# THE DOWNWARD MOVEMENT OF DISSOLVED ORGANIC CARBON EXISTS IN THE BOREAL PEATLANDS OF WEST SIBERIA

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A younger age of gases ($CO_2$, $CH_4$) compared to the surrounding peat at the same depth of 500 and 2000 yearshas has been reported from several boreal and temperate peatlands in North America and Europe (Charman et al., 1994, 1999; Clymo & Bryant, 2008). It is suggested that downward transport of younger carbon as dissolved organic carbon (DOC) exist which decompses easier that peat. Indications that dissilved carbon originating from younger peat may have infiltrated to deeper strata have been also found in a dating studies of peat fragments (Törnqvist et al., 1992; Nilsson at al., 2001). The presence of $^3$H and tritium from nuclear tests at in peat pore water of greater depth has confirmed that the water precipitated after 1950, when thermonuclear testing began (Aravena et al, 1993; Charman et al., 1994, 1999). This fact suggests significant role of movement of dissolved organic carbon in peat deposits and export of carbon outside of peatlands with ground water.

In this study we attempt to examine the hypotesis that similar processes occure in the continental environment conditions of Western Siberia. At present there are no data to estimate the age of DOC and its contribution to regional giogeochemical cycles in Siberia.

In order to study carbon balance and the movement of DOC in peatlands knowledge about mire typology, peat stratigraphy, bulk density, carbon concentrations are needed. Here we investigate the diversity of peatland types and deposits in relation to carbon cycle.

**Study area**

The investigatons were carried out in boreal forest zone in eastern part of West Siberia adjoining to the left bank of Yenissey River between its two left tributaries – Sym and Dubches Rivers (60˚02’ – 61˚00’ N, 88˚05 ‘– 89˚56’ E). The area is covered by 40% by peatlands. Mean annual temperature according the nearest Bor weather station (61˚ 06´ N, 92˚ 01´ E) was – 3.6˚C between 1936 and 2012. Mean annual precipitation was 554 mm, about 265 falling at temperatures >5°C.

**Methods**

29 peat cores were collected on representative wetland sites. Macrofossils, C concentrations and bulk density were measured at 10 cm intervals along the cores.

In each peat core a basal 1 cm slice lying immediately above the peat-mineral interface were taken for radiocarbon analysis. For 9 peat cores the samples for $^{14}$C age determination were taken contiguously every half meter.

Radiocarbon measurements using AMS $^{14}$C method were carried out in MPI of Biogeochemistry in Jena (Germany). We separate dissolved organic carbon (DOC) from particulate organic matter (POM) of peat by centrifugation. $^{14}$C was measred of DOC (< 1,6 μm fraction) and of POM (< 35 > 1,6 μm) from the same samples. For peat sequestration chronology only calibrated $^{14}$C dates of POM-age were used.

**Results**

Based on macrofossils 5 main types of peat deposits were distinguished:

I – ***Shallow ombrotrophic sphagnum peat deposit*** representing mordern paludification of raised bogs on sandy soils. Peat profiles originate from poorly to moderately decomposed sphagnum moss. Only shallow basal layer (0.1–0.2 m) of deposit is formed often from well decomposed transitional cotton-grass-wood peat. The average peat depth is 0.8 meter; the maximal depth recorded was 1 m.

II – ***Mixed type of peat deposits*** in the centres of origin of well-developed raised bogs composed from three (low, transitional and ombrotrophic) peat layers reflecting the change of peatland vegetation with changing of water and nutrient condition during the Holocene. The lowest layer (0,5–1 m thick) originates from brown moss, sedge-moss or herbaceous peat. This vegetation was replaced by transitional *Scheuchzeria* or *Scheuchzeria*-sedge-sphagnum moss peat. At a later stage Sphagnum peat accumulated as raised bog. The peat thickness ranges between 2 and 5 meters. The average peat depth is about 3 m.

III – ***Low and transitional (sedge-moss) peat deposits*** associated with minerotrophic sedge-moss through-flow fens which changed into the transitional sedge-sphagnum bogs. The constant water and nutrient conditions during the whole period of peat accumulation caused the homogenous peat deposit composed by herbs, sedges and brown mosses. Only upper layer (0.1-0.2 m) is composed by sedge-sphagnum moss. Rarely the whole deposit is formed from moderately decomposed transitional *Scheuchzeria*-sedge peat. The thickness of peat deposits varies between 0.5 and 2 meters. The average peat depth is 1.5 m.

IV –***Herbaceous & herb-sedge-wood peat deposits*** developed on wetlands without trees and on wooded fens located in the old river valleys. The peat profiles consist of changing herb-sedge remains. Only upper part (0.5-0.8 m) is sometimes represented by woody peat. The average peat depth is about 4 meter; the maximal depth recovered was 5.6 m.

V – ***Shallow low sedge-wood peat deposits*** on the loamy soils, combined with the paludified forest vegetation widespread on the young left terrace of Yenissey River. These deposits are formed by dense and well decomposed tussock sedge-wood peat. The thickness varies between 0.2 and 1.5 meters. The average peat depth is about 0.5 m.

The radiocarbon $^{14}C$ dates measured as particulate organic matter (POM) show a maximum age of 12 000 yr BP in the old valleys (e.g. Dubches River). Upland from river valleys lake sediments of 0.5-1.0 m thickness were accumulated between 13 000 and 11 000 yr PB. The main fen peat accumulations started 10300 – 9500 yr BP.

The peat profiles show that minerotrophic fens dominated during the whole Holocene. First raised bogs appear about 1000 yrs ago. Presently 80 % of the wetlands are covered by *Sphagnum-Pine* communities (‘ryams’). About 7 % is occupied by transitional bogs. 12.4% remain as fens.

**DOC – POM ages**

$^{14}C$ dating of DOC and POM indicates that radiocarbon ages of DOC are mostly 300 to 4000 yr younger than those of POM. The age difference increases with the depth (Fig. 1).

The maximal age differences recorded between DOC and POM was 5370-6500 years at the peat base. This can only be explained if young dissolved organic carbon transported downwards due to water movement. The results confirm studies from Western Europe and Canada, but differences were larger in this study.

Only in the upper 1 m peat layers mostly of moss dominated peat the age of DOC was 180 to 1775 years older than POM. The maximal difference in upper layers was recorded 2620 years. This fact suggests that DOC may principially move up and down.

There is a linear relation between DOC and POM (Fig. 2, $y = 593 + 0.66x$, $r^2 = 0.84$) with slope of about 0.66. Thus there is a constant loss of DOC proportional to age.

**Depth – POM-age relation**

Peat accumulation rate was not constant during the Holocene. The relation between peat depth and POM-age is described by three linear regressions. In the early Holocene (12 500 and 9 000 cal. BP) lake sediments and low peat deposits originate from old valleys (e.g. Dubches River) accumulated at a rate of 0.8mm $yr^{-1}$ (Fig. 3, A).

Lake sediments and peat developed outside of old river valleys accumulated at constant rate of 0.2 mm $yr^{-1}$ since 14000 years (Fig. 3, B). The same peat accumulation rate is typical for the river valley peatlands since 9 000 cal. BP.

There is an indication of the most rapid peat accumulation rate about 2.0 mm $yr^{-1}$ over the last 1000

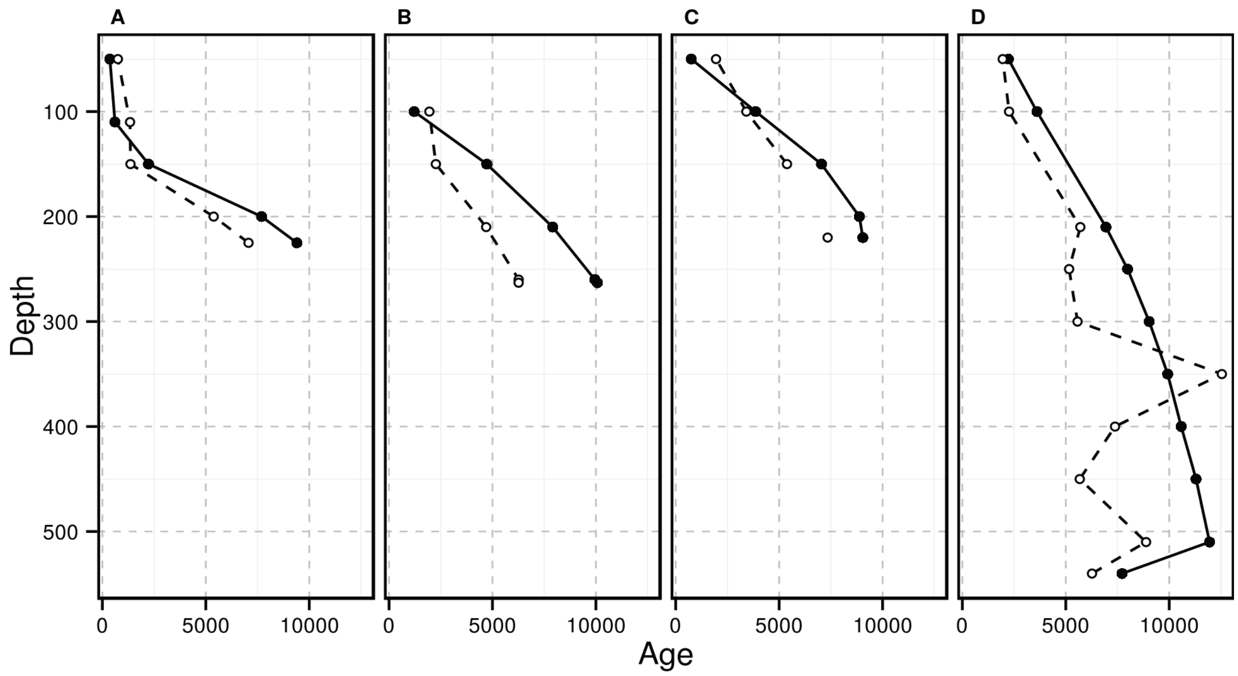


***Fig. 1.*** *Relationship between age and depth in individual peat cores: A – mixed peat deposit under raised bog; B, C – low through flow fen deposits, D – low herbaceous-wood fen deposit in old river valley. Radiocarbon dates: DOC age (black circles), POM age (light circles)*

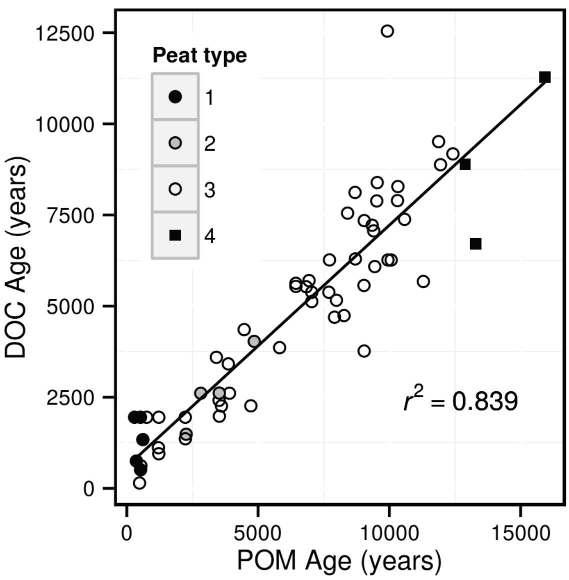


***Fig. 2.*** *Linear relationship between DOC- and POM-14C ages with RMA regression. Peat types: 1 – raised bog, 2 – transitional bog, 3 – fen; 4 – lake sediments*

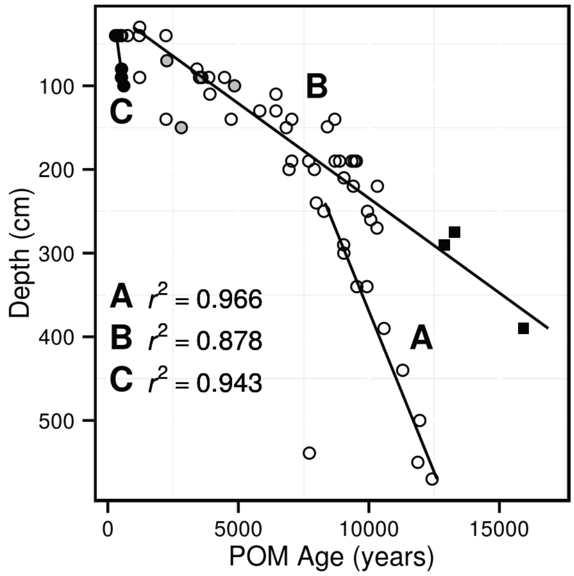


***Fig. 3.*** *Relationship between POM-14C age and peat profile depth*

years, when the ombrotrophic raised bogs were appeared (Fig. 3, C).

**Conclusion**

This study confirms the existence of movement of dissolved organic carbon in boreal peatlands even in the continental environment of West Siberia. It has been found that DOC may transported in vertical direction throughout the peat profiles both up and downwards, but downwards flow has been dominating during the long-term peat accumulation time.

The DOC movement in peat deposits is likely to be a significant component in the overall C budget of majority of peatland types and carbon export via discharge to ground water flow may be an important component, which underestimate in the most estimates of contributions to the carbon.

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