Polish Geological Institute Special Papers, 16 (2005): 123–126
Proceedings of the Workshop "Reconstruction of Quaternary palaeoclimate
and palaeoenvironments and their abrupt changes"

CALIBRATION OF TEMPERATURE CARBON ISOTOPIC EFFECT (PEAT BOGS HALA IZERSKA, IZERSKIE MTS. AND SZRENICA, KARKONOSZE MTS.)

Grzegorz SKRZYPEK[1], Mariusz O. JĘDRYSEK[1], Anna KELLER-SIKORA[2]

Abstract. Two Polish peat cores, from Karkonosze and Izerskie Mts., have been selected to calibrate carbon isotope ratios in peat *versus* temperature of vegetation. The vertical peat cores, *c.* 160 to *c.* 195 cm long, representing the last 4500 years, were divided into 4–6 cm thick intervals. The $\delta^{13}C$ value ranges from –26.85 to –21.81‰. Peat profiles analysed have been correlated due to ^{14}C dating. Temperature and humidity have been monitored by means of HOBO Oneset automatic system. The vegetations periods determined for Karkonosze (1240 m altitude) was from 29 April to 7 October with average temperature *c.* 9.2°C and for two points at Hala Izerska — from 27 April till 7 October with average temperature 10.4°C (at 857 m a.s.l., forest) and 11.5°C (at 843 m a.s.l., open area). It has been concluded that change of temperature of vegetation by about 1°C result in about –0.83 ‰ decrease in carbon isotope ratio of peat forming plants.

Key words: stable isotopes, carbon, temperature, peat core.

Abstrakt. Dwa rdzenie torfowe pochodzące z Karkonoszy i Gór Izerskich zostały przeanalizowane pod kątem zależności składu izotopowego węgla i temperatury powietrza okresu wegetacji w miejscu poboru. Ciągłe rdzenie torfowe o długości całkowitej 160 cm i 195 cm, obejmujące ostanie 4500 lat, podzielono na próbki o miąższości 4–6 cm. Uzyskane wartości $\delta^{13}C$ zawierają się w przedziale od –26,85‰ do –21,8‰. Próbki z poszczególnych części rdzeni zostały skorelowane wiekowo na podstawie datowań radiowęglowych (^{14}C). Temperatura powietrza była monitorowana za pomocą automatycznych rejestratorów HOBO Oneset podczas sezonu wegetacyjnego 2004. Na podstawie analizy temperatur stwierdzono, że sezon wegetacyjny w Karkonoszach (punkt na wysokości 1240 m n.p.m.) trwa od 29 kwietnia do 7 października przy średniej temperaturze powietrza 9,2°C, natomiast na Hali Izerskiej od 27 kwietnia do 7 października przy średniej temperaturze 10,4°C (wysokość 857 m n.p.m., las) i 11,5°C (843 m n.p.m., otwarta przestrzeń, hala). Wzrost temperatury powietrza sezonu wegetacyjnego o 1°C powoduje zmianę wartości $\delta^{13}C$ materii organicznej roślin torfotwórczych o –0,83‰.

Słowa kluczowe: izotopy trwałe, węgiel, temperatura, profil torfowy.

INTRODUCTION

The carbon isotopic composition of the plant tissue is the effect of complex factors, particularly environmental conditions and metabolism. The role of these factors is referred in the equation proposed by Farquhar *et al.* (1989). The isotopic fractionation proceeds in two stages: 1 – adsorption and diffusion of CO_2 into the plant tissue and 2 – the initial carboxylation (O'Leary, 1981; Park, Epstein, 1960). Consequently, the cumulated of ^{12}C-enrichment of the plant tissue with respect to the atmospheric carbon dioxide is about 18–27‰ (C3 plants) and 4–6‰ (C4 plants), (O'Leary, 1981; Lajtha, Marshal, 1994). Therefore, from thermodynamic point of view, the temperature is the most important factor controlling carbon isotope fractionation in plant tissue — CO_2 system.

Generally, the parameter *Fq* value varies from –1‰/°C to –2.4‰/°C, but other authors presented other *Fq* values, e.g. –0.7‰/°C (Leavitt, Long, 1986) or 0.33‰/1°C by Lipp *et al.* (1991). According to calibrations of peat (Skrzypek, Jędrysek, 2005; Jędrysek, Skrzypek, 2005) the *Fq* value is –0.6‰/°C. Likewise, Ménot and Burns (2001) found that, in the peat-forming *Sphagnum*, the *Fq* vary from –0.2 to –0.4‰/°C.

[1] Institute of Geological Sciences, University of Wrocław, Cybulskiego 30, 50-205 Wrocław, Poland; e-mail: buki@ing.uni.wroc.pl, morion@ing.uni.wroc.pl
[2] Polish Geological Institute, Królowej Jadwigi 1, 41-200 Sosnowiec, Poland; e-mail: ankel@interia.pl

On the base of *Sphagnum* and *Polytrichum* plants analyses it has been concluded that the conservation of the primary carbon isotopic composition of organic plant matter in peat is very good. It has been calculated that the variation of *Fq* value for peat is –1.68‰/°C, i.e. 1°C increase in daytime temperature (during vegetation period) results in –1.68‰ change in $\delta^{13}C$ value in peat. It seems that, in contrast to temperature, the humidity show no influence to carbon isotope composition of peat-forming plants (see Skrzypek, Jedrysek, 2004).

MATERIALS AND METHODS

Two Polish peat cores have been selected for temperature calibration of carbon isotope effect. The selected cores are collected from the raised peat bogs existed in similar climatic condition and located in close distance (*c.* 20 km) in Sudety Mountains. The Szrenica Peatbog is at about 1249 m altitude, at exposed mountain pass above timberline at alpine level westward from Szrenica. The mean annual temperatures at Szrenica are about 2°C and 3.5°C respectively, and the rainfall is about 1300 cm/year (Atlas klimatyczny..., 1973). The vertical peat cores, *c.* 160 cm to *c.* 195 cm long, representing the last 4500 years, were divided into 4–6 cm thick intervals. The last 1400 years only have been presented in this paper. ^{14}C dating has been used to correlate respective profiles. Automatic measurements of temperature and humidity at the same sampling stations at Hala Izerska have been carried. The closest point for temperature monitoring in Karkonosze is located about 5 km eastwards from Szrenica below Śmielec Pass (1395 m a.s.l.) at altitudes of 1240 m. HOBO temperature and humidity Oneset sensors have been located 1–1.5 m above the ground, under trees (24 hour shadow) or covered by solar protection shield. Automatic measurements of temperature and humidity with 1-hour interval, since 19 April till 15 October 2004 have been carried out. The altitudes and geographical position of each sampling point have been measured by mean of respectively GPS with a calibrated altimeter (Gramin eTrek Summit), the horizontal and vertical accuracy were 10 m and 5 m. Samples have been frozen at temperature –20°C to store for later isotope preparation and analysis. Details concerning analytical techniques have been described earlier (Jędrysek *et al.*, 1995). The $\delta^{13}C$ values are quoted relative to the V-PDB international standard.

RESULTS AND DISCUSSION

FIELD CLIMATIC OBSERVATIONS AND SAMPLING

On the base HOBO Oneset measurements the average temperature and humidity of each day have been calculated for each location (19 April–15 October 2004). The vegetations period determined for Karkonosze (1240 m altitude) is from 29 April to 7 October with average temperature 9.16°C and for two points at Hala Izerska — from 27 April till 7 October with 10.36°C (at 857 m a.s.l., forest) and 11.48°C (at 843 m a.s.l., open area partial covered by *Pinus mungo*). Seasonal variations in temperature and humidity have been presented at the Figures 1 and 2, respectively.

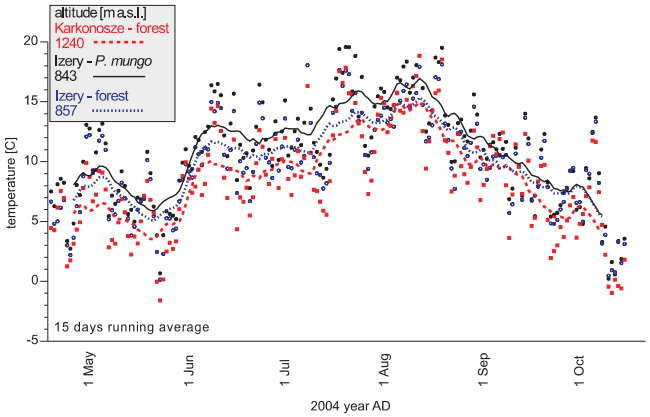

Fig. 1. Variation in the temperature at Karkonosze and Izerskie Mountains (27 April–7 October 2004)

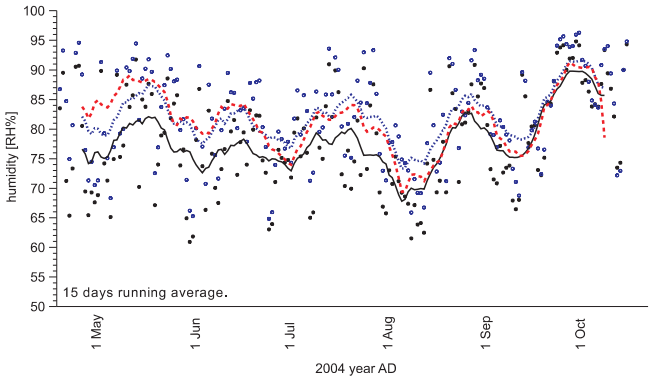

Fig. 2. Variation of relative humidity in Karkonosze and Izerskie Mountains (27 April–7 October 2004)

For explanation see Fig.1

$\delta^{13}C$ ISOTOPIC SIGNALS IN PEAT CORES FROM HALA IZERSKA AND KARKONOSZE

Peat profiles analysed have been correlated due to ^{14}C dating. All $\delta^{13}C$ data obtained, are presented in Figure 3. The different distances between points on the *x*-axis (time scale) on the same profile are the result of different growth rates of peat. The $\delta^{13}C$ profiles show generally similar trends (Fig. 3). Despite these differences, the profiles show well-correlated changes of $\delta^{13}C$ values during the Little Ice Age. Therefore,

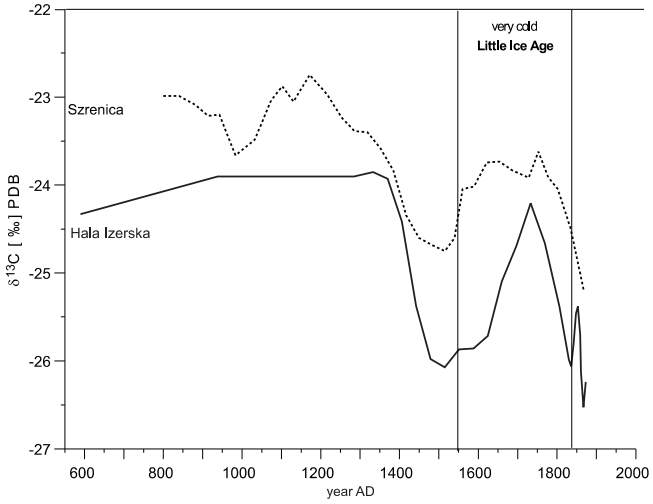

Fig. 3. Calculated plots: Szrenica — three points running average filter, Hala Izerska — raw data

one can expect that in this period sudden variations in the temperature are well reflected in $\delta^{13}C$ variations in the peat.

The average temperature of the vegetation season at 850 m a.s.l. at Hala Izerska corresponds to temperature at 1100 m a.s.l. in Karkonosze Mts. The average difference in the temperature is about 1.7°C.

CALCULATIONS OF ISOTOPIC TEMPERATURE EFFECT (‰/°C)

Parameter *Fq* represents the ratio of isotope differences between two samples to differences in temperature of vegetation period. We assume that, despite variation in temperature, differences in temperature during growing period between the peat-bogs studied were rather similar throughout the last millennium. Thus, we have calculated differences between average ^{13}C values of the analysed profiles and the differences in modern temperatures of vegetation period in these regions. In the constructed equations following symbols have been used:

—T_{HI} – the current average temperature of vegetation period 2004, Hala Izerska (Izery Mountains),

—T_{Szren} – the current average temperature of vegetation period 2004 for the ridge of the Karkonosze Mountains (area of Szrenica peat bog),

—$^{13}C_{HI}$ – the average ^{13}C value calculated for 1551–1859 AD period for cores from the Hala Izerska peat bog,

—$^{13}C_{Szren}$ – the average ^{13}C value calculated for the 1547–1850 AD period for core from Szrenica peat bog.

The equation to calculate the current difference in temperature between Hala Izerska and Karkonosze areas ($T_{HI\text{-}Szren}$) is as follows (see Eq. 1.):

$$T_{HI} - T_{Szren} = \Delta T_{HI-Szren} \quad [^{\circ}C] \tag{1}$$

The ($T_{HI\text{–}Szren}$) corresponds to $^{13}C_{HI\text{–}Szren}$ which can be calculated due to following equation (see Eq. 2.):

$$\delta^{13}C_{HI} - \delta^{13}C_{Szren} = \Delta^{13}C_{HI-Szren} \quad [\%] \tag{2}$$

Thus, we can define the Fq value. The *Fq* represents the difference in ^{13}C values corresponding to the difference in temperature of the growing seasons (‰/°C). The difference in ^{13}C between Hala Izerska and Szrenica cores may be shown as (see Eq. 3.):

$$\frac{\Delta^{13}C_{HI-Szren}}{\Delta T_{HI-Szren}} = Fq \tag{3}$$

The example of Fq value calculated has been shown in the Tables 1and 2. It represents Little Ice Age period *c.* 1550 to 1850 AD.

Table 1

Calculation of the *Fq* value [‰/°C] (Szrenica–Hala Izerska, forest)

Profiles / Parameters	Szrenica 1249 m a.s.l.	Hala Izerska 857 m a.s.l., forest	difference $\Delta^{13}C$	$\delta^{13}C/\Delta T$ [‰/°C]
$\delta^{13}C$ – Carbon isotope composition [‰]	–24.07	–25.39	–1.32	–1,1
T – average temperature of vegetation season [°C]	9.16	10.36	1.20	

Table 2

Calculation of the *Fq* value [‰/°C] (Szrenica–Hala Izerska, open area)

Profiles / Parameters	Szrenica 1249 m a.s.l.	Hala Izerska 843 m a.s.l., open area, *P. mungo*	difference $\Delta^{13}C$	$\delta^{13}C/\Delta T$ [‰/°C]
$\delta^{13}C$ – Carbon isotope composition [‰]	–24.07	–25.39	–1.32	–0.57
T – average temperature of vegetation season[°C]	9.16	11.48	2.32	

SUMMARY

The Fq value is –1.1 or –0.57 for the Szrenica-Hala Izerska pairs, respectively for two points of temperature measurements at Hala Izerska measured at forest (857 m a.s.l.) and open area (843 m a.s.l.). It means that change of 1°C can results in the change of about –0.83‰ in carbon isotope composition of peat forming plants.

Acknowledgments. This study was supported from the 2022/W/ING/04, 2P04G 00426 and 1017/S/ING/03-04 grants.

REFERENCES

ATLAS KLIMATYCZNY POLSKI — 1973. PPWK. Warszawa.

JĘDRYSEK M.O., SKRZYPEK G., 2005 — Hydrogen, carbon and sulphur isotope ratios in peat: the role of diagenessis and water regimes in reconstruction of past climates. *Environ. Chem. Letter* **2**, 4:179–183

JĘDRYSEK M.O., SKRZYPEK G., WADA E., DOROSZKO B., KRAL T.E., PAZDUR A., VIJARNSORN P., TAKAI Y., 1995 — $\delta^{13}C$ and $\delta^{34}S$ analysis in peat profiles and global change. [in Polish with English Abst.]. *Prz.Geol.*, **12**: 1004–1010.

FARQUHAR G.D, EHLERINGER J.R., HUBIC K.T., 1989 — Carbon isotope discrimination and photosynthesis. *An. Rev. Plant Physiol.,* **40**: 503–537.

LAJTHA K., MARSHAL J.D., 1994 — Sources of variation in the stable isotopic composition of plants. *In:* Stable Isotopes in Ecology and Environmental Sciences (eds. K. Lajtha and R.H. Michener): 1–21. Blackwell Scientific Publication. Oxford.

LIPP J., TRIMBORN P., FRITZ P., MOSER H., BECKER B., FRENZEL B., 1991 — Stable isotopes in tree ring cellulose and climatic change. *Tellus*, **44B**: 322–330.

LEAVITT S.W., LONG A., 1986 — Stable-carbon isotope variability in tree foliage and wood. *Ecology,* **67**:1002–1010.

MÉNOT G., BURNS S.J., 2001 — Carbon isotopes plants as climatic indicators: calibration from an altitudinal transect of ombrogenic peat bogs in Switzerland., *Org. Geochem.,* **31**, 2: 233–245

O'LEARY M.H., 1981 — Carbon isotope fractionation in plants. *Phytochem.*, **20**, 4: 553–567.

PARK R., EPSTEIN S., 1960 — Carbon isotope fractionation during photosynthesis. *Geochim. Cosmochim. Acta*, **21**: 110–126.

SKRZYPEK G., JĘDRYSEK M.O., 2004 — Carbon isotopic calibration of peat-forming plants (*Sphagnum* sp.*, Polytrichum* sp..) and peat with respect to air-humidity and temperature of vegetation (Smielec–Jagniątów, Giant Mountains, Poland). *In:* Geoecological Problems of the Giant Mountains (eds. J. Stursa *et al.*). Sborn. Mez. Ved. Konf. Listopad 2003. Szklarska Poręba. *Op. Corcont.,* **41**: 185–193

SKRZYPEK G., JĘDRYSEK M.O., 2005 — $^{13}C/^{12}C$ ratio in peat cores: record of past climates., In: Environmental Chemistry — Green Chemistry and Pollutants in Ecosystems (eds. E. Lichtfouse *et al.*): 65–73. Springer-Verlag