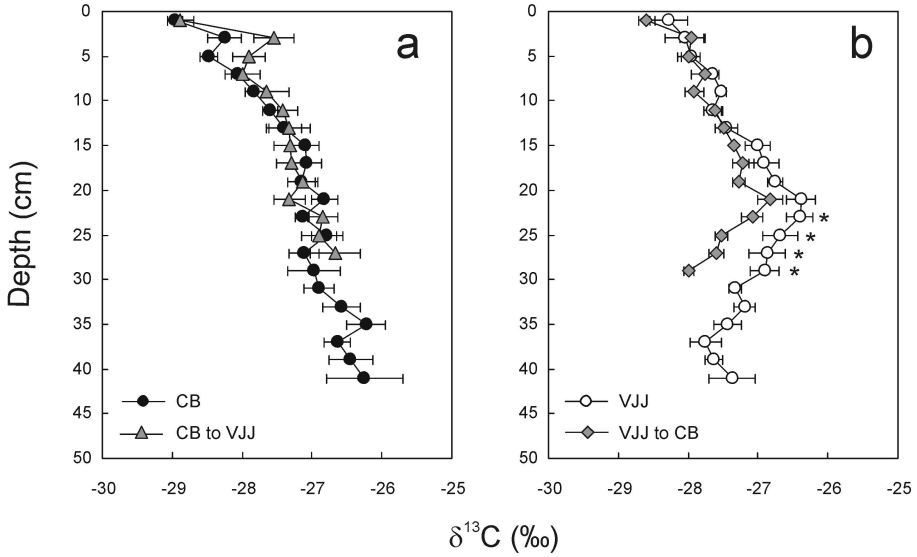

Fig. 5. Effect of the peat transplant on $\delta^{13}C$ values (means±SE, n=5).

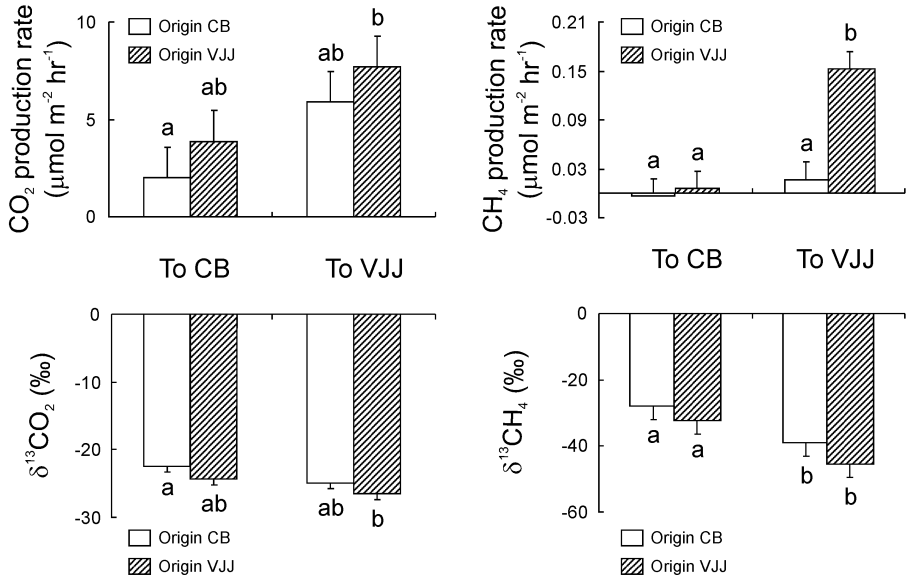

Fig. 6. The amount and C isotope composition of CO_2 and methane emanating from peat at the end of the transplant experiment (means±SE, n=3). Different letters denote statistically significant differences ($p<0.05$).

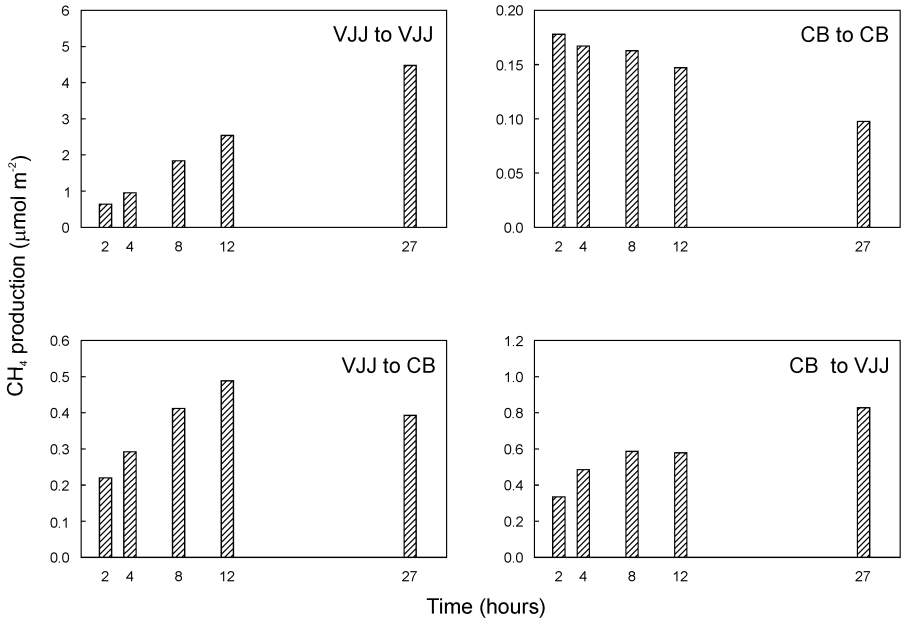

Fig. A1. Methane production during laboratory peat incubation.

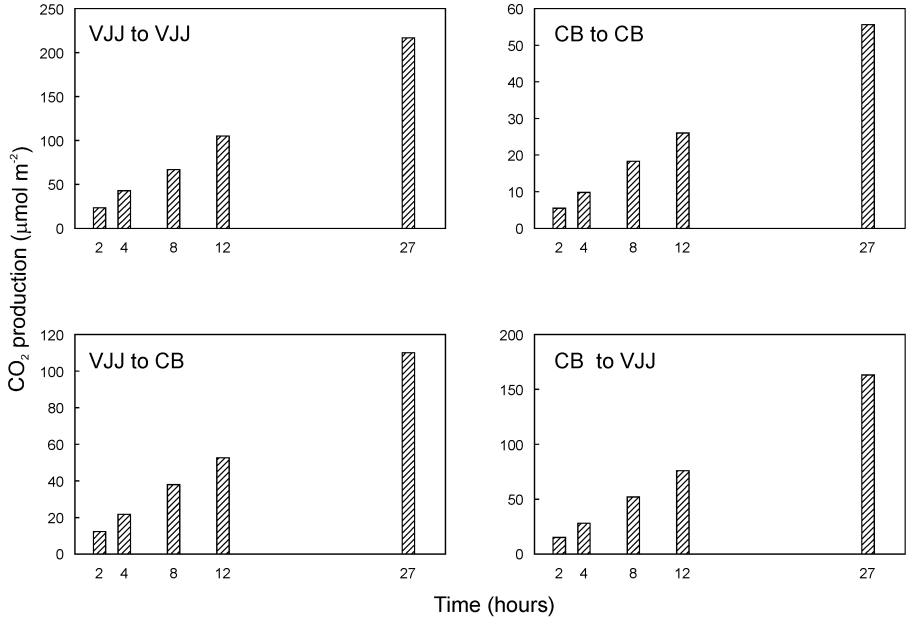

Fig. A2. CO_2 production during laboratory peat incubation.

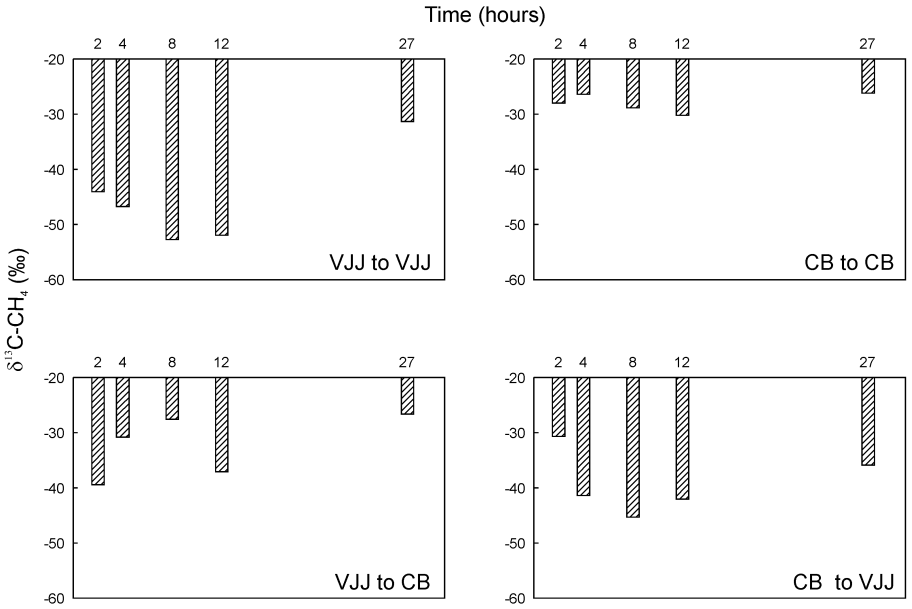

Fig. A3. $\delta^{13}C$–CH_4 values during laboratory peat incubation.

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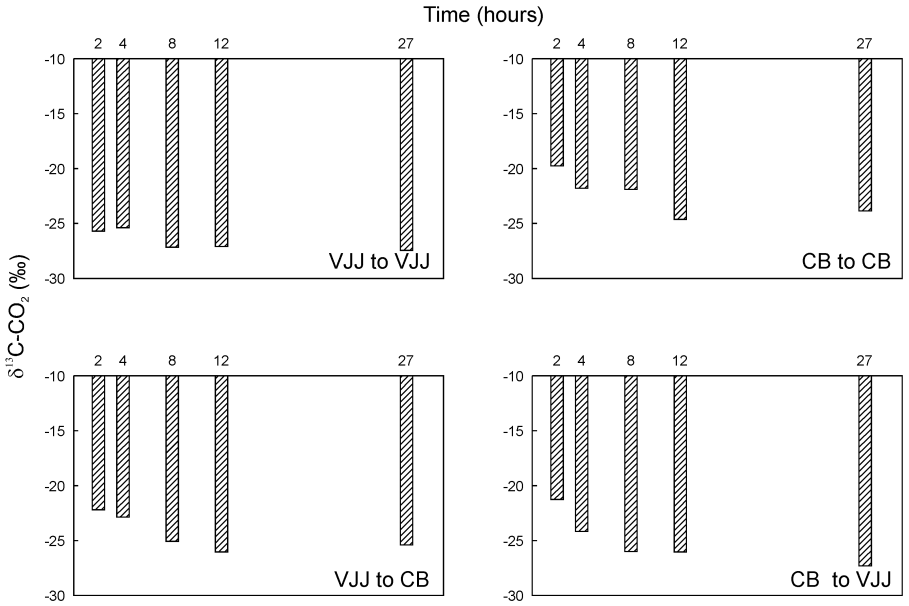

Fig. A4. $\delta^{13}C–CO_2$ values during laboratory peat incubation.

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