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Grzegorz Skrzypek, Mariusz O. Jędrysek

CLIMATIC VARIATION IN THE LAST MILLENNIUM IN POLAND: $\delta^{13}C$ PEAT PROFILES

Abstract: Three carbon isotope profiles from the raised Polish peat bogs Zieleniec, Szrenica, and Suche Bagno, representing the last Millennium have been analysed. $\delta^{13}C$ in the peat profiles vary from -31 to -22‰. Isotopic composition and directions of $\delta^{13}C$ variations in the profiles in the same age horizons were similar. It has been suggested that variation in $\delta^{13}C$ of peat is dominantly governed by variations in temperature of vegetation of Sphagnum Sp. composing given strata. It has been shown also, that increase in the vegetation temperature by 1°C results in decrease in $\delta^{13}C$ value by about -0.6‰ (we have expressed this as -0.6Fq). Based on $\delta^{13}C$ calibration, the following sequence in the climate variations between 600 and 1950 BP in Poland has been proposed: about 600-1050 AD cold period, 1050-1200 AD very cold period, 1200-1550 AD very warm period - Little Climatic Optimum, 1550-1820 AD very cold period - Little Ice Age, 1830-1960 AD warm moderate period - Global Climatic Warming.

Key words: peat, carbon isotopes, climate, temperature, Poland.

1. Materials and Methods

Carbon stable isotope analyses have been carried out in three raised Polish peat bogs. These are „Zieleniec" and „Szrenica" in the Sudety Mountains (Southwest Poland) and Suche Bagno in the Wigry Lake District (Northeast Poland), Fig.1. The peat bogs are situated in different climatic conditions. Zieleniec is situated on a wooded mountain ridge at about 800 m a.s.l., the mean summer temperature is 14.7°C and rainfall is about 1300 mm/year. Szrenica is situated on an exposed mountain pass above the timberline at 1249 m a.s.l. The mean summer temperature is 12.8°C and rainfall averages about 1300 mm/year. Suche Bagno is situated in wooded lowland at about 140 m a.s.l. Summer average temperature is 15.4°C and rainfall is 600 mm/year. The lakeland peat-bogs is situated about 600 km NE from the mountain peat-bogs.

Carbon isotope analyses of peat from Polish peat-bog have been carried out and results have been compared to isotopic data from the Bacho peat bog in Thailand.

Fig. 1. Map of localisation of sampling areas.

The Thai peat bog is situated close to sea level on a large area of wetland. It has a tropical monsoon climate where the average temperature is 25°C and the rainfall is about 2500 cm/yr. Both Polish and Thai peat bogs contain the same flora with the C3 photosynthetic pathway.

The vertical peat cores, from c.a. 60 to c.a. 153 cm long, cover approximately the last Millennium (about 1300 years BP). The cores were divided into 3 to 5 cm thick intervals and ^{14}C dating was used to correlate corresponding profiles. The preparation technique has been described earlier (Skrzypek 1999). Values of $\delta^{13}C$ are quoted relative to the Pee Dee Belemnite.

2. Discussion

2.1 Previous studies

The $\delta^{13}C$ composition of organic mater is governed by a few factors: the isotopic composition of CO_2 assimilated, the photosynthetic pathway (C3, C4, CAM),

temperature, species, salinity, light intensity, humidity (O'Leary 1981). Many of these factors can be neglected here as each peat bog studied shows negligible biodiversity, similar light intensity, hydrological regime, etc. Also, differences in temperature of vegetation and difference in atmospheric pressure in the two regions studied were probably similar. Numerous calibrations of $\delta^{13}C$ in plants and temperature, resulted in very contrasting values, i.e. the change in isotope value to change in temperature of vegetation varied from –1.2 ‰/1°C to +0.33 ‰/1°C (e.g. Smith et al. 1973; Troughton, Card 1989; White 1989; Lipp et al. 1991).

2.2 Calculations of isotopic temperature effect (‰/1°C)

Present difference in temperature of vegetation between the Szrenica, Zieleniec and Suche Bagno peat-bogs is up to 2.6°C. We have compared average temperature of June, July and August, as during these months only vegetation is remarkable. We assume also that, despite variation in temperature, differences in temperature during growing seasons between the peat-bogs studied were rather similar, throughout the Millennium. Thus, we have calculated differences between average $\delta^{13}C$ value at the profiles analysed and the difference in recent temperatures of vegetation period at these regions. For example:

$\mathbf{T_{SB}}$, $\mathbf{T_{Szren}}$ – the current average temperature of summer months June, July, August calculated for 10 years (1976-1985) for: Wigry Lake District, area of Suche Bagno peat bog (SB) and for Szrenica (Szren)

$\mathbf{\delta^{13}C_{SB}}$, $\mathbf{\delta^{13}C_{Szren}}$ – the average $\delta^{13}C$ value calculated for 1550-1850 AD period for cores from: the Suche Bagno peat bog (SB) and Szrenica peat bog (Szren)

The current difference in temperature and in $\delta^{13}C$ values between Wigry (T_{SB}) and Karkonosze (T_{Szren}) areas is expressed as $\Delta T_{SB\text{-}Szren}$ (°C) and the difference in $\delta^{13}C$ between Suche Bagno $\delta^{13}C_{SB}$ and Szrenica $\delta^{13}C_{Szren}$ cores may be shown as $\Delta^{13}C_{SB\text{-}Szren}$ (‰). The $\frac{\Delta^{13}C_{SB\text{-}Szren}}{\Delta T_{SB\text{-}Szren}}$ ratio, we define here as *Fq* value (Farquhar unit).

We have calculated *Fq* values (‰/1°C) for three pairs of bogs in Poland: Szrenica-Zieleniec, Szrenica-Suche Bagno and, Zieleniec-Suche Bagno and three pairs of profiles Polish-Bacho (Thai) peat bog. The average of *Fq* value for the peat bog pairs from Poland is –0.81 and for the Poland-Thai pairs the *Fq* value is –0.45. The average *Fq* value for these two groups of peat profiles pairs is –0.6 *Fq*.

2.3 The last 1400 year climatic variations evidence for Poland

The $\delta^{13}C$ variations can be rather different from sample to sample in different profiles. Therefore, each sample at each profile should represent the same time period, thus similar sampling resolution would be required to make the profiles comparable. However, the average time span represented by three samples in the Szrenica profile, corresponds to one sample from Zieleniec. To make these profiles comparable, 3 point running average filter was drawn through the Szrenica profile and the curve of Suche Bagno is an average of 3 profiles from the same peat bog, Fig. 2.

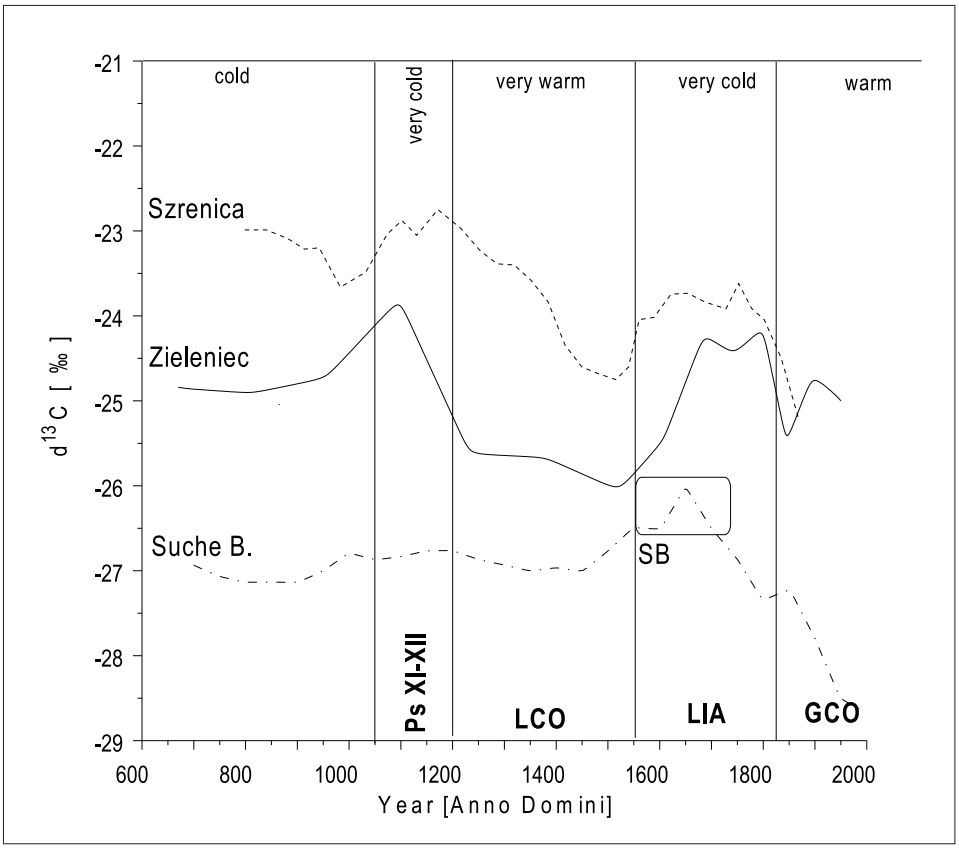

Fig. 2. Calculated plots: Szrenica – three point running average filter, Zieleniec – raw data, Suche B. – curve calculated from three profiles (Suche B.1, Suche B.2, Suche B.3).

The calculated Szrenica profile and Zieleniec profile show significant similarity. Also, the Suche Bagno calculated profile shows a degree of similarity to these previous profiles. Based on these three $\delta^{13}C$ profiles and our *Fq* calibration, the following model of climate history between 600 and 1950 BP in Poland is proposed (Fig. 2):

1. about 600-1050 AD cold period:

Little variations and high $\delta^{13}C$ values in the Zieleniec and Suche Bagno profiles suggest that the temperature was relatively stable and low. In the Szrenica profile, significant variations in $\delta^{13}C$ values suggest remarkable temperature variations during this period on the ridge of the Karkonosze Mountains. At about 700 AD the temperature first increased, followed by a decrease and then decreased again at about 900 AD.

2. 1050-1200 AD very cold period, Pessima 11th-12th Centuries (Ps XI-XII).

Between 1050 and 1200 AD the temperature in the Sudety Mountains (cores Szrenica and Zieleniec) was probably the lowest during the last 1000 years as the $\delta^{13}C$ value show its maximum, higher than during the LIA. The maximum $\delta^{13}C$ value in the Szrenica profile corresponds to the maximum in the Zieleniec profile and a slight pessimum is also recorded in the Suche Bagno profiles. The difference between the $\delta^{13}C$ values of these two periods in the Szrenica and Zieleniec profiles is about 1‰. It can be considered to a decrease of about 2°C in the average annual vegetation period temperature. In the Northeast Poland this cold period was not so clearly visible, the change of $\delta^{13}C$ was below 0.5‰. This period can be compared to the "Little Climatic Optimum" (LCO) in the English lowlands (Lamb 1977, 1985; Barber 1981).

3. 1200-1550 AD very warm period, Little Climatic Optimum (LCO)

The $\delta^{13}C$ decrease in the Szrenica and Zieleniec profiles is about 2‰. This may correspond to an increase in the temperature of growing season by about 3.5°C. This range and timing climatic optimum is generally in agreement with Lamb (1985). However, the time between 1200-1550 AD was a relatively warm period in Poland. This means that the cold period described by Barber (1981) between 1320-1500 AD in England did not take place in Poland.

4. 1550-1820 AD very cold period, Little Ice Age (LIA)

The cold period of LIA is very clear in all the peat cores analysed. The 1‰ (Szrenica and Suche Bagno) and 1.8 ‰ (Zieleniec) increase in the $\delta^{13}C$ value is rather rapid. However, it can be regarded as a decrease in the growing season temperature of about 2-3°C in the Sudety and Wigry areas. However, the shape of the $\delta^{13}C$ curves are different for both areas. In the case of the Szrenica profile especially, several short colder and warmer periods have been observed (seen clearly on Fig. 2). Moreover, it seems that the LIA in these two areas took place at different time i.e.: 1550-1750 AD in Suche Bagno (field SB Fig. 3) and 1550-1830 AD in Sudety (Fig. 3). Very clear expression of the LIA in both areas suggests that the atmospheric circulation during that time, was uniform in the larger scale. Lamb (1985) suggested that the LIA started in England about 1400 AD. This contradicts to the results obtained for Poland. However, it is well correlate to the LIA (1550-1850) presented earlier by Barber (1981). There is good agreement in the timing of variation in temperature in Poland and England which suggests that the atmospheric circulation in the Western and Central European can be consisted the same system during the LIA.

5. 1830-1960 AD, warm moderate period, Global Climatic Warming

In Poland between 1850-1960, the climate became warmer. The temperature first increased (1850-1900), then slightly decreased (1900-1930) and than again increased, 1930-present. It is visible in cores from Suche Bagno (Fig. 2). These observations are generally in agreement with the record of the meteorological station (started at 1826 AD) from Jagiellonian University (Cracow).

3. Conclusions

–Homogeneity of isotopic composition in one peat bog scale in the same layer is good.

–Variations in $\delta^{13}C$ value of total organic matter in peat is governed by temperature. The increase of air temperature during growing season of about 1°C results in change of $\delta^{13}C$ value of organic matter for about –0.6‰.

– $\delta^{13}C$ profiles in peat bogs could be a valuable tool to reconstruct past climates.

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Grzegorz Skrzypek, Mariusz O. Jędrysek
Institute of Geological Sciences
University of Wrocław
Wrocław
Poland